IDENTIFICATION AND REPRESENTATION OF INFORMATION ITEMS REQUIRED FOR VULNERABILITY ASSESSMENT AND MULTI-HAZARD EMERGENCY RESPONSE OPERATIONS

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IDENTIFICATION AND REPRESENTATION OF INFORMATION ITEMS REQUIRED FOR VULNERABILITY ASSESSMENT AND MULTI-HAZARD EMERGENCY RESPONSE OPERATIONS

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ABSTRACT

IDENTIFICATION AND REPRESENTATION OF INFORMATION ITEMS REQUIRED FOR VULNERABILITY ASSESSMENT AND MULTI-HAZARD EMERGENCY RESPONSE OPERATIONS

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Emergency response teams, need various internal information about facilities such as building usage type, number of floors, occupancy information, building contents and vulnerable locations in facility during and immediately after multi hazard emergencies. Accessing such information accurately and timely is very important in order to speed up the guidance of occupants in a facility that is under the effect of multi-hazards to safe exits and speed up the decision process of emergency response teams to identify vulnerable locations (e.g. locations where secondary disasters can arise following an earthquake; fires, explosions). In the current practice, emergency response teams access such vital information to respond the emergency by visual investigating the environment and by asking the people in the neighborhood which causes gaining wrong and misleading information and results in loosing time and increasing the hazardous effect of emergency. Hence, there is a need for an approach to enable emergency response teams to access timely and accurate needed information items. To start the first step of this approach, the information items needed by emergency response teams to guide occupants the safe exits, to direct emergency response teams to vulnerable locations of the facility are identified and classified. Identified information items will be represented to emergency response teams by a model based system (BIM). The opportunities of model based system (BIM) will enable fast and safe evacuation of the facility, identification of vulnerable locations within the facility in a multi hazard emergency.

Keywords: Multi hazard emergency, Vulnerability assessment, Emergency response teams, BIM

ÖZ

ARDIŞIK TEHLİKELER İÇEREN ACİL DURUMLARDA BİNALARDA HASAR GÖREBİLİRLİK ANALİZİ VE ACİL DURUMA MÜDAHALE İÇİN İHTİYAÇ DUYULAN BİLGİLERİN BELİRLENMESİ VE GÖSTERİLMESİ

Gökdemir, Nuray

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Deprem ve onun hemen sonrasında yangın, patlama gibi ardışık tehlikeler içeren acil durum vakalarında, acil durum müdahale ekipleri olay yerine gittiklerinde, (bina kullanım amacı, bina kat sayısı, bina içerisindeki insan sayısı, bina içerisinde tehlikeli maddelerin varlığı, afet oluş saati gibi) çok çeşitli bilgilere ihtiyaç duymaktadırlar. Bu bilgilere hızlı ve güvenilir bir şekilde ulaşılması, yapıların güvenli tahliyesi ve acil durum müdahale ekiplerinin hassas noktaları (örneğin bina içerisinde ikincil afete; deprem sonrası yangın veya patlamaya neden olabilecek bölgeler) belirlemesi ve dolayısıyla yıkıcı sonuçların azaltılması açısından önem arz etmektedir. Hali hazırda kullanılan yöntemler, bu tür kritik bilgileri bina ve çevre sakinlerinden sorarak belirlemeyi kapsadığından, çoğu zaman yanıltıcı olabilmekte, zaman kaybı ve dolayısıyla maddi kayıplarda artışlara neden olabilmektedir. Belirlenen bu problem kapsamında, acil durum müdahale ekiplerinin ihtiyaç duydukları önemli bilgilere hızlı ve doğru şekilde ulaşmalarını sağlamak amacıyla bir yöntem geliştirilmesi önerilmektedir. Bu tez çalışması kapsamında ise, bu yöntemin ilk basamağı olarak, afetzedeleri güvenli çıkış noktalarına yönlendirmek ve acil durum müdahale ekiplerini bina içi hassas ve hemen müdahale edilmesi gereken bölgelere yönlendirmek için acil durum müdahale ekiplerinin deprem, patlama, yangın gibi acil durum vakalarında hangi bilgilere ihtiyaç duyacakları araştırılmış ve bu bilgiler sınıflandırılmıştır. Belirlenen bilgilerin bina bilgi modelleri (BIM) üzerine kurulu bir sistem yardımıyla acil durum müdahale ekiplerine sunulması amaçlanmıştır. Bina bilgi modelleri üzerine kurulu bu sistem yardımıyla, ardışık tehlikelerin etkisindeki binada, bina tahliyesinin hızlı ve güvenli bir şekilde yapılması, acil durum müdahale ekiplerinin ise bina içi hassas noktalara yönlendirilmesi sağlanmış olacaktır.

Anahtar Kelimeler: Ardışık tehlikeler, Hasar görebilirlik, Acil durum müdahale ekipleri, Bina bilgi modelleri

To My Beloved Family

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LIST OF ABBREVIATIONS

AEC	Architecture Engineering Construction
BIM	Building Information Modeling
CBRN	Chemical Biological Radioactive and Nuclear
EMF	Electro Magnetic Field
FM	Facility Management
HVAC	Heating, Ventilation, and Air Conditioning
IAI	International Alliance for Interoperability
IFC	Industry Foundation Classes
ISO	International Organization for Standardization
NIBS	National Institute of Building Sciences
STEP	STandard for Exchange of Product Data

CHAPTER 1

INTRODUCTION

During earthquake response operations, various parties such as first responders, emergency response teams are often faced with unfamiliar and chaotic environments where people in the affected areas are in shock and the properties are damaged (Son et al., 2007; Ergen and Seyis, 2008; Leite et al., 2008). Therefore when an earthquake is occurred it is important to respond to the situation timely and effectively to minimize impacts of the emergency, such as losses to properties and human lives (NSTC, 2003). Earthquakes are especially vital in Turkey, since Turkey is located on the earthquake prone lands (JICA, 2008a) and only earthquakes constitute 61% of the hazards caused by natural disasters (Nurlu et al., 2007). Most of the industrial facilities are located on these earthquake sensitive regions. Since the industry is developed on these areas population is also increased on these earthquake sensitive regions (JICA, 2008a). Also it is indicated in the Ministry of Public Works and Settlement's hazard zone map, 71% of the population lives in the first and second degree seismic hazard zones, and 76% of the industries and 69% of the dams are also located in high degree seismic zones (Ganapati, 2008).

A total of 131 earthquakes were recorded between 1902 and 1999 and these earthquakes composes the 60% of all disasters between 1902 and 1999 (Ergunay, 1999). More than 20,000 people died in the latest five earthquakes, between 1992 and 1999 (Gulkan, 2002). Therefore, both locally and nationally it is vital for Turkey to take actions in order to reduce the impacts of earthquakes on human lives and property.

In 1999 Marmara earthquake which is the most damaging earthquake in Turkey was occurred and 1999 Marmara earthquake resulted in more than 15,000 died people and more than 250,000 people lost their homes (Steinberg et al., 2004). Moreover, 214,000 residents and 30,000 business units were destroyed which resulted in an economic loss of $16 billion (Steinberg et al., 2004).

Earthquake response operations are also very important in many other countries. For example in United States, thousands of earthquakes occur in each year. Averagely seven of these earthquakes have a magnitude of 6 or larger which is very large and these earthquakes cause serious damage (USGS). In 39 states of America there are approximately seventy-five million people that face significant risk from earthquakes (USGS, 1999). Losses of life and property from natural disasters in the United States and throughout the world have been enormous (NRC, 1999). In United States effects of only fire and flood emergencies on human lives, property, disruption of commerce, and recovery costs, is estimated $20 billion annually (NSTC, 2003).

According to United Nations estimates each year 100,000 lives are lost due to disasters caused by nature, and the global cost of disasters will top $300 billion annually by 2050 (UNISDR, 2002). Moreover, McDonald (2003) estimated that impacts of disaster on economy have increased ten-fold in the last four decades. Since the impacts of emergency situation both on human lives and on property are so high that efforts to decrease the harmful effects of the disasters have increased in every level that are in the global, national, state, and local levels (Harris, 2005).

When looking at such cases, it is seen that because earthquakes are unpredictable and difficult to control something must be done at the response stage of the earthquake in order to decrease the economic effects of the earthquakes and the fatalities caused by the earthquake. The impacts of the earthquakes to human life and economy are much more than the other natural disasters, since earthquakes occur in seconds and their extents are huge and unpredictable.

In addition to earthquakes, post-earthquake induced fires or explosions are additional threatening consequences and necessitate rapid evacuation and vulnerability assessment in facilities. These post-earthquake induced consequences can be more harmful than earthquakes, as in the cases of 1906 San Francisco, the 1923 Great Kanto and 1995 Kobe earthquakes (Scawthorn et al., 2005; Haddow et al., 2007). Therefore in this study earthquakes and earthquake induced emergencies in facilities are studied.

In a multi hazard emergency, first responders and emergency response teams are faced with unfamiliar and chaotic environments, therefore conducting effective and successful operations in these environments requires an appropriately managed and timely flow of information (Betts et al., 2005). In the current practice, when first responders and emergency response teams arrive at the scene, they usually have limited information about the situation, where to go, how to start, how to communicate with other rescue teams and government officials (Worldbank, 1999; Ergen and Seyis, 2008). Moreover, due to limited access to critical situational information, first responders and emergency response teams have difficulties in understanding the situation, which results in having late decisions and responding the situation in an ineffective way.

In order to respond to the emergency in an effective way and react quickly and safely, first responders and emergency response teams need internal information about facilities, such as building structure, floor plans, usage of the facility, location of stairs, exits, building material of the facility as well as their occupancies and schedules. Besides, first responders and emergency response teams need to identify vulnerable locations and vulnerable contents in a facility, since these are potential hazardous building contents or systems that can be triggered right after an earthquake, and can trigger threats within the facility which can have more harmful effects than earthquake both on human lives and facility itself.

In order to achieve timely and effective evacuation of occupants and vulnerability assessment in facilities it is required to access needed information by first responders and emergency response teams (Jones and Bukowski, 2001; Son and Pena Mora, 2006). Lack of such needed information during evacuation and rescue operations affect the speed and efficiency of these operations and might result in increased number of casualties (Leite et al., 2008; Leite et al., 2009; Kwan and Lee, 2005). It is evident that accurate and relevant information could significantly reduce the impacts of earthquake such as loss of lives and financial costs. Hence, there is a need for an approach to enable rapid evacuation and vulnerability assessment in building emergencies, in order to guide occupants during evacuation by accessing to building information and directing first responders and emergency response teams to vulnerable locations. In order to achieve this approach the needed internal information about the facilities and vulnerability assessment information is identified and the presentation of this information to the first responders and emergency response teams is studied.

In order to enable rapid and safe evacuation of a damaged facility by guiding the occupants to safe exits and to direct the first responders and emergency response teams to vulnerable locations firstly, information items and vulnerability assessment information needed by first responders and emergency response teams right after an earthquake are identified in this thesis study. Three activities were performed. These three activities are listed below:

1. Literature survey was performed and the research studies on identifying the information items and vulnerability assessment information needed by first responders and emergency response teams to respond the incident were examined.
2. Face to face and semi-structured interviews were conducted with first responders, emergency response team members, and experts on the disaster management. Particularly, during this study, I had access to responders and experts from Turkish Disaster and Emergency Management Directorate, Education Center for Turkish Disaster and Emergency Directorate Management, Ankara Fire Brigade, Ankara Civil Defense General Directorate of the Search and Rescue Unit, İstanbul Civil Defense General

Directorate of the Search and Rescue Unit, İstanbul Provincial Disaster and Emergency Directorate.

3. The documents that Turkish Disaster and Emergency Management Directorate, and Civil Defense General Directorate use, keep track for specific emergencies, or use for training novice first responders and emergency response teams were analyzed and the information items needed by first responders and emergency response teams documented in these documents were determined.

After identifying the information items and vulnerability information needed by first responders and emergency response teams by performing the three activities listed above section, representation of this information to first responders and emergency response teams is studied. With the aim of guiding the occupants to safe exits rapidly from the damaged facility, and also to identify the vulnerable locations within a facility and to react the emergency accordingly in a timely and effective manner the identified information items and vulnerability assessment information needed by first responders and emergency response teams will be displayed by a model based system which is Building Information Modeling (BIM). Facility under consideration will also include a limited number of sensors to give information about the real time information of the facility. Local monitoring approach is achieved by these sensors which are put in the facility. Moreover, the model based guidance and vulnerability assessment system (BIM) for facilities under the threat of multi hazard emergencies will also be integrated with the local monitoring system. By this integrated model based system (BIM), the presentation of information items needed by first responders and emergency response teams in order to guide evacuation and help first responders and emergency response teams in rescue operations by pinpointing vulnerable locations in a facility under the threat of multi hazard emergencies will be achieved.

A model based (BIM) approach will be used to display needed information since, BIM is designed to facilitate the information sharing among the stakeholders in different phases for better decision (NBIMS, 2007), and is capable of storing spatial, geometrical, topological and properties information about facilities and their components. In addition, BIM can be augmented with additional project information in different stages of a construction project; for example, building energy simulation at the design stage can be added to the building information model; information required to perform quantity take off operations at the tendering stage can be added to the building information model. Because of these properties of BIM, the information items needed by first responders and emergency response teams will be represented by BIM in a multi hazard case.

The exploration of integration of the identified information items, vulnerability assessment information needed by first responders and emergency response teams in this mentioned model based system will be explained in detail throughout this thesis study.

As stated above section building information model (BIM) will be used to represent the identified information items to first responders and emergency response teams. By BIM first responders and emergency response teams will access the accurate needed information and guide the occupants accordingly and they will also identify the vulnerable places within the facility therefore impacts of the earthquake both on occupants and facility will be decreased. In order to represent the identified information items in BIM, firstly the expression of these identified information items by Industry Foundation Classes (IFC) is checked. IFC is the major and the international data standard of BIM. IFC represent an open specification for Building Information Modeling (BIM) data that is exchanged and shared among the various participants in a building construction or facility management project (http://www.iaitech.org/ifc/IFC2x4/rc2/html/index.htm). Therefore BIM and the data standard IFC is chosen to represent the needed information items and vulnerability assessment information by first responders and emergency response teams.

In order to present the identified information items and vulnerability information to first responders and emergency response teams in BIM Every identified information item's expression by IFC is searched by looking into the Industry Foundation Classes release 2x4 (IFC2x4) (release candidate1 rc1) carefully and in detail. After checking the expression of needed information by IFC, a data model is prepared by converting every identified entity's Express-g diagrams to Unified Modeling Language (UML) format and required attributes and the relations are presented on this diagram. Data model is prepared both for the identified information items, and also for vulnerability assessment information.

In short, to give a brief description of each subsequent chapter; Chapter 2 outlines the literature survey of this study. Chapter 3 explains the identified information items needed by first responders and emergency response teams in order to respond to emergency quickly, safely and effectively. Chapter 4 represents the vulnerability assessment information. Potential threats upon earthquake in facilities and the building content that can trigger these threats are discussed in this chapter. Chapter 5 outlines the data models that can represent the identified information items by using IFC. Finally Chapter 6 concludes the study by presenting the overall contributions of this study and the future research directions of this study. Within the context of this thesis there are also two appendixes Appendix A and Appendix B. Appendix A presents the terms and their meanings related to emergency and disaster management which are used throughout this study. Appendix B presents the questionnaire used in the study discussed in Chapter 3 and 4.

CHAPTER 2

LITERATURE REVIEW

In this part of the study the literature relevant to information items required by first responders and emergency response teams for multi-hazard emergency response operations and vulnerability assessment is reviewed.

2.1 Literature Review on Information Items needed by First Responders and Emergency Response Teams

Emergency is a natural or man-made situation that has harmful effects on human lives and also on properties (Shen and Shaw, 2004). Emergency response which is the process of collecting needed resources to respond the emergency situation (Shen and Shaw, 2004) is very vital and should be performed as soon as the emergency occurred. Terms related to disaster management and those used in this study like emergency, disaster, risk, hazard, etc. can be seen at Appendix A.

Emergencies are difficult to predict that is forecasting the magnitude, extend and the effects of the emergency is difficult and therefore it is difficult to control emergencies (Son et al., 2007). Therefore when an emergency is occurred it is important to respond to the situation timely and effectively to minimize impacts of the emergency, such as losses to properties and human lives (NSTC, 2003).

During earthquake response operations, various parties such as first responders, emergency response teams are often faced with unfamiliar and chaos environments and stressful situations which people in the area have shocked and the areas are destroyed (Son et al., 2007; Ergen and Seyis, 2008; Leite et al., 2008). Since emergency responders face dangerous environments and situations, ones ranging from fires to explosions and flood, conducting effective and successful operations in

these environments requires appropriate training, and an appropriately managed flow of information (Betts et al., 2005).

Disaster response under chaos environment and stressful conditions has often been insufficient and ineffective since there are various limitations upon disaster at the disaster area (McKinsey, 2002; NCSEA, 2003; Ergen and Seyis, 2008). One of the most important limitations during disaster response is inability to access the information or lack of information about the area and situation.

Because first responders have difficulties in understanding the situation, they have difficulties in making decisions and responding the situation accordingly (Son and Pena-Mora, 2006). In order to react appropriately it is important to immediately gain precise and adequate information about the constructional environment of the situation during and just after the disaster (Schütz et al., 2008).

It is evident that accurate and relevant information could significantly reduce the impacts of a disaster such as loss of life and financial costs (NRC, 1999). The information needed by first responders upon disaster must be timely and in a form that is understandable by decision makers in order to be most effective (NRC, 1999). Moreover, the needed information for the effective and timely response must also be adaptable to the decision-making process (NRC, 1999).

In the current practice, the emergency responders know very little about the situation until they arrive on the scene and they always have no idea about the situation that is where to go, how to start, how to communicate with other rescue teams and government officials (Davis and Evans, 2004; World Bank, 1999; Ergen and Seyis, 2008). They gain the needed information when they arrive on the incident by visual investigating the environment and by asking the people in the neighborhood who are always the ones experienced the disaster and under trauma (Davis and Evans, 2004; Ergen and Seyis, 2008).

When first responders arrive at an emergency scene they want some questions to be answered, some of these questions are: “Where am I?” “What do we know about the scene?” “What hazards exist?” “Where are other responders located?” “Where are the victims?” By providing appropriate and timely answers to these kinds of questions, first responders will be better prepared to response and manage emergencies (Betts et al., 2005). Moreover, without adequate answers to such questions and overall awareness of the situation, disaster responders run the risk of becoming casualties themselves because they do not know enough about the incident scene when they arrive (NRC, 2006).

It is also evident that answers to such questions should be accurate and accessed timely in order to speed up the guidance of occupants in a facility that is under the effect of multi-hazards to safe exits and speed up the decision process of first responders and react appropriately.

The following observations made from the case studies presented by the Resources National Research Council (1999) highlight the importance of the need of the timely and accurate information about the facility in a case of multi hazard emergency:

- Timely and accurate information can significantly reduce loss of life and financial impacts from a natural disaster.

- For most natural disasters, time is of the main principal in the delivery of information for the purpose of decision making.

- Disaster information must be in a form that is readily understandable by the potential user.

- When conflicting sources of information exist in an emergency situation, the potential for incorrect decisions is increased, with costly or even life-threatening consequences.

- Acting on incorrect information can be as costly as not acting on correct information.

These observations demonstrate the importance of timely and accurate information at the response stage of an emergency.

Moreover, as mentioned above, currently after an earthquake, first responders and emergency response teams collect the related internal and surrounding information intuitively either by asking people in the neighborhood or by visual investigation of the area (Davis and Evans, 2004; Ergen and Seyis, 2008). This was very time consuming and gathered information may not be reliable. Since local people who have already experienced the earthquake are under trauma and they may want to save firstly their relatives or their goods therefore they can give misleading information and misdirect the emergency response teams. Moreover, first responders need to spend extra time diagnosing the problem, for which they first need to gather information. Therefore lack of information about the current conditions in a facility is a challenge in emergency response, and to enable better decisions by first responders, timely information about the state of an emergency and a facility is needed (Ergen and Seyis, 2008).

Response time to earthquake emergency is vital for saving more lives. This fact is highlighted in a study made by Turkish Civil Defense General Directorate. In this study it is showed that the first hours after an earthquake are the critical hours to save more lives. The survival rate is 93% in the first 30 minutes but this rate dramatically drops as the time passes; 7% at the fifth day after the earthquake (Table 2.1). This study highlights the importance of the response time. In order to respond to the emergency in a timely manner, response teams need information about the emergency environment and about the facility.

Table 2.1: Survival rate of the rescued people according to time after earthquakes

Survival Rate of the Rescued People According to Time after Earthquakes	
Time	**Survival Rate**
First 30 minutes	93%
First Day	81%
Second Day	36%
Third Day	19%
Fifth Day	7%
After the Fifth Day	2%

Kwan and Lee (2005) also stated in their study that availability of information related to buildings and their occupants during evacuation and emergency response operations is an important factor that affects both the time spent for response operations and the effectiveness of the response operations.

Improved collection and management of building related information and emergency environment information can support planning and decision-making by emergency response teams during all phases of the disaster cycle (Harris, 2005) and upon earthquake it is important to immediately gain precise information about the constructional environment in order to react appropriately (Schütz et al., 2008). Moreover, NIST (2005) highlighted that "What types of data are most useful to emergency responders" and "at what time" are the two main questions to be answered.

According to a study by O'Brien and Hammer (2004) emergency response teams need information about the plan of the building, including access paths, location of load bearing walls, lockboxes, fire walls, stovepipes. Moreover information from building sensors about heat and smoke are also desirable and location of fire hydrants, utility shutoffs, and reports on water pressure are critical while distributing the resources.

In the same study the approximate number and location of building occupants is needed to coordinate search and rescue operations. Moreover, hazardous materials in the building and surrounding facilities must be quickly determined. All of this information must be combined and considered to provide a common operational view for response operations (O'Brien and Hammer, 2004).

Furthermore, the common operational view must be quickly and continuously updated, since fire and smoke can develop rapidly, and new information becomes available such as structural conditions, location of operational personnel, and presence of building occupants (O'Brien and Hammer, 2004).

Betts et al. (2005) also indicated that emergency responders at an emergency scene need answers to questions: "Where am I?" "What do we know about the scene?" "What hazards exist?" "Where are other responders located?" "Where are the victims?". By providing appropriate and timely answers to these kinds of questions, first responders will be better prepared to respond to and manage emergencies.

In another study by Son et al. (2007) it is emphasized that availability of core information related to buildings and infrastructure systems such as access to building drawings, availability of hazardous materials, site contamination and current and forecasted work demand improve effectiveness of engineers involved in post-disaster damage assessment.

Tsai et al. (2008) stated first responders need critical building information such as building evacuation plans, design records, drainage, sewage and HVAC system layout.

Bernoulli et al. (2008) also emphasized not only the location of objects like exits, stairways are the critical information but also any other semantic information like destroyed fire extinguishers, hazardous areas, structural element collapse are critical and needed by emergency response teams for effective response operations.

In the studies on disaster management, the information items needed by first responders are generally categorized as static information and dynamic (real-time) information. Jones et al. (2005) defines static and dynamic information and gives examples of these information about a facility.

2.1.1 Static Information:

Static Information is defined as building information that is available before an incident (Jones et al., 2005). Examples of static information items are the ingress/egress locations in the building, location of hazards and obstructions in the building, location of stairwells, elevators, cameras, and water sources, etc. In this study it is indicated that static information about the facility that is needed by first responders and emergency response teams should be identified before the emergency and represented to first responders and emergency response teams in a multi hazard emergency.

2.1.2 Dynamic (Real-Time) Information:

Dynamic information is a set of information that comes from real-time status of building system controllers and sensors, including fire alarms, security sensors, mechanical system status, elevator location, lighting system activation, occupancy sensors, etc. (Jones et al., 2005). Examples of dynamic information items are; location of the incident within the building, size of the fire and its duration, location of the occupants, available or blocked evacuation routes, available stairwell, etc.

In this study all the information items mentioned in the literature are identified and those information items are categorized under six topics and these are listed below. The studies reviewed in the literature were generally fire response cases, however the focused case in this thesis study is earthquake and the hazards occurred upon earthquake.

1. Building information
2. Occupancy information
3. Disaster information

4. Information about transportation to the scene
5. Information about surrounding of the facility
6. CBRN (Chemical, Biological, Radioactive and Nuclear) material information

After categorizing the information items, the identified information items are listed in a table with the sources they are identified in the literature (Table 2.2).

Table 2.2: Identified information items needed by emergency response teams by literature survey

Identified Information Items		**Source**
Building Information		
1	Location of emergency exits in the facility	Isıkdag et al. (2007), Jones et al.(2005), Bernoulli et al. (2008), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
2	Electrical installations and pipelines	Isıkdag et al. (2007)
3	Type of building / Building material (reinforced concrete, steel etc.)	Jones et al. (2005), Ergen E., Sariel-Talay S., Guven G. (2009)
4	Floor plans of the facility	W. J. O'Brien (2004), Bernoulli et al. (2008), Jones et al. (2005), R. P. Payant and B. T. Lewis (2007), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
5	Evacuation plans	W. J. O'Brien (2004), Bernoulli et al. (2008), Jones et al. (2005), R. P. Payant and B. T. Lewis (2007)
6	Location of access points in the facility	Isıkdag et al. (2007), Bernoulli et al. (2008), R. P. Payant and B. T. Lewis (2007), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)

Table 2.2: Identified information items needed by emergency response teams by literature survey (continued)

7	Simplified drawings of the building	Jones et al. (2005), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
8	Roof access of the facility	Jones et al. (2005)
9	Location of stairwells in the facility	Bernoulli et al. (2008), Jones et al. (2005), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
10	Location of elevators in the facility	Bernoulli et al. (2008) Jones et al. (2005), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
11	Location of security and fire control rooms in the facility	Jones et al. (2005), R. P. Payant and B. T. Lewis (2007)
12	Type of usage of the facility (school, single family etc.)	Jones et al. (2005), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
13	Number of floors / style of the facility (one story, n story, sublevels etc.)	Jones et al. (2005), Ergen E., Sariel-Talay S., Guven G. (2009)
14	Condition of the facility (safe, unsafe etc.)	Jones et al. (2005)
15	Main material of the roof	Jones et al. (2005)
16	Mechanical system status for water, power and ventilation	Jones et al. (2005)
17	Location of fire sensors and alarms in the facility	W. J. O'Brien (2004), Isıkdag et al. (2007), Jones et al. (2005), R. P. Payant and B. T. Lewis (2007)
18	Existence of electronic control system in the facility	Isıkdag et al. (2007), Jones et al. (2005)
19	Opening directions of doors and windows	Isıkdag et al. (2007)
20	Physical transitions between rooms, floors	Bernoulli et al. (2008)
21	Camera locations in the facility	Jones et al. (2005)
22	Location of standpipes in the facility	Isıkdag et al. (2007), Jones et al. (2005), A. M. Levitt (1997)
23	Location of water sources in the facility	Isıkdag et al. (2007), Jones et al. (2005), A. M. Levitt (1997)

Table 2.2: Identified information items needed by emergency response teams by literature survey (continued)

24	Facility systems information	R. P. Payant and B. T. Lewis (2007)
25	Location of the emergency in the facility	R. P. Payant and B. T. Lewis (2007)
26	Emergency exists is locked or unlocked	R. P. Payant and B. T. Lewis (2007)
27	Location of all utility shutoff valves and disconnect switches (Location of main natural gas valve, main domestic water valve, main fire valve)	W. J. O'Brien (2004), R. P. Payant and B. T. Lewis (2007), A. M. Levitt (1997), E. Ergen and S. Seyis (2008),Ergen E., Sariel-Talay S., Guven G. (2009)
28	Existence of underground storage tanks	R. P. Payant and B. T. Lewis (2007)
29	Location of buried electrical cables	A. M. Levitt (1997)
30	Location of buried pipelines	A. M. Levitt (1997)
31	Location of buried telecommunications cables	A. M. Levitt (1997)
32	Location of heavy machinery if there are any	E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
33	Age of the facility	Ergen E., Sariel-Talay S., Guven G. (2009)
Occupancy Information		
34	Abandoned, vacant	Jones et al. (2005)
35	Number of people living in the facility	W. J. O'Brien (2004), Jones et al. (2005), R. P. Payant and B. T. Lewis (2007), E. Ergen and S. Seyis (2008)
36	Time period when occupants stay in the facility	E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
37	Location and condition of the victims in the facility	W. J. O'Brien (2004), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
38	Name, age and health information of the occupants	E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
39	Number of young children in the facility	Jones et al. (2005), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)

Table 2.2: Identified information items needed by emergency response teams by literature survey (continued)

40	Number of elderly people in the facility	Jones et al. (2005), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
41	Number of handicapped in the facility	Jones et al. (2005)
42	Location of handicapped in the facility	Jones et al. (2005)
43	Who has the knowledge of the area	R. P. Payant and B. T. Lewis (2007)
44	If the emergency exits are locked who has the keys	R. P. Payant and B. T. Lewis (2007)
Disaster Information		
45	Emergency type	R. P. Payant and B. T. Lewis (2007)
46	Time of disaster	Jones et al. (2005)
47	Magnitude	Jones et al. (2005)
48	Duration	Jones et al. (2005)
49	Information about growth rate of fire	Jones et al. (2005)
Information about transportation to the scene		
50	Road to access to the incident	Isıkdag et al. (2007)
51	Type of road (asphalt, gravel etc.)	Isıkdag et al. (2007)
52	Slope of road	Isıkdag et al. (2007)
53	Seasonal condition of road	Isıkdag et al. (2007)
54	Traffic information about the area	Isıkdag et al. (2007)
55	Building location (street etc.)	Isıkdag et al. (2007), Jones et al. (2005)
56	Can on-site roads and bridges support the weights of emergency vehicles	A. M. Levitt (1997)
57	Helicopter landing area	Jones et al. (2005)
Information about Surrounding of the Facility		
58	Information about the surrounding of the facility (a layout plan of the neighborhood)	Isıkdag et al. (2007), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
59	Risk level of surrounding buildings of the effected facility	Isıkdag et al. (2007), Jones et al. (2005)
60	Type of hazardous materials that the surrounding facilities have	W. J. O'Brien (2004), Jones et al. (2005), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)

Table 2.2: Identified information items needed by emergency response teams by literature survey (continued)

61	Location of the hydrants in the surrounding of the facility	W. J. O'Brien (2004), Jones et al. (2005), A. M. Levitt (1997)
62	Location of water sources in the surrounding of the facility	Jones et al. (2005), A. M. Levitt (1997)
63	Location of potential potable water sources	R. P. Payant and B. T. Lewis (2007)
64	Any high voltage, or very high voltage power lines	A. M. Levitt (1997)
65	Existence of electric railways or trams (possible source of EMFs)	A. M. Levitt (1997)
66	Existence of radio, tv, radar, microwave transmitters, relays (possible source of EMFs)	A. M. Levitt (1997)
Information about Surrounding of the Facility		
67	Existence of water courses, rivers or streams	A. M. Levitt (1997)
68	Existence of underground water courses beneath building or site	A. M. Levitt (1997)
69	Existence of buried petroleum pipelines beneath building or site	A. M. Levitt (1997)
70	Freight railways pass near building or site	A. M. Levitt (1997)
71	Trucks carrying hazardous substances routinely pass near building or site	A. M. Levitt (1997)
CBRN (Chemical, Biological, Radioactive and Nuclear) Material Information		
72	Existence of CBRN materials in the facility	Jones et al. (2005), R. P. Payant and B. T. Lewis (2007), E. Ergen and S. Seyis (2008),Ergen E., Sariel-Talay S., Guven G. (2009)
73	Location of CBRN materials in the facility	Jones et al. (2005), R. P. Payant and B. T. Lewis (2007)
74	Type (Ph level) of CBRN materials in the facility	R. P. Payant and B. T. Lewis (2007), E. Ergen and S. Seyis (2008), Ergen E., Sariel-Talay S., Guven G. (2009)
75	Who is in charge of that hazardous material	R. P. Payant and B. T. Lewis (2007)

By analyzing the studies on emergency management in the literature seventy five information items needed by first responders and emergency response teams in a multi hazard case were identified.

2.2 Literature Review on Vulnerability Assessment

Vulnerability assessment is a term used in many fields, such as finance, engineering, computer science, emergency management and public policy. Vulnerability assessment in emergency management is assessment of a list of types of potential emergencies and its impact to human, property and business (Lewis and Payant, 2003).

There are a lot of studies in literature that defines the term vulnerability. Ezell (2007) indicates that vulnerability is often confused with risk in the literature and Ezell (2007) presents a summary of vulnerability definitions used in literature. The summary of vulnerability definitions, that Ezell (2007) presented can be seen in Table 2.3.

Table 2.3: Summary of vulnerability definitions in literature (Ezell 2007)

Author	Vulnerability Definition and Uses in the Literature
Blaikie et al. (1994)	"A characteristic of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard"
National Security Telecommunications Advisory Committee (NSTAC) (1997)	"A function of access and exposure. NSTAC (1997) argues that vulnerable systems are systems that are exposed and accessible and therefore susceptible to tampering, or terrorism natural hazards as well as willful intrusion, tampering, or terrorism"
Emergency Management Australia (1998)	"The degree of susceptibility and resilience of the community and environment to hazards"
Dictionary.com (2000)	"Susceptibility to attack"
Buckle (2000)	"A broad measure of the susceptibility to suffer loss or damage. The higher the resilience, the less likely damage may be, and the faster and more effective recovery is likely to be. Conversely, the higher the vulnerability, the more exposure there is to loss and damage"

Table 2.3: Summary of vulnerability definitions in literature (Ezell 2007) (continued)

Nilsson et al. (2002)	"Vulnerability exists as a result of a collection of risks and the ability of a society, local municipal authority, company, or organization to deal with and survive external and internal emergency situations"
Ezell et al. (2000a, 2000b)	"The Infrastructure Risk Analysis Model (IRAM) mathematically modeled vulnerability as a function of access and exposure, building upon NSTAC's (1997) ideas of access and exposure"
Nilsson et al. (2001)	"The collective result of risks and the ability of a society, local municipal authority, company, or organization to deal with and survive external and internal emergency situations"
Gheorghe and Vamanu (2001)	"The susceptibility and resilience/survivability of the community/system and its environment to hazards. Vulnerability is a function of susceptibility, resilience, and the environment"
Association of State Drinking Water Administrators National Rural Water Association (2002)	"Developed self-assessment vulnerability checklists as well as American Water Works Association (AWWA)"
International Strategy for Disaster Reduction (2001)	"A status resulting from human action. It describes the degree to which a society is either threatened by or protected from the impact of natural hazards"
National Oceanic and Atmospheric Administration (2002)	"Susceptibility of resources to negative impacts from hazard events"
National Waterworks of Rural America (2002)	"Vulnerability assessment is the identification of weaknesses in security, focusing on defined threats that could compromise its ability to provide a service"
Willis et al. (2005)	"Vulnerability is the probability of damage given an attack"

After giving the different uses of vulnerability in literature Ezell (2007) compared these definitions with each other and finalized that the term vulnerability "highlights the notion of susceptibility to a scenario". According to Ezell (2007) vulnerability is, therefore, a condition of the system and it should be assessed within the context of a scenario. Therefore Ezell (2007) concludes that vulnerability assessment is different from risk assessment. According to Ezell (2007), risk assessment is used to help understand what can go wrong, estimate the likelihood and the consequences, and to develop risk mitigation strategies to counter risk whereas vulnerability assessment is a measure of susceptibility to scenarios.

Baker (2003) is investigated vulnerability assessment under risk assessment and Baker (2003) indicated that vulnerability assessment involves looking at the system elements and layout and their failure modes based on a given set of threats. The vulnerability assessment answers the basic question, "what can go wrong should the system be exposed to threats and hazards of concern?" Baker (2003). According to Baker (2003) vulnerability assessment is subset of risk assessment. Baker (2003) shows this by using a risk assessment figure (Figure 2.1).

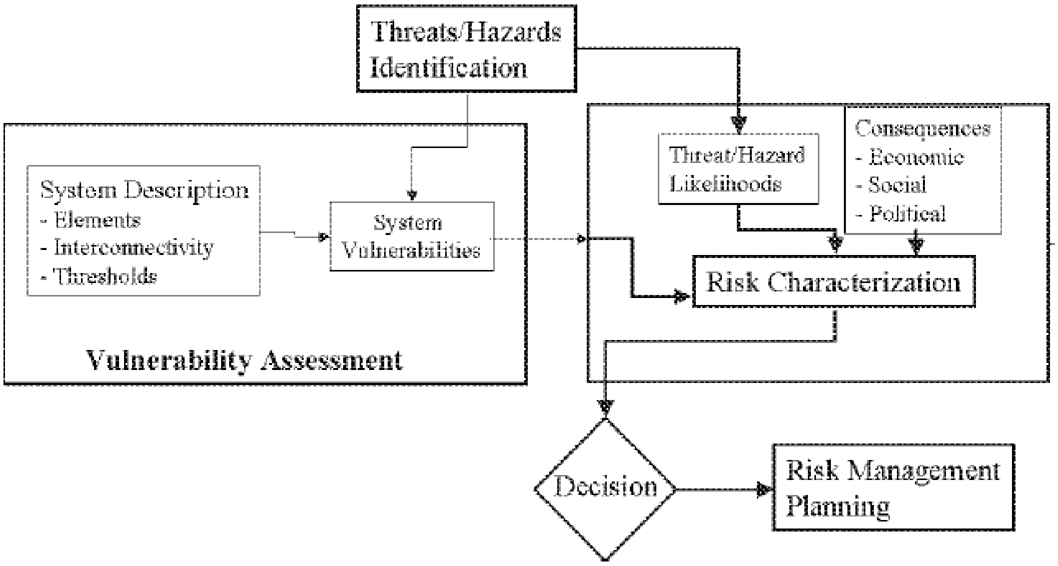

Figure 2.1: Vulnerability assessment as a subset of risk assessment process in Baker (2003)

As can be seen also in the figure, the identification of risk starts with the results of the vulnerability assessment and consideration of the likelihood of threats coupled with the economic, political and social consequences of the system failure is also added (Baker 2003). At the end of the risk assessment process one can decide on whether to take action or not based on the identified risks (Baker 2003). It is also depicted in figure (Figure 2.1) threat/hazard identification is a process of vulnerability assessment. Here comes the question what is threat? and what is hazard? Baker (2003) defined threat as "malicious insults including both cyber and physical attack or sabotage" and hazard as "natural disasters or normal accidents that may occur on a random basis". In this thesis study potential threats within facilities will also be identified to employ vulnerability assessment in facilities under the threat of multi hazard emergencies.

SANS Institute Reading Room (2001) also defined vulnerability and vulnerability assessment in its study which is about security field. According to SANS, "vulnerabilities are the gateways by which threats are manifested". In other words, a system can be put at risk because of a weakness found in the system. Vulnerability assessment is a "search for these weaknesses/exposures in order to apply a patch or fix to prevent a compromise".

Yodmani (2001) is also indicated vulnerability assessment is a subset of risk assessment and presents it as one of the four main components of risk assessment (*hazard assessment, vulnerability assessment, capacities assessment*, *people's perception of risk)* and defines vulnerability assessment as "defining what elements are at risk and why they are at risk".

In a hazard mitigation planning study by Caribbean Hazard Mitigation Capacity Building Programme (CHAMP) vulnerability assessment is defined as "systematic examinations of building elements, facilities, population groups or components of the economy to identify features that are susceptible to damage from the effects of natural hazards" CHAMP is also uses the word susceptible to define the vulnerability assessment as seven references uses in Table 2.3. Moreover, CHAMP indicates that vulnerability assessment can be used to help inform disaster recovery, mitigation and response planning.

As indicated above there are a lot of studies in literature on defining vulnerability assessment, vulnerability assessment models, and vulnerability assessment methodologies. However, few studies have been carried out in the field of vulnerability assessment in emergency management in building emergencies. Vulnerability assessment to help disaster recovery, mitigation or disaster response planning studied in literature is throughout a city or a town to be applied. In this study, vulnerability assessment in buildings to find out the potential threats and the contents that can trigger these threats within a facility are focused.

Vulnerability assessment during and right after earthquakes in facilities is identification of potential building contents and potential threats that can be triggered by these contents and susceptible to these contents within the facility and can cause further hazards both on human lives and on economy. In order to do vulnerability assessment during emergency management, firstly the information needs of first responders and emergency response teams should be identified, that is to say first responders and emergency response teams need to be aware of potential threats and contents that trigger these threats in a facility. Then response teams will be able to perform vulnerability assessment and they will be able to quickly identify which areas to protect in facilities.

Vulnerability assessment in facilities after earthquake is very important because of the fact that in addition to earthquakes, post-earthquake induced fires or explosions are additional threatening hazards and necessitate rapid evacuation in facilities. Post earthquake induced hazards can be more harmful than earthquakes, as in the cases of 1906 San Francisco, the 1923 Great Kanto and 1995 Kobe earthquakes (Scawthorn et al., 2005; Haddow et al., 2007). After these earthquakes fires occurred and they were all terribly destructive. Also after 1999 Marmara Earthquake a big fire occurred at TÜPRAŞ caused a loss of 80 million US Dollars (Danış and Görgün, 2005).

Earthquake induced fires had also very serious problems in Turkey, as in the cases 1999 Marmara Earthquake, Düzce Earthquake, 1970 Gediz Earthquake, Sakarya Earthquake and Bolu Earthquake. Common properties of Düzce Earthquake, 1970 Gediz Earthquake, Sakarya Earthquake, and Bolu Earthquake induced fires are their causes. They were all caused by the heaters in the facilities. Heaters in the facilities turned over because of the shaking impacts of the earthquake.

As looking such cases it is evident that fires following earthquakes are a serious problem, due to multiple simultaneous initiating combustions of fires (Scawthorn et al., 2005). In order to decrease the secondary disasters like fires and explosions upon earthquake in the facilities and also to achieve effective evacuation of occupants vulnerability assessment should be done by emergency response teams in facilities in case of multi-hazard emergencies. Lack of vulnerability assessment information such as potential threats and contents that can trigger these threats during evacuation and emergency response operations affect the speed and efficiency of emergency response operations and might result in increased number of casualties (Leite et al., 2008; Leite et al., 2009; Kwan and Lee, 2005). There is a need for an approach to enable rapid vulnerability assessment in facilities, guiding occupants during evacuation by accessing to building information and directing emergency response teams to vulnerable locations within the facility.

Levitt (1997), investigated the process of vulnerability assessment in facilities in three stages. These are vulnerability search, vulnerability analysis and vulnerability rectification. According to Levitt (1997), the vulnerability search process concerns identifying the potential hazards that may occur due to an event and/or a target of an event. In vulnerability analysis, the focus is on determining the level of risk and the nature and extent of the impact. Finally, vulnerability rectification deals with the actions taken to reduce the levels of risk and impacts.

Leite (2009) has also indicated that to perform effective vulnerability assessments during and right after a building emergency, professionals need to be aware of the possible threats and vulnerable contents in a facility. However Leite (2009) focused on the threats that are generally failures in a building system like water line break and power failure. Leite (2009) is also focused on documenting, identifying and prioritizing contents, threats, building systems and spaces in order to support a set of core vulnerability assessment and defined threats and contents in her research study.

According to Leite (2009) contents are entities in a facility which are needed for the building's indented functioning, as well as activities carried out in the facility. Examples of contents include freezer, transformer, server computer and also a laptop computer might be described as a content that needs power to function and cannot come into contact with water and Leite (2009) defined threats as events that can be the potential loss of life, property and disruption of service in a facility like water leakage and power outage. In short threats are the events that have harmful effects on functioning of above mentioned facility contents. However in this study the contents are different from the ones that Leite (2009) has investigated and threats that are identified in this study has similarities with the ones Leite has defined. For example water leakage within the facility is also identified as threat in this study. Threat is also defined as potential loss of life, property and disruption of service in a facility with the effect of uncontrolled state of building content. In this research study focused contents are the building entities or systems that can trigger a threat and provides a threat to be induced. Building content examples that can be identified after an earthquake by first responders and emergency response teams to reduce the harmful effects of earthquake are hazardous materials within the facility, explosive materials, gas distribution system, and electric distribution system. Threat examples that are triggered by those contents and should be known by the first responders and emergency response teams are gas leakage, water leakage, failures in electric distribution system and spill and leakage of hazardous materials. Identifying these building contents and possible potential threats that can be triggered by these contents to support vulnerability assessment after an earthquake are the aim of this thesis study.

CHAPTER 3

INFORMATION ITEMS REQUIRED BY FIRST RESPONDERS AND EMERGENCY RESPONSE TEAMS

In this chapter of the thesis, I provide the research method, research findings and validation effort in relation to the identification of information items required by first responders and emergency response teams during earthquakes and earthquake induced post-earthquake multi-hazard emergencies.

3.1 Research Methodology

In order to identify the information items needed by first responders and emergency response teams, the research activities can be grouped under three categories as listed below and as depicted in Figure 3.1:

1. Literature survey was performed and the research studies on defining the information items needed by first responders and emergency response teams to respond the incident quickly and safely were examined.
2. Face to face and semi-structured interviews were conducted with the emergency response team members, and experts on the disaster management. Particularly, during this study, we had access to responders and experts from Turkish Disaster and Emergency Management Directorate, Education Center for Turkish Disaster and Emergency Directorate Management, Ankara Fire Brigade, Ankara Civil Defense General Directorate of the Search and Rescue Unit, İstanbul Civil Defense General Directorate of the Search and Rescue Unit, İstanbul Provincial Disaster and Emergency Directorate.

3. The documents that Turkish Disaster and Emergency Management Directorate, and Civil Defense General Directorate use, keep track for specific emergencies, or use for training novice first responders and emergency response teams were analyzed and the information items needed by first responders and emergency response teams documented in these documents were identified.

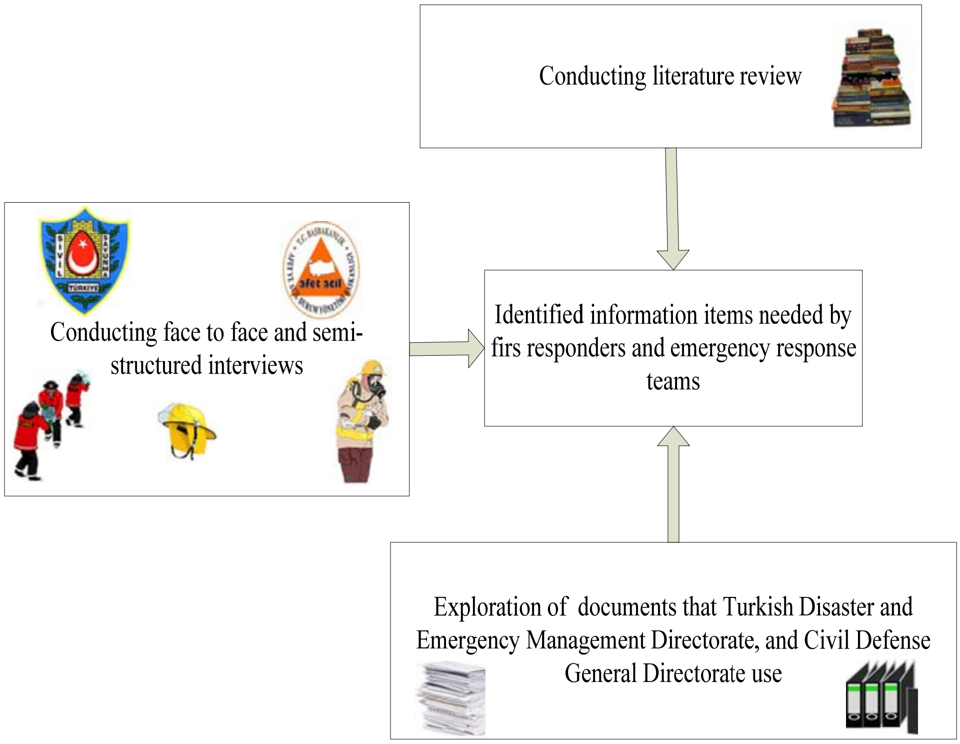

Figure 3.1: Research activities for identification of information items required by first responders and emergency response teams

3.1.1 Research Activity: Identification of Information Items through Literature

As it is discussed in Chapter 2.1 research studies on identification of needed information items by first responders and emergency response teams in any kind of emergency were investigated through the literature. Most of the studies investigated were on fire emergency response. The emergency focused in this thesis study is earthquake and earthquake induced emergencies like fires, explosions that is multi-hazard emergencies. Therefore the identified information items needed by first responders and emergency response teams in any kind of emergencies are analyzed in this thesis study and the findings are presented in Table 2.2 in chapter 2.

3.1.2 Research Activity: Identification of Information Items through Interviews

Face to face and semi structured interviews with emergency response team members, and experts on the disaster management from Turkish Disaster and Emergency Management Directorate, Education Center for Turkish Disaster and Emergency Directorate Management, Ankara Fire Brigade, Ankara Civil Defense General Directorate of the Search and Rescue Unit, İstanbul Civil Defense General Directorate of the Search and Rescue Unit, İstanbul Provincial Disaster and Emergency Directorate were conducted to determine the information items needed by first responders and emergency response teams in a multi hazard case.

Face to face interview approach was chosen in order to use the advantage of the interaction with the participant and right questioning of the participant. Therefore it is possible to eliminate the misunderstanding and gathering right and accurate information is achieved.

Interviews were conducted with the experts in their fields. Predetermined questions were asked to participants. At the same time the participant told about his/her experience. The questionnaire asked to the participants had three main parts; first part was about the general information on what happens after an emergency like earthquake, fire or explosion, which emergency response teams are involved in such emergencies and the information items needed by these emergency response teams to respond to the incident timely and accurately. Second part was about an actual emergency case, the aim in that part was understanding the situation and the need of the information items in that actual case. Third part was about threats upon earthquake, the vulnerabilities in facilities and the potential threats that can be triggered by the failures in building contents and systems upon earthquake. Each interview was lasted approximately 2 hours. The questions that are asked to the participants can be seen in Appendix B.

21 participants from Turkish Disaster and Emergency Management Directorate, Education Center for Turkish Disaster and Emergency Directorate Management, Ankara Fire Brigade, Ankara Civil Defense General Directorate of the Search and Rescue Unit, İstanbul Civil Defense General Directorate of the Search and Rescue Unit, İstanbul Provincial Disaster and Emergency Directorate were met to find out the needed information items, however 11 of them were interviewed because of their knowledge on this area. Common and the most important features of the participants were that they were very experienced and they took part actively in many earthquakes in Turkey and abroad within the framework of search and rescue operations. The list of the participants; their institution, roles, and experience on their field were summarized in Table 3.1.

Table 3.1: Summary of the participants interviewed in this study

Institution	**Role**	**Experience on the field (year)**
Turkish Disaster and Emergency Management Directorate	European Natural Disasters Training Centre (AFEM) Director	-
	Forecasting and early warning systems group member	-
	Forecasting and early warning systems group member	-
	Research Planning and Coordination (APK) Specialist	-
	Head of Department of Emergency Response	-
	Department of Emergency Response Personnel	-
Architectural Engineering Consulting Company	Civil Engineer Msc.	40

Table 3.1: Summary of the participants interviewed in this study (continued)

Education Center for Turkish Disaster and Emergency Directorate Management	Assistant Director of Education Center for Disaster and Emergency Directorate Management	30
	Assistant Director of Education Center for Disaster and Emergency Directorate Management	22
	Education Center for Turkish Disaster and Emergency Directorate Management Teacher	33
Education Center for Turkish Disaster and Emergency Directorate Management	Education Center for Turkish Disaster and Emergency Directorate Management Teacher	25
	Education Center for Turkish Disaster and Emergency Directorate Management Teacher	16
	Education Center for Turkish Disaster and Emergency Directorate Management Teacher	2
Ankara Civil Defense General Directorate of the Search and Rescue Unit	Ankara Civil Defense General Directorate of the Search and Rescue Unit Manager	25
	Ankara Civil Defense General Directorate of the Search and Rescue Unit Chief	17
	Ankara Civil Defense General Directorate of the Search and Rescue Unit Chief	16
İstanbul Civil Defense General Directorate of the Search and Rescue Unit	İstanbul Civil Defense General Directorate of the Search and Rescue Unit Manager	23
İstanbul Provincial Disaster and Emergency Directorate	Provincial Director of Disaster and Emergency	28
	National Palaces of Civil Defense Expert	20
Ankara Fire Brigade	Fire Branch Manager	-
	Teacher	-
Total Participants		**21**

11 participants, marked with blue in the table, were interviewed to identify the information items, and 3 participants, marked with orange in the table, were also interviewed to validate the outcomes of the 11 participants' interviews.

During the interviews notes were taken and these notes were analyzed and the identified information items through interviews were classified under 6 category as also done in identification of information items through literature review. These categories will be discussed under research findings section.

3.1.3 Research Activity: Identification of Information Items through Documents

As mentioned at section 3.1.2, interviews with emergency response team members, and experts on the disaster management from Turkish Disaster and Emergency Management Directorate, Education Center for Turkish Disaster and Emergency Directorate Management, Ankara Fire Brigade, Ankara Civil Defense General Directorate of the Search and Rescue Unit were conducted. After making the interviews, the participants were asked which documents, materials they use for training and education to manage the emergencies in facilities. The participants shared the documents, materials that contain the information about civil defense, emergency and disaster response, emergency and disaster process with us. The topics of the documents which were gathered to identify information items mentioned in these documents are listed in Table 3.2.

Table 3.2: Topics of the received and reviewed documents

Topic
Civil Defense, Disaster, Search and Rescue
Basic Disaster Preparedness and Disaster Consciousness Overview
First Search and Rescue
Damage Classification of Buildings
Life Saving Precautions
Non-medical Triage
Public Health After Disasters
Psychological First Aid After Disasters
Neighborhood Attendances During Civil Defense
Neighborhood Disaster Preparedness
Incident Command System (ICS) Principles
CBRN Threat
CBRN Radiological Risks
Earthquake Search and Rescue Works

Each document listed in Table 3.2 was analyzed and the information items needed by first responders and emergency response teams after an emergency were identified. The identified information items through documents were also classified under 6 topics which will be discussed under research findings section.

3.2 Research Findings

Results of each method are analyzed under three topics:

1. Identification of information items needed by first responders and emergency response teams through literature review.
2. Identification of information items needed by first responders and emergency response teams by face to face and semi-structured interviews.
3. Identification of information items needed by first responders and emergency response teams through documents that Turkish Disaster and Emergency Management Directorate, and Civil Defense General Directorate use to manage multi-hazard emergencies.

3.2.1 Information Items Identified Through Literature Review

Information items identified through literature were presented under literature review section in Table 2.2. The research studies investigated through literature and information items identified through these studies were presented in a table by indicating the source that the specified information item was identified. The identified information items needed by first responders and emergency response teams through literature will be compared with the other two methods (identification of information items needed by first responders and emergency response teams by face to face and semi-structured interviews and identification of information items needed by first responders and emergency response teams through documents) in section 3.3 of this thesis study.

3.2.2. Identified Information Items Needed by First Responders and Emergency Response Teams Through Face to Face and Semi-Structured Interviews

As it is discussed under the section 3.1.2 face to face and semi structured interviews with emergency response team members, and experts on the disaster management from Turkish Disaster and Emergency Management Directorate, Education Center for Turkish Disaster and Emergency Directorate Management, Ankara Fire Brigade, Ankara Civil Defense General Directorate of the Search and Rescue Unit were conducted to determine the information items needed by first responders and emergency response teams in a multi hazard case. Predetermined questions were asked to participants (Appendix B). Notes were taken during the interviews. These notes were analyzed and the information items needed by first responders and emergency response teams were listed in a table (Table 3.3). Every mentioned information item were presented in this table and also one column was inserted to represent percentage identification of the information item by 11 participants of the interviews. As it can be seen in the prepared table some of the information items were identified by all the 11 participants (depicted in the table as 100%) and some of them were identified only 1 of the participants (depicted in the table as 9%). Identified information items through interviews were also classified under 6 category.

Table 3.3: Identified information items needed by first responders and emergency response teams by face to face and semi-structured interviews

Information Items Determined by Interviews		Percentage of Identification
Building Information		
1	Floor plan of the facility (where is the bedrooms etc.)	100%
2	Number of floors	100%
3	Type of usage of the facility (school, hospital etc.)	100%
4	Is there a storage area in the facility: laboratory, pharmaceutical warehouse ,paint factory, shop, medicine production office, LPG, gas tube, fuel tank, gunpowder store	100%
5	Heating system of the facility	100%
6	Is there a water tank in the facility	100%

Table 3.3: Identified information items needed by first responders and emergency response teams by face to face and semi-structured interviews (continued)

7	Main material of building / Type of building (reinforced concrete, etc.)	100%
8	Plan of the structural frame of the facility	9%
9	How old is the facility	27%
10	Risk of the roof (condition of the roof)	18%
11	Electricity on/off	100%
12	Water valve on/off	100%
13	Gas valve on/off	100%
14	Location of the main gas valve in the facility	100%
15	Location of the main electric interrupter in the facility	100%
16	Location of the main water valve in the facility	100%
17	Simplified drawings of the facility	64%
18	Location of stairwells in the facility	36%
19	Type of damage of the facility (sideward, over and over, etc.)	82%
20	Damage category of the facility (slight, moderate, heavy damage)	82%
21	Condition of the facility (safe/unsafe etc.)	100%
22	Size of the facility	82%
23	Location of the big nonstructural elements in the facility	18%
Occupancy Information		
24	Number of people living in the facility	100%
25	Number of people in each floor	18%
26	Where can people be in the facility in the event of earthquake	82%
27	Is there anyone in the facility who has knowledge of civil defense	9%
28	Is there any handicapped people in the facility	18%
29	Location of handicapped in the facility	18%
30	Anything special during the time of the earthquake in the facility (party, ceremony etc.)	9%
31	Information about the person that you are looking for	27%
Disaster Information		
32	Time of earthquake	82%
33	Season of earthquake occurred	73%
34	Weather at the time of the disaster	18%
35	Magnitude of the earthquake	82%
36	Epicenter of the earthquake	82%
37	Duration of the earthquake	64%
38	Duration of the fire	18%

Table 3.3: Identified information items needed by first responders and emergency response teams by face to face and semi-structured interviews (continued)

39	Fire spread, and growth rate	18%
Information about transportation to the scene		
40	Road to access the incident	27%
41	Traffic information about the area	27%
42	Building location (address, street etc.)	45%
Information about Surrounding of the Facility		
43	Risk level of surrounding buildings of the effected facility	45%
44	Type of materials that the surrounding buildings have	82%
45	The condition of the lamp posts	18%
46	Underground and over ground risks of surrounding of the facility	18%
CBRN (Chemical, Biological, Radioactive and Nuclear Material) Information		
47	Existence of CBRN material in the facility	100%
48	Location of CBRN material in the facility	100%
49	Amount of the CBRN material in the facility	100%
50	Type (Ph level) of the CBRN material in the facility (how to deactivate it, to give suggestions)	100%

There are 50 information items under 6 categories identified through face to face and semi-structured interviews with 11 experts on emergency response operations. As it can be seen in Table 3.3, 19 of the information items were identified by 100% of the participants that is to say 36% of the information items were identified by all the participants. These are the information items very urgently needed by the first responders in order to understand the situation and accordingly respond to the emergency timely and effectively. 8 of them were identified by 82% of the participants, 1 of the information items was identified by 73% of the participants, 2 of the information items were identified by 64% of the participants, 2 of the information items were identified by 45% of the participants, 1 of the information items was identified by 36% of the participants, 4 of the information items were identified by 27% of the participants, 10 of the information items were identified by 18% of the participants, and 3 of the information items were identified by 9% of the participants. Number of information items determined versus how much percentage of participants determined those information was summarized in Figure 3.2.

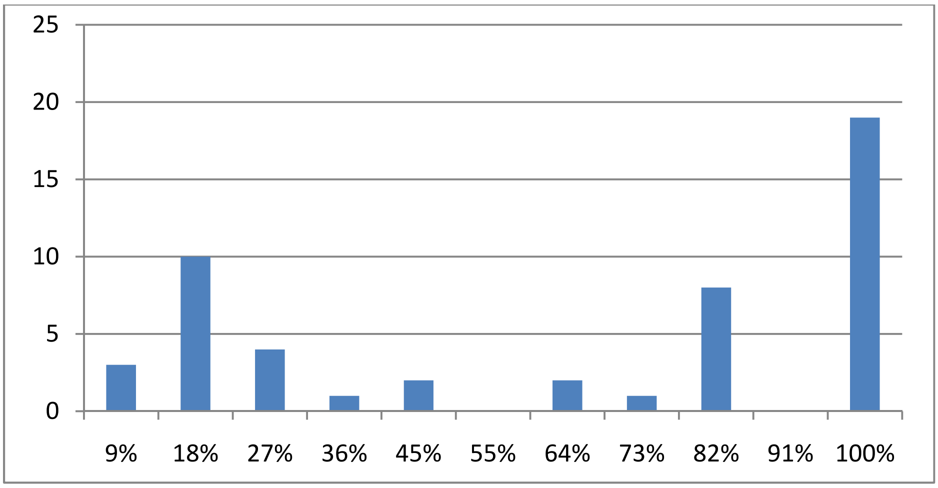

Figure 3.2: Number of information items determined versus how much percentage of participants determined those information.

3 of the information items were identified by only 9 % of the participants, however when looking at these information items which are; is there anyone in the facility who has knowledge of civil defense, anything special during the time of the earthquake in the facility (party, ceremony etc.), plan of the structural frame of the facility, it is easily seen that these information items are not unnecessary to use in order to respond to the emergency, in fact they are very essential to understand the situation, to react accordingly and save more lives in a multi hazard case.

3.2.3 Identified Information Items Needed by First Responders and Emergency Response Teams through Documents that Turkish Disaster and Emergency Management Directorate, and Civil Defense General Directorate Use to Manage Multi-Hazard Emergencies

As it is discussed under the section 3.1.3, emergency response team members, and experts on the disaster management from Turkish Disaster and Emergency Management Directorate, Education Center for Turkish Disaster and Emergency Directorate Management, Ankara Fire Brigade, Ankara Civil Defense General Directorate of the Search and Rescue Unit shared the documents with us that they use, keep track for specific emergencies, or training novice first responders and emergency response teams. These documents were analyzed and the information items needed by first responders and emergency response teams were also identified through these documents. The identified information items were listed in a table (Table 3.4) under 6 categories.

Table 3.4: Identified information items needed by first responders and emergency response teams through documents that Turkish Disaster and Emergency Management Directorate, and Civil Defense General Directorate use to manage multi-hazard emergencies

Building Information	
1	Size of the facility
2	Number of floors
3	Type of usage of the facility (school, hospital etc.)
4	Type of building / main material of building (reinforced concrete, etc.)
5	Simplified drawings of the condition of the facility
6	Electricity off /on
7	Water valve off /on
8	Gas valve off /on
9	Location of the main gas valve in the facility
10	Location of the main electric interrupter in the facility
11	Location of the main water valve in the facility
12	Floor plan of the facility (where is the bedrooms etc.)
13	Areas to easily access the facility (ingress locations)
14	Location of the big nonstructural elements in the facility
15	Location of stairwells in the facility
16	Type of damage of the facility (sideward, over and over, etc.)
17	damage category of the facility (slight, moderate, heavy damage)
18	Condition of the facility (safe, unsafe etc.)
Occupancy Information	
19	Number of people living in the facility
20	Where can people be in the facility in the event of earthquake
21	Information about the person that you are looking for
Disaster Information	
22	Time of earthquake
23	Duration of earthquake
24	Magnitude of earthquake
25	Region / Location of earthquake
Information about transportation to the scene	
26	Road to access the incident
27	Traffic information

Table 3.4: Identified information items needed by first responders and emergency response teams through documents that Turkish Disaster and Emergency Management Directorate, and Civil Defense General Directorate use to manage multi-hazard emergencies (continued)

Information about Surrounding of the Facility	
28	Risk level of surrounding buildings of the effected facility
29	Type of materials that the surrounding buildings have
30	Underground and over ground risks of surrounding of the facility
31	Information about the surrounding of the facility
CBRN (Chemical, Biological, Radioactive and Nuclear) Material Information	
32	Existence of CBRN material in the facility
33	Location of CBRN material in the facility

There are 33 information items identified under 6 categories by analyzing the documents that Turkish Disaster and Emergency Management Directorate, and Civil Defense General Directorate use. All of these 33 information items identified by analyzing the documents were also identified by the interviews with the emergency response team members, and experts on the disaster management.

3.3 Combination of the Findings through Three Methods

The information items needed by first responders and emergency response teams to respond an emergency effectively, safely and timely were identified by using three methods; by literature survey, by face to face and semi-structured interviews with emergency response team members, and experts on the disaster management, and finally by analyzing the documents that Turkish Disaster and Emergency Management Directorate, and Civil Defense General Directorate use.

The results of the three methods were combined in one table (Table 3.5). Each information items' sources, that is from literature, interview or documents were specified in this table. Combination of all the identified information items by three methods will be investigated in the representation of them in BIM in chapter 5 of this study.

Table 3.5: The information items needed by first responders and emergency response teams and sources they are obtained

Information Items		Source		
Building Information		**Literature**	**Interview**	**Document**
1	Floor plans of the facility	x	x	x
2	Building material / Type of building (reinforced concrete, steel etc.)	x	x	x
3	Type of usage of the facility (school, single family etc.)	x	x	x
4	Number of floors / Style of the facility (one story, n story, sublevels etc.)	x	x	x
5	Condition of the facility (safe, unsafe etc.)	x	x	x
6	Type of damage of the facility (sideward, over and over, etc.)		x	x
7	Damage category of the facility (slight, moderate, heavy damage)		x	x
8	Main material of the roof	x		
9	Evacuation plans of the facility	x		
10	Location of access points in the facility	x		x
11	Roof access of the facility	x		
12	Location of stairwells in the facility	x	x	x
13	Location of elevators in the facility	x		
14	Location of security and fire control rooms in the facility	x		
15	Location of emergency exits in the facility	x		
16	Electrical installations and pipelines of the facility	x		
17	Simplified drawings of the facility	x	x	x
18	Is there a storage area in the facility: laboratory, pharmaceutical warehouse, paint factory, shop, medicine production office, LPG, gas tube, fuel tank, gunpowder store		x	
19	Heating system of the facility		x	
20	Plan of the structural frame of the facility		x	
21	Risk of the roof (condition of the roof)		x	
22	Electricity on/off		x	x
23	Water valve on/off		x	x

Table 3.5: The information items needed by first responders and emergency response teams and sources they are obtained (continued)

24	Gas valve on/off		x	x
25	Size of the facility		x	x
26	Location of the big nonstructural elements in the facility		x	x
27	Mechanical system status for water, power and ventilation	x		
28	The location of fire sensors and alarms in the facility	x		
29	Existence of electronic control system in the facility	x		
30	Opening directions of doors and windows	x		
31	Physical transitions between rooms, floors	x		
32	Camera locations in the facility	x		
33	Location of standpipes in the facility	x		
34	Location of water sources in the facility	x	x	
35	Facility systems information	x		
36	Location of the emergency in the facility	x		
37	Area the emergency exists are locked or unlocked	x		
38	Existence of underground storage tanks	x		
39	Location of all utility shutoff valves and disconnect switches (Location of main natural gas valve, main domestic water valve, main fire valve)	x	x	x
40	Location of buried electrical cables	x		
41	Location of buried pipelines	x		
42	Location of buried telecommunications cables	x		
43	The age of the facility	x	x	
Occupancy Information				
44	Abandoned, vacant	x		
45	Number of people living in the facility	x	x	x
46	Number of people in each floor		x	
47	Where can people be in the facility in the event of earthquake		x	x
48	Is there anyone in the facility who has knowledge of civil defense		x	

Table 3.5: The information items needed by first responders and emergency response teams and sources they are obtained (continued)

49	Time period when occupants stay in the facility	x		
50	Location and condition of the victims in the facility	x		
51	Name, age and health information of the occupants	x		
52	Number of young children in the facility	x		
53	Number of elderly people in the facility	x		
54	Number of handicapped in the facility	x	x	
55	Location of handicapped in the facility	x	x	
56	Anything special during the time of the earthquake in the facility (party, ceremony etc.)		x	
57	Information about the person that you are looking for		x	x
58	If the area is locked who has the keys	x		
59	Who has the knowledge of the area	x		
60	Who is available that understands the utility situation	x		
Disaster Information				
61	Emergency type	x		
62	Time of disaster	x	x	x
63	Magnitude	x	x	x
64	Duration	x	x	x
65	Season at the time emergency occurred		x	
66	Weather when emergency occurred		x	
67	Epicenter of the earthquake		x	x
68	Information about growth rate of fire	x	x	
Information about transportation to the scene				
69	Road to access to the incident	x	x	x
70	Type of road (asphalt, gravel etc.)	x		
71	Slope of road	x		
72	Seasonal condition of road	x		
73	Traffic information about the area	x	x	x
74	Building location (street etc.)	x	x	
75	Can on-site roads and bridges support the weights of emergency vehicles	x		
76	Helicopter landing area	x		

Table 3.5: The information items needed by first responders and emergency response teams and sources they are obtained (continued)

Information about Surrounding of the Facility				
77	Information about the surrounding of the facility (a layout plan of the neighborhood)	x		x
78	Risk level of surrounding buildings of the effected facility	x	x	x
79	Type of hazardous materials that the surrounding facilities have	x	x	x
80	The condition of the lamp posts		x	
81	Underground and over ground risks of surrounding of the facility		x	x
82	Location of the hydrants in the surrounding of the facility	x		
83	Location of water sources in the surrounding of the facility	x		
84	Location of potential potable water sources	x		
85	Any high voltage, or very high voltage power lines	x		
86	Existence of electric railways or trams (possible source of EMFs)	x		
87	Existence of radio, tv, radar, microwave transmitters, relays (possible source of EMFs)	x		
88	Existence of water courses, rivers or streams	x		
89	Existence of underground water courses beneath building or site	x		
90	Existence of buried petroleum pipelines beneath building or site	x		
91	Freight railways pass near building or site	x		
92	Trucks carrying hazardous substances routinely pass near building or site	x		
CBRN (Chemical, Biological, Radioactive and Nuclear) Material Information				
93	Existence of CBRN materials in the facility	x	x	x
94	Location of CBRN materials in the facility	x	x	x

Table 3.5: The information items needed by first responders and emergency response teams and sources they are obtained (continued)

95	Amount of the CBRN material in the facility		x	
96	Type (Ph level) of CBRN materials in the facility	x	x	
97	Who is in charge of that hazardous material	x		
TOTAL Information Items Identified		**75**	**50**	**33**

There are totally 97 information items needed by first responders and emergency response teams in order to understand the situation and to respond an emergency in an effective way.

By knowing these information items about the facility, its surrounding and the emergency environment, saving more lives can be achieved and therefore the harmful effects of the emergency on human lives and economy can be reduced.

After combining the information items identified from three sources in Table 3.5 we analyzed the table. As it can be seen in Table 3.5 all the information items identified through the documents were also identified through both the interviews and the literature survey. The analyses of 97 identified information items can be seen in Table 3.6.

Table 3.6: Number and the percentage of all the information items according to their identified sources.

Source	Number of Information Items Identified	Percentage of Information Items Identified
Only from literature	49	51%
Only from interviews	11	11%
Only from documents	0	0%
Both the literature, and interviews, as well as documents	18	19%
From multiple sources	19	20%
TOTAL	**97**	**100%**

As it is presented both in Table 3.5 and 3.6, 19% of the information items, marked with orange in Table 3.5, like floor plans of the facility, type of building such as reinforced concrete, steel, building material, type of usage of the facility such as school, single family etc. were all identified from both the literature and interviews, as well as from documents.

51% of the information items, marked with yellow in Table 3.5, like location of elevators, security and fire control rooms, emergency exits, fire sensors, and standpipes in the facility were determined only from the literature survey.

11% of the information items, marked with green in Table 3.7, like heating system of the facility, is there anyone in the facility who has knowledge of civil defense, anything special during the time of the earthquake in the facility like party or ceremony, the condition of the lamp posts were determined only from the interviews.

3.4. Validation of the Results

Validity defines the appropriateness, meaningfulness, correctness, and usefulness of the specific results of a survey or research and validation is the process of collecting and analyzing evidence to support results of the survey (Fraenkel and Wallen, 2006). In order to validate the identified information items from interviews two methods were used which are internal and external validation methods.

Firstly, internal validation; in this method to confirm the determined information items after the interviews, face validation approach was used. The prepared table "Determined Information Items Needed by Emergency Response Teams by Face to Face and Semi-Structured Interviews" was presented to the participants of the interviews. They were asked whether this table includes the right information items, or are there any more information items that they can add or are there any information items that should not be included in the table. The participants were met again to receive the results of the evaluation of the table a week later the table was presented to the participants. All the participants confirmed the prepared table.

External validation, which is the process taken for generalizing the results of a particular study to people or settings that go beyond the particular people or settings used in the study (Fraenkel and Wallen, 2006) was used to generalize the defined information items by asking another group. In order to achieve this, 3 participants from İstanbul Civil Defense General Directorate of the Search and Rescue Unit and İstanbul Provincial Disaster and Emergency Directorate (Table 3.1) were also interviewed. Same questions were asked to them (Appendix B). The aim of this approach is to compare the identified information items with the information items specified by a different group and so generalize the identified information items.

By comparing the information items between the first interview group and external validation group, similarities and differences were examined, thus the information items needed by first responders and emergency response teams were finalized. The information items identified by external validation group were also categorized under 6 topics and they were summarized in a table (Table 3.7).

Table 3.7: Identified information items needed by emergency response teams by external validation group

Building Information	
1	Floor plan of the facility
2	Number of floors
3	Type of usage of the facility (school, hospital, industrial place, etc.)
4	Is there a storage area in the facility: laboratory, pharmaceutical warehouse ,paint factory, shop, medicine production office, LPG, gas tube, fuel tank, gunpowder store
5	Heating system of the facility, natural gas or a heating stove
6	Type of building (reinforced concrete, etc.)
7	Building material
8	Electricity on/off
9	Water valve on/off
10	Gas valve on/off
11	Location of the main gas valve in the facility
12	Location of the main electric interrupter in the facility
13	Location of the main water valve in the facility
14	Simplified drawings of the facility

Table 3.7: Identified information items needed by emergency response teams by external validation group (continued)

15	Location of stairwells in the facility
16	Location of access points in the facility
17	Condition of the facility (safe/unsafe etc.)
Occupancy Information	
18	Number of people living in the facility
19	Where can people be in the facility in the event of earthquake
Disaster Information	
20	Time of earthquake
21	Season of earthquake occurred
22	Weather at the time of the disaster
23	Magnitude of the earthquake
24	Epicenter of the earthquake
25	Duration of the earthquake
26	Duration of the fire
27	Fire spread, and growth rate
28	Type of damage of the facility (sideward, over and over, etc.)
29	Damage category of the facility (slight, moderate, heavy damage)
Information about transportation to the scene	
30	Road to access the incident
31	Traffic information about the area
32	Building location (address, street etc.)
Information about Surrounding of the Facility	
33	Risk level of surrounding buildings of the effected facility
34	Type of materials that the surrounding buildings have
CBRN (Chemical, Biological, Radioactive and Nuclear Material) Information	
35	Existence of CBRN material in the facility
36	Location of CBRN material in the facility
37	Amount of the CBRN material in the facility
38	Type (Ph level) of the CBRN material in the facility (how to deactivate it, to give suggestions)

There are 38 information items identified by the interviews with external validation group. It is easily seen from the table that all the 38 information items are same with the ones identified by the interviews with first interview group.

The information items that are mentioned by first interview group but not by external validation group are;

1. Is there a water tank in the facility,
2. Plan of the structural frame of the facility,
3. Size of the facility,
4. Location of the big nonstructural elements in the facility,
5. Number of people in each floor,
6. Where can people be in the facility in the event of earthquake,
7. Is there anyone in the facility who has knowledge of civil defense,
8. Is there any handicapped people in the facility,
9. Anything special during the time of the earthquake in the facility (party, ceremony etc.),
10. Information about the person that you are looking for,
11. The condition of the lamp posts,
12. Underground and over ground risks of surrounding of the facility.

As it can be seen most of the information items that are not mentioned by external validation group are under occupancy information category. External validation group only mentioned the number of occupants in the facilities and their possible locations within the facility. However to give detailed information about the occupants of the facility can accelerate the response operations after an earthquake and more effective response operations can be achieved. Therefore, it is finalized that the listed information items needed by emergency response teams determined by face to face and semi-structured interviews in Table 3.3 are valid and can be generalized.

In this chapter the information items needed by first responders and emergency response teams are identified and finalized. In addition to information items like building structure, building type, damage condition, hazardous materials that the facility has, number of occupants in the facility, first responders and emergency response teams need to identify vulnerable locations and potential threats and building contents that can trigger threats in the facility following an earthquake. By identifying the vulnerable locations, potential threats and building contents in the facility, speeding up the guidance of occupants to safe exits and directing of first responders, emergency response teams to vulnerable locations within the facility can be achieved. Therefore, vulnerability assessment information in a multi hazard case is also studied in this thesis study. Vulnerability assessment in a multi hazard emergency case is discussed in Chapter 4 of this study.

CHAPTER 4

VULNERABILITY ASSESSMENT

In order to reduce the harmful effects of the earthquake and to prevent further hazards both on human lives and economy it is very essential to quickly identify potential threats upon earthquake, and vulnerable contents that can trigger these threats in a facility. Vulnerability assessment is a term used in many fields, such as finance, engineering, computer science, emergency management and public policy. Vulnerability assessment in emergency management is assessment of a list of types of potential emergencies, list of weaknesses in facility, and its impact to human, property and business (Lewis and Payant, 2003), and in this thesis study vulnerability assessment after a building earthquake emergency is studied to find the potential threats and vulnerable locations, contents within a facility and react accordingly to guide the occupants of the facility to safe exits and to reduce the harmful effects of earthquake both on human lives and facility itself.

In order to do vulnerability assessment in facilities the terms threat and content in a facility should be defined. Content and threat in a facility in a case of building emergency were defined in Leite et al. (2008), and in Leite (2009). According to Leite (2009) contents are entities in a facility which are needed for the building's indented functioning, as well as activities carried out in the facility. Examples of contents include freezer, transformer, server computer and also a laptop computer might be described as a content that needs power to function and cannot come into contact with water and Leite (2009) defined threats as events that can be the potential loss of life, property and disruption of service in a facility like water leakage and power outage. In short threats are the events that have harmful effects on functioning of above mentioned facility contents However in this study the contents are different from the ones that Leite (2009) has investigated and threats that are identified in this study have similarities with the ones Leite has defined. For example water leakage within the facility is also identified as threat in this study. Threat is also defined as potential loss of life, property and disruption of service in a facility with the effect of uncontrolled state of building content. In this research study focused contents are the building entities or systems that can trigger a threat and provides a threat to be induced. Building content examples that can be identified after an earthquake by first responders and emergency response teams to reduce the harmful effects of earthquake are hazardous materials within the facility, explosive materials, gas distribution system, and electric distribution system. Threat examples that are triggered by those contents and have harmful impacts both on human lives and property and therefore should be known by the first responders and emergency response teams are gas leakage, and water leakage, failures in electric distribution system, explosion of hazardous materials, and leakage of chemical materials. Identifying these building contents and possible potential threats that can be triggered by these contents to support vulnerability assessment after an earthquake are the aim of this thesis study.

4.1 Research Methodology

In order to guide occupants to safe exits during evacuation and to guide emergency response teams to vulnerable locations of the facility to prevent further hazards on human lives and on facility, first responders and emergency response teams need to quickly identify threats upon earthquake and contents in a facility that can trigger these threats causing high impact hazards after an earthquake.

In order to achieve this first of all the categories of the threats in a facility upon earthquake were identified. Moreover, categories of contents that can trigger these threats were then identified.

In order to define the categories of contents and the categories of threats in a facility during a multi hazard emergency two activities listed below were performed:

1. Research studies on performing vulnerability assessment; identifying which areas to protect in facilities during emergency and identifying contents of facilities which are vulnerable to potential threats in emergencies were examined.

2. Face to face and semi-structured interviews were conducted with same group of experts that participated in the study detailed in Chapter 3. The aim is to identify general list of possible potential threats and the contents that can trigger these threats upon earthquake in different types of facilities (e.g. hospitals, schools, residential buildings, industrial facilities).

4.2 Overall Assumptions and Domain of the Proposed Research

The general scenario thought in this study is a multi-hazard emergency case, which includes secondary disasters such as fire, explosion initiated by an earthquake. Therefore, to prevent the secondary disasters upon earthquake and to reduce the impacts of these emergencies to building, its occupants and response teams, the threats and the contents that can trigger these threats within the facilities should be identified.

The triggering activities following an earthquake are represented in a figure by giving examples of building content, threat and consequence (secondary disaster upon earthquake e.g. fire, explosion) (Figure 4.1 and Figure 4.2). Secondary disasters that can occur after an earthquake is defined as a consequence in this thesis study. Examples of consequences upon earthquakes in facilities are fires, explosions, and floods (All of them are listed in Table 4.1).

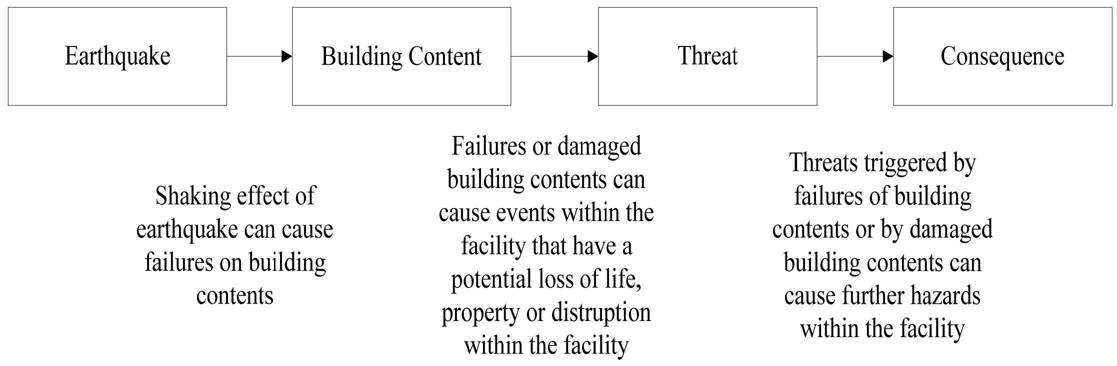

Figure 4.1: Vulnerability assessment terminology used through this study

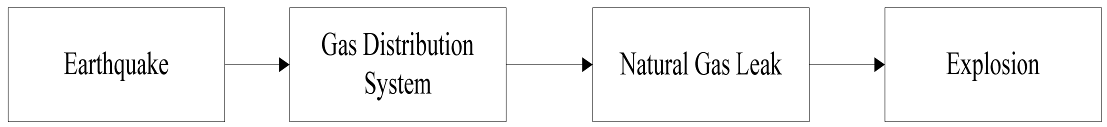

Figure 4.2: An example of vulnerability assessment terminology (*content, threat* and *consequence*)

The arrows in Figure 4.1 represent the steps of actions initiated by earthquake to the end of occurrence of secondary disaster during a multi-hazard emergency case. Earthquake is the natural disaster that this thesis study is based on and earthquake followed disasters such as fires, explosions are also studied in this study. Figure 4.1 and 4.2 is generated by the data gained from the interviews that were conducted with the emergency response teams, and experts on the disaster management. The participants of the interviews mentioned that shaking effect of the earthquake can cause failures in building content (e. g, gas distribution system of the facility). That is to say, failures/breaks in the gas distribution system of the facility can cause leakage of the natural gas, which is noted as threat in Figure 4.2. Natural gas released from the system can cause explosion or fire (i.e., consequence) in the facility upon earthquake which can have more harmful effects on the facility and its occupants. Figure 4.2 represents just an example of content-threat and consequence relationship in a facility after an earthquake. Research studies were examined and face to face semi-structured interviews were conducted with the emergency response teams, and experts on the disaster management to identify the possible potential threats and the contents that are vulnerable to these threats upon earthquake in a facility. After identifying the potential threats and the contents that are vulnerable to these threats upon earthquake, threat-content table was prepared.

4.3 Threat-Content Table for Vulnerability Assessment

Threats and contents that can trigger these threats upon earthquake in a facility were identified by examining the prior research studies and by interviews with the emergency response teams and experts on the disaster management. The determined contents and the threats with the consequences (secondary disasters and impacts of the threats to building and its occupants) were summarized in a Threat-Content Table (Table 4.1).

In this thesis, the secondary disasters which can occur in facilities were searched through the literature and by interviews. Much of the studies in literature mentioned secondary disasters occurred upon earthquakes as tsunami, landslides, ground subsidence, fires, explosions, floods, dam failures, road failures, bridge failures, harbor failures, water and wastewater network failures, natural gas network failures, sanitary sewerage failures. However, in this thesis study secondary disasters in facilities (e.g. hospitals, schools, residential buildings, and industrial facilities) are studied. Moreover, the secondary disasters that can be occurred within a facility are listed in the prepared table.

During interviews, the participants were asked what other hazards can be triggered by earthquake and what are the examples of building contents, material or equipments that can cause secondary disasters in facilities? The questions asked for identifying content and threat types were for all of the building types (e.g. hospitals, schools, residential buildings, industrial facilities) (Appendix B). Consequences in facilities upon earthquake with the impact of threats were identified as fires, floods and explosions, smoke, suffocation, genetic diseases, skin burns and injuries by interviews.

All the participants of the interviews (14 participants as mentioned at section 3.1.2) responded the question “what other hazards can be triggered by earthquake” as fires, floods and explosions in the facility. After defining consequences upon earthquake the participants were asked what are the threats that can be the potential loss of life, property and disruption of service in a facility, and what are the contents that can trigger these threats and can create high impact hazards to building and its occupants. The identified threats and contents are presented in a table with the consequences (Table 4.1).

Table 4.1: Threat-Content-Consequence table for vulnerability assessment

Threat	Content	Consequence
LPG tube explosion	LPG tube	Explosion, Fire, Smoke, Suffocation
Overturning of the heater with the effect of earthquake shake	Heating stove	Fire
Natural gas leak	Gas distribution system	Explosion, Fire, Smoke, Suffocation
Electricity leak	Electricity distribution line	Fire, Explosion, Smoke
Water leak	Water distribution system	Flood
	Water tank	
	Roof-mounted water tank	
Potable water leak	Water distribution system	Flood
Release of explosive materials	Dynamite	Explosion, Fire, Smoke, Suffocation
	Bullet	
	Gun Powder	
	Firework	
	Sparkler	
	Ammonium Nitrate-Fuel Oil mixture	
Release of pressurized gases	LPG	Explosion, Fire, Smoke, Suffocation
	Acetylene	
	Azote	
	Argon	
	Hydrogen	
	Oxygen	
	Hydrogen Fluoride	

Table 4.1: Threat-Content-Consequence table for vulnerability assessment (continued)

Release of pressurized gases	Phosgene	Explosion, Fire, Smoke, Suffocation
	Formic Acid	
	Perfume	
	Chlorine	
Liquid Chemical Substance Spill	Gasoline	Explosion, Fire, Smoke, Suffocation
	Benzole	
	Fuel Oil Tank	
	Toluene	
	Ethyl Acetate	
	Butanol	
	Gasoil	
	Diesel Oil	
	Adhesive	
	Tar	
	Paint	
	Solvent	
	Cleaning chemicals	
	Lubricating Oil	
Release of Solid Chemical Substance	Red Phosphorus	Explosion, Fire, Smoke, Suffocation
	White Phosphorus	
	Magnesium	
	Proksilin plastics	
	Sulphur	
	Wood dust	
	Coal dust	
	Flour	
	Celluloid	
	Aluminum Powder	
	Sodium-Potassium-Calcium-Phosphorus compounds	
	Cleaning materials	
	Naphthalene	

Table 4.1: Threat-Content-Consequence table for vulnerability assessment (continued)

Oxidizing material Spill	Hydrogen peroxide	Explosion, Fire, Smoke, Suffocation
	Perchloric acid	
	Sodium-Potassium metal nitrates	
	Permanganate	
	Chlorates	
	Per chlorates	
	Calcium carbonate	
	Chromic acid	
	Ammonium nitrate	
	Organic peroxides	
Corrosive Chemical Liquid Spill	Hydrochloric acid	Skin burns, Suffocation
	Sulfuric acid	
	Nitric acid	
	Sodium Hydroxide	
	Potassium hydroxide	
	Sodium hypochlorite	
Release of Carcinogenic Material	Asbestos	Genetic diseases
Biological spill	Virus	Genetic diseases
	Laboratory research instruments	
	Pesticide	
	Bacteria	
Radiological spill	X-ray machine	Genetic diseases
	Conductor	
	Lithotripter	
	Cobalt	
	Iridium	
	Technetium	
	Cesium	
	Americium	
	Iodine	
Loss of steam	Heating system	Skin burns
	Water heating devices	
Loss of hot water	Heating system	Skin burns
	Water heating devices	

Table 4.1: Threat-Content-Consequence table for vulnerability assessment (continued)

Temperature rise in the facility	Heating system	Fire, Skin burns
	Bakery	
	Boiler room	
Broken glasses	Windows	Injuries
	Doors	
	Roof	
Overturning or falling	Furniture	Injuries, Blockage
	Infill Wall	

As can be seen in Table 4.1 there are 20 threat-content relationships that are vulnerable and should be determined in order to reduce the harmful effects of the earthquake. The description of each threat is given below:

LPG tubes in facilities and its explosion; during the interviews participants noted the importance of identification of areas in facilities where LPG tubes can be; those areas are generally kitchens and bathrooms. They noted this is essential because LPG tubes explode or they cause fires following the shaking effect of earthquakes. Also in the industrial zones of the urban cities, facilities have industrial tubes. These tubes are huge tubes of 50 kg. Moreover, during response activities to collapsed buildings, emergency response teams pay attention to the possible locations of the LPG tubes while working with spark producing machines in order not to cause explosions and fires.

Heating stoves in facilities and its overturning with the effect of earthquake shake. Heating stoves in facilities whose heating system are not natural gas are very important contents to be determined after earthquakes during the winter. As mentioned above, fires were triggered by earthquakes after Düzce Earthquake, Gediz Earthquake, Sakarya Earthquake, and Bolu Earthquake. In these cases earthquakes occurred in winter and heating system of the facilities were stove. Fires occurred due to overturning of the stoves in the facilities. Therefore it is very essential to determine the location of the heating stoves in facilities and to take appropriate actions in order not to cause further hazards upon earthquake.

Both participants and studies in literature noted failures in gas distribution system, electricity distribution system and water distribution system occur after earthquakes in facilities. These failures cause fires, explosions and floods in the facility. All of the 14 participants of the interviews highlighted the importance of checking the electricity, gas and water valves on/off situation in the facility in order to prevent the dangerous situation that can be caused by electricity, gas and water leakage.

Emergency response teams should be aware of the gas distribution system, electricity distribution system and water distribution system not only to respond to situation efficiently and effectively but also in order not to put their own lives at risk. Emergency response team members died during response to World Trade Center - New York City 9-11 Terrorist Attacks (421 first responders) (NIST, 2005) and also during response to Mexico City Earthquake (100 responders) (SSAAK, 2008) because of the additional threatening hazards.

Participants also noted that broken electrical wires in the facility or at the incident area cause electric shocks on occupants or on people at the area therefore people can die not because of the earthquake but because of the broken electrical wires. Therefore broken electrical wires should be determined and appropriate precautions should be taken.

Release of explosive materials, pressurized gases, solid chemical substance, carcinogenic material and spill of liquid chemical substance, oxidizing material, corrosive chemical liquid are other threats upon earthquake. Contents in facilities that are vulnerable these threats were listed in Table 4.1. Emergency response teams immediately and urgently determine these contents in facilities to reduce the harmful effects of these substances to building, its occupants and emergency response teams.

Identification of these contents is also essential for emergency responders for the situation awareness which helps to increase responder safety and improve scene management (Betts et al., 2005).

Biological spills are very important to human lives because bacteria or organisms spreading out of the broken tubes of laboratory research instruments cause new and deadly infectious diseases. Responders should be aware of the biological threats, contents and take response with appropriate clothing and equipment.

A new disease called “blue mold” appeared in France after a kind of scientific test bacteria tube was broken and spread out accidentally at the upper floor of the building. The location of the biological materials and their safety after earthquakes in the facilities are very important.

Responders noted that x-ray machines, lithotripters in hospitals and conductors at the roof of the facilities are the contents of radiological threats after earthquakes. Special response activities should be performed in case of radiological threats. Identification of radiological contents should be performed immediately and urgently by emergency response teams.

Loss of steam, loss of hot water, and temperature rise in the facility can cause hazards on both occupants and emergency response teams. Emergency response teams encounter difficulties in such cases which prevents them to response the emergency.

Broken glasses take place with the shaking effect of earthquake on doors, windows and also on roof. Occupants and emergency response teams should be aware of the glassed doors, windows and roofs even if they are not broken. Because, they can be dangerous in a new earthquake after shock. Glassed roofs are especially very dangerous to occupants and emergency response teams.

During the interviews, emergency response teams and experts on the disaster management emphasized on the threat of earthquake after shock. They noted that this was the most important threat upon earthquake. Because facilities that are not destroyed or damaged during the earthquake can collapse aftershock. Therefore emergency response teams should be very careful while responding the facility even if the facility has no destroys.

It is also important to identify the locations of the big and heavy furniture and infill walls within the facility. Because, overturning or falling of these objects with the shaking effect of the earthquake can cause injuries both on occupants and emergency response teams. Moreover, occupants can be blocked in the destroyed facility because of these objects.

These are the potential threats and the contents that can trigger these threats upon an earthquake. Emergency response teams should be aware of these threats and contents to respond the emergency effectively and reduce the effects of the emergency to occupants and to facility itself.

4.4 Validation of the Results

As it is mention at section 4.1 to define the categories of contents and the categories of threats in a facility during a multi hazard emergency two activities were performed: Prior research studies on performing vulnerability assessment, in buildings during and right after emergency were examined and face to face and semi-structured interviews were conducted with emergency response team members and experts on disaster management. Through these two methods identification of general list of possible potential threats and the contents that can trigger these threats upon earthquake in different types of facilities (e.g. hospitals, schools, residential buildings, industrial facilities) were finalized in this study. After preparing the threat-content-consequence table internal validation of the results are tested by using face validation approach. In order to achieve this, the identified category of threats, category of contents and consequences table was presented to the participants of the interviews. They were asked whether this table includes the right categories of threat-content-consequence, the relationship between them is right or wrong, and are there any missing data that they can add or are there any information that should not be included in the table. This time the prepared table is presented to the participants via e-mail. All the participants were agree on the prepared table. Therefore it is finalized that the prepared list of vulnerability information that first responders and emergency response teams should be aware of the possible potential threats within a facility upon earthquake and the building contents that can trigger these threats for all the building types are valid and can be generalized. First responders and emergency response teams when responding to an earthquake emergency should be aware of if the building has the listed contents in Table 4.1 or not to prevent further hazards on human lives and on the property.

Vulnerability information needed by first responders and emergency response teams right after earthquakes in facilities is finalized and in the next chapter of this study representation of this information in BIM is investigated in detail.

CHAPTER 5

REPRESENTATION OF IDENTIFIED INFORMATION ITEMS AND VULNERABILITY ASSESSMENT INFORMATION IN BUILDING INFORMATION MODEL

During earthquake response operations, first responders and emergency response teams are often faced with unfamiliar and chaos environments and stressful situations which people in the area have shocked and the areas are destroyed (Son et al., 2007; Ergen and Seyis, 2008; Leite et al., 2008). Emergency response operations under such adverse conditions has often been inadequate (McKinsey, 2002; NCSEA, 2003).

When first responders and emergency response teams arrive at the incident area, they need some internal information about the facility. In addition to internal information about facilities, such as building structure, building type, floor plan, occupant information, damage condition, they also need to identify vulnerable locations in the facility that is building contents and potential threats that can be triggered by failures or destruction in the building contents with the effect of earthquake in order to guide occupants to safe exits and prevent further hazards within the facility following an earthquake.

Such information should be accurate and accessed timely in order to speed up the guidance of occupants in a facility that is under the effect of multi-hazards to safe exits and speed up the decision process of first responders and emergency response teams to identify vulnerable locations in that facility.

In Chapter 3 the information items required by first responders and emergency response teams during a multi hazard emergency and in Chapter 4 threats and the contents that can trigger these threats upon earthquake in a facility were identified for effective response operations and also for rapid and safe evacuation of a damaged facility.

With the aim of guiding the occupants to safe exits rapidly from the damaged facility, by pinpointing vulnerable locations the identified information items and vulnerability assessment information needed by first responders and emergency response teams will be displayed by a model based system which is Building Information Modeling (BIM). Facility under consideration will also include a limited number of sensors to give information about the real time information of the facility. Local monitoring approach is achieved by these sensors put in the facility. Moreover, the model based guidance and vulnerability assessment system (BIM) for facilities under the threat of multi hazard emergencies will also be integrated with the local monitoring system. The information items needed by first responders and emergency response teams to guide evacuation and help first responders and emergency response teams in rescue operations in a facility under the threat of multi hazard emergencies by pinpointing vulnerable locations will be presented by this integrated model based system (BIM). The exploration of integration of the identified information items and vulnerability assessment information needed by first responders and emergency response teams in this mentioned model based system will be explained in detail throughout this chapter of this thesis study.

At this point the question comes what is BIM? BIM has attracted and gained acceptance in the architecture, engineering, construction and facility management (AEC/FM) industries for many applications, such as constructability analyses, design checks, commissioning, life cycle assessment, and facility management in the last decades. The building information model represents digitally used and shared information and integrated semantic concepts in all the stages of the building from design to building maintenance/repair.

BIM is designed to facilitate the information sharing among the stakeholders in different phases for better decision (NBIMS, 2007). Needed information to analyze the different stages of the project for example, building energy simulation at the design stage can be added to the building information models. Moreover, needed information to analyze operations for example, quantity take off operations at the tendering stage can be added to the building information models. Likewise BIM provides and includes building related information items for example, building type, building material, building occupancy, building hazardous content, and so on. Table 5.1 presents some more definitions of BIM and their sources in the literature.

Table 5.1: Definitions of BIM in the literature

Source	Definition
NIBS - Facility Information Council	BIM is "A computable representation of the physical and functional characteristics of a facility and its related project/life-cycle information using open industry standards to inform business decision making for realizing better value."
AEC Infosystems	BIM is "Information use, reuse, and exchange with integrated 3D-2D model-based technology, of which electronic documents are just a single component."
ArchiCAD	BIM is "A single repository including both graphical documents - drawings - and non-graphical documents - specification, schedules, and other data."
Bentley	BIM is "A modeling of both graphical and non graphical aspect of the entire Building Life cycle in a federated database management system."
AutoDesk	BIM is "A building design and documentation methodology characterized by the creation and use of coordinated, internally consistent computable information about a building project in design and construction."

Information models in the construction industry are usually developed by adopting ISO 10303 (STandard for Exchange of Product data- STEP) technologies. STEP, is a comprehensive ISO standard (ISO 10303) that describes how to represent and exchange digital product information. Important efforts in this area include COMBINE, STEP Part225, BCCM RATAS, EDM, SME, CIMSteel/CIS2 and IFC (Eastman, 1999; Zamanian and Pittman, 1999; Isikdag et al., 2007). As a major data standard for BIM, the IFC (Industry Foundation Classes) standard published by the IAI (International Alliance for Interoperability) (Bazjanac and Crawley, 1997) plays a very important role in the process, since it is a standard for sharing data throughout the project lifecycle, across disciplines and across technical applications in the AEC/FM industry (http://www.buildingsmart.com/bim). The IFC effort closely parallels another collaborative representation effort known as STEP (STandard for the Exchange of Product model data) (AECbytes Feature, 2004). IFC uses same modeling language with STEP which is EXPRESS for developing and defining the model (AECbytes Feature, 2004). However, most contemporary commercial software applications use some form of UML (Unified Modeling Language) for developing their data models (AECbytes Feature, 2004). In this study the generated data models for representing the identified information items and vulnerability information will also be in the form of UML.

The IFC standard is a data standard covering currently nine domains namely architecture, HVAC, electrical, construction management, facility management, building controls, plumbing-fire protection, structural elements, structural analysis. IFC Standard denotes the data structure based on object-oriented representation and 3D geometric model (Zhiliang et al., 2010). IFC represent an open specification for Building Information Modeling (BIM) data that is exchanged and shared among the various participants in a building construction or facility management project (http://www.iai-tech.org/ifc/IFC2x4/rc2/html/index.htm). IFC's are the international open BIM standard (http://www.iai-tech.org/ifc/IFC2x4/rc2/html/index.htm).

In this chapter the application of the IFC standard in the identified needed information items and vulnerability assessment data by first responders and emergency response teams was studied in order to respond the situation quickly, effectively and safely after an earthquake.

5.1 A Short Overview of the IFC Standard

The IFC model represents not just tangible building components such as walls, doors, beams, ceilings, furniture, etc., but also more abstract concepts such as schedules, activities, spaces, organization, construction costs, etc. in the form of entities. All entities in IFC have a number of properties such as name, geometry, ID and relationships (AECbytes Feature, 2004). The actual development effort of the IFC model is undertaken by the Model Support Group of the IAI (AECbytes Feature, 2004). The development work has been underway for several years, with regular releases of new versions and the first version of the IFC, version 1.0, was released in 1997 (AECbytes Feature, 2004). Each subsequent version adds capabilities to represent more entities and more relationships related to a building's lifecycle (AECbytes Feature, 2004).

Currently, the official version of the IFC standard is the IFC2x4 final version, which covers nine domains, including architecture, HVAC, electrical, construction management, facility management, building controls, plumbing-fire protection, structural elements, and structural analysis. In this thesis study, the discussion on the IFC standard will be based on this version.

The IFC standard owns a hierarchical and modular framework, which is divided into four bottom-up layers, namely resource layer, core layer, interoperability layer and domain layer, and each layer consists of a number of modules which further contain various entities, types, enumerations, rules and functions. The layering system is designed in such a way that an entity at a given level can only be related to or reference an entity at the same level or at a lower level, but not an entity at a higher level (AECbytes Feature, 2004).

Entity represents the abstraction of objects which have the same properties, and is the information agent to describe the information of building and surrounding components when the IFC standard is used. Types, enumeration, rule and functions are defined to express the properties of entities and to provide additional constraints and methods for the properties.

The latest release of the IFC, IFC2x4 has a total of 801 entity definitions, which means that it represents 801 different kinds of components or concepts. Since IFC has this much entities and a huge hierarchy, it is difficult to make full use of all of them when developing BIM based application software, so it is necessary to establish an information model based on the entities needed to be presented (Zhiliang et al., 2010). As mentioned above, IFC standard represents the entities by using an object-oriented approach and entities in IFC correspond to objects (Zhiliang et al., 2010).

It must be pointed out by using the inheritance relationship the work of redefining the content inherited from the super entity is reduced. Correspondingly, the description of both the entities and their inheritance relationship is required in the information model to give a full picture of the use of the related entities.

In order to generate the information model the entities that will be needed in BIM were selected according to the identified needed information items and vulnerability assessment information by first responders and emergency response teams. Then, every identified entity's Express-g diagrams were converted to Unified Modeling Language (UML) format and required attributes and the relations were presented on this diagram.

Express is a language developed within ISO-STEP community for representing data models aiming to represent a product model in an implementation independent manner. By Express a schema which includes definition of things (entities, types, functions, and procedures), relationship between things, and rules on relationships can be developed. Express G is a "block structured" language begins with the declaration of an entity, function, procedure rule or schema. IFC uses EXPRESS for developing and defining the model as STEP (AECbytes Feature, 2004).

UML is the standardized language of object-oriented analysis and design methods and it is used to define attributes and methods within objects, to describe relationship types, and to annotate the various constructs (Tah and Carr, 2000). UML is the standard language for visualizing, specifying, constructing, and documenting the artifacts of a software intensive system. Different diagrams is used within UML such as use case diagrams, class diagrams, interaction diagrams, state diagrams, activity diagrams, deployment diagrams, component diagrams.

In this study entity's Express-g diagrams of IFC are converted to Unified Modeling Language (UML) format and required attributes and the relations were presented on this diagram. Data models are developed in UML class diagram. A class diagram describes the types of objects in the system and various kinds of static relationships exist among them which are very suitable to describe the identified information items. UML modeling elements in class diagrams are classes, their structures, behaviors, association, dependency and inheritance relationships, multiplicity indicators and finally role names.

5.2 Representation of the Identified Information Items in IFC

In this step of this thesis study the identified information items' expression by using IFC standard was checked. As explained in the previous sections in chapter 3 the information items required by emergency response teams during a multi hazard emergency were identified under 6 categories: 1. Building information, 2. Occupancy information, 3. Disaster information, 4. Information about transportation to the scene, 5. Information about surrounding of the facility, 6. CBRN (Chemical, Biological, Radioactive and Nuclear) material information. In order to start the investigation of the IFC expression of these identified information items, firstly the selection of these categories must be done. Because, BIM cannot represent the information items under "disaster information", and "information about transportation to the scene" categories. The information items under these categories are needed by emergency response teams in order to understand the situation and also to arrive at the scene as soon as possible.. However those information (information about transportation to the scene) is already gathered by emergency response teams before they arrive at the related building area and also they are not related about the building itself (disaster information). Therefore in this section the other four categories' IFC expressions were investigated (1.Building information, 2.Occupancy information, 3.Information about surrounding of the facility, 4.CBRN (Chemical, Biological, Radioactive and Nuclear) material information)

In detail every determined information item under these four category was searched by looking into the Industry Foundation Classes release 2x4 (IFC2x4) (release candidate1 rc1) and Table 5.2 expression of the information item by IFC was prepared.

Table 5.2: Identified information items and representation of them in IFC

Building Information		**IFC Standard**
1	Floor plans of the facility	IfcBuilding, IfcBuildingStorey, Pset_BuildingStoreyCommon, IfcSpace, IfcSlab
2	Type of building / Building Material (reinforced concrete, steel etc.)	IfcBuildingElement, IfcMaterial
3	Type of usage of the facility (school, single family etc.)	IfcBuilding, Pset_BuildingUse
4	Number of floors, Style of the facility (one story, n story, sublevels etc.)	IfcBuildingStorey, IfcElementQuantity
5	Condition of the facility (safe, unsafe etc.)	-
6	Type of damage of the facility (sideward, over and over, etc.)	-
7	Damage category of the facility (slight, moderate, heavy damage)	-
8	Main material of the roof	IfcRoof, IfcMaterial
9	Evacuation plans of the facility	IfcBuildingStorey, IfcDoor, IfcWindow, IfcStair, IfcTransportElement
10	Location of access points in the facility	IfcBuildingStorey, IfcDoor, IfcWindow
11	Roof access of the facility	IfcRoof, IfcStair, IfcTransportElemet, IfcDoor
12	Location of stairwells in the facility	IfcStair, IfcLocalPlacement
13	Location of elevators in the facility	IfcTransportElement, IfcLocal Placement
14	Location of security and fire control rooms in the facility	IfcSpatialZone, IfcFireSuppressionTerminal, IfcLocalPlacement
15	Location of emergency exits in the facility	IfcLocal Placement, IfcDoor, IfcWindow

Table 5.2: Identified information items and representation of them in IFC (continued)

16	Electrical installations and pipelines of the facility	IfcDistributionSystem, Pset_DistributionSystemTypeElectrical, IfcDistributionFlowElement, IfcDistributionChamberElement, IfcElectricDistributionBoard, IfcElectricFlowStorageDevice, IfcDistributionPort
17	Simplified drawings of the facility	IfcBuilding, IfcBuildingStorey, IfcSpace, IfcStair, IfcDoor, IfcColumn, IfcBeam, IfcWall
18	Is there a storage area in the facility: laboratory, pharmaceutical warehouse, paint factory, shop, medicine production office, LPG, gas tube, fuel tank, gunpowder store	IfcTank, IfcSpatialZone, IfcFlowStorageDevice
19	Heating system of the facility	IfcSapaceHeater
20	Plan of the structural frame of the facility	IfcBuilding, IfcStorey, IfcColumn, IfcBeam, IfcCurtainWall
21	Risk of the roof (condition of the roof)	-
22	Electricity on/off	IfcSwitchingDevice
23	Water valve on/off	IfcValve
24	Gas valve on/off	IfcValve
25	Size of the facility	IfcBuilding, Pset_BuildingCommon
26	Location of the big nonstructural elements in the facility	IfcFurniture, IfcLocalPlacement
27	Mechanical system status for water, power and ventilation	IfcDistributionFlowElement, IfcBuildingSystem
28	The location of fire sensors and alarms in the facility	IfcLocal Placement, IfcAlarm, IfcSensor
29	Existence of electronic control system in the facility	IfcDistributionControlElement, IfcController
30	Opening directions of doors and windows	IfcDoor, IfcWindow
31	Physical transitions between rooms, floors	IfcDoor, IfcWindow, IfcStair, IfcTransportElement
32	Camera locations in the facility	IfcController
33	Location of standpipes in the facility	IfcFireSuppressionTerminal
34	Location of water sources in the facility	IfcBuilding, Pset_BuildingWaterStorage, IfcFireSuppression
35	Facility systems information	IfcBuildingSystem, IfcDistributionSystem

Table 5.2: Identified information items and representation of them in IFC (continued)

36	Location of the emergency in the facility	-
37	Emergency exists is locked or unlocked	-
38	Location of all utility shutoff valves and disconnect switches (Location of main natural gas valve, main domestic water valve, main fire valve)	IfcFlowController, IfcValve, IfcSwitchingDevice, IfcLocalPlacement
39	Existence of underground storage tanks	IfcFlowStorageDevice, IfcTank
40	Location of buried electrical cables	-
41	Location of buried pipelines	-
42	Location of buried telecommunications cables	-
43	The age of the facility	Pset_BuildingCommon
Occupancy Information		-
44	Abandoned, vacant	IfcOccupant
45	Number of people living in the facility	IfcOccupant, IfcBuilding
46	Number of people in each floor	IfcOccupant, IfcBuildingStorey
47	Where can people be in the facility in the event of earthquake	-
48	Is there anyone in the facility who has knowledge of civil defense	-
49	Time period when occupants stay in the facility	
50	Location and condition of the victims in the facility	IfcOccupant, IfcSpatialStructureElement
51	Name, age and health information of the occupants	-
52	Number of young children in the facility	-
53	Number of elderly people in the facility	-
54	Number of handicapped in the facility	-
55	Location of handicapped in the facility	-
56	Anything special during the time of the earthquake in the facility (party, ceremony etc.)	-
57	Information about the person that you are looking for	-
58	Who is available that understands the utility situation	IfcActorRole
59	If the emergency exits are locked who has the keys	IfcActorRole
60	Who has the knowledge of the area	IfcActorRole
Information about Surrounding of the Facility		-
61	Information about the surrounding of the facility (a layout plan of the neighborhood)	IfcExternalSpatialElement

Table 5.2: Identified information items and representation of them in IFC (continued)

62	Risk level of surrounding buildings of the effected facility	-
63	Type of hazardous materials that the surrounding facilities have	-
64	The condition of the lamp posts	-
65	Underground and over ground risks of surrounding of the facility	-
66	Location of the hydrants in the surrounding of the facility	-
67	Location of water sources in the surrounding of the facility	-
68	Location of potential potable water sources	-
69	Any high voltage, or very high voltage power lines	-
70	Existence of electric railways or trams (possible source of EMFs (Electro Magnetic Field)	-
71	Existence of radio, TV, radar, microwave transmitters, relays (possible source of EMFs (Electro Magnetic Field)	-
72	Existence of water courses, rivers or streams	-
73	Existence of underground water courses beneath building or site	-
74	Existence of buried petroleum pipelines beneath building or site	-
75	Freight railways pass near building or site	-
76	Trucks carrying hazardous substances routinely pass near building or site	-
CBRN (Chemical, Biological, Radioactive and Nuclear) Material Information		-
77	Existence of CBRN materials in the facility	-
78	Location of CBRN materials in the facility	-
79	Amount of the CBRN material in the facility	-
80	Type (Ph level) of CBRN materials in the facility	-
81	Who is in charge of that hazardous material	IfcActor

The identified information items and their representation in IFC were presented in Table 5.2. As it can be seen from Table 5.2, most of the building related information items can be expressed by IFC. Information about surrounding of the facility, CBRN (Chemical, Biological, Radioactive and Nuclear) material information cannot be expressed by IFC because IFC represents a specification for Building Information Modeling (BIM) data in a building construction or facility management project. However, these not expressed information items by IFC will also be included in the generated data model by assigning them appropriate classes and appropriate relationships.

5.3 Developing Data Model to Represent the Information Items Needed by First Responders and Emergency Response Teams

After examining the information items and their expression by IFC a data model was prepared by converting every determined entity's Express-g diagrams to Unified Modeling Language (UML) format and required attributes and the relations were presented on this diagram. Data model was prepared for the four categories of information items; building information, occupancy information, information about surrounding of the facility, CBRN (Chemical, Biological, Radioactive and Nuclear) material information, and also for vulnerability assessment data.

5.3.1 Representing Building Information and Extending IFC Data Model

For developing a data model for building related information items this category was analyzed under two sub category; building shell information which includes number of floors, building material, location of stairs, elevators, column, beam, slab information, and building distribution system information which includes building system information, alarm, sensor information mechanical system information for electric, gas and water, heating system information.

5.3.1.1 Representing Building Shell Information and Extending IFC Data Model

Building shell information items and their expression by IFC were presented in Table 5.2. All of the building shell information items; floor plans of the facility, type of usage of the facility (school, single family etc.), number of floors, style of the facility (one story, n story, sublevels etc.), type of building / building material (reinforced concrete, steel etc.), main material of the roof, location of stairwells in the facility, location of elevators in the facility, location of access points in the facility, evacuation plans of the facility, roof access of the facility can be expressed by IFC.

Related entities in IFC to express these information items were identified with the corresponding relationships. Building shell information data model UML class diagrams, relationships between these classes and attributes of each class were represented in Figure 5.1.

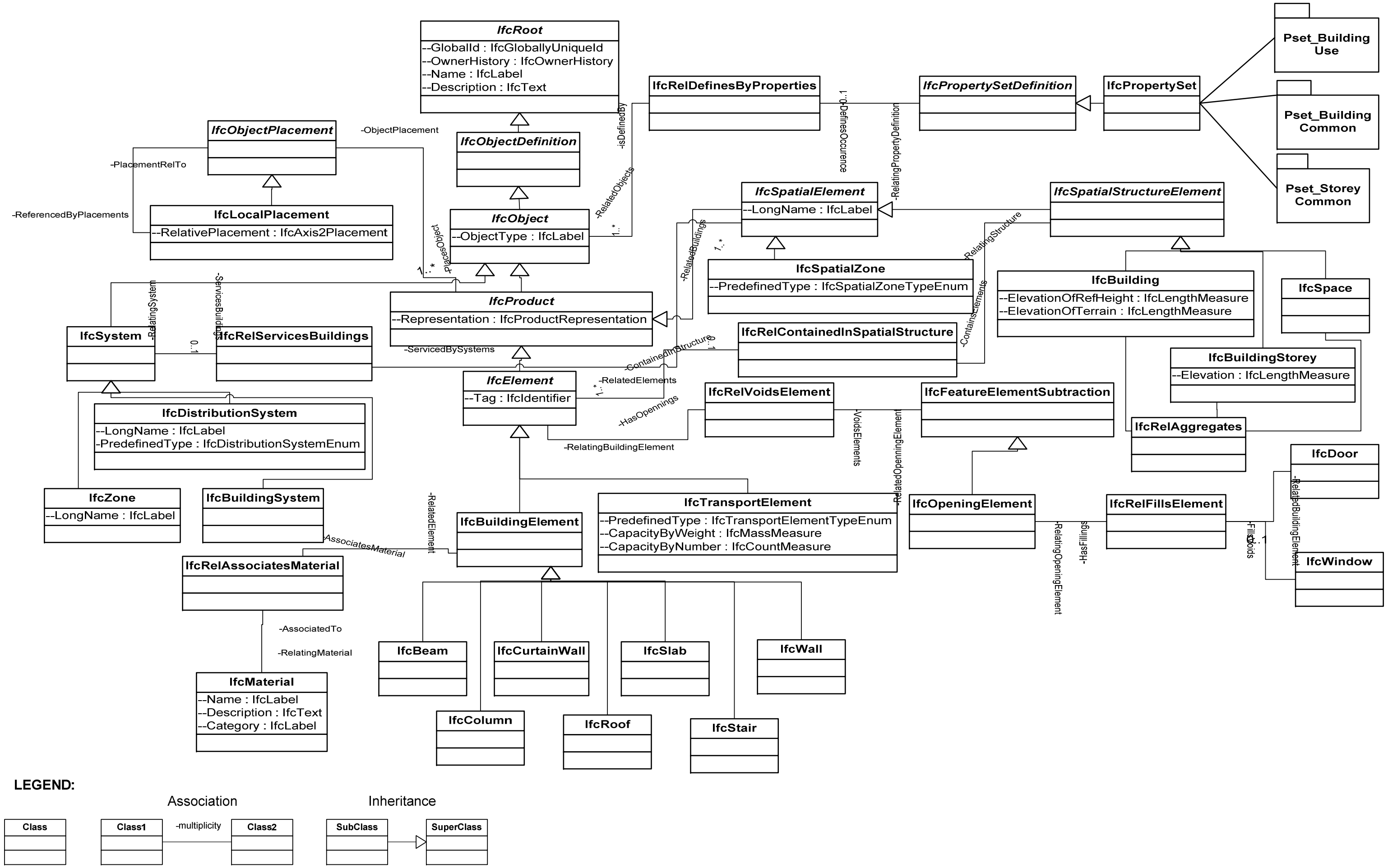

Figure 5.1: Data model for building shell information

Attributes that can be expressed by IFC were presented in the data model. These attributes are Global ID, Owner History, Name, Description, Object Type, Representation, and Tag. Beside these attributes there are also attributes which are defined by relationships such as *IfcObjectPlacement*. Attributes that can be defined in IFC and their descriptions are given below:

- Global ID: This attribute comes from the inheritance relationship (from *IfcRoot*) and assigns a globally unique identifier within the entire software world.
- Owner History: This attribute comes from the inheritance relationship (from *IfcRoot*) and assigns information about the current ownership of that object, including owning actor, application, local identification and information captured about the recent changes of the object.
- Name: This attribute comes from the inheritance relationship (from *IfcRoot*) and assigns a name for use by the participating software systems or users.
- Description: This attribute comes from the inheritance relationship (from *IfcRoot*) and describes the needed information of the entity.
- Object Type: This attribute comes from the inheritance relationship (*IfcObject*) and denotes a particular type that indicates the object further.
- Representation: This attribute comes from the inheritance relationship (from *IfcProduct*) uses for representations of the product both geometrical and topological.
- Tag (IFC Identifier): This attribute comes from the inheritance relationship (from *IfcElement*). It is used for the tag (or label) identifier at the particular instance of a product, e.g. the serial number, or the position number.

The *IfcObjectPlacement* is used for placement of the product in space and provide a placement and an object coordinate system for one or many instances of *IfcProduct*.

IfcRelServicesBuildings defines the relationship between a system such as heating, cooling, waste water system and the sites, buildings, storeys or spaces that it serves.

IfcRelContainedInSpatialStructure, is used to assign elements to a certain level of the spatial structure such as site, building, space.

IfcRelAssociatesMaterial assigned to an element for defining its material.

IfcRelAggregates is a special type of the general composition/decomposition (or whole/part) relationship for example a building is the aggregation of building storeys.

IfcPropertySet which is used for dynamically extensible properties was also used in the data model.

The classes whose names were written in *italics* in the figure are abstract classes. An abstract class cannot be instantiated, but they can be sub classed as in the case of developed data model.

5.3.1.2 Representing Building Distribution System Information and Extending IFC Data Model

As indicated in the above section for developing a data model for building related information items, this category was analyzed under two sub category building shell information and building distribution system information. Building distribution system information indicates building system information, building services systems information such as heating, cooling, plumbing, alarm, sensor information and mechanical system information for electric, gas and water. Related entities in IFC to express these information items were identified with the corresponding relationships.

Building distribution system information data model by UML class diagrams, relationships between these classes and attributes of each class were represented in Figure 5.2.

The attributes coming from the inheritance relationship are also same as the building shell information data model for this part of the model.

IfcRelConnectsElements relationship provides the generalization of the connectivity between elements.

IfcRelFlowControlElements is used for relationship between a distribution flow element instance and one-to-many control element occurrence instances indicating that the control element sense or control some aspect of the flow element. It is applied to *IfcDistributionFlowElement* and *IfcDistributionControlElement*.

IfcRelAssignsToGroup is used to assign the *IfcDistributionFlowElement* and *IfcDistributionControlElement* to *IfcDistributionSystem*.

IfcPropertySet was also used in the data model.

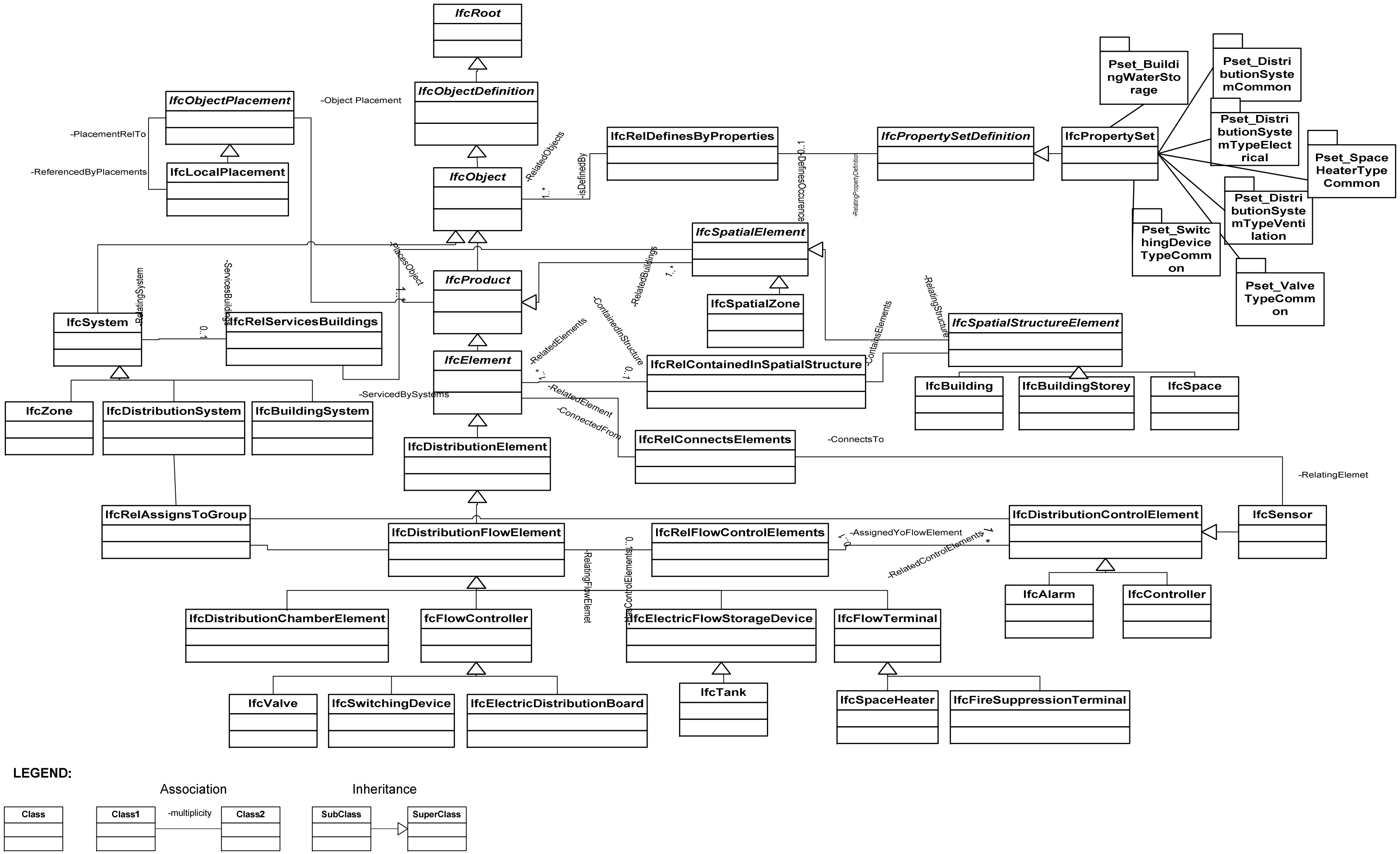

Figure 5.2: Data model for building distribution system information

5.3.2 Representing Occupancy Information and Extending IFC Data Model

Building occupancy information such as number of people living in the facility, number of people in each floor, and the roles performed by each occupant can be expressed by *IfcOccupant* and *IfcActorRole.* However the information items number of children, elderly people and handicapped in the facility and name, age and health information of the occupants cannot be expressed by IFC. For these information items that cannot be defined by IFC new classes were generated; handicapped, children, and elderly. Name, age and health are the attributes of these classes. These classes were represented with filled classes in the data model. They are subtypes of *IfcOccupant* class. Figure 5.3 presents data model for occupancy information.

The attributes coming from the inheritance relationship are also same as the building shell information data model for this part of the model.

IfcRelAssignsToActor handles the assignment of *IfcSpatialStructureElement* to subtypes of *IfcActor* that is *IfcOccupant.*

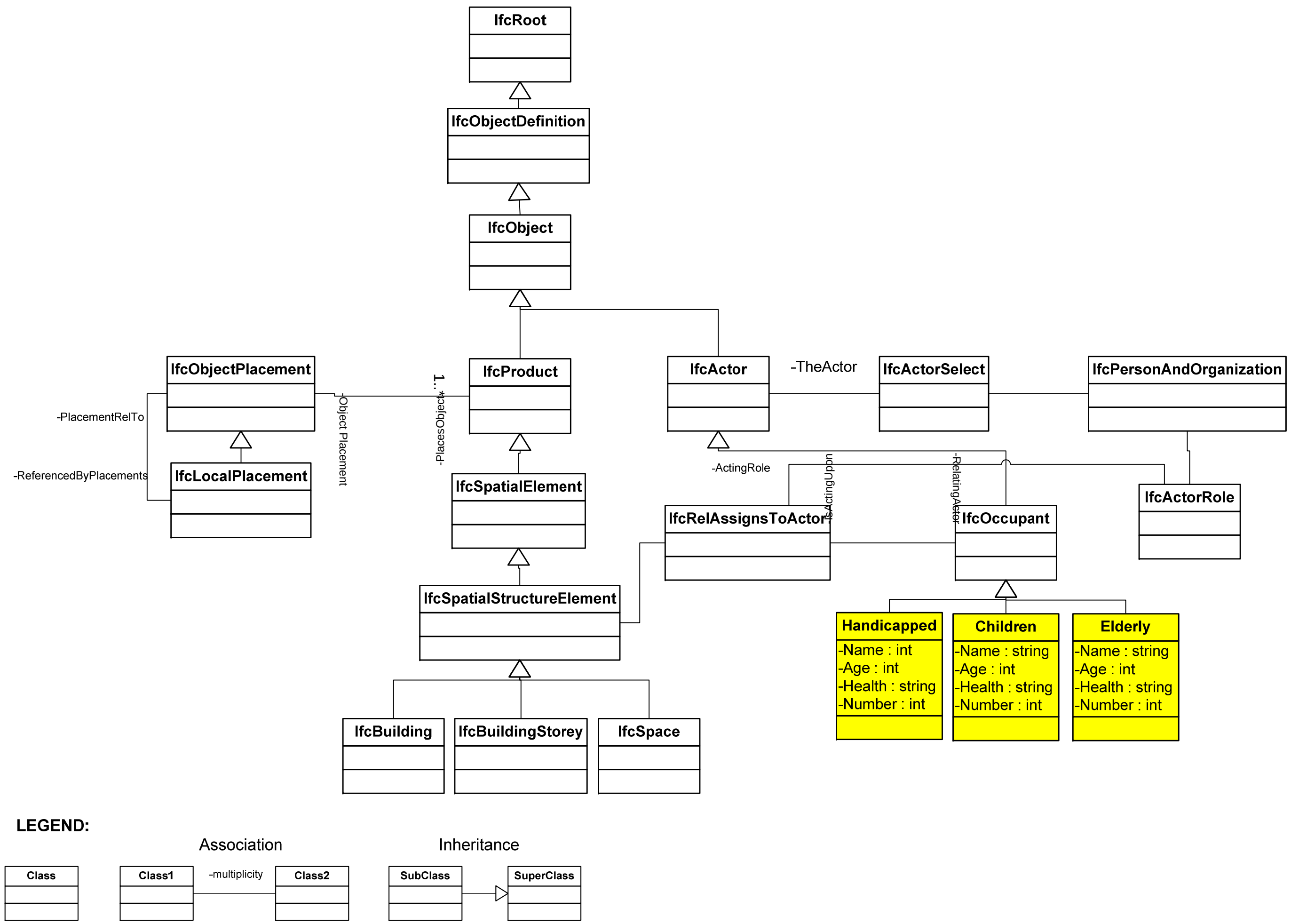

Figure 5.3: Data Model for building occupancy information

5.3.3 Representing Surrounding Information and Extending IFC Data Model

As indicated in Table 5.2 information about the surrounding of the facility can be expressed by IFC; *IfcExternalSpatialElement* which defines external regions at the building site. Other information items listed under this category cannot be expressed by IFC. For these information items four new classes were generated namely; *WaterSources*, *HazerdousMaterial*, *OverGroundRisk* and *UnderGroundRisk*. The information items under this category listed in Table 5.2 are summarized by these 4 extended new classes. These classes were filled in the data model. These classes have associations with the *IfcExternalSpatialElement* in the formed data model. Since when it is looked at IFC 2x4, *IfcExternalSpatialElement* is defined as "external regions at the building site" Those regions can be defined:

- logically - e.g. an instance of *IfcExternalSpatialElement* could represent the air space around the building without having an own shape representation, or
- physically - e.g. an instance of *IfcExternalSpatialElement* could represent the sloping ground around the building to identify the part of the external building envelop that is below ground.

Therefore extended new classes have associations with *IfcExternalSpatialElement* entity.

By this relationship surrounding information of the facility can be expressed by developed model. Figure 5.4 presents the developed data model for the surrounding information of the facility.

The attributes coming from the inheritance relationship are also same as the building shell information data model for this part of the model.

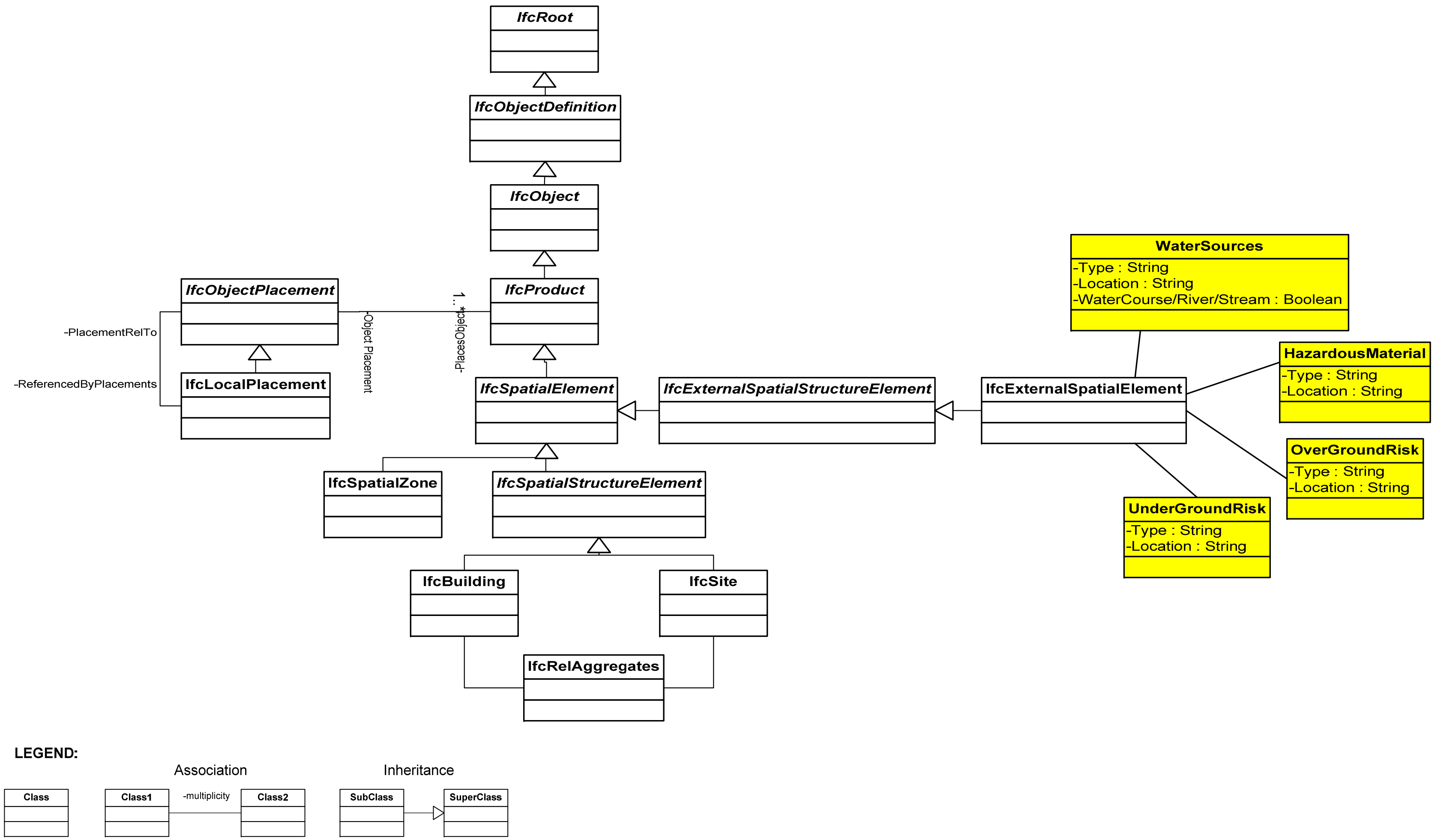

Figure 5.4: Data model for surrounding information of the facility

5.3.4 Representing Chemical, Biological, Radioactive and Nuclear (CBRN) Material Information and Extending IFC Data Model

Table 5.2 shows the information items under this category and as indicated in Table5.2 only the information item; who is in charge of hazardous material in the facility can be expressed by IFC by the entity *IfcActor*. Other information items under this category cannot be expressed by IFC. For these information items that cannot be expressed by IFC a new class was generated namely *CBRNMaterial* which is showed as filled in the data model. This class has associations with *IfcSpace* and *IfcActor* by *IfcRelAssignsToActor* entity. Since spaces are areas or volumes that provide for certain functions within a building, *CBRNMaterial* class has association with this class. CBRN material in the facility can be expressed within the facility by its relationship with *IfcSpace*. Figure 5.5 presents the developed data model for the CBRN material information of the facility.

The attributes coming from the inheritance relationship are also same as the building shell information data model for this part of the model.

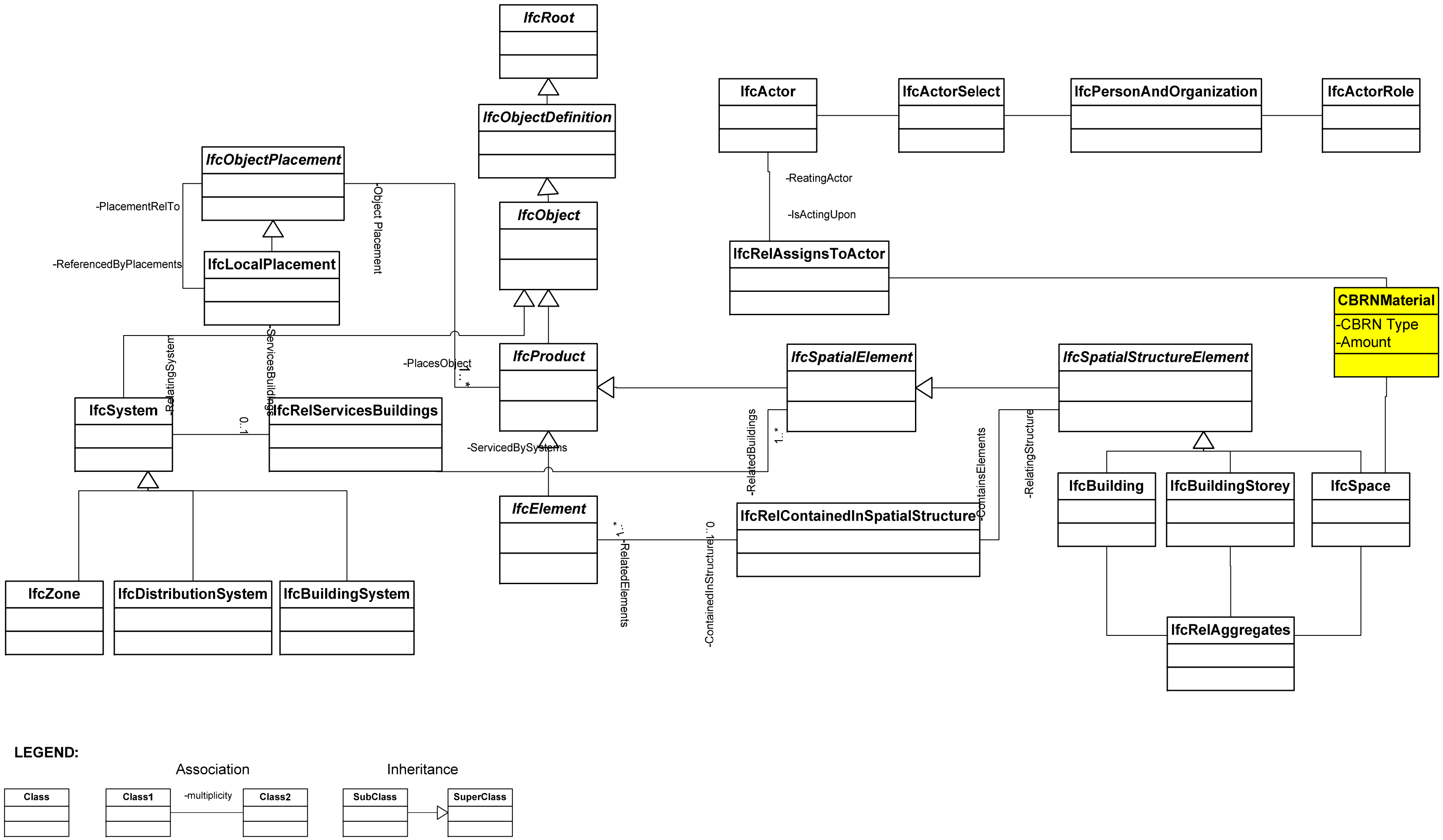

Figure 5.5: Data model for the CBRN material information of the facility

5.3.5 Representing Vulnerability Assessment Information and Extending IFC Data Model

It is explained in Chapter 4 that in addition to internal information about facilities, such as building structure, building type, floor plan, occupant information, damage condition, emergency response teams need to identify vulnerable locations in the facility that is potential hazards, threats that can be triggered by earthquake, and vulnerable contents in the facility during and right after multi-hazard emergencies in order to speed up the guidance of occupants to safe exits, and in Chapter 4 threats and the contents that are vulnerable to these threats upon earthquake in a facility were identified.

Identified threats and the contents that can trigger these threats upon earthquake were presented in Table 4.1. In the data model to represent the identified contents and threats *Threat* and *Content* classes were generated. Content class has an association with *IfcSpace. Content* has a space and a space may have 0 to many contents. Threat has an association with *IfcSystem* and also with *Content* class. As can be seen in Table 4.1 threats can be caused by failures in the building system, in the building distribution system and the hazardous effect of the some of the contents in the facility. A threat may triggered by 0 to many contents and a content may cause 0 to many threats. Both *Threat* and *Content* class have an attribute “name” which represents the name of the threat and the content. With all above knowledge data model for representing vulnerability assessment information was formed in Figure 5.6.

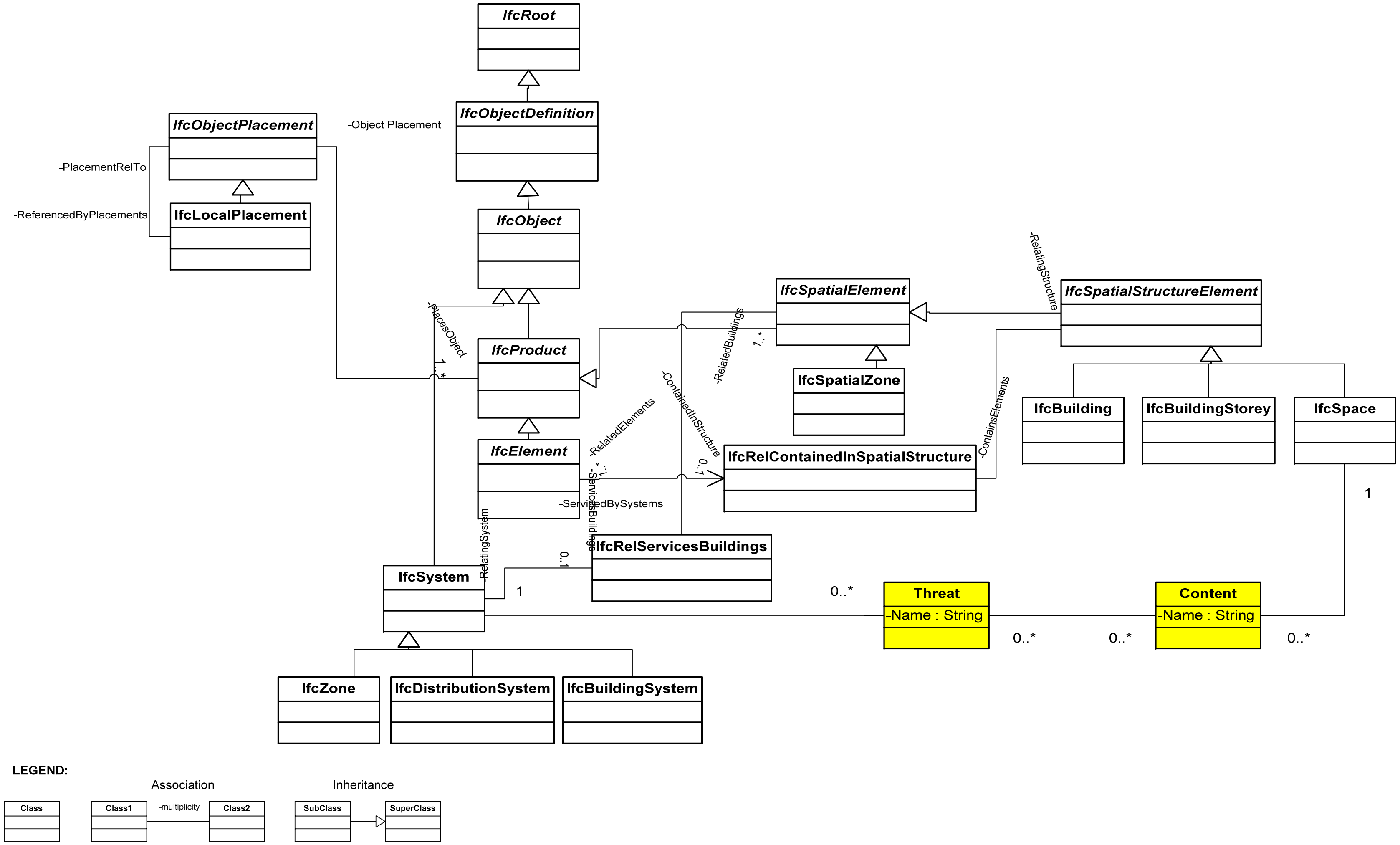

Figure 5.6: Data model for expressing the vulnerability assessment information

CHAPTER 6

CONCLUSION AND FURTHER WORK

Earthquake is an unpredictable and uncontrollable disaster. Following an earthquake, when first responders and emergency response teams arrive at the scene, they need information about facilities, such as building structure, damage condition, number of occupants in the facility, building content and vulnerable locations within the facilities. In the current practice first responders and emergency response teams gather this information by visual investigation of the area or by asking people who has just come out of the facility and who are shocked and under trauma. People under trauma may give wrong information or misleading information which is also very undesirable. Under such conditions first responders and emergency response teams loose very much time in order to understand the situation and to react accordingly which increases the harmful effects of earthquake such as effects on human lives and economy.

Moreover, response time to earthquake is very vital in order to save more lives and in order to prevent the secondary disasters upon earthquake such as fires and explosions. Since, seconds are very important to save more lives in a multi hazard emergency case it is required to access right and timely information to guide the occupants to safe exits and to speed up the decision process of responders by identifying vulnerable locations in the facility. Hence, in this thesis study it is highlighted that there is a need for an approach to enable rapid evacuation and vulnerability assessment in building emergencies, in order to guide occupants during evacuation by accessing to building information and directing first responders and emergency response teams to vulnerable locations. In order to achieve this approach, the needed internal information about the facilities and vulnerability assessment information is identified and the presentation of this information to the first responders and emergency response teams is studied. This study has three main parts:

1. Identifying information items needed by first responders and emergency response teams in order to understand the situation and react accordingly.
2. Identifying threats following an earthquake in facilities and building contents that can trigger these threats causing additional consequences in addition to earthquakes such as post-earthquake induced fires or explosions.
3. Developing data model to represent the identified information items and vulnerability assessment information to first responders and emergency response teams by applying the IFC standard.

In order to identify the information needed by first responders and emergency response teams to guide the occupants to safe exits and to save more lives three methods are conducted to decrease the subjectivity of the identified information. Firstly, related literature is surveyed and the needed information in order to react a disaster appropriately is identified. Face to face and semi-structured interviews are conducted by experts on disaster management from different institutions, and they share their disaster management knowledge with us. Finally, documents on disaster and emergency management that those experts use are reviewed and the mentioned information items in those documents are identified. Findings of these three methods are combined and the needed information items by emergency response teams upon earthquake are finalized. The needed information items by first responders and emergency response teams are categorized under six topics: 1. Building information, 2. Occupancy information, 3. Disaster information, 4. Information about transportation to the scene, 5. Information about surrounding of the facility, 6. CBRN (Chemical, Biological, Radioactive and Nuclear) material information.

Following an earthquake in a facility first responders and emergency response teams also need to identify the location of possible potential threats and facility contents that can trigger such threats. In order to identify the threats and the contents that can trigger these threats again the related literature is surveyed and face to face and semi structured interviews are conducted with the experts on disaster and emergency management from different institutions. The threats in facilities upon earthquake and the contents that can trigger these threats are identified and presented in a table.

In the above mentioned two parts the needed information by first responders and emergency response teams in order to respond to earthquake immediately and effectively by understanding the situation, guiding the occupants to safe exits and identifying the potential threats upon earthquake is identified. In the third part of this study the representation of this identified information items to first responders and emergency response teams in order to guide the occupants to safe exits rapidly from the damaged facility by pinpointing vulnerable locations is studied and a model based guidance and vulnerability assessment approach which is based on building information modeling (BIM) is suggested.

The approach that will be presented to the first responders and emergency response teams will also include a limited number of sensors to give information about the real time information of the facility. Local monitoring approach is achieved by these sensors put in the facility. Moreover, the model based guidance and vulnerability assessment system (BIM) for facilities under the threat of multi hazard emergencies will also be integrated with the local monitoring system. The information items needed by first responders and emergency response teams to guide evacuation and help first responders and emergency response teams in rescue by pinpointing vulnerable locations will be presented by this integrated model based system (BIM). The exploration of integration of the identified information items and vulnerability assessment information needed by first responders and emergency response teams in this mentioned model based system is explained at the third part of study.

For the representation of the identified information items and vulnerability information Building Information Model (BIM) is suggested in this study, since BIM is designed to facilitate the information sharing among the stakeholders in different phases for better decision. Needed information to analyze the different stages of the project for example, building energy simulation at the design stage can be added to the building information models. Moreover, needed information to analyze operations for example, quantity take off operations at the tendering stage can be added to the building information models. Likewise BIM provides and includes building related information items for example, building type, building material, building occupancy, building hazardous content, and so on.

As a major data standard for BIM, the IFC (Industry Foundation Classes) standard published by the IAI (International Alliance for Interoperability) plays a very important role in the process, since it is a standard for sharing data throughout the project lifecycle, across disciplines and across technical applications in the AEC/FM industry . In this study the application of the IFC standard to represent the identified needed information items and vulnerability assessment information is studied in order to respond the situation quickly, effectively and safely after an earthquake. By using IFC standard, data models for the needed information by first responders and emergency response teams are developed for the four identified information item categories; 1. Building information; this category is investigated under two sections: 1.a. Building shell information and 1.b. Building distribution system information, 2. Occupancy information, 3. Information about surrounding of the facility, 4. CBRN (Chemical, Biological, Radioactive and Nuclear) material information and for the vulnerability assessment information separately. By using the developed data models a BIM-based application software for displaying the needed information by first responders and emergency response teams can be developed and by using this BIM-based model, emergency response teams gather the needed information to respond situation. Figure 6.1 represents this situation.

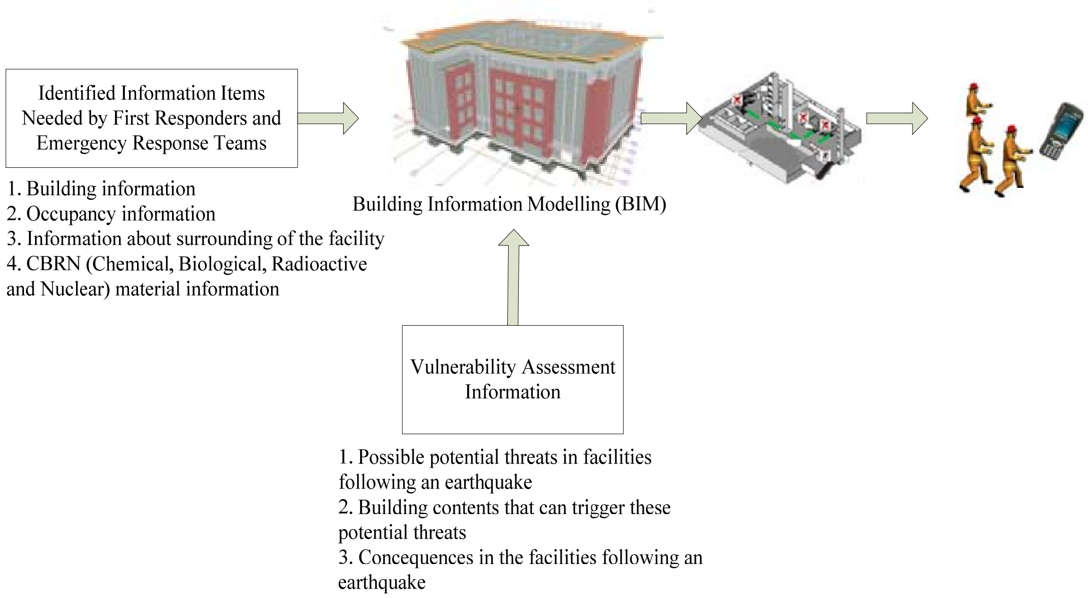

Figure 6.1: Representation of BIM-based model to first responders and emergency response teams

In the further studies following this thesis study, this model based system will be developed and the information items and the vulnerability assessment information needed by first responders and emergency response teams identified in this thesis study will be displayed to the first responders and emergency response teams by the help of the generated data models in this thesis study. This developed model will provide first responders and emergency response teams the critical needed information such as number of occupants, number of floors, building material, structural system of the facility, utility shut off valves, building content and vulnerable locations within the building. First responders and emergency response teams will gather the information from this model they will not ask the people under trauma or they will not investigate the scene area and lose time to gather information. They also will be surer and more confident about the accuracy of the information gathered from the model. By using BIM-based model:

- Fast, effective and organized emergency response will be achieved by accessing the needed internal information of the facility.
- Identification of the vulnerable locations in the facility will be achieved and the post earthquake induced fires, explosions and floods will be reduced.

- Safe, timely and effective guidance of emergency response teams will be achieved.
- Rapid and safe evacuation of occupants from damaged facility will be achieved.
- Harmful effects of the earthquakes both on human lives and economy will be reduced by using BIM-based model.

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APPENDIX A

CONCEPTS AND THEIR MEANINGS USED IN EMERGENCY MANAGEMENT

Obtained from reference JICA (2008b), Ergünay, O., Gülkan, P. and Güler, H. H., (2008), "Afet Yönetimi ile İlgili Terimler Açıklamalı Sözlük", Japan International Cooperation Agency (JICA), Turkey Office Publications No: 2, Ankara, pp. 301-353".

Emergency: States and refers to the events that response and emergency aid activities urgently need to be carried out. It can also be expressed as a state of disaster occurrence.

Emergency Manager: Is the professional person that has knowledge and experience and works as a manager in a corporation or organization during disaster or emergency situations.

Emergency Management: Management process starting immediately after the occurrence of the disaster, aiming to meet all the needs of affected communities in a quick and effective way. It is not continuous. Emergency management starts with the occurrence of an event that is considered an emergency, till the end of the emergency situation disappears.

Emergency Relief: It involves the activities such as searching for people affected by the disaster or emergency situations, rescue operations, first aid, medical treatment, evacuation of the affected facility, shelter and nutrition support, security actions, and psychological support. Main goal was to save the lives of many people, to provide treatment for the wounded, and to meet the vital needs of rescued people from the facilities as soon as possible.

Disaster: Natural, technological or manmade events that the affected community cannot cope with it by using owned sources and affect the communities economically, physically and socially.

Disaster Response Team: Refers to groups of people who are specially trained and who take place in disaster response and emergency relief teams from all the institutions and organizations belonging to the public or private. Disaster response teams take place in many areas of emergency management such as search and rescue, logistics support, psycho-social support, first aid, education, information and awareness.

Disaster Risk: It presents the likelihood of loss or damage of humans, human settlements and the natural environment by occurrence of a particular danger in the future in a certain period of time. Disaster risk can be formulate by "Disaster Risk = Hazard x Vulnerability" equation.

Disaster Hazard: Natural, technological and manmade events with a certain degree of probability of having adverse consequences that are loss of life and property and the physical, social, economical, political and environmental losses.

Search and Rescue: Searching, finding, rescuing people after the emergency is occurred work by specially trained and equipped team members from public or private organizations. Search and rescue operations not only include the searching, finding, rescuing activities but also it includes first aid of the victims and transportation of the victims to the nearest health center.

Secondary Disaster: A new disaster that occurred by the effect of a disaster. Earthquakes can also cause secondary disasters like tsunami, landslides, fires, epidemics, and dam failures.

Evacuation: Leaving the facilities or a region in a fast and regular way by using the pre-designated roads and empty the region or facility on.

Evacuation route: Pre-determined and marked paths that are used in immediate danger to leave the dangerous areas safely and quickly.

Hazard: General name given to the physical situations which have a certain degree of probability of having adverse consequences like life and property losses, personal injury, corruption of social and economic balances, losses in environment damage.

APPENDIX B

QUESTIONNAIRE FOR THE FACE TO FACE AND SEMI STRUCTURED INTERVIEWS

Information about the person interviewed

Name:

Occupation:

Institution:

Experience in Task:

Topic: A Real-Time Damage Assessment and a Model-Based Evacuation and Guidance Approach in Facilities for Managing Emergency Response Operations During Multi-Hazard Emergencies

First Part: General Information About What is Happening After an Emergency

1. How the process after an earthquake, fire and explosion is developed? How Information about the emergency comes and to whom? (General description of the process).
2. Which teams are involved in the case of such emergencies?
3. What information do they need upon arrival to the scene?(On the basis of the team or general)
4. How emergency response teams are responding to the situation? (How they are entering to the facility, etc.).

5. What is the speed of responding to the emergency and its relation with the information about the facility?

   a. The fastest response of the event and what kind of existing information has increased the response in that event?

   b. The slowest response of the event and what kind of lack of information slowed the response in that event?

Second Part: Description through a Case

Actual Example of an Emergency

1. Emergency location?
2. Which teams responded?
3. How many members do the teams include?
4. What kind of information needed?
5. Was the needed information accessed quickly?
6. Which team was involved and by using which technique?
7. What was the response speed of the incident? And the relation of this speed with the information items needed?
8. How was the exchange of information between emergency response teams? And how they used the information?

Third Part: Other Hazards Triggered by the Earthquake

1. What other hazards can be triggered by earthquake? (Can be defined by using an actual case)
2. What are the examples of building contents, material or equipments that can cause secondary disasters?
3. How the vulnerable places, potential hazards and risks that can trigger secondary disasters in a facility can be determined?
4. Which factor in a facility can trigger which hazard in a case of an emergency?