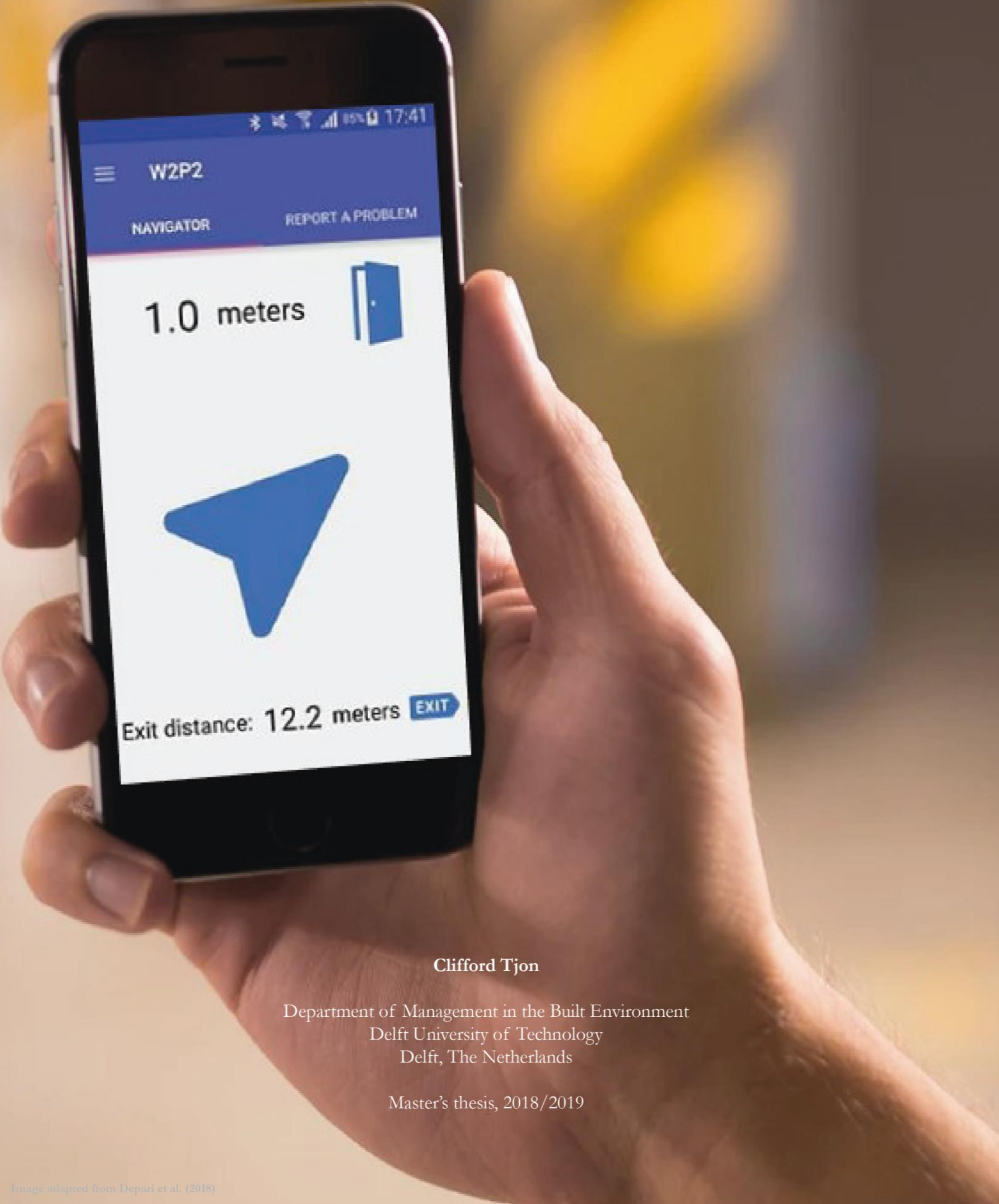
'Smart' Facility Management in building fire emergency response operations

An empirical research with the focus on multi-criteria analysis for supporting the selection of smart emergency applications in the Facility Management



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Master's thesis, 2018/2019

Image adapted from Depari et al. (2018)

Colophon

This written report of scientific research is carried out for the completion of the Master track Management in the Built Environment at Delft University of Technology, Delft, The Netherlands

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Preface

This masters' thesis has been carried out from September 2018 which is presented to aid readers with specific interest and priority to gain a better understanding about the contribution of current smart emergency applications to the facility manager during a fire incident. In particular, this study provides the reader comprehension of the facility management domain in relation to the safe environment, and an evaluation of the necessary information during a fire emergency according to a variety of current smart emergency apps.

During the fire incident at higher education institutions in the past twenty years, facility and emergency managers were being challenged to mitigate fire and, more importantly, to save lives. By doing so, receiving correct and sufficient time-dependent information is of essential importance. Up until now, traditional communication tools support their building emergency response operations, and some researchers suggest that 'smart' tools are able to help them as well. In this respect, my curiosity towards safety management, facility management, and 'smart' tools fostered my passion to gain greater insight into the contribution of the current smart emergency apps to the facility managers during a fire incident. Even more important, I am very enthusiastic to provide the reader with valuable insight into this subject matter and add value to the existing body of knowledge.

In truth, without the fruitful conversations with different experts in the field of safety from a variety of Dutch universities, this masters' thesis could not have achieved the depth and extent it currently has. Above all else, from the bottom of my heart, I would like to express my sincere gratitude and deep appreciation to Prof.dr.ir Alexandra Den Heijer, Prof.dr.ir Pieter van Gelder and ir. Bart Valks for their valuable guidance and support. In particular, Prof.dr.ir Alexandra Den Heijer have been doing a great effort in providing guidance to the author's decision during the graduation process in order to ensure that the best decisions were made. Prof.dr.ir Pieter van Gelder has provided useful suggestions regarding risk management and research in general. In addition, ir. Bart Valks did the greatest possible effort in providing value-added recommendations and constructive feedback on the content of the research and smart tools. Again, I am very grateful for their valuable support and guidance over the past months. Thank you very much.

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Abstract

Purpose – The purpose of this study is to add to the existing body of knowledge and increase the understanding of the contribution of current smart emergency applications to the facility manager with the focus on required information during building fire emergency response operations.

Design/methodology/approach – Semi-structured interviews with different safety professionals from Dutch universities are used to identify their role during a fire incident, an acceptable level of fire cause, necessary information items and, their viewpoint on the use of smart emergency applications. The results are translated to a multi-criteria analysis in which different smart emergency applications are evaluated according to a variety of information items.

Main finding – This study reveals that not all required information is integrated into the current smart emergency apps. In fact, each smart emergency apps have a unique information provision which can be useful during a specific phase of a building fire emergency operation. In addition, the findings show that the use of smart emergency apps is partially supported by the participants of the interviews.

Research limitations/implications – This study was confined to universities in The Netherlands and the semi-structured interviews have limited population size. A larger population with the focus on international universities would have allowed for more important data, but the findings do provide valuable and essential insight into the contribution of smart emergency apps to the facility managers.

Practical implications – The empirical results provide guidance to the emergency and facility managers to opt for the smart emergency app(s) according to their required information and, give valuable insight to app developers and researchers for further improvement and development of the emergency apps.

Originality/value – Most studies focus on the benefits and technical aspects of the smart emergency app. This research provides readers with more insight into the extent of the required information on current smart emergency apps in favor of the facility manager who needs to perform during a building fire emergency operation.

Executive summary

This final research in the master program Management in the Built Environment at Delft University of Technology was written for emergency app developers, researchers, emergency and facility managers with specific interest and priorities. In the context of building fire emergency operations at universities, this empirical research provides an analysis and evaluation of the current smart emergency apps with the focus on information requirements. By doing so, the readers will increase their understanding of the contribution of current smart emergency applications to the facility manager with the focus on required information during building fire emergency response operations.

In this respect, the research design of this study includes literature study, semi-structured interviews, and multi-criteria analysis. Literature is reviewed to gain more insight in the role of corporate real estate management and facility management during an emergency situation, the risk scenario's (e.g. BowTie method and ALARP), information needs during a fire incident at the building level and a variety of smart emergency app in favor of the facility manager. Subsequently, this empirical research used a certain research instrument: semi-structured interviews with 12 safety professionals from both strategic and operational level at Dutch universities. By doing so, the purpose is to identify their role during a fire incident, an acceptable level of risk, necessary information items and, their viewpoint on the use of smart emergency applications. Eventually, a multi-criteria analysis of different smart emergency apps and information needs is conducted in order to examine the extent of information on these smart tools.

The main results of this research show that each smart emergency app has a unique way of information provision during a building fire emergency response operation. Some smart emergency app only provides information about the location and status of the victim, and others give valuable information about the development of the fire. In other words, smart emergency apps do not provide all the required information that is examined by Li et al. (2014) and suggested by the participants. Moreover, some participants point out that smart emergency apps can make a positive contribution to their emergency activities because they believe it will increase their situational awareness. However, several participants are doubtful and negative about the contribution of smart emergency apps. An explanation is that some participants do not rely on the current technologies and network (e.g. WI-FI), do not believe it will increase their situational awareness, and, even more important, they have more confidence in manpower.

In conclusion, the research reveals that current smart emergency applications, in terms of information provision, contribute to the emergency activities and situational awareness of the facility manager to a certain extent. Nonetheless, the empirical results provide guidance to the emergency and facility managers to choose for the smart emergency app(s) according to their information requirements and, give important insight to app developers and researchers for further improvement of their emergency apps.

Lastly, it must be noted that this empirical research has certain limitations. The scope of this research was focused on universities in The Netherlands and, besides, the semi-structured interviews have limited population size. Recommendation for further research is to examine a larger population with a focus on international universities. This would have allowed for more important data, but the current findings do provide valuable and essential insight into the contribution of smart emergency apps to the facility managers.

Table of content

Introduction

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1.1 Background information

Universities have a mix of different functions in which education and research activities take place such as lecture halls and laboratories to name a few (Den Heijer, 2011). While there is a variety of functions in a university, it is also worthwhile to note that, in particular, Dutch universities vary in size. The average size of Dutch universities involves 16300 students and 3000 staff members (Den Heijer, 2011). Considering the fact that many students, staff and a variety of functions need to be accommodated, much attention has also been paid to the overall property conditions of Dutch universities. In this respect, Den Heijer et al. (2016) stated that Dutch universities became the owner of their real estate properties since 1995 and, at the same time, these higher educational institutions inherited aging buildings. Continuing on this line, the same applies to European campuses which have a lifespan of 50 years or older. Most of them need to improve their technical condition, functionality, and energy-efficiency (Den Heijer & Tzovlas, 2014). It should be reminded that universities in the United States have the same issues in which buildings and facilities are aging (Canfield and Graff, 2015).

In this respect, lack of maintenance and the corresponding investment may have consequences in terms of safety and health of users of buildings (Den Heijer et al., 2016). From this perspective, what *if* a building fire incident occurs at a university? Attention should also be given to this aspect because fire incidents at higher education institutions occurred annually in the past twenty years. It took place at both the national and international level. For instance, building fire incidents occurred at Georgetown University (USA) in 2018, Tsinghua University (China) in 2015, Delft University of Technology (The Netherlands) in 2008 and Moscow University (Russia) in 2006. The causes of the fire incidents are different and the same applies to the consequences. According to Statistics Netherlands, causes of the fire incidents at Dutch educational institution are due to arson, firework, cigarette, fire hazardous activities, spontaneous combustion, and failure of a device (Brandweer statistiek, 2013). The potential consequences vary from business continuity to loss of lives and property damage.

From this perspective, the facility manager needs to act during the fire emergency and, in particular, ensures a safe environment to empower the business or educational activities to operate again (CoreNet Global, 2015; Davies et al., 1998). In this regard, understanding and receiving sufficient information is of essential importance during a fire emergency. It is examined that the development of fire and, location and status of first responders and building occupancy are considered as the most important information during a building fire emergency operation. Insufficient and poor understanding of this information will lead to a lack of situational awareness which may result in a complicated emergency situation (Li et al., 2014). Therefore, some researchers suggest that computer technologies and (emergency) applications may help them to gain a greater insight of the emergency situation (Cheng et al., 2017; Jiang et al., 2004) and in general context (Gheisari et al., 2011).

With these technologies and (emergency) emergency applications in mind, smart tools have been already examined in the context of universities by Valks et al. (2018) which focusses specifically on determining space use with the aid of smart tools. Continuing on this line, this master thesis also focusses on smart tools at universities. However, special attention is given to the contribution of smart emergency applications to the facility managers during a fire emergency at universities.

1.2 Problem definition

'*Major events and local catastrophes demand that colleges and universities remain vigilant and responsive to emergencies.*' (Farris et al., 2014, p.74). During such events and catastrophes in universities, one of the challenging tasks is to locate victims and keep monitoring the development of fire (Li et al., 2014; Radianti, 2018). By doing so, situation awareness, acquiring and understanding information during the emergency event are important in order to make an informed decision (Li et al., 2014). In the course of the emergency response operation, the facility manager plays a crucial role: overseeing the property management functions while creating awareness of the situation in terms of risk and disaster (Davies et al., 1998) and being responsible for the fire safety and protection (European standard, 2006; CoreNet Global, 2015).

However, there are different problems identified by several studies: (1) *Lack of situation awareness in the emergency situation* can be an issue due to the problems with understanding, filtering and gathering time-dependent information (Groner et al., 2012; Li et al., 2014) which may lead to various consequences such as property damages and casualties (Li et al., 2014). In general, (2) Endsley et al. (1995) argued that *lost in situation awareness can cause slower detection of problems* which result in the need for extra time to identify the problem and take corrective actions. (3) In the event of an emergency, *risks are not communicated properly to the management level* (Blaauwgeers et al., 2013). (4) According to Carver et al. (2007), Perry et al. (2003) and Kowalski-Trakofler et al. (2003), there is either *incomplete information, an overload of information or incorrect information during an emergency*. As a consequence, information that is not complete may result in inadequate protective measures (Perry et al., 2003) and an overload of information makes it harder to extract relevant information (Carver et al. 2007). (5) Similar to Gheisari et al. (2011), they point out, from the perspective of the facility management practices, that the facility managers have *difficulties in managing and separating a large amount of information* in a precise manner.

1.3 Research gap and purpose of this study

As a solution to these problems, Jiang et al. (2004) suggest that the use of the sensor, wireless networking, and computing technologies have a great potential in gathering information during the event of an emergency and using these technologies is promising for communicating important information in real time. Cheng et al. (2017) believe that computing technology is able to provide accurate information to help rescuers for planning the most favorable rescue route in fire scenarios. Gheisari et al. (2011) assumed that the applications and computer technologies, in general, can assist the managers in the facility management domain. Hence, it can be seen that most research focus specifically on the benefits and technical elements of computing technologies and applications in order to provide accurate and essential information in emergency situations and in general.

However, less attention has been given to *what* information is needed, through the lens of a facility manager, during a building fire emergency operation. In addition, *which* current smart emergency apps are able to contribute to these managers according to their required information items? Therefore, the purpose of this study is to add to the existing body of knowledge and increase the understanding of the contribution of current smart emergency applications to the facility manager with the focus on required information in building fire emergency response operations.

1.4 Societal and scientific relevance

By doing this research, one may ask: what is the societal and scientific relevance of this subject area? With regard to societal relevance, this thesis has an impact on various stakeholders through several pathways. (1) The approach and the outcome of the research add value to the researchers, facility managers, and emergency app developers. (2) It can be a resource for the researchers for reviewing their smart emergency applications in terms of information provision. (3) The outcome of the research provides constructive feedback to the facility managers about what smart emergency applications are advantageous to them according to their required information during an emergency situation.

With reference to the scientific relevance, as discussed earlier, most research focuses on the benefits and technical aspects of smart tools during emergency situations. A need was identified for a detailed analysis from a different angle. Therefore, the intention of this research is to create new insight and findings based on the prior available knowledge by doing empirical research with the focus on multi-criteria analysis for supporting the selection of smart emergency application in the facility management.

1.5 Research limitation

Although it is registered that the fire incidents at higher education institutions occurred at both the national and international level in the past twenty years, this study mainly focusses on universities in The Netherlands. Further, another restriction relates to the population size of the semi-structured interviews. To date, twelve interviews have been conducted by the author of this masters' thesis while a facility manager and emergency managers from Erasmus University Rotterdam has not accepted the invitation. A larger population would have allowed for more important data. The reason for these research limitations is due to time constraints. However, the results presented in this Masters' thesis do provide valuable and essential insight into the contribution of smart emergency applications to facility managers during a fire emergency at the building level.

Hypothesis & Research Questions

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1.6 Hypothesis

‘The information provision of current smart emergency applications improves the situational awareness of the facility manager by the ability to make the right informed decisions in the event of a fire emergency.’

1.7 Main research question

How can current smart emergency applications, in terms of information provision, contribute to the mitigative barrier in order for the facility managers to improve their situational awareness in building fire emergency response operations?

1.8 Sub research questions

Corporate Real Estate Management and Facility Management

1. What is the role of the Corporate Real Estate Management and Facility Management with regard to a safe environment in a university?

Risk scenario and acceptable level of risk

2. What are the typical scenario and acceptable level of risk in a fire emergency event with regard to a BowTie risk assessment method and ALARP?

Information items in building fire emergency response operations

3. What information items are required and relevant in building fire emergency response operations?

Current smart emergency applications

4. What current smart emergency applications, in terms of information provision, contribute to building fire emergency response operations?

Readers’ guide

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1.9 Readers guide

The purpose of this readers' guide is to help potential readers navigate through this masters' thesis and select their readings on the basis of their interests and priorities. By doing so, the layout of the masters' thesis is structured in the following manner:

Chapter 1 - The context of the study is established by presenting the general introduction to the subject matter, problem, research gap, relevance and research questions. It provides fundamental information to the reader which is needed to comprehend the next chapters.

Chapter 2 – This chapter provides an outline of the research methodology. In other words, it provides the reader with a better understanding of *how* the researcher is going to conduct the study and deal with ethical issues.

Chapter 3 to 6 – In these chapters, substantive findings of the current knowledge is elaborated in more detail. By doing so, the reader will gain a better understanding of the corporate real estate management and facility management in relation to a safe environment, causes and consequences of the fire incident, an acceptable level of risk, necessary information items during a building fire emergency and, finally, various smart emergency applications.

Chapter 7 to 13 – Attention has been given to the interviews with various experts in the field of safety from Dutch universities. The reader will gain insight into the role of facility and emergency managers during a fire incident, subjective and objective data regarding causes of fire, *how* interviewees perceive the use of smart emergency apps and *what* information is essential for them during a fire incident. In addition, a multi-criteria analysis is established in order to evaluate different smart emergency apps according to a variety of information items. Lastly, recommendations regarding smart emergency apps are given and suggestions about the desired smart emergency app are provided.

Chapter 14 – Conclusion is drawn in which answers are provided to the main research question and sub-research questions

Chapter 15 – In this 'Discussion' section, the author of this masters' thesis provides the reader with an outline of the major findings of the study, the importance, and limitation of this research and, lastly, how the results extend the findings of previous studies.

Chapter 16 – Reflection on the research process is given in order to demonstrate the authors' learning in the research project.

Chapter 17 – At the final stage, in the section 'recommendation for further research' important suggestions are given in regard to gathering more essential data and conducting research in an international context.

Empirical research methodology

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2.1 Research design

This study relates to empirical research because the purpose is to increase the understanding and gain new knowledge about the contribution of the current emergency apps to the facility manager. By doing so, a particular research approach is used with a specific focus on *'How can current smart emergency applications, in terms of information provision, contribute to the mitigative barrier in order for the facility managers to improve their situational awareness in response to a fire emergency event?'.*

In essence, the research approach of this study is more or less related to the empirical research process of Kumar (2011) which is also examined by Binnekamp et al. (2012) (fig 1). Kumar (2011) stated that the empirical research process starts with 'formulating a research problem' which is explained in more detail in chapter 1.2 of this study. Subsequently, the researcher points out that the second, third and fourth step is 'conceptualizing a research design', 'Constructing an instrument for data collection' and 'selecting a sample' which is elaborated in this chapter. Thereafter, Kumar (2011) suggest that step five relates to 'writing a research proposal' which has been already achieved during the P2 graduation project. Further, step six and seven refers to 'collecting data' and 'processing data' which is explained in chapter 7 to 12 of this research and relates to the P3 phase of this graduation project. Finally, 'writing a research report' is the final step (Kumar, 2011) which is done during the P4 graduation project.

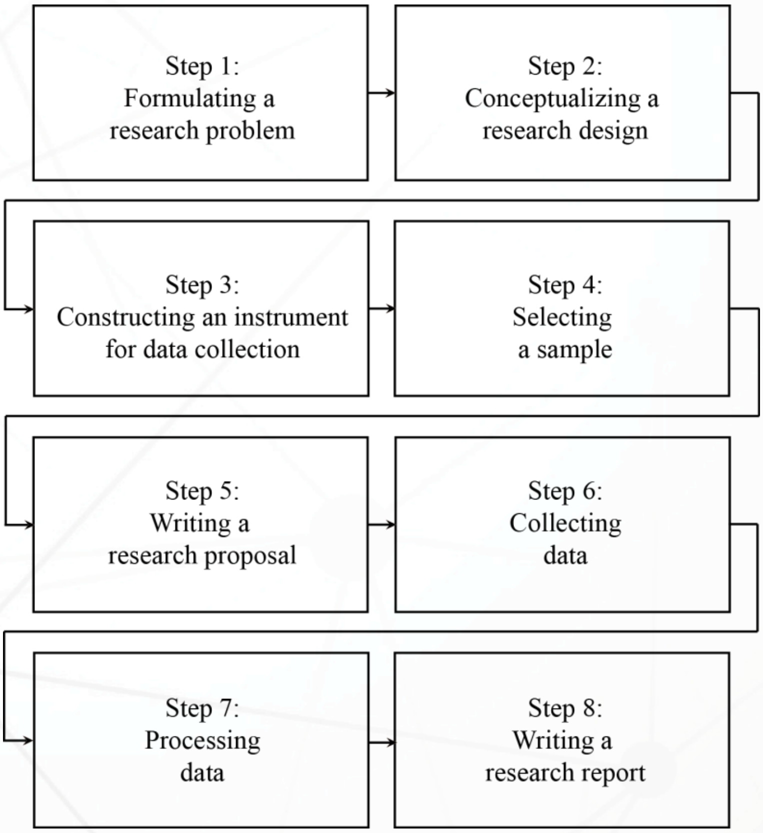

Figure 1 the empirical research process of Kumar (2011)

As noted, the research design of this study is more or less similar to the empirical research process of Kumar (2011). In this context, this paragraph explains in more detail how the author will find answers to the research question with the focus on the theoretical framework, research instrument, data collection, and multi-criteria analysis. The research design of this study is depicted in figure 2.

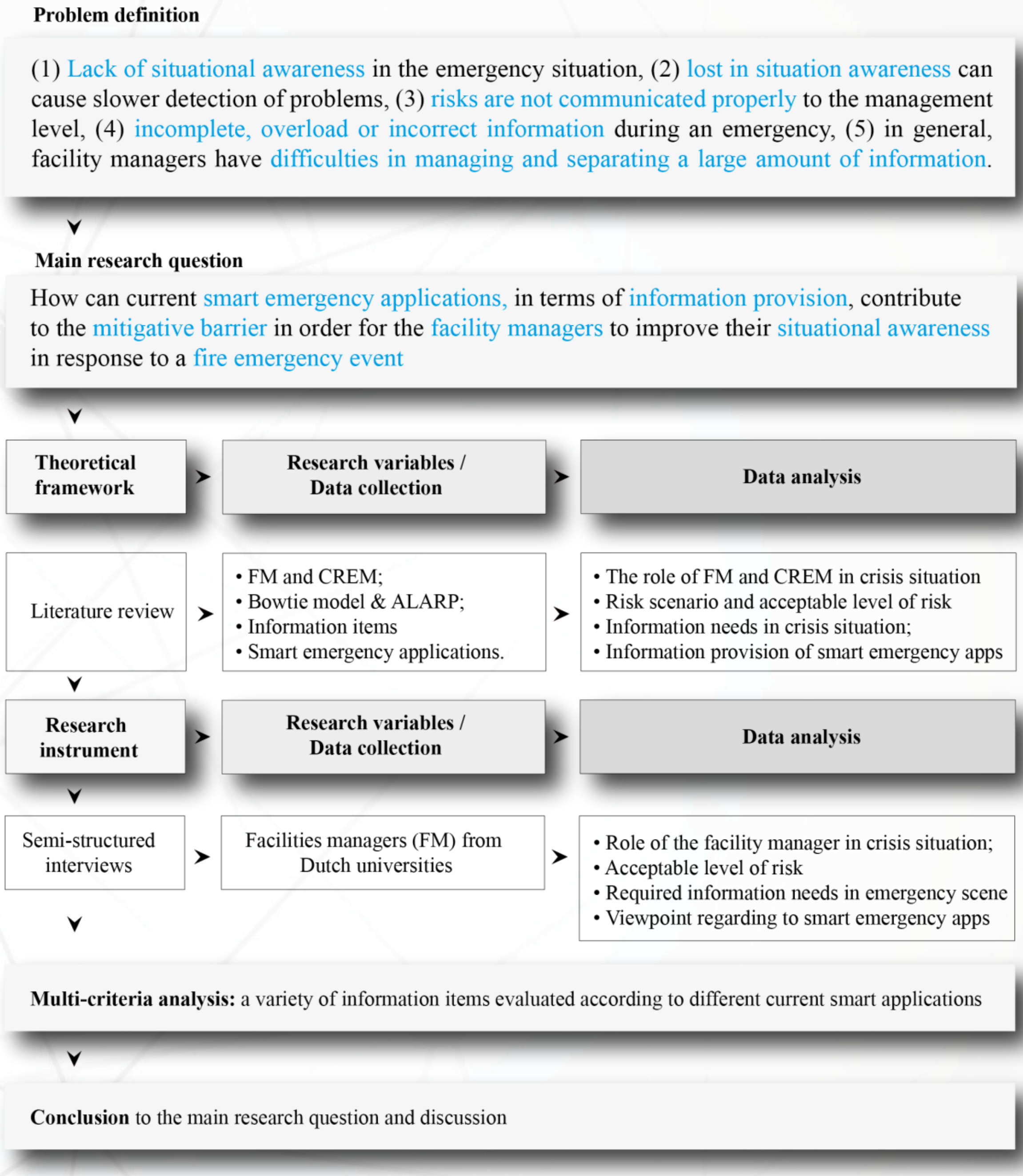

Figure 2 research design of this study (author's illustration, 2019)

2.2 Theoretical framework: a literature review

According to Hart (2018, p.3), a literature review is defined as: *'the analysis, critical evaluation, and synthesis of existing knowledge relevant to your research problem…'*. Conducting a literature review is vital because the author acquires a greater understanding of the previous scientific work concerning the subject area, and how it has been examined. Additionally, it enables the author to have a better awareness of what has already been explored and what needs to be addressed. In this respect, the author intends to gain more insight into (1) the role of the Corporate Real Estate Management and Facility Management in regard to safe environments, (2) the typical causes, top events, consequences due to fire incident and the acceptable level of risk, (3) information needs through the lens of the rescuer during an emergency situation, and (4) the current smart emergency apps that helps the facility manager during emergencies (fig 3).

2.3 Research instrument: semi-structured interviews

A literature review is used as a fundamental basis for the semi-structured interview. Using open-ended question stimulates facility managers to provide answers in a more detailed and meaningful way instead of 'yes' or 'no' response (Mack, 2005). In addition, it allows the author to ask 'why' and 'how' questions after the facility manager has responded. By doing so, the author intends to gather new useful data based on the participant's experience and point of view which are not explored by researchers in the literature review. In this respect, this research uses semi-structured interviews to collect data about the role of the participants during an emergency, their perception in regard to the acceptable level of risk and the use of smart emergency apps in general and, even more important, the required information that is needed in a building fire emergency response operation according to the participants (fig 3).

Sub - research questions	Literature review	Semi-structured interview
'What is the role Corporate Real Estate Management and Facility Management with regard to a safe environment in a university?'	✓	✓
'What is the typical scenario and acceptable level of risk in a fire emergency event with regard to a BowTie risk assessment method and ALARP?'	✓	✓
'What information items are required and relevant during the event of a building fire emergency?'	✓	✓
'What current smart emergency applications, in terms of information provision, contribute during an emergency situation?'	✓	✓

Figure 3 sub-research questions in relation to the literature review and semi-structured interview (author's illustration, 2019)

2.4 Data collection: selecting a sample

According to Kumar (2011), selecting a sample in qualitative research is influenced by multiple considerations: (1) easy access to the potential participants, (2) the researcher believe that the participants have certain expertise, and (3) a situation or event that hold the attention of the researcher. In particular, this research mainly selects a sample based on principle two and three of Kumar (2011). In other words, this study invites facility managers with expertise in safety who performs at Dutch universities that had to face with fire incident(s) in the past twenty years. To be more specific, facility managers from the following universities in The Netherlands are invited for a semi-structured interview: Delft University of Technology, Erasmus University Rotterdam, Leiden Medical University Center, University of Amsterdam, Utrecht University, University of Twente and Radboud University Nijmegen.

2.5 Multi-criteria analysis

The purpose of the multi-criteria analysis is to evaluate different current smart emergency apps according to a variety of information items examined by Li et al. (2014) and suggested by the participants. In this respect, the criterion relates to the information items and the option refers to the current smart emergency apps. The results of this multi-criteria analysis find out the extent of information on the current smart emergency apps (fig. 4). Further, this approach might appropriate for the facility manager in order to define which smart emergency app is the most suitable during a building fire emergency operation according to their required information needs.

Criteria	Importance based on Li et al. (2014) (ranking)	Agreement Respondents (#)	Options								
			Emergency app 1	Emergency app 2	Emergency app 3	Emergency app 4	Emergency app 5	Emergency app 6	Emergency app 7	Emergency app 8	Emergency app 9
Information item 1	2nd	xx/xx				✓	✓				✓
Information item 2	1st	xx/xx	✓				✓		✓		

Figure 4 an example of a multi-criteria analysis in this study (author's illustration, 2019)

2.6 Ethical consideration in data collection

Miles et al. (2014) and Fouka et al. (2011) did research in ethical issues in research and the researchers stated that ethical questions may involve the following: is it worthwhile to conduct the project? Do the interviewers have a right to look at the report? Both authors categorized different ethical issues in research: (1) Risk and harm; (2) trust and honesty; (3) anonymity, confidentiality and privacy. In addition, Miles et al. (2014) added (4) advocacy and intervention; (5) quality and research integrity as ethical considerations as well.

The ethical issue regarding risk and harm refer to whether the author in his or her study can hurt individuals involved and what is the likelihood that this harm will take place. Additionally, trust and honesty involved in ethical considerations. Here, researchers may ask whether they are telling the truth or individuals may feel betrayed at the time that they read your report. Furthermore, Miles et al. (2014) and Fouka et al. (2011) point out that anonymity, confidentiality, and privacy are also important aspects of ethical matters. For example, how will the gathered information be protected? in what manner will the research intrude and are the individuals or organizations in the research identifiable? Moreover, the authors mentioned advocacy and intervention as ethical issues. In the case of the researcher that identified the wrongful, harmful, or illegal part in a study of others, the researcher may consider how to deal with this situation. Finally, quality and research integrity are related to whether the researcher has done the study in a careful, thoughtful and correct manner.

Therefore, in regard to the semi-structured interviews, this research uses a consent form that is retrieved from Delft University of Technology. By doing so, the participants will be aware of the purpose of the study, benefits, and risk to take part in the research, and whether their identity (e.g. name) will be used for quotations to name a few. In essence, the consent form is to provide evidence that the participants provide permission to use the information from the interview and to archive in TU Delft Repository.

Theoretical framework

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Corporate Real Estate Management and Facility Management

Image retrieved from unsplash.com

3.1 University campuses

The focus of this Master thesis is related to a university campus with specific attention to Dutch universities. Den Heijer (2011) examined various university campuses in The Netherlands, for example, regarding the number of personnel, students and buildings, and the specific function within a university building. The research of Den Heijer (2011) shows that Dutch universities have around 1200 buildings and, according to Den Heijer & Tzovlas, 2014, an estimated number of nearly 240.000 students and 23.000 academic staff need to be accomodated. In comparison, higher education institutions in the United Kingdom accommodates around 2 million students and 146.000 academic staff, whereas universities in Germany have a student population of 2.4 million and 337.000 academic staff (Den Heijer & Tzovlas, 2014). In other words, the university buildings are utilized by a great number of individuals using the facilities with research and educational purposes and, additionally, it is also used for cultural activities (Chung et al., 2014).

The facilities in a university building involves research and educational purposes (Chung et al., 2014) and contain various specific areas or academic functions such as lecture halls for large groups, office space for academic personnel, laboratories, libraries and study places (Den Heijer, 2011) (fig 5). The university functions examined by Den Heijer (2011) is similar to Davis III et al (2010). The latter authors point out that a typical university building contains general areas such as office area, meeting rooms, study area, classroom area, laboratory, and common area. The difference between Den Heijer (2011) and Davis III et al (2010) is that the latter authors have added the service area and support facilities to the university function. The service area is related to mechanical and electrical areas with building equipment. The support facilities refer to the computer service area, storage rooms with hazardous materials, and repair shops.

In addition, IFV (2017), the Dutch Institute of Physical Safety (Dutch: Instituut Fysieke Veiligheid), specified that the opening hours of these institutions is in some cases open until late and risk are exposed during practice lessons in which students conduct risky operations that may lead to the occurrence of fire.

functions	who manages / own / uses?			similar city functions
	university	municipality	3rd party	alternative available in city? examples
ACADEMIC • EDUCATION & RESEARCH				
class rooms and studio spaces (small groups)	x			
lecture halls (large groups)	x			cinema, theater
office space academic staff	x			
office space support staff	x			
laboratories	x		x	R&D facilities of businesses
study places for individual use / small groups	x			inner city coffee bars
library	x			community library
special places for ceremonies (graduation)	x	x		city halls, churches
special conference facilities	x		x	conference center
special educational facilities (dance, media, arts)	x	x		theather, studios, musea
academic hospital			x	other hospital
medical school			x	

Figure 5 Various university functions which is managed by the university. Retrieved from Den Heijer (p184, 2011)

It can be seen that a variety of functions, students and employees need to be accommodated at the university. However, how about the condition of the university buildings? Canfield and Graff (2015) point out that most of the universities in the United States need to deal with more or less the same issue as the university campuses in The Netherlands as examined by Den Heijer et al. (2016). In particular, the issue refers to the fact that almost every university in the United States is faced with aging buildings and facilities. Canfield and Graff (2015) provide the example that university campuses in the United States that were constructed between 1951 and 1990 need to be renovated.

It is also worthwhile to mention that Den Heijer & Tzovlas (2014) did a comprehensive research of the European campuses in which the researchers reveal that campuses in Europe face with aging buildings. In particular, the researchers point out that over fifty percent of the floor area at the campuses in Europe having a lifespan of 50 years or older. In this respect, the concerning researchers state that most of the European campuses need to improve in terms of technical condition, functionality, and energy-efficiency (Den Heijer & Tzovlas, 2014).

Continuing on this line, since 1995, universities in The Netherlands inherited aging buildings with a strong need for maintenance and investment. At the same time, there was a lack of capital injection to address the aging university buildings in The Netherlands. However, from 2006 to 2016, it must be noted that the technical condition of the university buildings in The Netherlands was improved in general while the functional condition of these buildings was considered to be obsolete. Taken this circumstance into account, a lack of maintenance backlog investment impulse, in terms of functional and technical condition of the universities, can be a threat for the higher education institutions. In particular, this can lead to major issues related to the well-being and safety of the users of the university buildings Den Heijer et al. (2016).

3.2 Maslow's hierarchy of needs

First, safety demand from clients and users should be taken into account in the facility management domain. In this respect, Maslow's hierarchy of needs, examined by Den Heijer (2011), is used a basis to align the built environment in order to meet the needs of the individuals and, in the context of this research, the need for safety. Maslow's hierarchy of needs offers the theory of human motivation and needs which is applicable to justify the measure of the quality of life. Maslow's hierarchy of needs refers to a pyramid in which it contains five different levels of needs (fig 6): (1) basic needs for survival such as eat, drink and sleep. (2) The need for safety from the perspective of an individual. It must be noted that (1) and (2) refers to the 'primary needs.' (3) the need for a social place to contact with each other including friends and relationships. (4) Esteem needs such as prestige, approval, and recognition. The needs refer to (3) and (4) are related to the 'psychological needs.' (5) the need for self-actualization of the self-fulfillment needs indicates the individual full potential (Davey et al. 2014; Den Heijer, 2011). Den Heijer (2011) points out that the Maslow's hierarchy of needs has a particular level of hierarchy: once the basic needs are accomplished, individuals tend to achieve a higher need, psychological needs and higher. In the interest of this Master thesis, Den Heijer (2011) explains the relevance of Maslow's hierarchy of needs in relation to the field of (Dutch) university campuses. First, Maslow's hierarchy of needs is an accepted theory among Dutch campus managers. Second, it is a competent tool for deciding priorities of needs. Ultimately, accommodation in, for example, the University campus is an essential need to offer a place that gives protection and safety. This is related to the basic needs of Maslow's hierarchy (1 and 2). As soon as the basic needs have been satisfied, other needs from this hierarchy become relevant.

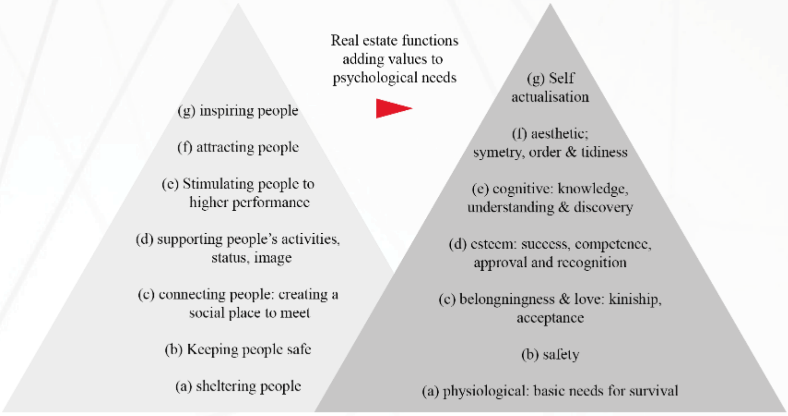


Figure 6 Maslow hierarchy of needs aligning to the built environment. Retrieved from Den Heijer (2011)

As noted, the facility management domain has a wide range of scope such as achieving a safe and secure environment. Maslow's hierarchy of needs explains the importance of primary needs (basic and safety needs) before fulfilling the higher needs. In relation to the University campus, the responsibilities related to offering education, safety, and welfare to the students. In line with Farris et al. (2014), the authors point out that significant events and disasters request that universities should stay attentive, careful and aware of crises. However, Connolly (2016) stressed that the institutions of higher education are, in recent years, not well prepared for providing the 'primary needs' including the safety of students. For the reason, the campuses have been the targets of various occurrences such as fire, violence, disasters. Therefore, Connolloy (2016) believes that universities need to consider preventive measures so that the institution of higher education can respond to any crisis that may develop at the university.

3.3 Stakeholder and CREM perspectives

According to Den Heijer (2011), there are four stakeholder perspectives to consider and the corresponding Corporate Real Estate Management perspectives. The stakeholder perspectives are related to the strategic, functional, financial and physical aspects. Each perspective has a particular objective. From the (1) strategic perspective, the goals referred to, for instance, stimulating collaboration and innovation, supporting image, and improving the quality of the place. The (2) functional perspective has various goals including supporting user activities, increasing user satisfaction and increasing flexibility which is covered by the facility management domain. The objective of the (3) financial perspective is related to the decreasing costs, controlling risks, and increasing real estate value. The (4) physical perspective specifies certain goals including reducing the footprint in a square meter and CO2 (fig 7).

As noted, the objective of the functional perspective is to increase user satisfaction to name a few. In addition, the Maslow' hierarchy of needs is elaborated earlier which indicates that individuals must satisfy the primary needs before progressing on the higher level of needs. Therefore, the facility managers are in charge of achieving the concerning objective and to satisfy the individual's needs. In particular, their responsibility is to offer a healthy, secure and safe environment in order to meet the demand of the client (CoreNet Global, 2015; European Standard, 2006).

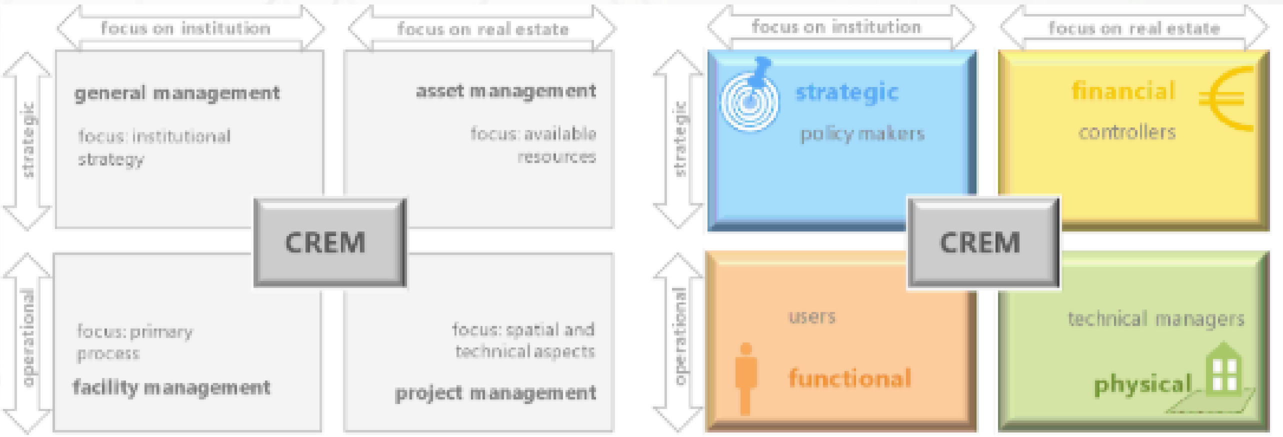


Figure 7 Stakeholder perspectives in relation to Corporate Real Estate Management (CREM). Retrieved from Den Heijer (2011)

3.4 The general management in CREM

According to Den Heijer (2011), there are four stakeholder perspectives to consider in the Corporate Real Estate Management (CREM) including general management, facility management, asset management, and project management. The focus of this research is on the higher educational institution and, therefore, it aims attention at two domains: general management and facility management. In particular, the general management focusses institutional strategy with the purpose to support image and improve the quality of the place to name a few. Whereas, the facility management focus on the primary processes such as increasing user satisfaction and safety-related activities (fig 8).

As noted, the general management focusses on the strategic level which involves establishing long-run and overall goals of an organization in strategic plans (Johnson et al., 2011). In this context, this is similar to the role of a crisis manager at the strategic level. In particular, Lerbinger (2012) indicate that the crisis manager is responsible for the preparation for the crisis which covers crisis communication planning. Moreover, in order to support the image, the crisis manager is responsible for determining (crisis response) strategies in order to avoid and minimize reputational damage of the organization (Coombs, 2007). Further, the (crisis response) strategy also covers (1) corrective action in which the crisis manager has the responsibility to keep the crisis from happening and restore the damage due to the crisis (Coombs & Holladay, 2002), and (2) develop a crisis plan for a specific emergency situation (Coombs, 2006). While Coombs (2006, 2007) and Coombs & Holladay (2002) did an extensive study in crisis management, both King (2002) and Taneja et al. (2014) agree that a crisis manager needs to determine a crisis plan and the corresponding issues to overcome the crisis situation. In other words, from the strategic point of view, the crisis manager in the general management domain of CREM is in charge to determine a crisis plan in order to overcome crisis situation and to support the image of the organization. Further, from the operational viewpoint, the facility manager is also responsible for a safe work environment which is elaborated in more detail in the next section.

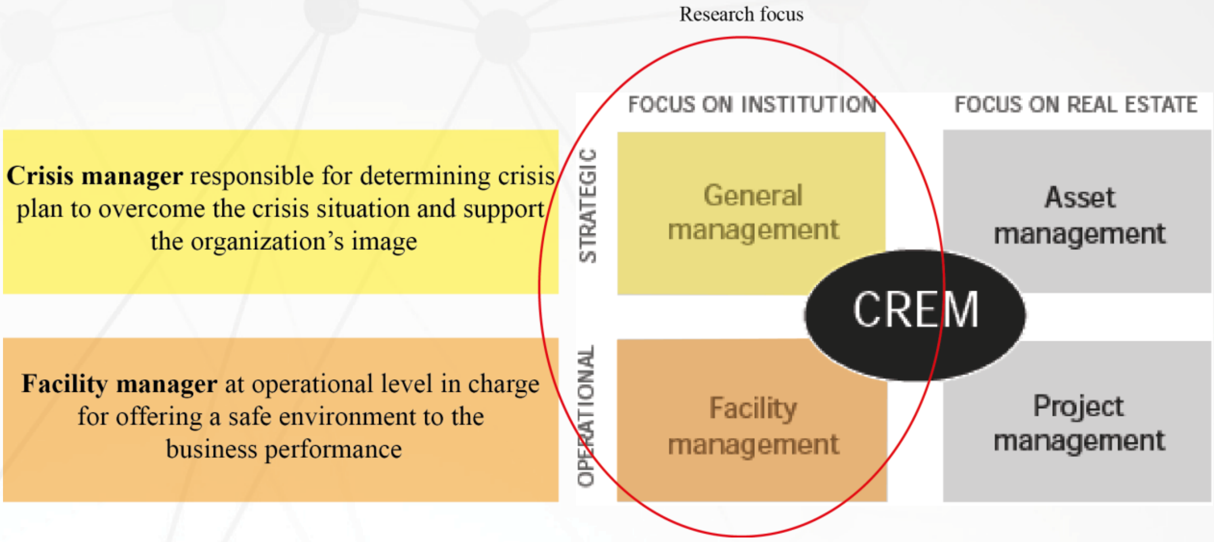


Figure 8 the general management and facility management in relation to the crisis manager and facility manager in the context of safety (author's illustration, 2019)

3.5 The facility management in CREM

In general, the definition of facility management is widespread and evolving which is by cause of the development and the growing role of this domain (Duffy, 2000; Prevosth et al., 2011; CoreNet Global, 2015). According to Becker (1990), facility management has the responsibility to the design, planning, and management of the buildings and their related furnishings and system. In contrast to Barrett et al. (2003), the facility management domain is related to an integrated approach. This means that maintenance, improvements, and adaptations are the key elements that contribute to the fundamental objectives of an organization. The facility management is also defined by the Dutch Normalisation Institution (Dutch: Nederlands Normalisatie Instituut) NEN2748 which stated that the facility manager provides guidance to the facility processes in which the facilities are inspected on its quality and price. On top of that, facilities are monitored and controlled in such a way that the organization can optimally carry out its policy and tasks. Corenet Global (2015) defines facility management as a profession with different discipline which ensures the performance of the built environment by incorporating place, technology, and individuals. Despite the extensive definition of facility management over the years, van der Voordt (2017) point out that the following definition of facility management is often chosen by academics and professionals: *'the total management of property, plant, and human resources to improve service quality, reduce operating costs and increase business value to provide competitive advantage.'* (van der Voordt, p.245, 2017). On the basis of this definition, van der Voordt (2017) indicates that the facility management is, therefore, related to the input (e.g. financial and human resources, and property), throughput which refers to the management, and output (e.g. competitive advantage, and business value).

In the interest of this Master thesis, Davies et al. (1998) defined the facility manager as the responsible individual that have an overview of the property management functions while being aware of the disasters and risks. Another important working definition for this thesis about 'the facility manager' is defined by European Standard (2006). The scope of facility management is extensive but the most relevant aspect regarding this Master thesis is related to health, safety and security: *'client demand for a safe environment (health, safety, and security) is satisfied by services that protect from external dangers or internal risks as well as the health and well-being of the people. Examples of services related to this demand are security management, disaster planning, and recovery, fire safety and protection, …'* (European Standard, pp.14, 2006). This is in agreement with Corenet Global (2015).

The authors of CoreNet Global (p80, 2015) point out that the facility management services include the various discipline of safety and security such as ‘Security services’, ‘Environment, health and safety’, and ‘Emergency preparedness’. On top of that, Corenet Global (2015) make a distinction between ‘hard’ and ‘soft’ facility management services. ‘Hard’ facility management services are, for example, related to fire safety system maintenance. The ‘soft’ facility management services refer to the security, health, and safety to name a few. Therefore, this research focusses on the soft side of facility management services.

The importance of (effective) facility management is essential for any organization that wants to achieve success. This can be accomplished at an operational level through offering an efficient working environment with a safe surrounding to the business performance, regardless of the size and scope (Corenet Global, 2015)

3.6 The role of the facility manager in emergency events

As noted, the definition of facility management is, in general, widespread which is examined by numerous studies. Research of European Standard (2006) and Corenet Global (2015) have defined, more specifically for this research, that the facility management is in charge of safety and security.

Additionally, Davies et al. (1998), Marchant (2000) and Hassanain (2006) explained in detail about the role of the facility manager in a disastrous situation. Davies et al. (1998) indicate that the facility manager has several responsibilities in catastrophic events: (1) Recover supporting services that will empower the business to operate again. (2) The facility managers should develop an awareness of the characteristics of emergency events and risk. (3) Facility managers should provide a suggestion about crisis-mitigating strategies that can be implemented by a property manager. Lastly, (4) Davies et al. (1998) recommend the facility manager to conduct disaster planning and a risk assessment. Marchant (2000) examined the role of the facility manager in relation to fire safety systems. The author state that the facility manager should be aware of both the fire safety systems and the day-to-day operational systems. Besides, they are responsible for conducting a fire risk assessment and applying installations that could be an improvement for the fire safety system. Hassanain (2006) suggest that facility managers should have situational awareness about the number of combustible materials within a specific area of the building, which eventually will burn and cause the growth of the fire. The authors further specified that it is important for the facility manager to be aware of how fast the release on burning can take place.

3.7 Situational awareness in the facility management domain

On the one hand, Davies et al. (1998), Marchant (2000) and Hassanain (2006) point out that facility managers should have situational awareness of emergency events, risks, fire safety systems and a number of combustible materials in a room respectively. On the other hand, Gheisari et al. (2011) explained, in general, the importance of situational awareness related to the facility management domain. In other words, why is it important for the facility manager to develop situational awareness in their facility management practices? Gheisari et al. (2011) believe that an improved situational awareness, in a general context, can lead to better decision making and performance of the facility manager (fig 9). However, it must be noted that the authors believe that this is partly true since it depends on the facility manager’s experience, personality, training, strategy, and technical constraints which can influence the process of decision-making.

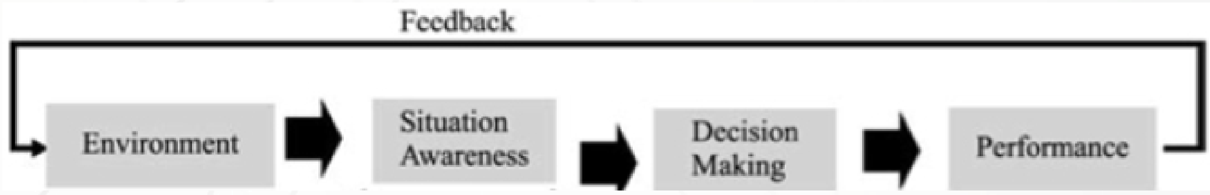


Figure 9 Situation awareness feedback loop in relation to the facility manager. Image retrieved from Gheisari et al. (2011)

3.8 Issues concerning the role of the facility manager in general

There are some issues regarding the performance of a facility manager. Gheisari et al. (2011) indicate that, in general, facility managers are facing difficulties regarding the management of information. Managing multiple information in a complex environment and in a precise manner is a challenging task for the facility manager. Therfore, Gheisari et al. (2011) believe that applications and computer technologies can support the activities of the facility manager including managing multiple information for their decision-making process (fig 10). In addition, the authors point out that using applications and computer technologies will help to achieve success in decision making and to accomplish their objective in the facility management domain.

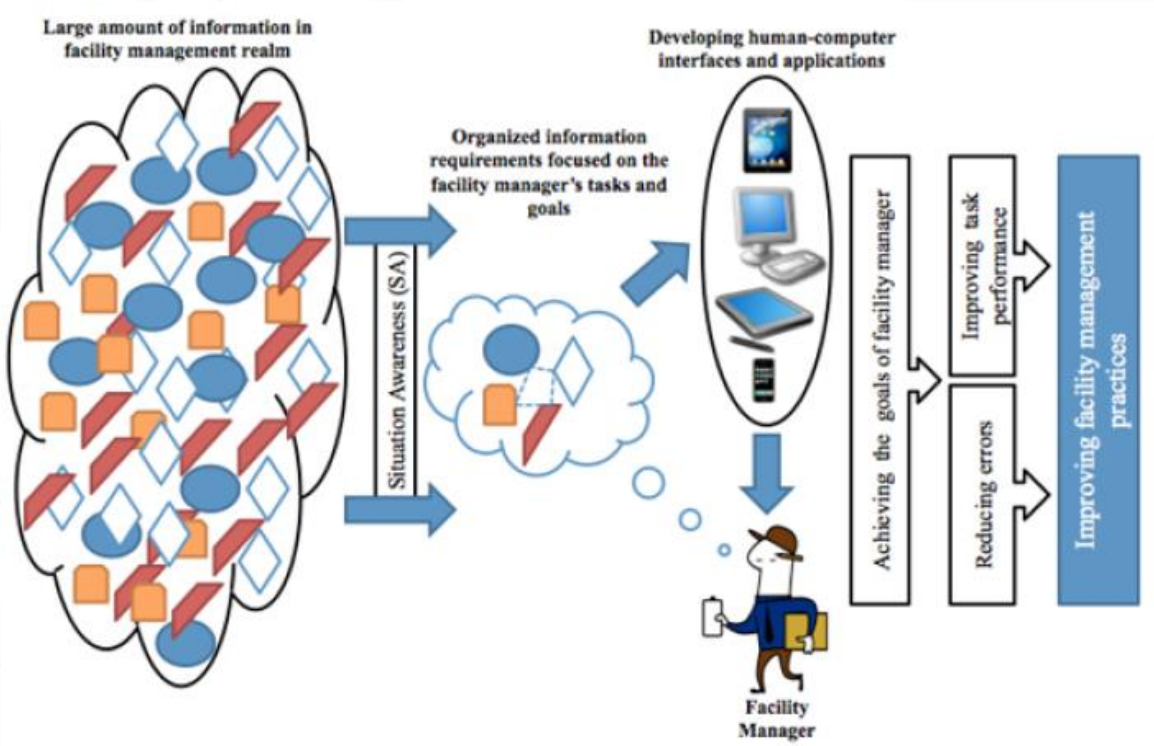


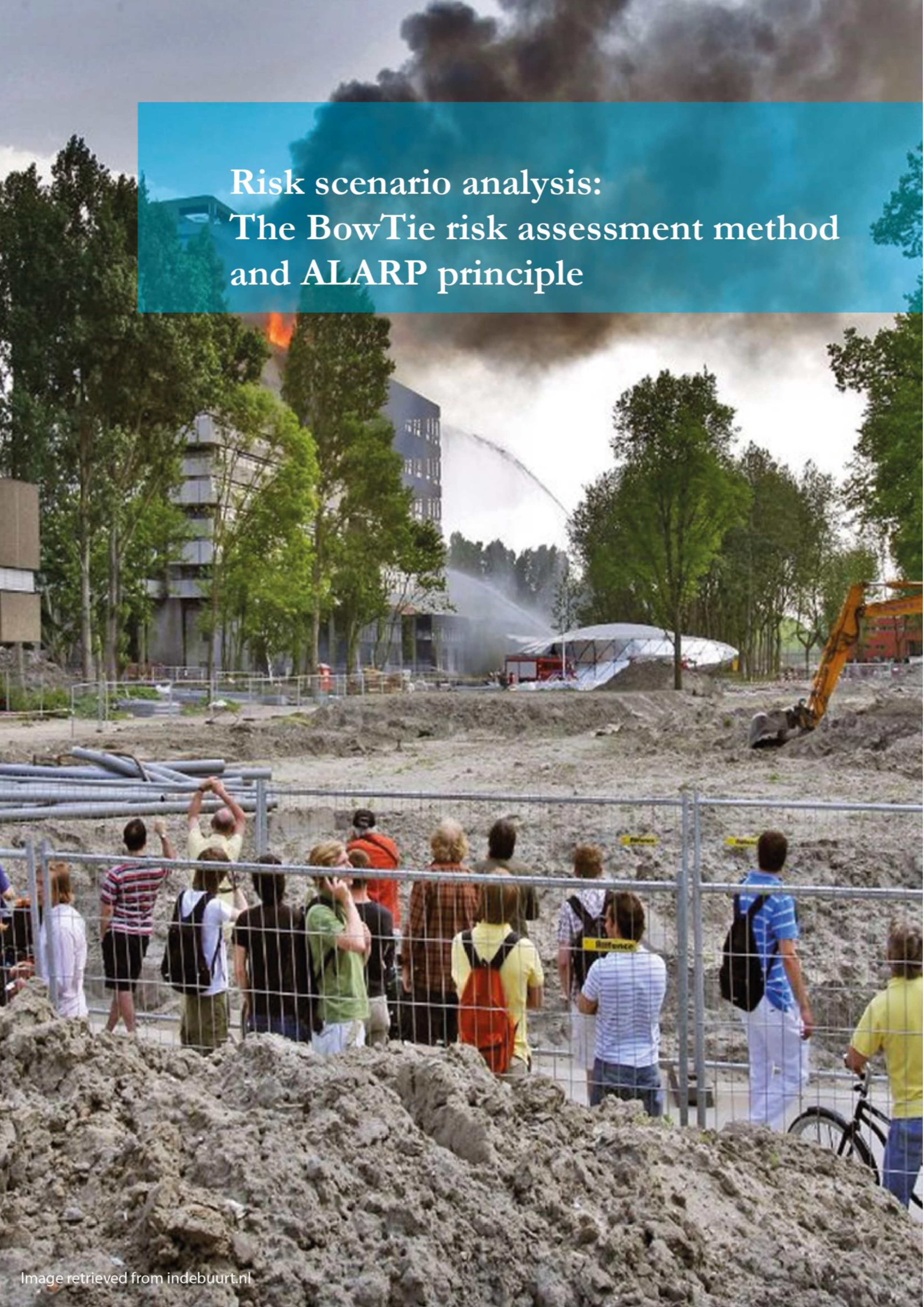
Figure 10 Situation awareness concept by means of computer technologies and applications. Image retrieved from Gheisari et al. (2011)

3.9 Conclusion

The purpose of this chapter is to examine the following: *'what is the role of the General Management and Facility Management in the Corporate Real Estate Management with regard to a safe environment in a university?'*

- Maslow's hierarchy of needs is examined by Den Heijer (2011) which is used a basis to align the built environment in order to meet the needs of the individuals and, in the context of this research, the need for safety;
- The General Management domain focusses on the strategic level which involves establishing long-run and overall goals of an organization in strategic plans. This is similar to the role of the crisis manager which determine crisis plan to overcome the crisis situation and support the organization's image;
- The Facility Management domain aims attention at the operational level in which the Facility manager is in charge of offering a safe environment of the business performance and having a variety of emergency duties during a catastrophic event;
- Facility managers should have situational awareness in this catastrophic event and, even more important, the risks, fire safety systems and a number of combustible materials in a room.

Risk scenario analysis: The BowTie risk assessment method and ALARP principle



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4.1 Definition, characteristics, and terminology related to a BowTie diagram

A BowTie diagram is a cause-consequence diagram (De Ruijter et al., 2014) which is presented in a graphical manner. Here, a risk scenario is determined and its corresponding safety barriers including the preventive and mitigative barriers (Badreddine et al., 2010). In addition, Acfield et al. (2012) explained that the BowTie diagram is a graphical representation for presenting risk information.

According to Blaauwgeers et al. (2013), the BowTie method is characterized by two aspects: (1) providing a visual overview of the scenario of the (fire) accident. In particular, the BowTie method illustrates and examines the causal relationship in a hazardous situation. It provides a clear overview of all conceivable scenarios (threat – top event – consequences) of a particular hazard. Therefore, the authors point out that the BowTie diagram is *'a powerful graphical representation of the risk assessment process'* (Blaauwgeers et al., 2013, p.233). (2) The Bowtie diagram determines and demonstrates various preventive and mitigative measures that an organization has applied. To be more specific, the scenario-based BowTie diagram describes and visualize the following main elements (fig 11): (a) threats, (b) top / initiating event, (c) consequences, (d) preventive measures, and (e) mitigative measures. (1) 'Threats' is related to the circumstances or fault that can lead to the occurrence of the top event. (2) 'Top event' is the accident that needs to be prevented. (3) 'Consequences' is when the Top event can cause various impact including damages and losses. (4) Preventive measures are actions to prevent the accident in the top event, and (5) mitigative measures are preparations and actions needed to mitigate the likely consequences (Acfield et al. 2012; Harris et al., 2012; Blaauwgeers et al., 2013).

Figure 11 Graphic presentation of the scenario-based BowTie diagram. Retrieved from Harris et al. (2012)

Likewise, De Ruijter et al. (2014) stated that all BowTie diagrams contain threats on the left side of the BowTie diagram, consequences or outcomes on the right side and a top event. However, it should be noted that various authors use different terminology for safety barriers. For example, the difference between Blaauwgeers et al. (2013) and Acfield et al. (2012), is that the first authors relate the safety controls to *preventive* and *mitigative measures,* while the latter authors refer it to *proactive* and *reactive controls*. Acfield et al. (2012) define the proactive controls as a measure to prevent a threat that can lead to the Top Event, and reactive controls as a measure to mitigate the likelihood and/or severity of a potential outcome (consequence). At the same time, Badreddine et al. (2010) relate the safety barriers as the *preventive and protective barriers,* which is the prevention of the occurrence of the Top event and the measure to decrease the severity of the outcome respectively. However, this different terminology for safety barriers has the same function or goal. In particular, *preventive measures/proactive controls/preventive barriers* refer to the control or prevent the Top Event from happening.

In addition, *the mitigative measures/reactive controls/protective barriers* are related to the measures which decrease or mitigate the severity and the likely consequences. Therefore, despite the fact that the authors are using different terminology for the safety controls, it can be concluded that the meaning of preventive measure/proactive control and mitigative measure/reactive control is more or less the same. In order to ensure that this Master thesis readable, this research uses 'preventive and mitigative measures' as terminology for the safety barriers.

Another difference in terminology observed by De Ruijter et al. (2014) is that a widespread of researchers use various synonyms for the terminology 'Top Event'. For example, 'Central Event', 'Critical Event', and 'the Centre/Central Event'. In the article by De Ruijter et al. (2014), the authors use the term 'Top Event' in their research because they believe that this word has the widest support. Therefore, this Master thesis focus on the term 'Top Event' instead of 'Central Event', 'Critical Event', or 'the Centre/Central Event'.

4.2 The reasons for using the BowTie diagram

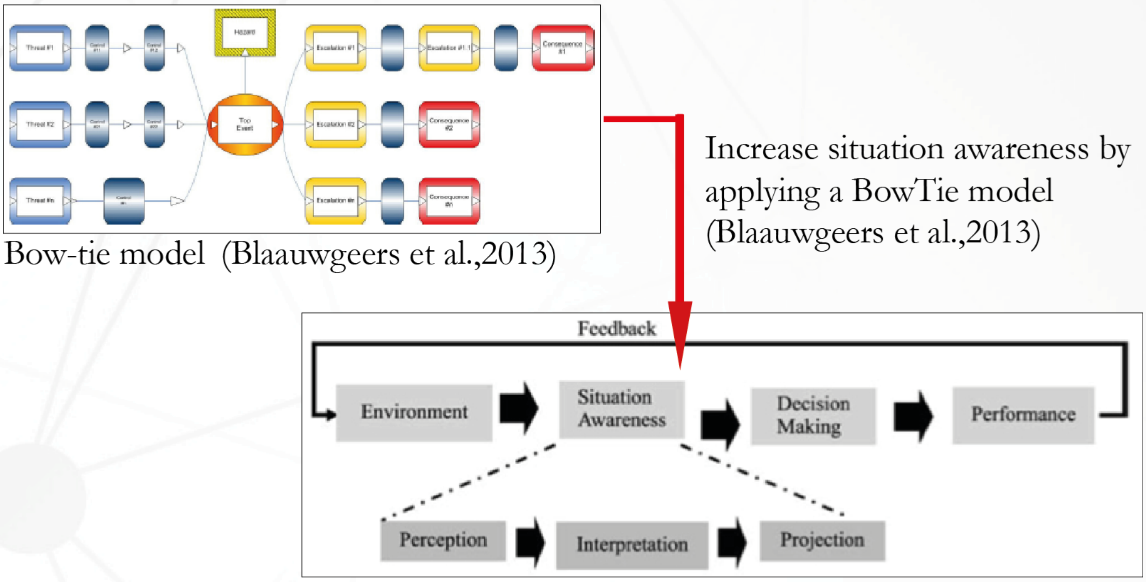
Blaauwgeers et al. (2013) indicate that risks in recent emergency scenes are not communicated properly to the management level. In particular, risk in the operational context is challenging to assess and difficult to communicate. Therefore, a BowTie diagram is a useful method to communicate the risk between the experts in safety and risk, and non-specialists because the diagram is readily understood for the latter audience. In addition, Badreddine et al. (2010) stated that the BowTie diagram is a popular method to analyze risk and utilize it in the safety management domain. De Ruijter et al. (2014) agree that this is a popular method because they believe that it is a simple cause-consequence diagram which can be communicated to the audience.

4.3 The advantage of the BowTie diagram

Acfield et al. (2012) point out that the use of a BowTie diagram is beneficial because the threats and consequences can be readily determined. Additionally, the authors stated that the diagram is advantageous due to its visual representation to present the risk and the relationship between each element (threat, top event, and consequences). Another advantage of using the BowTie diagram is that this method integrates different domains. To be more specific, threats due to equipment failure, human fault, procedure error, management and organizational mistake that can cause the accident to occur (top event) can be illustrated and visualized in a single Bowtie diagram instead of considering these domains in a separate way. Therefore, Acfield et al. (2012) concluded that the BowTie method is a strong approach for risk management and they encourage to use this framework for assessing risks. Blaauwgeers et al. (2013) stated that there are various benefits of the BowTie method: (1) The authors consider that the Bowtie method, the so-called graphical representation of risk, can contribute to the situation awareness because it shows and visualizes various relevant information about the causes of the accident and consequences. (2) BowTie can be used in a pro-active manner to inform the stakeholders about the increased risks. (3) it is a useful method to communicate what the consequences are and that different threats may lead to a single Top Event.

As mentioned, a BowTie model contributes to situation awareness when analyzing risk scenario's (Blaauwgeers et al., 2013). Therefore, what is the relation between a BowTie model and the previous section about the situation awareness diagram (fig 9) of Gheisari et al. (2011)?

The relation is visualized in figure 12: the situation awareness of a facility manager in an emergency situation can be improved by the use of the BowTie method. This should help to raise the situational awareness of a facility manager, and subsequently, their decision-making and performance.



Bow-tie model (Blaauwgeers et al.,2013)

Situation awareness feedback loop (Gheisari et al.,2011)

Figure 12 Improved situation awareness of the facility manager by means of the BowTie model. (author's illustration, 2019)

4.4 BowTie method as a qualitative or quantitative tool.

As noted, De Ruijter et al. (2014) stated that all BowTie diagrams are more or less the same which contain essential characteristics including threats, top event, consequences, preventive and mitigative barrier. Despite the similarity, De Ruijter et al. (2014) analyzed the difference of the BowTie diagram and refers to (a) quantitative risk assessment and (b) qualitative communication tool.

The (a) quantitative risk assessment results in a detailed BowTie diagram which is characterized by a fault tree and event tree analysis (fig 13). The use of this technique, with fault and event tree in the BowTie, lead to more detailed risk analysis. By doing so, the goal is to determine the frequency of the occurrence of the consequences and to compute the effectiveness of the barrier.

Another type of BowTie is related to the (b) qualitative communication tool (fig 13). This is a BowTie diagram without fault tree and event tree analysis. Instead, the concerning diagram has communicative value and it presents various conceivable scenarios which visualize and describes an easy to understand and uncomplicated cause-consequences relationship. In other words, the left side of the BowTie diagram pertains various threats which can lead to the top event, and the right side relates to different consequences which are caused by the top event.

Additionally, it must also be noted that the study of Blaauwgeers et al. (2013) focusses on the qualitative BowTie method. They suggest that this method enable organizations to determine the risk that is present in their firm and the available preventive and mitigative measures. De Ruijter et al. (2014) point out that the main goal of a BowTie is to communicate the risk to a target audience and not calculate. For example, the authors mentioned that the use of a BowTie as a qualitative communication tool must not be too detailed, scientific and technical for the management and execution personnel for risk identification. In addition, Cockshott (p308, 2005) indicate that the main purpose of this type of Bowtie is *'assembling information on hazards, initiating event, control measures and consequences in a form suitable for understanding and training.'* The target audience of this Master thesis refers to the facility management, and therefore, the BowTie diagram as a qualitative communication tool is utilized in this report.

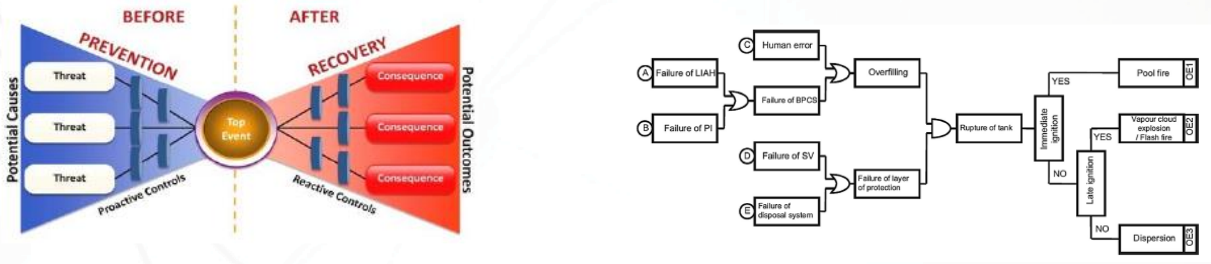


Figure 13 Qualitative BowTie (left) retrieved from Acfield et al. (2012) and Quantiatative BowTie (right) retrieved from De Ruijter et al. (2014)

4.5 The typical scenario in a fire emergency event regarding educational institutions

4.5.1 Threats/causes

The Dutch fire authorities have examined relevant statistics of all educational institution in the Netherlands that were exposed to fire. The concerning statistics shows various causes of fire (e.g. smoking and arson) in relation to a specific building type (e.g. education institution, offices, prison). The statistics of 2013 reveal that the most important cause of fire in any education institution in The Netherlands is due to arson (32.1%) which is followed by human error or wrong use of any device (29.5%), work that causes fire (Dutch: brandgevaarlijke activiteiten) (11.5%), spontaneous combustion (Dutch: zelf-verhitting) and firework (10.3%) and smoking (1.3%) (fig 14). As noted, arson in 2013 is the most frequent cause of the fire in educational institutions in the Netherlands which also applies to the year 2010 and 2011. IFV (2017), the Institute of Physical Safety (Dutch: Instituut Fysieke Veiligheid), also points out that arson is the most frequent cause of fire in an educational institution. According to the statistics (adopted from CBS, Statistics Netherlands) of the Dutch fire authorities, 40.2% is caused by arson in 2010 and 39.1% in 2011 (CBS Brandweerstatistiek, 2010; CBS Brandweerstatistiek, 2011; CBS Brandweerstatistiek, 2013).

According to Mousavi et al. (2008), another potential cause of the fire is due to the Post-Earthquake Fire (PEF) or, 'Fire Following Earthquake' (FFE) which is used as a synonym by Jelinek et al. (2017). To this matter, little attention has been given to post-earthquake fire in the building design, while it may lead to devastating consequences Mousavi et al. (2008).

		waarvan met als oorzaak								
	Totaal	brand-stichting	spelen met vuur door kinderen	roken	brand-gevaarlijke werkzaam-heden	defect/ verkeerd gebruik apparaat/ product	broei/ zelf-verhitting	vuurwerk	anders	onbekend
	x 1 000									
1995	13,6	2,3	0,6	0,4	0,8	4,1	0,6	0,1	2,3	2,3
2000	13,9	2,5	0,4	0,5	0,7	3,8	0,5	0,1	2,5	2,9
2005	13,1	1,5	0,2	0,4	0,5	3,2	0,4	0,1	2,5	4,3
2009	15,4	1,4	0,1	0,4	0,5	2,8	0,5	0,1	3,5	6,1
2010	15,6	1,1	0,1	0,4	0,4	2,5	0,5	0,1	4,1	6,3
2011	14,5	1,1	0,1	0,4	0,5	2,3	0,7	0,1	4,0	5,4
2012	14,3	0,8	0,1	0,3	0,5	2,1	0,7	0,1	3,8	6,0
2013*	15,0	0,7	0,0	0,3	0,5	1,6	0,7	0,1	3,4	7,7
	x 1 000	**% van de binnenbranden (excl. anders/onbekend)**								
2013*	15,0	19,2	1,3	6,7	12,0	42,1	17,1	1,6	.	.
waaronder										
woongebouwen	4,7	16,5	1,7	6,0	8,2	48,7	17,3	1,7	.	.
logiesgebouw	0,2	6,6	2,6	17,1	18,4	42,1	13,2	–	.	.
kantoorgebouw	0,2	10,3	–	8,0	19,5	39,1	19,5	3,4	.	.
onderwijsgebouw	0,1	32,1	5,1	1,3	11,5	29,5	10,3	10,3	.	.

Figure 14 Fire outbreak in educational buildings and the corresponding causes in 2013 in The Netherlands. Retrieved from Brandweer statistiek, 2013

In general, the Dutch fire authorities and IVF (2017) examined the causes of fire in relation to all educational institution in The Netherlands. In contrast to Helsloot and Jong (2006) and Meacham et al. (2010), they focus specifically on the fire emergency event of a computing center in Twente University of Technology and the faculty of architecture in Delft University of Technology respectively.

According to Helsloot and Jong (2006) and Barzak et al., 2014, the educational institutions such as universities are responsible for the health and safety of the students and personnel and in any campus activity. At the same time, the authors noted that fire and burglary are considered the most important risk for any institutions. An example of an emergency event at the higher institution was presented by Helsloot and Jong (2006). For example, the fire outbreak at Twente University of Technology (The Netherlands) which took place on 20 November 2002. The cause of this devastating event was due to arson. The reason for arson could be revenge from personnel or students (Helsloot and Jong, 2006). Helsloot and Jong (2006) believe that preventing arson can be achieved through three different approaches: (1) effective surveillance, (2) raise situational awareness among employees and students, (3) apply or improve early warning systems. It must be noted that Helsloot and Jong (2006) did not indicate the use of smart technologies as an early warning system to prevent and combat arson.

On 13 May 2008, a disastrous fire emergency event took place at a higher institution which is the faculty of Architecture in Delft University of Technology (The Netherlands). Meacham et al. (2010) did a preliminary study of this disastrous event which includes a timeline of the event, building analysis, material, and construction analysis. For example, the result shows that the cause of this fire emergency event is due to the malfunctioning of a coffee vending machine on the 6^{th} floor which leads to big flames coming out of this machine. The cause of fire from the coffee vending machine can be categorized as ‘self-heating’.

The results of the Dutch fire authorities show that, for example, arson (e.g. the case of Twente University of Technology), is not an incident, but a structural problem and the most frequent cause of the fire. Therefore, arson is taken into account in this Master thesis but attention should also be given to other causes of fire including human error, fire-susceptible activities, self-heating (e.g. the case of Delft University of Technology), firework and smoking.

4.5.2 Top event

With reference to the BowTie risk assessment, the aforementioned causes of fire lead to a certain ‘top event’. As mentioned by Acfield et al. (2012) and Blaauwgeers et al. (2013), a top event is an accident that needs to be prevented. In this case, the top event is related to fire building, which is by cause of arson, self-heating or smoking to name a few.

As indicated earlier, a higher institution such as Twente University of Technology and Delft University of Technology faced with fire building in the year 2002 and 2008 respectively. To date, various fire emergency events at different universities in The Netherlands took place in the last nineteen years which is from 2000 to 2019 (fig 15). In 2011, there was a building of the University of Amsterdam (UVA) on fire (NU, 2011). In 2015, fire building occurred at Leiden University Medical Center (LUMC) (NRC, 2015; NOS,2015). At the same year, the fire took place at Erasmus University of Rotterdam by cause of a cigarette (Rijnmond, 2015). In 2017, a fire occurred at the Spinoza Building in Radboud University Nijmegen (NOS, 2017), and fire also took place at the Grotius Building (Faculty of Law) in Radboud University Nijmegen (RU, 2017). Furthermore, a fire occurred in 2017 at the David de Wied Building in the University of Utrecht which happened in a technical area (DUIC, 2017). To date, the most recent fire in a university building in The Netherlands happened in 2018 at the laboratory in David de Wied Building in the University of Utrecht (NU, 2018). At the international level, examples of fire outbreaks in university buildings in the past nineteen years are shown in figure 16.

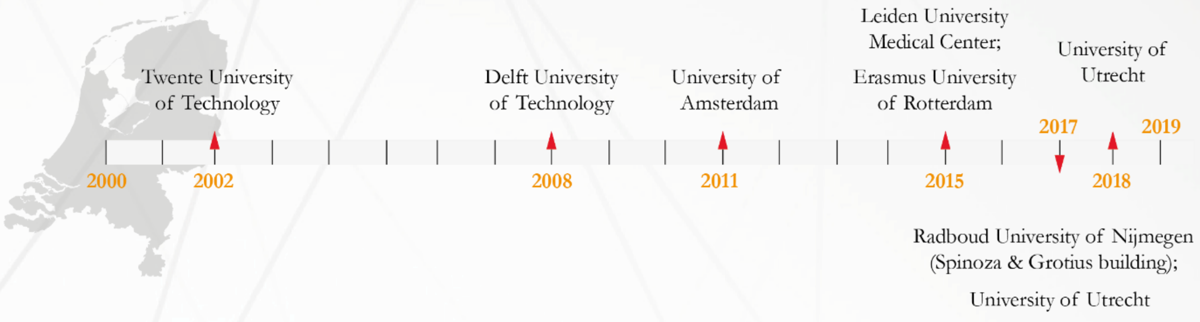


Figure 15 Fire outbreak at various university buildings in The Netherlands during the period 2000 to 2019. (Author's illustration, 2019)

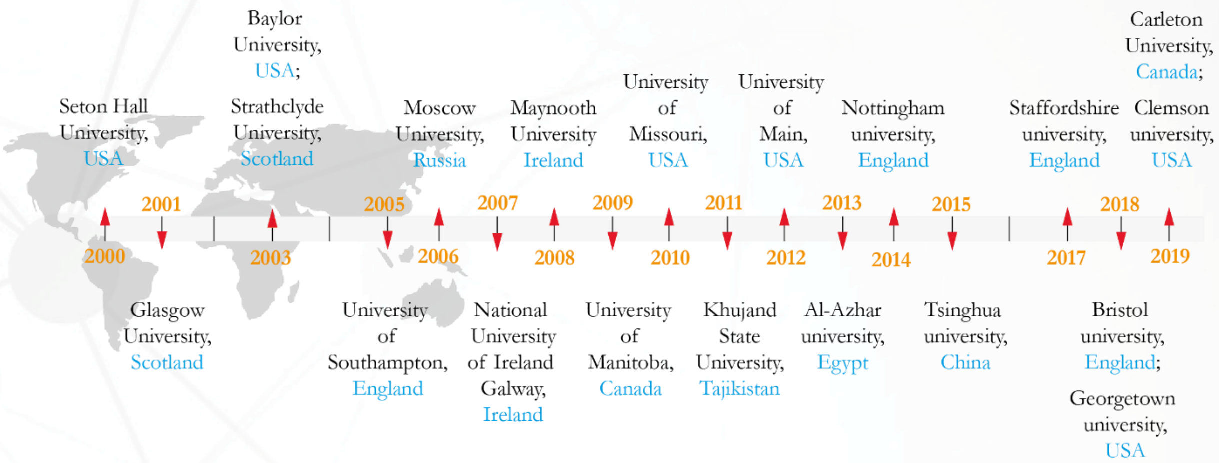


Figure 16 Several fire outbreak at international university buildings during the period 2000 to 2019. (Author's illustration, 2019)

4.5.3. Consequence

Any organization or institutions is exposed to issues on safety, security, fire, and risk which could have a direct influence on them (Barzak et al., 2014; Helsloot and Jong, 2006) such as the continuous operations of the higher institution (Helsloot and Jong, 2006). Additionally, it may have an impact on their operational, financial and strategical level (Barzak et al., 2014). For example, on 20 November 2002, there was a fire emergency event at Twente University of Technology (The Netherlands). As a consequence, the property damage was devastating with the loss of the computing center and experiment data (Helsloot and Jong, 2006). Another example is the fire emergency event at Delft University of Technology in 2008 which lead to a structural collapse of a high-rise building (Meacham et al., 2010).

As mentioned by Mousavi et al. (2008) and Jelinek et al. (2017), a potential cause of fire in the building is due to post-earthquake fire (PEF). The consequences of this event can be disastrous such as property loss Jelinek et al. (2017), property damage, infrastructure (e.g. life-line systems), and loss of human lives Mousavi et al. (2008).

With reference to the fire outbreak in a university building, an overview is presented in figure 17 which summarizes various potential causes and consequences.

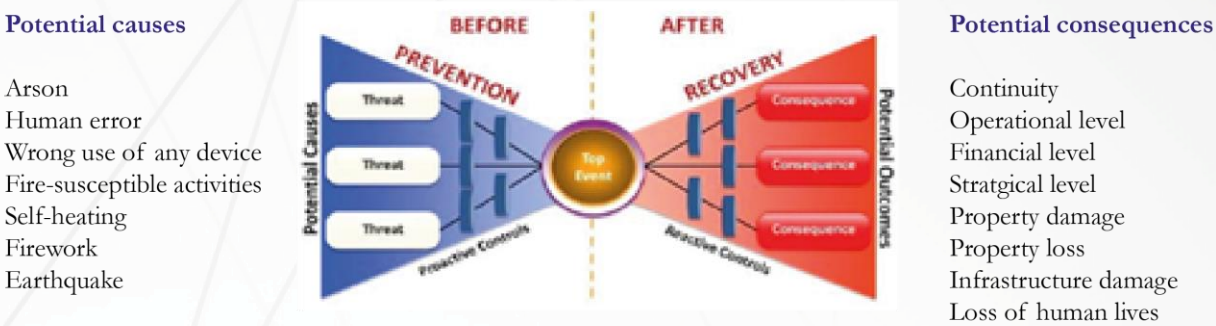


Figure 17 Potential causes and consequences presented in a BowTie diagram. Image retrieved from Acfield et al. (2012) (Author's illustration, 2019)

4.6 Acceptable level of risk

As discussed earlier, potential causes of the fire incident vary from arson to smoking and firework at educational institutions in The Netherlands. However, what risk is acceptable and not acceptable at the university? Is firework near the campus acceptable? Is smoking at a university not acceptable? In this respect, Van Gelder et al. (2012) point out that the acceptable level of risk is highly subjective. Therefore, whether a risk is acceptable or not, it depends on the acceptance of an individual, expert, and what the society is willing to accept (Van Gelder et al., 2012; Bell et al., 2006; Hunter and Fetrell, 2001). In this respect, a risk analysis method to determine the acceptable level of risk relates to the principle 'As Low As Reasonably Practicable' (ALARP). To be more specific, this ALARP method divides the risk into three different areas: unacceptable risk, ALARP (e.g. tolerable risk) and acceptable risk (fig 18).

In the (1) 'unacceptable risk' area, the risk is considered by the society and individuals as too high regardless of the benefits. This need to be mitigated to a tolerable level (De Mare et al., 2018; Redmill, 2010; Bowles, 2013). The (2) 'ALARP' area refers to the tolerable risk. Here, the public and individuals are prepared to live with the risk to secure certain benefits on the condition that risk will be kept under review, correctly managed and reduced As Low As Reasonably Practicable (Bowles, 2013). But what does 'As Low As Reasonably Practicable' really mean? To be more specific, Melchers (2001, p.205-206) point out that Practicable refers to *`that can be done, feasible…'* and Reasonably Practicable is related to '…*the degree of risk is balanced against time, trouble, cost and physical difficulty of its risk reduction measures'*. Lastly, (3) the acceptable risk relates to risk where the society and individuals live with every day and, moreover, it is considered to be negligible and insignificant which is broadly accepted without reduction (Redmill, 2010; Bowles, 2013).

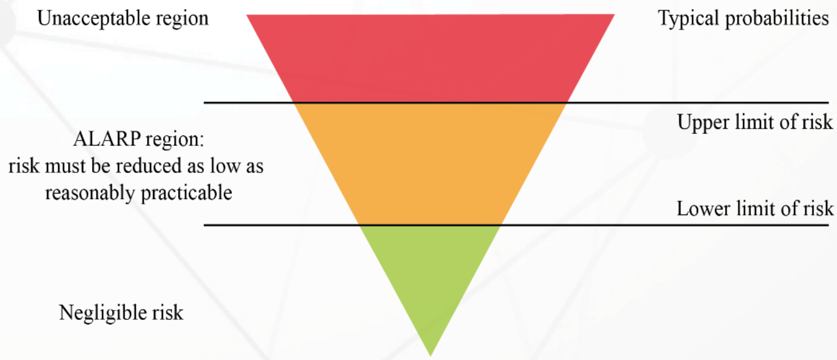


Figure 18 ALARP approach. Retrieved from Mou et al. (2008)

4.7 Conclusion

This chapter aims to provide a better understanding to the reader about '*what is the typical scenario and the acceptable level of risk in a fire emergency event with regard to a BowTie risk assessment method and ALARP?'*

- BowTie risk assessment method aims to provide a visual overview of typical scenarios (threat – top event – consequences) of a particular hazard;
- Main *causes/threat* of fire at Dutch education institution (2013) from most to least frequent: Arson (32.1%), human error or wrong use of device (29.5%), work that causes fire (11.5%), spontaneous combustion (10.3%), firework (10.3%) and smoking (1.3%);
- *Top event:* fire incidents at international universities occurred on a yearly basis, while eight fire incidents are determined at Dutch universities in the past twenty years;
- *Consequences:* business continuity, property damage, property loss, infrastructure damage, loss of human lives and, finally, impact on operational, financial and strategical level;
- The acceptable level of risk is related to subjectivity and, therefore, depends on the perception of society and individuals;
- Acceptable level of risk can be determined through the ALARP principle which divides the risk into three different regions: unacceptable risk, ALARP (e.g. tolerable risk) and acceptable risk.

Information items during a building fire emergency response operation

Image retrieved from Li et al. (2014)

5.1 The importance and issues of information sources in the emergency response

Major events such as disaster and emergencies bring confusion and disorder as mentioned by Barrantes et al. (2009). Therefore, the authors suggest that information management (collection, production, and dissemination of information) is essential in these circumstances. Van der Meer et al. (2018) agrees that information is important in fire emergencies for making the right decisions. However, as stated by Barrantes et al. (2009), the identified problem is that during the first hours of an emergency, information is not immediately available and not trustworthy. Another issue is the difficulties of getting and providing information. The key challenge is to guarantee that information is understandable and clear, and to generate and renew information on a regular basis.

As noted by Barrantes et al. (2009), information management is important in disaster and emergencies. For the reason, it is vital to the process of overseeing and decreasing the risk of tragedies. The authors point out that information is necessary during an emergency due to several reasons: (1) in order to make decisions in an effective and quick manner, (2) to offer effective and very quick assistance for the victims during a disaster, (3) effective and timely response in order to save lives (4) reduce the consequences amid the event of emergencies and disaster, (5) mobilize resources. Therefore, information is the main component in the event of an emergency and the basis for decision making in a disastrous circumstance. Moreover, information is important for evaluation, and to capture the lessons learned based on past failures and successes, with the objective to improve the performance in the future.

However, as explained in the section of the problem statement, various authors including Carver et al. (2007), Perry et al. (2003) and Kowalski-Trakofler et al. (2003) point out that there is an incomplete, incorrect or an overload of information in an emergency event. Therefore, the question is: what information sources are desired and necessary in such an event? The answer is provided by Li et al. (2014) and Van der Meer et al. (2018) in which they reveal the required information sources in an emergency event.

5.2 Desired and necessary information sources

As noted, Barrantes et al. (2009), Carver et al. (2007), Perry et al. (2003), Kowalski-Trakofler et al. (2003) indicate in their study about the problems of information provision. However, these authors did not identify and classify which information sources are, then, important and necessary in an emergency event. Therefore, Li et al. (2014) took a specific approach in which the authors analyzed the necessary information items during a building fire emergency and the importance of situational awareness in this kind of situation. The authors believe that situational awareness is vital during an emergency, in which they define situation awareness as: *'perception of environmental elements with respect to time and/or space, such as locations of occupancies, and status of fire growth, comprehension of their meaning, and a projection of their status after some variable has changed.'* (Li et al., 2014, p.17).

According to the authors, the situation awareness during an emergency are of essential importance for several reasons: (1) better assessment of the dynamic situation, (2) to make informed decision during the event of fire emergencies, (3) to understand the on-scene situation in a quicker and precise way, (4) to make more informed decision in the interest of saving lives. On the one hand, when there is a lack of situation awareness, the authors believe that it is by cause of insufficient understanding, collection and filtering time-dependent information. As a consequence, this can make the emergency response very difficult and it may lead to damages in properties and casualties. This is in line with Van der Meer et al. (2018). They believe that poor information could lead to the wrong judgment during the fire emergency scene, which in turn can cause casualties. On the other hand, well-developed situation awareness and good information supply can be beneficial to understand what is currently going on (Li et al., 2014), and to make the right decision amid a fire emergency scene Van der Meer et al. (2018).

In order to improve the situational awareness during the building fire emergency response operation, Li et al. (2014) indicate and evaluate the importance and necessity of the needed information (items) at emergency scenes. In particular, there are various information items needed in building emergency response operations which are distinguished in three different categories (fig 19): 'Before arrival to the scene', 'At emergency scene', and 'attack and mitigation'.

Moreover, the authors analyzed the order, frequency, and importance of the information items (fig 20). Other analysis specified the 'required format of representation' such as the presentation of information in graphics, 3D, and text to name a few (fig 21).

Category	Number	Description
Before arrival to scene	A1	Building occupancy (number and identities of occupants, based on time of day)
	A2	Building layout and site plan (building size, construction type, floor plans)
	A3	Location of water sources nearby (fire hydrants, fire department hookups for sprinkler system, standpipes)
	A4	Routing information to the building and area map of the neighborhood of the building
	A5	Contact information of building owners, managers and utility contacts
	A6	Hazards, location and identification of unusual hazards (above ground propane tanks, gas lines, chemicals, explosives, etc.)
	A7	Location of important objects (facilities, documents, equipment) to be saved
At emergency scene	B1	Location of fire in the building, fire size, and duration
	B2	Sprinklers' status (number of location of sprinklers that have gone off)
	B3	Presence and location of occupants in the building
	B4	Location and condition of smoke
	B5	Warnings of structural collapse based on material type, fire location, fire size and duration
	B6	Confidence in the fire being real
Attack and mitigation	C1	Required water flow (gallon/minute) or foam based on fire condition
	C2	Location of available areas of refuge, staging areas
	C3	Location and condition of deployed and standing-by responding units
	C4	Local weather conditions and predictions, wind direction and velocity
	C5	Locations of building entrance/exit signs
	C6	Contact information of other emergency agencies

Figure 19 Information items in different categories. Retrieved from Li et al. (2014)

	Order	Frequency	Importance
Before arrival to scene			
1st	A4: Routing information to the building and area map of the neighborhood of the building	A6: Hazards, location and identification of unusual hazards (above ground propane tanks, gas lines, chemicals, explosives, etc.)	A4: Routing information to the building and area map of the neighborhood of the building
2nd	A1: Building occupancy (number and identities of occupants, based on time of day)	A3: Location of water sources nearby (fire hydrants, fire department hookups for sprinkler system, standpipes)	A1: Building occupancy (number and identities of occupants, based on time of day)
3rd	A3: Location of water sources nearby (fire hydrants, fire department hookups for sprinkler system, standpipes)	A7: Location of important objects (facilities, documents, equipment) to be saved	A3: Location of water sources nearby (fire hydrants, fire department hookups for sprinkler system, standpipes)
At emergency scene			
1st	B1: Location, size, and duration of fire in the building	B3: Presence and location of occupants in the building	B1: Location of fire in the building, fire size, and duration
2nd	B3: Presence and location of occupants in the building	B1: Location of fire in the building, fire size, and duration	B3: Presence and location of occupants in the building
3rd	B4: Location and condition of smoke	B4: Location and condition of smoke	B4: Location and condition of smoke
Attack and mitigation			
1st	C3: Location and condition of deployed and standing-by responding units	C3: Location and condition of deployed and standing-by responding units	C3: Location and condition of deployed and standing-by responding units
2nd	C2: Location of available areas of refuge and staging areas	C2: Location of available areas of refuge, staging areas	C1: Required water flow (gallon/minute) or foam based on fire condition
3rd	C1: Required water flow (gallon/minute) or foam based on fire condition	C1: Required water flow (gallon/minute) or foam based on fire condition	C2: Location of available areas of refuge, staging areas

Figure 20 Information items distinguished in 'order', 'frequency' and 'importance'. Retrieved from Li et al. (2014)

Presentation	% of total response
Graphic representation, such as drawings and graphs	64.3
3D representation, showing space constraints and component volumes	50.0
Virtual representation, displaying fully simulated results	38.1
Augmented reality representation, with real building environment and virtual elements	33.3
Textual representation, such as messages	22.2
Numerical representation, such as numbers and tables	14.3
Phonetic representation, such as audio and sound	14.3

Figure 21 Required format. Retrieved from Li et al. (2014)

Li et al. (p.20-22, 2014) concluded that (1) 'Routing information to the building and area map of the neighborhood of the building, (2) 'location, size and duration of fire in the building' and (3) condition of deployed and standing-by responding units' are information items that need to be obtained first. However, according to the authors, the most important information during an emergency situation is related to (1) the position and condition of occupants and firefighters, and (2) the status and development of smoke and fire.

Van der Meer et al. (2018) agrees with the information items analyzed by Li et al. (2014) that is needed during the fire emergency scene. However, the difference between Van der Meer et al. (2018) and Li et al. (2014) is that the first authors added the following information items that are needed during the event of fire: '(1) fire behavior of building construction and materials, (2) fire preventive measures in general, (3) fire repressive resources in the building, (4) number of building levels, (5) building use type, (6) location of water riser pipes, (7) number of hose lengths between the water riser pipes and the fire, (8) accessibility of rooms, (9) number of staircases and their location, (10) number of firefighter's elevators and their location, (11) location and capacity of fire hydrants, (12) number of hose lengths between fire hydrant and vehicle.' Van der Meer et al. (p.656, 2018)

5.3 Conclusion

This chapter reveals '*what information items are required and relevant during the event of a building fire emergency?'*

- Li et al. (2014) reveal a variety of essential information items that are needed during three different phases: 'before arrival to the scene', 'at the emergency scene' and, 'attack and mitigation';
- The most important information during 'before arrival to the scene' is 'Routing information to the building and area map of the neighborhood of the building;
- Another essential information that is ranked in the first place is 'location of the fire in the building, fire size, and duration' during the phase 'at the emergency scene';
- During 'attack and mitigation', 'location and condition of deployed and standing-by responding units' is the most essential information item;
- In general, information items during an emergency situation is important to make effective and quick decisions, timely response, quick assistance for the victims, mobilize resources (Barrantes et al., 2009);
- Li et al. (2014) suggest that collecting, understanding and filtering sufficient time-dependent information will lead to situation awareness and, therefore, enabling to make right decisions during an emergency situation (Van der Meer et al., 2018).

Smart emergency applications

Image retrieved from Depari et al. (2018)

6.1 Characteristics and implementation of ‘Smart’

To date, more than twenty years ago, Goddard et al. (1997) introduced the concept ‘smart’ already in 1997 which can be used as a synonym for ‘intelligent’. Worden et al. (2003) and Neuhofer et al. (2015) agrees that ‘smart’ can be used as a synonym for ‘intelligent’.

According to Goddard et al. (1997), there is no common scientific description of the concept of ‘smart’. Nevertheless, the authors attempt to provide a working definition for the concept ‘smart’ in the context of technology: *‘an inherent ability to gather information on its operating environment or history, to process that information in order to draw intelligent inferences from it and to act on those inferences by changing its characteristics in an advantageous manner.’* Goddard et al. (p130, 1997). Additionally, the authors describe that ‘smart’ relates to sensors which are capable to gather information.

Over the course of time, several authors including Derzko (2006) and Debnath et al. (2014) characterize the concept ‘smart’ in a technological context. Derzko (2006) stated that ‘smart’ is related to sensing, which is similar to Goddard et al. (1997). Additionally, Debnath et al. (2014) expand the characteristics of the concept of ‘smart’ in the technological context. While Goddard et al. (1997) and Derzko (2006) suggest that sensors or sensing relate to the concept of ‘smart’, Debnath et al. (2014) have expanded this concept with elements such as sensing, controlling, processing, communicating, predicting, preventing and healing.

The concept of ‘smart’ has been mainly used on an urban level which is named as ‘smart cities’ (Gretzel et al., 2015). However, ‘smart’ can be used in various areas such as ‘smart’ buildings, ‘smart’ technology, and ‘smart’ infrastructure to name a few (fig 22) (Dameri, 2017). Therefore, one may question what elements are involved in these ‘smart’ concepts? According to Depari et al. (2018), the authors have recently noticed that smart devices including tablets and smartphones have been applied increasingly often in smart cities, smart buildings, and smart home to name a few. Hence, smart handheld devices play an important role in the ‘smart’ concept which is examined in the next sections.

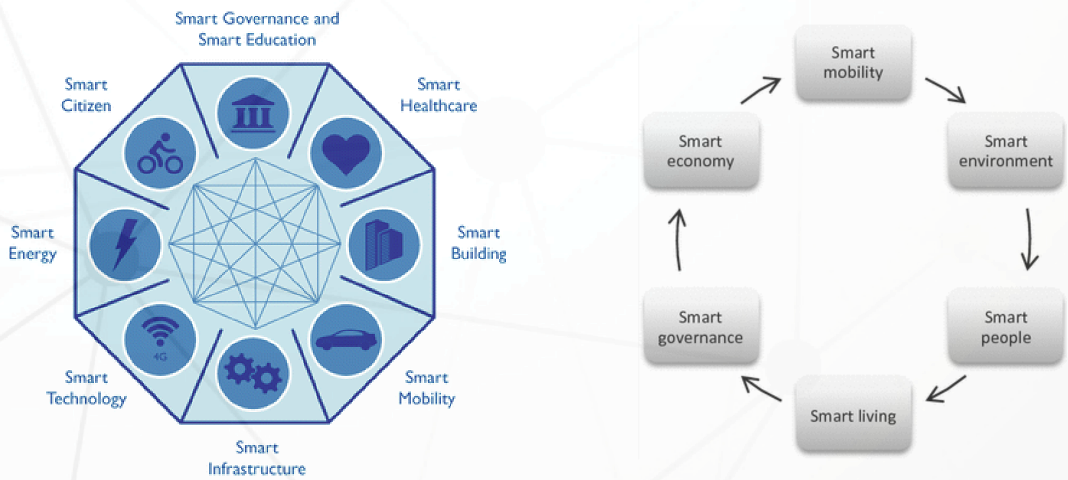


Figure 22 Different applications of ‘smart’ Retrieved from Dameri (2017)

6.2 Sensors and objective of smart tools

The previous section reveals that 'smart' has been widely used in different areas such as 'smart' healthcare, 'smart' building, or 'smart' education. For example, much attention has been given to 'smart' education and building in scientific research including Valks et al. (2018). In their study, the use of smart tools is examined which helps to determine the space use with the focus on a variety of types of sensors. In addition, as discussed in the prior section, 'smart' refers to sensors that gather information but what type of sensors need to be considered? In this regard, Valks et al. (2018) elaborated this aspect in more detail in which the authors present various sensors including WI-FI, Bluetooth, and RFID to name a few. In particular, Valks et al. (2018) point out that the WI-FI network contributes to measuring space use and finding people within buildings. Using the WI-FI network can also be seen in the next sections in which some emergency apps use this measurement method in favor of indoor localization of people. Further, Valks et al. (2018) stated that Bluetooth is a wireless technology that can be used to exchange data at close range and RFID helps to track objects which involves a chip with data and antenna, and a reading device. It must also be noted that these measurement methods are integrated into some smart emergency apps which is elaborated in the next sections.

Up till now, the characteristics of 'smart' and the use of different sensors has been discussed. On top of that, it is also essential to increase the understanding of the objective of smart tools. In other words, to which goals do the smart tools actually contribute?

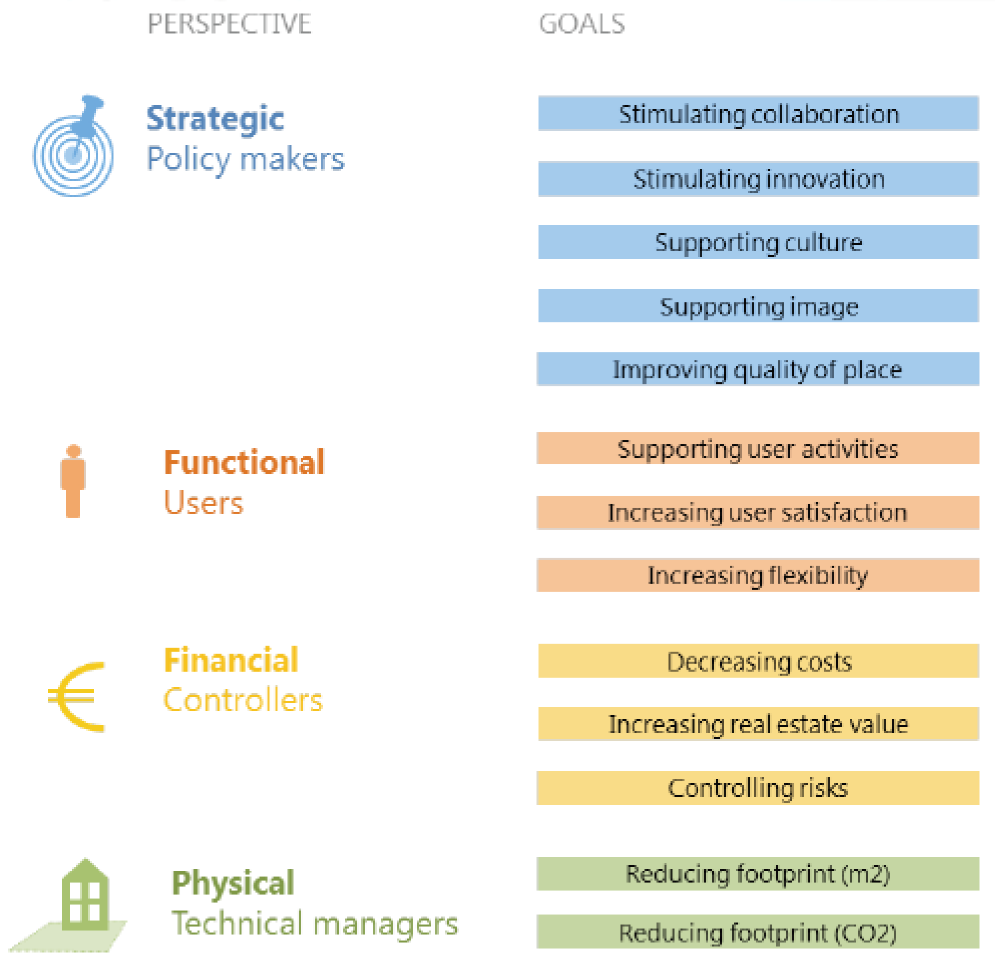


Figure 23 Four perspectives and the corresponding goals. Retrieved from Valks et al. (2018)

In this regard, using the research of Den Heijer (2011) as a fundamental basis, the same question is addressed in the research of Valks et al. (2016). In their study, the concerning researchers determined a variety of goals through the lens of the different stakeholders in the context of campus management. For example, as depicted in figure 23, it can be seen that policymakers from the strategic level aim to stimulate collaboration and innovation to name a few, and the intention of technical managers is to reduce the footprint in square meters and carbon dioxide. Based on the latter case, it must be noted that 'enhancing safety' is considered an objective as well (fig 24). In this respect, Valks et al. (2018, p.207) use this approach to determine *'to which goals the smart tool contribute?'* For instance, it is already known that a smart tool such as Study Spot (e.g. smart tool that shows the availability of study places) aims to contribute 'supporting user activities', 'increasing user satisfaction', and 'optimizing square meters use' Valks et al. (2018).

	Why: Objectives
question	Could you indicate to which goals the smart tool contributes?
options	Multiple options are possible: Strategic-> Stimulating innovation, stimulating collaboration, supporting image, supporting culture, improving quality of place Functional -> Supporting users, increasing user satisfaction, increasing flexibility Financial -> Increasing profits, reducing costs, reducing risks Physical -> Optimising m2, reducing CO2 emissions, Enhancing safety

Figure 24 Perspectives and the corresponding goals based on the research of Valks et al. (2018). Table Retrieved from Valks et al. (2018).

6.3 Smart tools usage

As discussed earlier, smart tools can contribute to a variety of goals and uses different measurement method (e.g. WI-FI, RFID, and Bluetooth). However, what can users actually do with smart tools? For example, various studies have recently examined the use of smart tools at both Dutch and international universities such as Valks et al. (2018) and Valks et al. (2016). In particular, users who are seeking for a suitable study place at the university may utilize Spacefinder. This smart tool provides information about the possible workspace Valks et al. (2018). Further, Smart library enables the users to become aware of the available workspace in the library and, on top of that, it provides the user's information about the essential elements of comfort in the workspace including the temperature, humidity, and lighting. Another example relates to Seated which enables students and employees to make a room reservation based on WI-FI and their proximity to the workspace Valks et al. (2016). Continuing on this line, this master thesis also focusses on smart tools at universities. However, special attention is given to the use of smart emergency applications by the facility managers in the context of a fire emergency at universities. Therefore, the use of various smart emergency applications on smart devices is elaborated in more detail throughout the next sections of this chapter.

6.4 Reasons for using smart emergency applications

As noted earlier, Gheisari et al. (2011) believe that applications and computer technologies are able to support the activities of the facility manager in general. It helps them to manage multiple information for their decision-making process. On top of that, Jiang et al. (2004) think that the use of the sensor, wireless networking, and computing technologies have a great potential in gathering information during the event of an emergency and using these technologies is promising for communicating important information in real time. For example, real-time communication about the different risk that is related to the temperature, the location, and status of the individual and toxicity. In addition, Sarshar et al. (2015) suggest that using a smartphone in the emergency event is the most practical solution for raising situational awareness: it enables the users to have an overview of the hazard and communicate between the rescue team and individuals in danger. On top of that, the smartphone enables to collect desirable information sources and emergency team are able to respond on time. Rajalakshmi et al. (2015) using smart emergency applications in the smartphone during an emergency event is advantageous because it provides valuable information to the users. Additionally, Lu et al. (2016) suggest that smartphones are potentially the most promising and feasible instrument to provide communication in an emergency situation. And most recently, Cheng et al. (2017) believe that computing technology is able to provide accurate information to help rescuers for planning the most favorable rescue route in fire scenarios. Hence, several authors think that using a smartphone (applications) is an added value in emergency and facility management practices.

In more detail, Maryam et al. (2016) estimated that the use of a smartphone in an emergency and the use of emergency app increases from 2014 to 2019 (fig 25). Therefore, there is more and more interest in smartphones among people which is still growing (Rajalakshmi et al. (2015). Moreover, Maryam et al. (2016) expected that 1873 million handheld devices will be sold in the period 2017 to 2018, and 84% of the people will use these devices in an emergency event Maryam et al. (2016), and 85% of the users make use of a smartphone in general (Valks et al., 2018). On top of that, Lu et al (2016) stated that users rely heavily on their smartphones during their day-to-day activities and they will always have their smartphone within reach even in an emergency situation

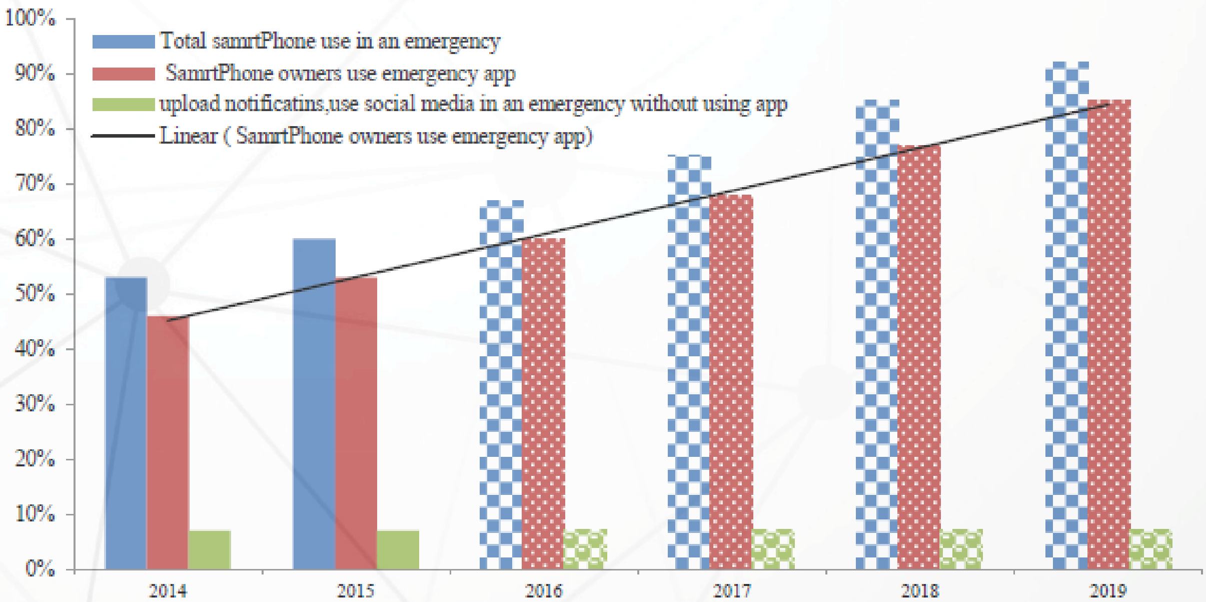


Figure 25 Increase in emergency app and smartphone use in an emergency. Retrieved from Maryam et al. (2016)

During a crisis, Maryam et al. (2016) believe that smartphones are able to respond in an efficient and effective manner in an emergency event, and the incident response team could be informed on time. Another research has found out that mainly younger individuals (18-29 year) in the United States of America uses their smartphone in an emergency event. While in general, 53 percent of the smartphone users in the same country point out that their phone is an added value in an emergency situation (Pewresearchcenter, 2015). In conclusion, more and more smartphones are used during an emergency. As mentioned earlier, this is similar to Depari et al. (2018) in which the authors stated that smart devices are more and more often used in, for example, smart cities.

In this respect, the next sections elaborate a variety of smart emergency apps in more detail (fig 26). In particular, the following emergency app is taken into account: (1) iRescue, (2) My Disaster Droid, (3) RescueMate, (4) RescuePal, (5) Rescuer app, and (6) Smartrescue. To date, it must be noted that these apps are still in the development stage. Other emergency apps in this research involves (7) EMS app, (8) NerveCentre, and (9) Picasse. These apps have been already implemented in a real-life context. All these emergency apps have a different and unique way of information delivery. The information varies from predicting the development of fire to finding victims and presenting the availability of first responders (Dutch: BHV-ers).

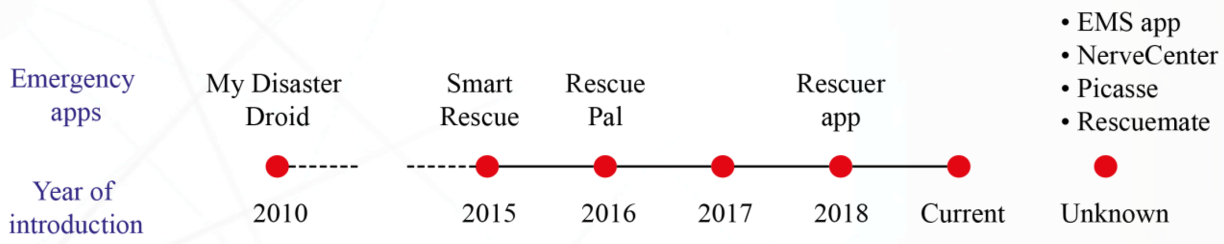


Figure 26 the focus on smart emergency apps in this masters' thesis (author's illustration, 2019)

As being part of the smart tools' lab, the analysis of these smart emergency apps is carried out on the basis of a similar approach of Valks et al. (2018). In particular, this involves the management information, project description, phase, functionalities, the objective (e.g. the goals that emergency apps contribute.), foreseen development and measurement of the smart tools (e.g. *what* and *how* does emergency apps measure?).

.

Smart emergency app

EMS app

Phase

Implementation

Source

Findwhere.com

Functionalities

- Fire crisis assessment
- Emergency list
- Attendance registration
- Localization first responders
- Localization victims
- Alert notification
- Navigator
- Victim assessment
- Direct communication

Project description

Findwhere is a platform that is composed of a dashboard on the computer and EMS app on mobile devices. The first method enables emergency managers to manage a variety of activities such as inventory and management of users, locations, competencies, agendas, and protocols. In particular, users such as first responders can be tracked based on their location and competency. Whereas, EMS app, allows users to send and receive alert notification through text, voice messages while enabling them to send videos and images of the incident with the corresponding protocols. In addition, this app enables users to communicate with each other during an emergency situation through push-to-talk, video calls, and chat.

Management information

First responders and emergency managers receive the following information:

- Indoor and outdoor localization of first responders (C3);
- Images, videos, text and voice message of incidents;
- Protocols;
- Agendas;
- Alert notification.

Android iOS Windows Unknown

Mobile operating system

Strategic Functional Physical (enhancing safety) Financial

Why: objective

What: measurement

- Location emergency source
- Emergency type
- Fire activity
- Location first responders
- Presence first responders
- Location victim
- Physical status victim

- Wi-Fi
- Mobile network
- Beacons
- Smartphone sensors
- RFID
- GPS
- Sound

How: Measurement method

Smart emergency app

iRescue

Phase

Product development

Source

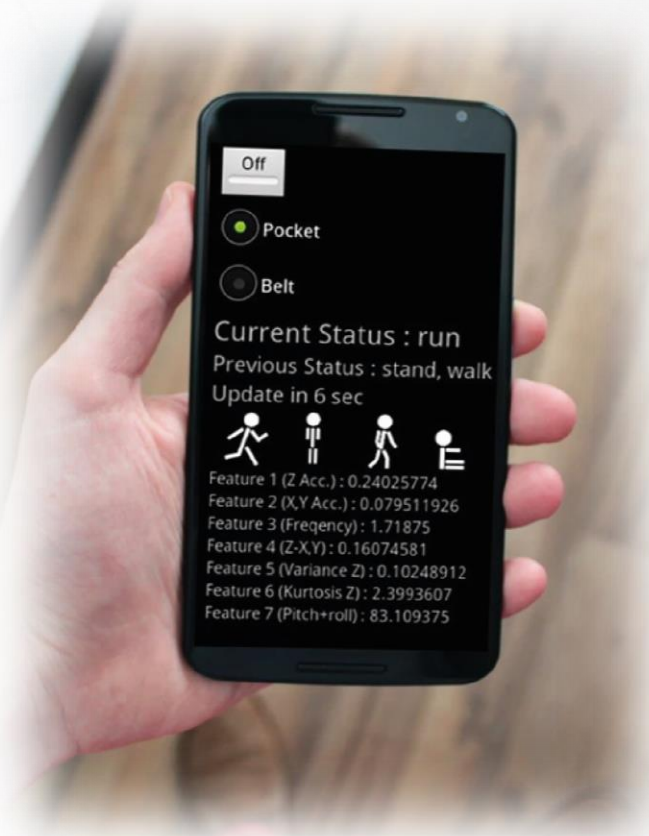
Yoon et al. (2016)

Functionalities

- Fire crisis assessment
- Emergency list
- Attendance registration
- Localization first responders
- Localization victims
- Alarm notification
- Navigator
- Victim assessment
- Direct communication

Project description

In the case of fires and earthquakes, individuals may be unconsciousness and trapped inside buildings. Therefore, Yoon et al. (2016) examine iRescue app which helps first responders to find the victim and gain awareness about the status of the victim. In particular, (1) location of victims can be tracked inside the building using wireless access points, (2) victims can send their status to the rescuers, for instance 'I am able to walk'. Whenever the victim is unconsciousness, the app sends the status of the victim to the rescuer: for instance, 'walking', 'fainting', or 'going downstairs'. This is achieved through the accelerometer, gyroscope, and magnetic field sensor (e.g. 'smartphone senors') that are embedded in the smartphone measures the status of the victim.



Foreseen development

Yoon et al. (2016) suggest that future development should elaborate on several aspects: (1) the use of other smartphone sensors to locate victims (2) examine the use of additional smartphone-embedded sensors such as pressure sensors to compute the status of the victim (3) full-scale and real-life life scenario test.

Management information

First responders and emergency managers receive the following information:

- Presence and location of occupants in the building (B3);
- Status of victim.

Mobile operating system

- Android
- iOS
- Windows
- Unknown

What: measurement

- Location emergency source
- Emergency type
- Fire activity
- Location first responders
- Presence first responders
- Location victims
- Physical status victims

Why: objective

- Strategic
- Functional
- Physical (enhancing safety)
- Financial

How: Measurement method

- Wi-Fi
- Mobile network
- Beacons
- Smartphone sensors
- RFID
- GPS
- Sound

Smart emergency app

My Disaster Droid

Phase

unidentified

Source

Fajardo and Oppus (2010)

Functionalities

- Fire crisis assessment
- Emergency list
- Attendance registration
- Localization first responders
- Localization victims
- Alert notification
- Navigator
- Victim assessment
- Direct communication

Project description

During a critical situation, one scenario is that victims are scattered around the university campus. In this circumstance, MyDisasterDroid app helps first responders to determine the optimal direction along a variety of geographical locations to help the most number of victims within the shortest possible time. The victims can send their location through SMS and another alternative is to insert their position in MyDisasterDroid app. Based on GPS and mobile network, their position within the affected area is determined.

Foreseen development

Any future studies or foreseen development in regard to MyDisasterDroid app has not been indicated by Fajordo and Oppus (2010).

Management information

First responders and emergency managers receive the following information:

- Presence and location of occupants in the affected area;
- Direction to serve the most number of victims within the shortest possible time

Mobile operating system

- Android
- iOS
- Windows
- Unknown

What: measurement

- Location emergency source
- Emergency type
- Fire activity
- Location first responders
- Presence first responders
- Location victim
- Physical status victim

Why: objective

- Strategic
- Functional
- Physical (enhancing safety)
- Financial

How: Measurement method

- Wi-Fi
- Mobile network
- Beacons
- Smartphone sensors
- RFID
- GPS
- Sound

Smart emergency app

NerveCentre

Phase

Implementation

Source

Nervecentre.nl

Functionalities

- Fire crisis assessment
- Emergency list
- Attendance registration
- Localization first responders
- Localization victims
- Alert notification
- Navigator
- Victim assessment
- Direct communication

Project description

NerveCentre provides the possibility to show the total number of available first responders per location and/or faculty to emergency managers. In the case of an incident, the emergency manager can send alert messages to the available first responders. The availability of first responders is registered through the following manner: at the time that the smartphone of the first responder is detected by a WI-FI access point, it will automatically be enrolled in the Nervecentre system. In addition, NerveCentre also provides an insight to emergency managers in regard to the indoor and outdoor position of first responders and objects using GPS, RFID or beacons.

Management information

- Real-time oversight in regard to the presence, availability and number of first responders per location and/or faculty;
- Indoor and outdoor localization of first responders (C3);
- Indoor and outdoor localization of objects (A7);
- Type of emergency source (e.g. fire);
- Location of the emergency source (B1);
- Contact information of managers and utility contacts (A5).

Android iOS Windows Unknown

Mobile operating system

Strategic Functional Physical (enhancing safety) Financial

Why: objective

What: measurement

- Location emergency source
- Emergency type
- Fire activity
- Location first responders
- Presence first responders
- Location victim
- Physical status victim

- Wi-Fi
- Mobile network
- Beacons
- Smartphone sensors
- RFID
- GPS
- Sound

How: Measurement method

Smart emergency app

Picasse

Phase

Implementation

Source

bhvalarmering.nl

Functionalities

- Fire crisis assessment
- Emergency list
- Attendance registration
- Localization first responders
- Localization victims
- Alert notification
- Navigator
- Victim assessment
- Direct communication

Project description

Picasse is a communication platform which helps the emergency managers to call and send alarm messages (e.g. sms, push notification, e-mail) on their tablet or PC to first responders in order to mobilize them to the emergency scene. Moreover, it helps the emergency managers to receive insight in the availability and presence of first responders. In addition, Picasse can be linked with a fire control unit. By doing so, smoke and fire alarms can be sent through push notification, sms, telephone call and e-mail to emergency managers and first responders.

Management information

- Realtime oversight in regard to the presence and availability of first reponders
- Type of emergency source (e.g. fire);
- Location of emergency source (B1);
- Contact information of managers and utility contacts (A5).

Android · iOS · Windows · Unknown

Mobile operating system

Strategic · Functional · Physical (enhancing safety) · Financial

Why: objective

What: measurement

- Location emergency source
- Emergency type
- Fire activity
- Location first responders
- Presence first responders
- Location victim
- Physical status victim

- Wi-Fi
- Mobile network
- Beacons
- Smartphone sensors
- RFID
- GPS
- Sound

How: Measurement method

Smart emergency app

RescueMate

Phase

Implementation

Source

rescuemate.eu

Functionalities

- Fire crisis assessment
- Emergency list
- Attendance registration
- Localization first responders
- Localization victims
- Alert notification
- Navigator
- Victim assessment
- Protocols first aid

Project description

RescueMate helps first responders and emergency managers to act quickly and according to the official procedures for first aid, acute illnesses, fire fighting, communication, and evacuation. Moreover, RescueMate informs emergency managers about the availability of first responders. In addition, this emergency app sends an alert notification through the app, voice message, SMS or e-mail to available first responders or all first responders. RescueMate also provides continuous-training to first responders. In this case, first responders and emergency managers do not necessarily have to follow training on a yearly basis, it can be done during their most convenient time through the RescueMate app. The RescueMate developer believes that this is an added value because first responders are perceived as flexworker. By doing so, it enables first responders to keep their skills and knowledge up to date.

Management information

First responders and emergency managers receive the following information:

- Presence and location of first responders
- Protocols for fire figthing
- Protocols for evacuation
- Protocols for first aid
- Protocols for acute illnesses
- Alert notications

Android iOS Windows Unknown

Mobile operating system

What: measurement

- Location emergency source
- Emergency type
- Fire activity
- Location first responders
- Presence first responders
- Location victim
- Physical status victim

Strategic Functional Physical (enhancing safety) Financial

Why: objective

- Wi-Fi
- Mobile network
- Beacons
- Smartphone sensors
- RFID
- GPS
- Sound

How: Measurement method

Smart emergency app

RescuePal

Phase

Product development

Source

Restuccia et al. (2016)

Functionalities

- Fire crisis assessment
- Emergency list
- Attendance registration
- Localization first responders
- Localization victims
- Alert notification
- Navigator
- Victim assessment
- Direct communication

Project description

People can be trapped in the building or being unconsciousness due to toxic exhalations. Based on this scenario, RescuePal comprises of Rescuer and Victim app. The Rescuer app allows first responders to discover victims while people in need do not need to activate their Victim app to call for help.

This system works as follows: (1) The Rescuer app sends a signal to the victim's mobile device by emitting a sound. (2) The signal is received by the Victim app which in turn activate the WI-FI of the victim's mobile (3) Using the WI-FI, victim's mobile scans and signals the presence of nearby rescuers (4) The rescuer receives and detects incoming WI-FI connections from victims and, thus, the location of the victim and the corresponding identity (e.g. name) of the victim

Foreseen development

The initial research of the RescuePal discovery system reveals that it has a high victim discovery ratio and it saves battery lifetime of victims' mobile phone. Moreover, Restuccia et al. (2016) point out that future research should evaluate a more complex sound generation equipment and other scenarios.

Management information

First responders and emergency managers receive the following information:

- Presence and location of occupants in the building (B3);
- Identity victim (e.g. name);

What: measurement

- Location emergency source
- Emergency type
- Fire activity
- Location first responders
- Presence first responders
- Location victim
- Physical status victim

Android | iOS | Windows | Unknown

Mobile operating system

Strategic | Functional | Physical (enhancing safety) | Financial

Why: objective

- Wi-Fi
- Mobile network
- Beacons
- Smartphone sensors
- RFID
- GPS
- Sound

How: Measurement method

Smart emergency app

Rescuer app

Phase

Product development

Source

Depari et al. (2018)

Functionalities

- Fire crisis assessment
- Emergency list
- Attendance registration
- Localization first responders
- Localization victims
- Alert notification
- Navigator
- Victim assessment
- Direct communication

Project description

In case of fire or other critical situation, Rescuer app support first responders and emergency managers during an emergency situation. In particular, this app helps them to reach emergency sources and people in trouble who uses the Worker app. The whole project works according to alarm sensors deployed in the building for alert information (e.g. smoke and fire), Bluetooth (beacons) for indoor localization, and WI-FI network.

Foreseen development

The development of rescuer app is still in progress and preliminary experiments with representative domain professionals and users reveal the effectiveness and usefulness of the rescuer app. Moreover, the researcher points out that future development should be focused on extended research in a realistic setting.

Management information

First responders and emergency managers receive the following information:

- Presence and location of occupants in the building (B3);
- Type of emergency source (e.g. alarm sensors and victim);
- Position and route of emergency source;
- Numbers of first responders that are going to reach an emergency source.

Android · iOS · Windows · Unknown

Mobile operating system

Strategic · Functional · Physical (enhancing safety) · Financial

Why: objective

What: measurement

- Location emergency source
- Emergency type
- Fire activity
- Location first responders
- Presence first responders
- Location victim
- Physical status victim

- Wi-Fi
- Mobile network
- Beacons
- Smartphone sensors
- RFID
- GPS
- Sound

How: Measurement method

Smart emergency app

SmartRescue

Phase

Product development

Source

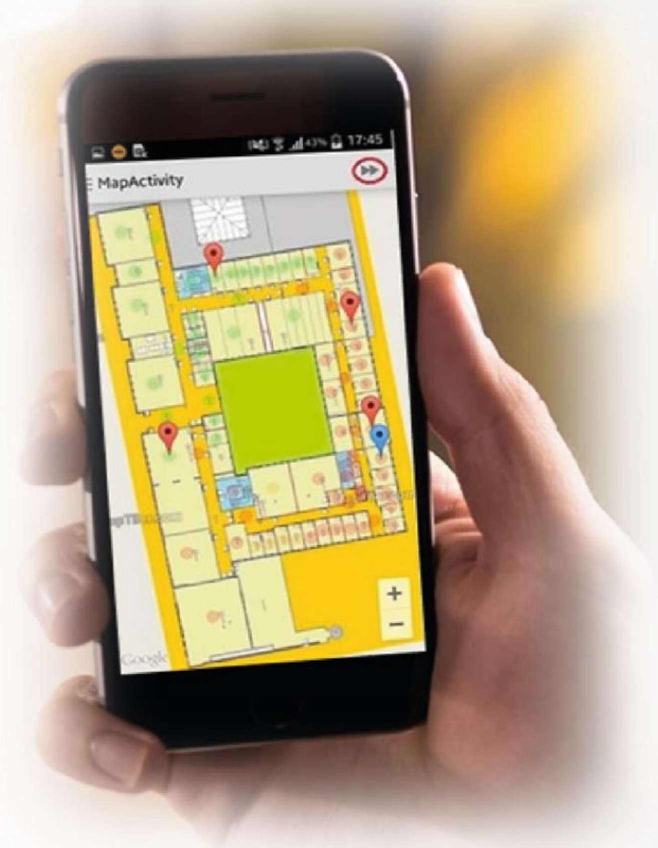
Lazreg et al. (2015)

Functionalities

- Fire crisis assessment ●
- Emergency list
- Attendance registration
- Localization first responders
- Localization victims ●
- Alert notification
- Navigator
- Victim assessment
- Direct communication

Project description

SmartRescue is a smartphone app for emergency managers and firefighters to assess the development and intensity of the fire in each room. Moreover, the SmartRescue app provides information about the position of the victim. A case study at the University of Agder (Norway) was conducted by Lazreg et al. (2015) which reveals that SmartRescue helps firefighters to fasten the intervention. In particular, the rescue process without the SmartRescue app took 15 minutes and 13 minutes with the concerning app. In order to assess the fire situation, SmartRescue app gather data from the mobile device and, subsequently, the Bayesian Network analyzes this data to predict the development of the fire. In addition, the WI-FI network is relevant for indoor localization of victims.



Foreseen development

The SmartRescue app is still in a development stage and, in regard to further research, Lazreg et al. (2015) recommend to use temperature and smoke sensors in the building with smartphones. Moreover, the researchers suggest to implement a navigator to assist people to the nearest exit in the building.

Management information

First responders and emergency managers receive the following information:

- Presence and location of occupants in the building (B3);
- Location and prediction of development of the fire.

What: measurement

- Location emergency source
- Emergency type
- Fire activity ●
- Location first responders
- Presence first responders
- Location victim ●
- Physical status victim

Mobile operating system

- Android
- iOS
- Windows
- Unknown ●

Why: objective

- Strategic
- Functional
- Physical (enhancing safety) ●
- Financial

How: Measurement method

- Wi-Fi ●
- Mobile network ●
- Beacons
- Smartphone sensors ●
- RFID
- GPS
- Sound

6.14 Conclusion

In this chapter, the reader gains more insight into '*what current smart emergency applications, in terms of information provision, contribute during an emergency situation?'*

- In general, Jiang et al. (2004) think that the use of the sensor, wireless networking, and computing technologies have great potential in gathering information during the event of an emergency;
- Sarshar et al. (2015) suggest that using a smartphone in the emergency event is the most practical solution for raising situational awareness;
- Rajalakshmi et al. (2015) using smart emergency applications in the smartphone during an emergency event is advantageous because it provides valuable information to the users;
- Cheng et al. (2017) believe that computing technology is able to provide accurate information to help rescuers;
- Maryam et al. (2016) believe that smartphones are able to respond in an efficient and effective manner in an emergency event, and the incident response team could be informed on time;
- The current smart emergency apps have a unique information provision and their contribution varies from predicting the fire development to finding victims in the building and showing the availability of first responders (Dutch: BHV'ers);
- SmartRescue provide information about the fire development and victim's location;
- EMS app displays information related to indoor and outdoor locations of responding units. In addition, it provides information through images, videos, text and voice message of incidents;
- iRescue provide facts about the status and location of victims;
- My Disaster Droid provides information about the location of the victim at the area level;
- NerveCentre shows the total number of available first responders per location and the indoor and outdoor location of first responders;
- Picasse provide oversight of the presence and availability of first responders, location of the emergency source, and type of emergency source;
- RescueMate displays the official procedures for first aid, firefighting, evacuation, acute illnesses, and communication. it also provides the information of first responders' location;
- RescuePal gives insight into the presence and location of occupants in the building and the ID of the victim (e.g. name);
- Rescuer app shows the location of first responders and victims, the route t the emergency source, type of emergency source and numbers of first responders who are heading to the emergency source.

Results empirical research

Image retrieved from unsplash.com

The role of the participants in building fire emergency reponse operations

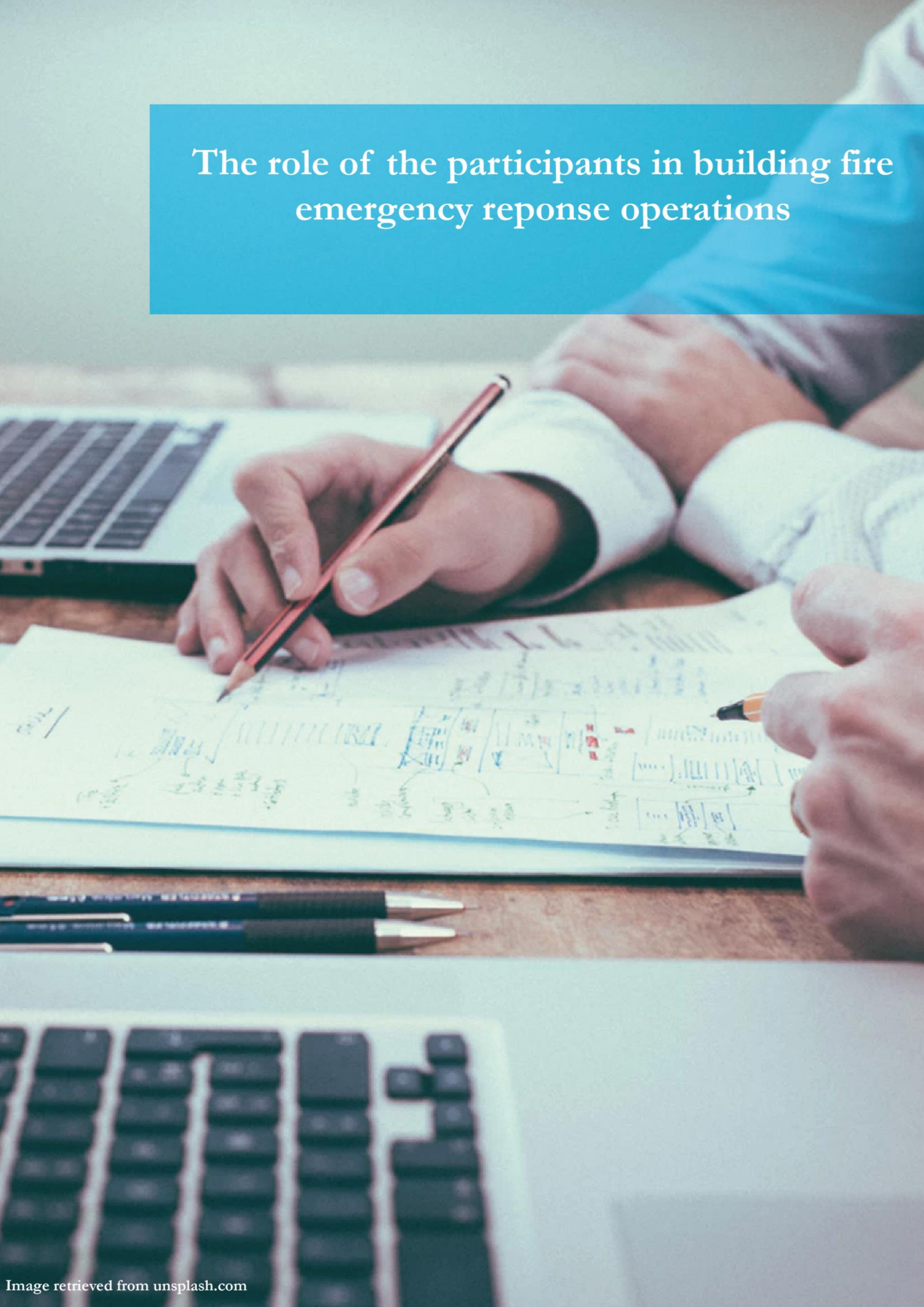


Image retrieved from unsplash.com

7.1 The role of participants in emergency situations

A variety of interviewees from Dutch universities participated during the semi-structured interviews (fig 27). Among them were experts in safety at both strategic and operational level from University of Amsterdam (UVA), Leiden University Medical Center (LUMC), Delft University of Technology (TU Delft), Utrecht University (UU), Radboud University Nijmegen (RU) and University of Twente (UU) (fig 28). The exception refers to the head of the emergency response team of Erasmus University Rotterdam. Each professional fulfills a different role at the operational, technical and strategic level during an emergency situation. Their experience in fire-related emergency, job title and the corresponding role in relation to the CREM perspective are elaborated in more detail in the next sections.

University	Interviewees	Function title
LUMC, Leiden	Piet van Egmond Linda van der Linden	Manager Crisis Management Team leader Safety & Crisis Management
TU Delft, Delft	Dennis Cruyen Bart de Jong Dennis Bommelé Hilda Alsemgeest	Facility Manager Facility Manager Fire Safety Coordinator Building Management Coordinator
RU, Nijmegen	Louis van den Berg Carlo Buise	Head of emergency response team Emergency Coordinator
UU, Utrecht	Rob Mulder Eddie Verzendaal	Project leader Facility Service Center Director Facility Service Center
UVA, Amsterdam	Roland Scholtz	Head of emergency response team
UT, Enschede	Richard Sanders	Safety officer

Figure 27 conducted (green) semi-structured interviews with different experts in the field of safety (author's illustration, 2019)

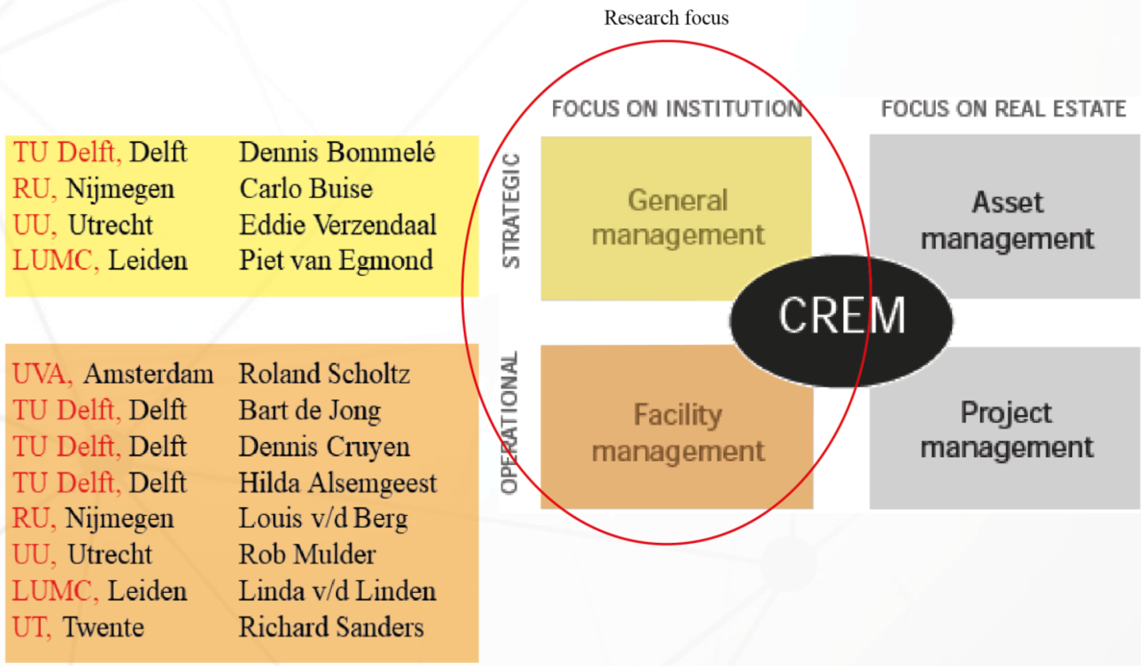


Figure 28 participants from both strategic level (General Management) and operational level (Facility Management) who provided valuable insight during the semi-structured interview (author's illustration, 2019)

7.2 University of Amsterdam

Roland Scholtz from University of Amsterdam is the head of the emergency response team (Dutch: Hoofd-BHV) and, in relation to the CREM perspective, he operates at the operational level of the institution in order to provide a safe workplace to all employees and students (fig 28). During the interview, Roland Scholtz explains that he provides guidance to his emergency response team and team leader. For example, at the time of fire alarm, he calls the emergency response team through a Picasse system. In particular, he notifies them about an incident and calls them to gather at the assembly point (Dutch: BHV verzamelplaats). Roland Scholtz was not in charge of the fire emergency that occurred at the University of Amsterdam in 2011. During his working period as the head of the emergency response team, there was no 'real' fire incident at the University of Amsterdam. However, in general, he had to manage several smoke incidents and false fire alarms in the past where individuals in the university need to evacuate.

7.3 Leiden University Medical Center

Piet van Egmond and Linda van der Linden function as manager Crisis Management and team leader Safety and Crisis Management respectively. Both professionals are from Leiden University Medical Center and had to deal with the fire incident in 2015 at LUMC. Piet van Egmond is responsible to keep an overview of the whole situation during a fire incident and mainly operates at the strategic level (fig 28). In particular, he discusses with his crisis team about a long-term strategic plan. Further, he mainly communicates with Linda about the emergency situation and communication with the fire authorities is not involved in his duties. Linda van der Linden is the person who has multiple tasks between the operational and tactical level (fig 28). If Piet van Egmond is absent during a fire incident, then she is the person who is able to take over his task. Actually, Linda is the calamity coordinator which means that she is the person who delegates the team leaders of the emergency response team (Dutch: BHV team) and the security officers. Moreover, Linda communicates with fire authorities and Piet van Egmond from the crisis team.

7.4 Delft University of Technology

A variety of professionals from TU Delft are involved with any fire-related incidents including Dennis Bommelé (fire safety coordinator), Hilda Alsemgeest (building management coordinator), Bart de Jong (Facility Manager and head of the emergency response team), and the Dennis Cruyen who was involved as a facility manager at TU Delft. To date, Hilda Alsemgeest is the building management coordinator who is responsible for the technical aspects at the operational level during any crisis. Dennis Bommelé has been working for 4.5 years as a fire safety coordinator at TU Delft and he has more than 10 years of experience in the field of safety and security. He is the advisor of the emergency response team and he provides necessary information such as the program of the building to the fire authorities and police. Therefore, Dennis Bommelé stated that he is from the strategic level (fig 28). At the operational level, Bart de Jong functions as the facility manager and head of the emergency response team for 2.5 years at TU Delft, while having 6 years' experience in the field of fire safety. He is the link between the crisis team and the emergency response team (Dutch: BHV ploeg). The team leader of the emergency response team communicates with him and, subsequently, Bart de Jong will communicate it with the crisis team (e.g. the dean and/or executive board of TU Delft). In other words, Bart de Jong provides recommendations to the crisis team and the emergency response team on how to act during an incident

Dennis Cruyen was the facility manager and the head of the emergency response team of TU Delft at the operational level (fig 28). He has 20 years' experience in the field of fire safety and 12.5 years working experience as a facility manager and the head of the emergency response team of TU Delft. In regard to the fire incident at the faculty of Architecture in TU Delft which occurred in 2008, the role of Dennis Cruyen was to ensure that the building is vacated as much as possible until the fire authorities have arrived. Subsequently, he had to inform the fire authority with correct information. For example, he had to provide information on whether the building contains specific hazards. At the time of the fire incident at the faculty of Architecture, he was not concerned with securing valuables, instead, he was more concerned with securing peoples. Moreover, his role was to share information and fulfilling the task that he received from the crisis team. He was also the link between the emergency response team and the crisis team. Thereafter, his role was related to the aftercare of his emergency response team. According to Dennis Bommelé and Dennis Cruyen, they were involved during the fire incident at TU Delft's Faculty of Architecture in 2008. Whereas, Hilda Alsemgeest have not experienced any fire incident in the past. Up to now, Bart de Jong had to deal with an explosion in a laboratory at TU Delft, power down of TNW south and he experienced fire alarms on a regular basis.

7.5 Utrecht University

To date, Rob Mulder and Eddie Verzendaal function as project leader Facility Service Center and Director Facility Service Center respectively. Both professionals from Utrecht University had to deal with a variety of fire alarms and fire incidents such as fire incident at Utrecht University in 2017 and 2018. It is worth mentioning that Rob Mulder and Eddie Verzendaal has 23 years and 5 years' experience in the field of fire safety respectively. The role of Eddie Verzendaal can be perceived as a link between the crisis team and the emergency response team. In addition, he stated that his role relates to the strategic/tactical level. Whereas, Rob Mulder's role refers to the operational activities during an emergency situation (fig 28).

7.6 Radboud University Nijmegen

Up to the present time, Louis van den Berg functions as Head of the emergency response team and Carlo Buise works as an emergency coordinator at Radboud University Nijmegen. Both specialists in an emergency situation experienced various fire alarms and the fire incident at Radboud University Nijmegen in 2017. In addition, Louis van den Berg has been working since 2012 in the field of fire safety at the Radboud University and Carlo Buise since 2005. In regard to their role during an emergency situation, Louis van den Berg stated that he works at the operational level (fig 28). This means that he has to provide guidance to the team leader of the emergency response team. Moreover, he communicates with Carlo Buise about the situation during a fire incident. However, he is able to take over the task of Carlo and vice versa if needed. Carlo Buise as an emergency coordinator operates at the strategic/tactical level together with the crisis team (fig 28). For example, Carlo Buise points out that his task relates to dealing with the media, students, employees, and aftercare of people.

Case	Job title	Emergency duties
	Strategic level	
TUD (2008)	**Fire Safety Coordinator**	• Advisor of the emergency response team to set and meet long-term goals.
RU (2017)	**Emergency Coordinator**	• Establish building's emergency action plans; • Conduct risk assessments; • Bringing emergency plans up to date; • Aftercare of students and employees; • Communication to the media.
UU (2017) **UU** (2018)	**Director Facility Service Center**	• Link between the emergency response team and crisis team; • Responsible for the safety and security issues.
LUMC (2015)	**Manager Crisis Management**	• Establish long-term strategic plan with the crisis team; • keep an overview of the whole situation during a fire incident.
UT (2002)	**Safety officer**	• Organize and evaluate evacuation exercises; • Provide feedback of results to the crisis team.
	Operational level	
TUD (2008) **UVA** (2011) **RU** (2017)	**Head of emergency response team**	• Take preventive measures to prevent and limit accidents; • Managing the emergency response team; • Coordinate the alarms and evacuation of person present in the building.
TUD (2008)	**Building Management Coordinator**	• Responsible for the technical elements such as fire safety system and building operational system.
UU (2017) **UU** (2018)	**Project leader Facility Service Center**	• Coordinate inspection rounds; • Coordinate evacuation of people present; • Provide suggestions about the emergency situation to the crisis team that operates at the strategic level.
LUMC (2015)	**Team leader Safety & Crisis Management**	• Delegate the teamleaders of the emergency response team and the security officers in emergency situations.
n/a	**Facility manager**	Davies et al. (1998): • Recover supporting services that will empower the business to operate again; • Prepare disaster planning and risk assessment. Marchant (2000): • Awareness of both the fire safety system and day-to-day operational systems. Yamashita et al. (2011) • Establishing evacuation plans and the most efficient evacuation by distributing routes of evacuees.

Figure 29 similarities between the emergency duties of participants and the facility manager according to the literature study (author's illustration, 2019)

7.7 University of Twente

Richard Sanders is a safety officer at the University of Twente who has 25 years' experience in the field of fire safety. In the past, he was involved in every fire alarm and the fire incident in the computer science building at the University of Twente which was occurred in 2001. His role is to provide expert advice to the crisis management team while playing an important role at the operational level (fig 28). For instance, he set up safety exercises, determine emergency scenarios and provides resources to the emergency response team.

7.8 Facility manager in comparison to the participants

Despite the fact that a variety of interviewees have different job title (e.g. head of emergency response team instead of facility manager), it must be noted that their emergency duties are more or less similar to the facility manager (fig 29). For example, professionals from the strategic level fulfill facility management tasks such as recover supporting services when they need to decide on future action. In regard to experts from the operational level, Hilda Alsemgeest (building management coordinator) from TU Delft need to manage fire safety system and other technical installations which are done by a facility manager. Moreover, Richard Sanders (safety officer) from University Twente also fulfills the task of a facility manager such as preparing disaster planning and risks assessment. Moreover, the role of the interviewees strongly relates to the facility management domain which aims to improve and offer a safe and secure environment to name a few (CoreNet Global, 2015). Therefore, due to the similarities, the assumption has been made that the task and aim of a facility manager and interviewees are interrelated to each other.

Acceptable level of fire cause

Image retrieved from researchgate.net

8.1 Subjective and objective data regarding the causes of fire

As stated in the literature study, objective data examined by CBS (Statistics Netherlands) in 2013 reveal that the most frequent cause of fire in any educational institution in The Netherlands is due to arson (32.1%) (fig 30). Continuing on this line, the results of the interview show that eight participants suggest that it is important to have information about the cause of the incident.

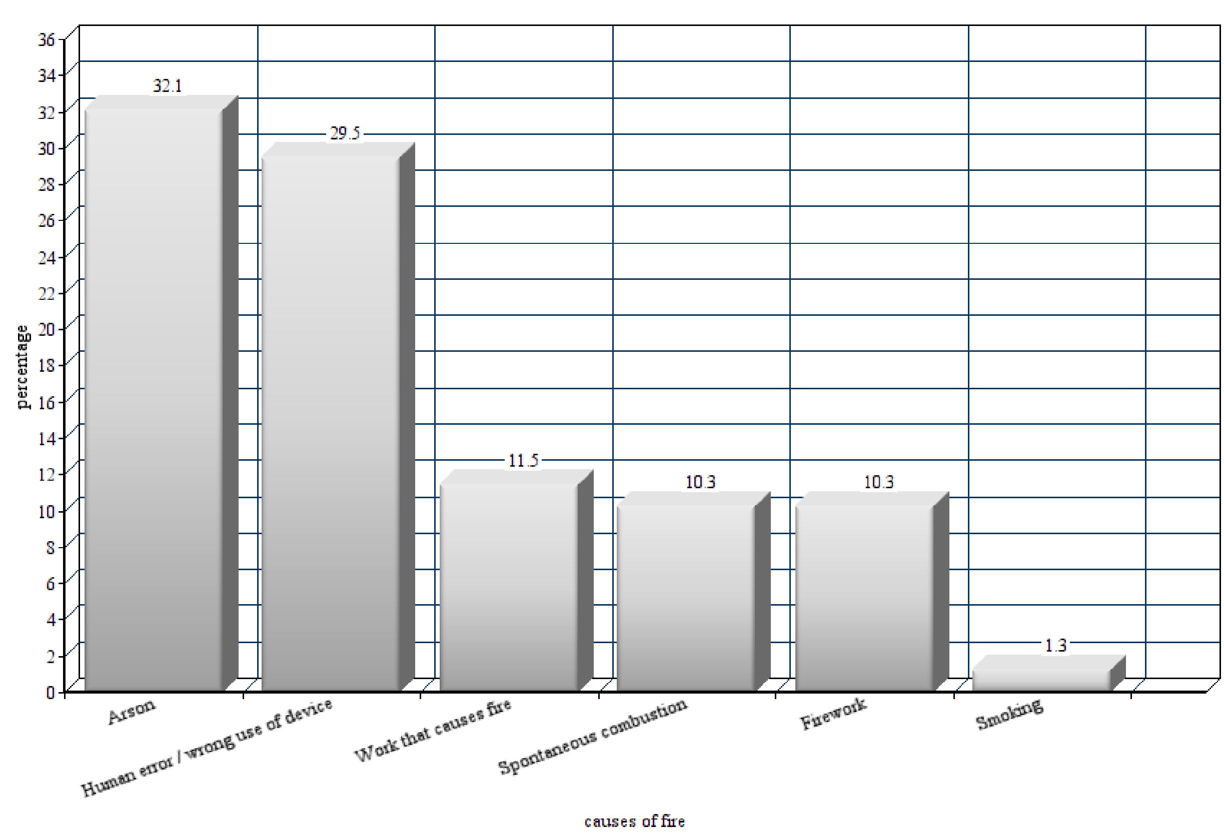


Figure 30 the frequency of causes of fire at Dutch education institutions in 2013 according to CBS (author's illustration, 2019)

While CBS showed essential objective data about the cause of fire at Dutch education institution, this research has collected subjective data of participants. In particular, participants were asked whether the examined cause of the fire by CBS are related to an acceptable, tolerable (ALARP) or unacceptable region. Acceptable region relates to causes of the fire that has a low impact while occurrence is unlikely. Therefore, it is acceptable which does not need to be mitigated. The tolerable region refers to medium impact and possible occurrence. Causes in the unacceptable region are linked with very high impact and the high probability that it will occur. Lastly, it must be noted that all participants were not aware of CBS statistics.

Most participants indicate that arson belongs to the unacceptable region which must be reduced. In line with CBS, arson is the most important cause of the fire (32.1%). Subsequently, participants point out that spontaneous combustion and fire-susceptible activities relate to the tolerable region. Finally, firework and smoking are perceived as an acceptable risk which it is not necessary to reduce. In figure 31, the results of the interview show the degree of undesired causes of fire on the basis of CBS (2013).

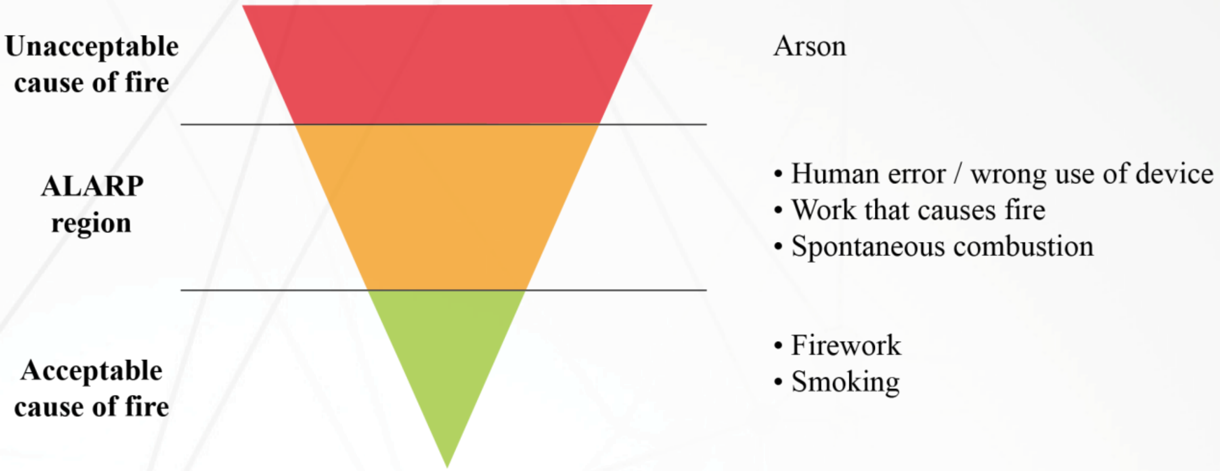
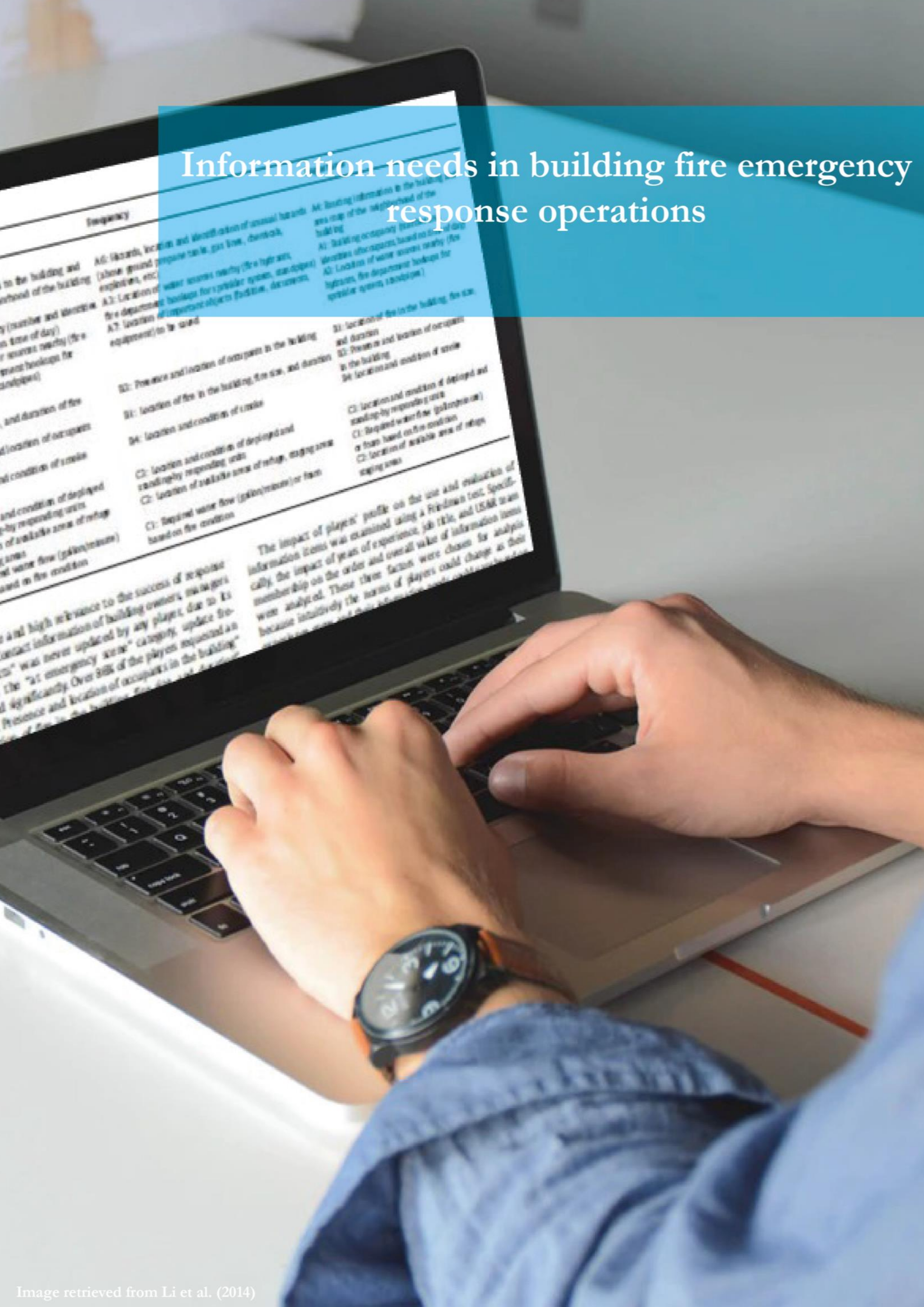


Figure 31 the degree of undesired causes of fire according to the participants in relation to the adapted ALARP method (author's illustration, 2019)

Therefore, much attention should be given to arson because objective data of CBS (2013) shows that arson is the main cause of the fire and the subjective data of this research reveal that arson is an unacceptable cause of fire among the participants. In addition, keep in mind that human error / wrong use of the device, work that causes fire and spontaneous combustion should be monitored regularly. In conclusion, it can be seen that the degree of undesired causes of fire seems to correspond to the frequency of the causes of fire that is examined by CBS (2013).



Information needs in building fire emergency response operations

Image retrieved from Li et al. (2014)

9.1 Information during an emergency situation

Literature study in this masters' thesis examined the information items that are required during an emergency situation (Li et al., 2014). In particular, the study of Li et al. (2014) reveals the importance of some information items according to the battalion chiefs, first responders, firefighters, paramedics, and engineers (fig 32). These experts are mainly from the firefighter-training center, local fire stations, and a safety department of a university campus in Los Angeles.

The importance of information items during an emergency situation

Before arrival to scene

1st	A4: Routing information to the building and area map of the neighborhood of the building
2nd	A1: Building occupancy (number and identities of occupants, based on time of day)
3rd	A3: Location of water sources nearby (fire hydrants, fire department hookups for sprinkler system, standpipes)

At emergency scene

1st	B1: Location of fire in the building, fire size, and duration
2nd	B3: Presence and location of occupants in the building
3rd	B4: Location and condition of smoke

Attack and mitigation

1st	C3: Location and condition of deployed and standing-by responding units
2nd	C1: Required water flow (gallon/minute) or foam based on fire condition
3rd	C2: Location of available areas of refuge, staging areas

Figure 32 the necessary information in a building fire emergency operation ranking from the first to the third place. Retrieved from Li et al., (2014)

9.2 Necessary information according to interviewees

As elaborated earlier, participants from the interview were experts from the strategic and operational level at various Dutch universities who fulfill similar tasks as a facility manager in an emergency situation. Based on the information list of Li et al. (2014), participants were asked to select whether the given information items are important and relevant during an emergency situation. In this respect, figure 33 shows the number of participants who agree that a certain information item is important (green), not important (red) and possibly important (orange).

It can be seen that most participants considered that *A11 Hazards, location, and identification of unusual hazard is the most important and relevant information items* is the most important information item at the time of 'before arrival to the scene'. This is followed by *A1 building occupancy, A5 contact information of building owners, managers and utility contacts, and A7 Location of important objects.*

However, the results of the interview also show that most participants believe that *A3 Location of water sources nearby* is less important while the study of Li et al. (2014) indicate it is the third important information item. The reason that most participants suggest that this information item is less important is the fact that first responders are very familiar with the location of water sources in the building. However, it must also be noted that the difference is minimal: 6 participants point out that it is less important while 5 participants believe it is an essential information item. Therefore, due to time limitation, further research should be conducted whether this information item is important or not.

Further, Li et al. (2014) show that *A1. Routing information to the building and area map of the neighborhood of the building* is the first important information item. In comparison, the interview shows that most participants believe that this information item is essential as well.

Li et al. (2014)	Interview results: Before arrival to scene	Yes	No	Maybe	N/a
2nd	**A1.** Building occupancy (number and identities of occupants, basd on time of day)	8	2	1	
	A2. Building layout and site plan (building size, construction tye, floor plans)	7	4		
3rd	**A3.** Location of water sources nearby (fire hydrants, fire department hookups for sprinkler system, standpipes	5	6		
1st	**A4.** Routing information to the building and area map of the neighborhood of the building	7	3	1	
	A5. Contact information of building owners, managers and utility contacts	8	3		
	A6. Hazards, location and identification of unusual hazards	11			
	A7. Location of important objects (facilities, documents, equipment to be saved)	8	3		

Figure 33 important and relevant information items during 'before arrival to scene' according to the number of participants compared to the results of Li et al. (2014) (author's illustration, 2019)

Subsequently, participants were also asked to select the information items that are considered as important when arriving at an emergency scene (fig 34). In general, the results reveal that all information items, from B1 to B6, are considered essential. However, it also can be seen that *B1 location of the fire in the building, fire size, and duration* is the most important information because all participants agree that this information item is required. This is in agreement with the findings of Li et al. (2014) which shows that the respondents believe that *B1 location of the fire in the building, fire size, and duration* is the most important as well. According to Li et al. (2014), the second and third important information item relates to B3 presence and location of occupants in the building and B4 location and condition of smoke. This result is similar to the findings of the interview which shows that most participants suggest that this information is important as well. Nevertheless, in general, the results of the interview reveal that all information items, from B1 to B6, are considered essential.

Li et al. (2014)	Interview results At emergency scene	Yes	No	Maybe	N/a
1st	**B1.** Location of fire in the building, fire size, and duration	11			
	B2. Sprinklers' status (number of location of sprinklers that have gone off)	9	2		
2nd	**B3.** Presence and location of occupants in the building	10	1		
3rd	**B4.** Location and condition of smoke	10	1		
	B5. Warnings of structural collapse based on material type, fire location, fire size, and duration	10	1		
	B6. Confidence in the fire being real	9	2		

Figure 34 essential information according to the number of participants compared to the results of Li et al. (2014) (author's illustration. 2019)

Finally, participants were requested to choose the information that is necessary during the 'attack and mitigation' phase (fig 35). By way of comparison, the results of the interview differ from the study of Li et al. (2014). In particular, the interview shows that *C6 contact information of other emergency agencies* is the most important information because most participants agree that this information is required. Whereas, According to Li et al. (2014), *C3 location and condition of deployed and standing-by responding units* is the most important information item. The reason why 3 participants believe that information item C3 is less relevant and important is due to the fact that some fire authorities are located nearby the university. For example, Rob Mulder from Utrecht University stated that the fire authority is located nearby the campus and, therefore, it is not necessary to be aware of the position of the responding unit.

Another difference relates to *C1 required water flow or foam based on fire condition.* 6 participants stated that is this information item is not necessary while the study of Li et al. (2014) indicate that it is the second important information item. However, it can be perceived that 6 participants do not agree, while 5 participants agree that information C1 is important. This difference is minimal and, therefore, further research should invite more participants in order to examine whether information item C1 is essential or not.

Li et al. (2014)	Interview results Attack and mitigation	Yes	No	Maybe	N/a
2nd	**C1.** Required water flow or foam basd on fire condition	5	6		
3rd	**C2.** Location of available areas of refuge, staging areas	8	3		
1st	**C3.** Location and condition of deployed and standing-by responding units	8	3		
	C4. Local weather conditions and predictions, wind direction and velocity	5	5	1	
	C5. Locations of building entrance/exit signs	7	4		
	C6. Contact information of other emergency agencies	10	1		

Figure 35 important information during the 'attack and mitigation' phase according to the number of participants compared to the results of Li et al. (2014) (author's illustration, 2019)

9.3 Missing information

Participants were asked an open question regarding what information is *missing* based on the given information list of Li et al. (2014). In this respect, as shown in figure 36, the following information items are missing according to the interviewees:

Missing information	Interviewee
Numbers of emergency response officers	Head of emergency response team (UVA)
Arrival time of responding units	Manager Crisis Management (LUMC)
Who is the security guard?	Head of emergency response team (UVA)
The person that reported a fire incident	Facility Manager (TUD)
The presence of asbestos *What* valuables should be kept safely?	Facility Manager (TUD)
Status of victims	Head of emergency response team (RU)
Is the building completely cleared?	Head of emergency response team (RU)
The location of the emergency assembly point	Head of emergency response team (RU)
Means of communication that is currently available	Team leader Safety & Crisis Management (LUMC)
No information is missing	Richard Sanders (UT), Rob Mulder (UU), Dennis Bommelé, Hilda Alsemgeest (TUD)

Figure 36 missing information based on the information list of Li et al. (2014) according to the participants (author's illustration. 2019)

9.4 Most important information in general

Subsequently, participants were asked *what information is considered as the most important during a fire incident?* It can be seen that most participants stated that *the number of individuals*/ victims *in the building* is essential information which relates to information item A1 of Li et al. (2014). This is followed by the *cause of fire incidents*, *location of the fire incident*, the *location of emergency response officers* and the *location of emergency service* such as fire authorities. Other information items that are considered as important involves (a) *Fire size*, (b) the *progress of emergency response officers*, (c) the *number of emergency response officers* (d) *building layout*, (e) what system does not function anymore (e.g failure of power supply), (f) the *status of the whole situation* (g) The *type of hazardous substances* and, finally (h) *which contact are informed* about the emergency situation (fig 37).

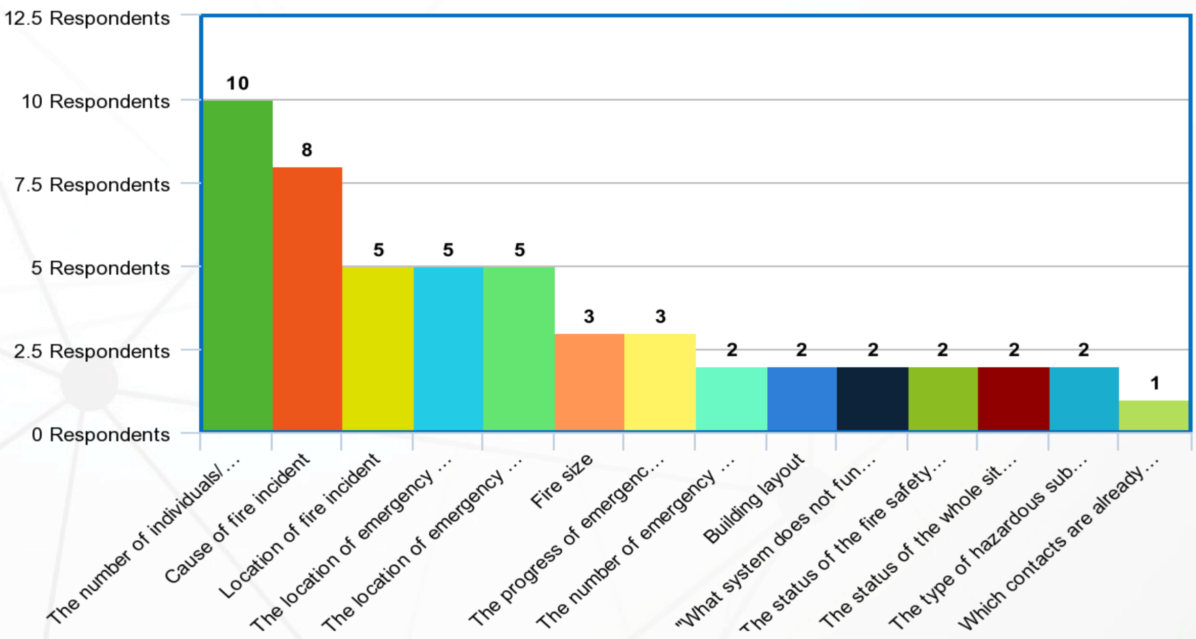


Figure 37 most important information according to the participants (author's illustration, 2019)

Perception of participants in regard to smart emergency apps

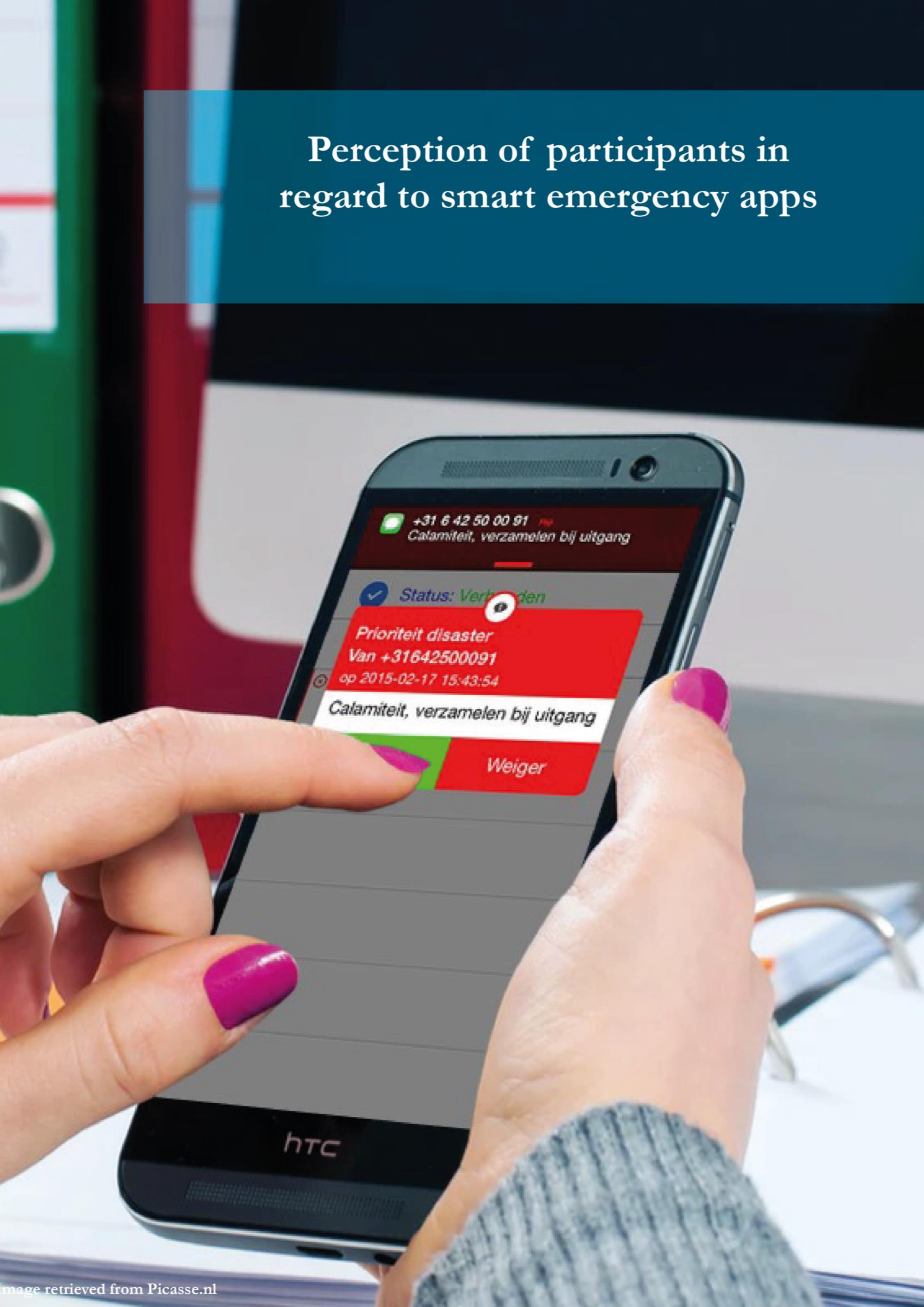


Image retrieved from Picasse.nl

10.1 Perception of participants in regard to smart emergency apps

As stated in the literature study, Cheng et al. (2017) believe that computing technology is able to provide accurate information to help rescuers for planning the most favorable rescue route in fire scenarios. Moreover, Jiang et al. (2004) think that the use of the sensor, wireless networking, and computing technologies have a great potential in gathering information during the event of an emergency and using these technologies is promising for communicating important information in real time. Gheisari et al. (2011) assumed that the applications and computer technologies, in general, can assist the managers in the facility management domain. Nonetheless, what is the perception of participants in regard to smart emergency apps? Do they share a similar view as stated by the aforementioned researchers?

In this respect, little research has examined the perception of first responders and emergency managers in regard to the use of smart emergency apps. Therefore, interviewees were asked for their opinion about whether smart emergency apps add value to their activities and situational awareness during a fire incident. As a result, most participants are negative with regard to the use of smart emergency apps. Specifically, Roland Scholtz (UVA), Piet van Egmond (LUMC), Carlo Buise (RU), Dennis Bommelé (TU) and Eddie Verzendaal (UU) are pessimistic about smart emergency apps. Further, 3 out of 12 interviewees are doubtful about the use of smart emergency apps including Dennis Cruyen (TU Delft), Louis van den Berg (RU), and Rob Mulder (UU). Finally, Hilda Alsemgeest (TU), Linda van der Linden (LUMC), Bart de Jong (TU Delft), and Richard Sanders (UT) are positive about the concerning apps.

Surprisingly, it can be seen that interviewees who have a negative opinion about smart emergency apps operate at the strategic level. An exception must be made for Roland Scholtz who works at the operational level as the head of emergency response team. Whereas, interviewees who work at the operational level are both positive and doubtful about the use of smart emergency apps (fig 38).

10.2 Positive perception

As stated, most interviewees from the operational level are positive about the use of smart emergency apps. In particular, Hilda Alsemgeest (TUD) indicates: *'I am positive about it because you can receive relevant information which influences positively my situation awareness'.* In addition, Bart de Jong (TUD) said: *'I believe that emergency apps help me to gather and receive facts which contribute to the situation awareness'.* Moreover, Richard Sanders (UT) believes that *'Emergency apps is interesting for the emergency response officers which helps them during their activities in a fire incident'.* Finally, Linda van der Linden (LUMC) points out the following: *'I believe that smart emergency apps can be valuable for my situation awareness. For example, it would be beneficial if an emergency response officer has oversight of the high-risk area with hazardous substances and the location of fire extinguishers.'*

10.3 Doubtful perception

Some participants are doubtful regarding the use of smart emergency apps. In particular, Dennis Cruyen (TUD) said: *'a smart emergency app should be used as a supplementary tool next to the existing communication methods. Moreover, I do not have any 'feeling' of the situation when using an emergency app. I prefer 'real-life contact' with individuals'.* Louis van den Berg (RU) mentioned that the technique of a smart emergency app should be reliable. Moreover, he prefers that the app should inform whether there is WI-FI activity at a certain building level or not. Lastly, Rob Mulder (UU) believes that *'Smart emergency apps would be useful when you have to alarm people. In the case of a smart emergency app that is able to locate people, it is necessary to implement Bluetooth or other techniques throughout the building which is an enormous financial investment. Nonetheless, on the one hand, the cost of smart emergency apps, in general, is subordinate (Dutch:ondergeschikt) to the efficiency and convenience of the app. On the other hand, I rely more on people than technology and I cannot communicate through an app during any fire incident and/or alarm.'*

Figure 38 perception of participants regarding to the use of smart emergency apps (author's illustration, 2019)

10.4 Unconvinced perception

As noted, most participants are pessimistic about the use of smart emergency apps. Specifically, Roland Scholtz (UVA) said: *'I don't believe a smart emergency app will improve my situation awareness. I need to see the incident by myself in order to develop situation awareness'*. Further, Piet van Egmond (LUMC) specifies: *'I know from my experience that an ICT network is not reliable and WI-FI network does not work 100 percent correctly. Moreover, all functions should be integrated into one single app.'* Moreover, Carlo Buise (RU) stated: *'We cannot totally rely on the techniques of a smart emergency app. In addition, why should we use an emergency app while we have well trained and skilled people to deal with a fire incident'*. Eddie Verzendaal (UU) said: *'I rely more on manpower than the current technology. The current manpower has the knowledge and expertise to deal with a fire incident. I do not see the added value of an emergency app.'* Finally, Dennis Bommelé (TUD) indicates: 'The biggest threat of using an app on a mobile device is reliability. This means we cannot communicate if the network is overloaded. This will affect the deployment of emergency response officers. Currently, a pager and a two-way radio transceiver are already sufficient to do our job during a crisis.'

10.5 Comparison with a literature study

As discussed in the literature study, some authors including Cheng et al. (2017), Jiang et al. (2004) believe that computing technologies are able to provide information that can assist individuals during the event of an emergency and Gheisari et al. (2011) assumed that these technologies can help the facility managers to improve their situational awareness and performance in general. This is in agreement with the interviewees who are positive about the smart emergency apps. They believe that the concerning apps will positively influence their situational awareness during a fire incident.

However, much attention should also be given to the challenges of smart emergency apps and it must be noted that little research has examined this aspect. Despite the fact that Cheng et al. (2017), Jiang et al. (2004) and Gheisari et al. (2011) suggest that technologies add value during an emergency and in the facility management domain, this study reveals that participants are doubtful and negative about it. In particular, they believe that certain aspects such as ICT network, WI-FI network and techniques should be reliable. In addition, it can be seen that many of them rely more on manpower during a fire incident than the current techniques of smart emergency apps.

10.6 Preferences regarding the use of smart emergency apps

As examined, most participants are pessimistic about the use of smart emergency apps while others are positive and doubtful about it. Subsequently, participants are asked their 5 most important preference when using smart emergency apps during a fire incident. It can be seen that most participants point out that *detailed and correct information* is the most important aspect. This is followed by *functionality, reliability app and mobile device, communication coverage, network reliability* and *battery lifetime*. However, during the interviews, it must be noted that the author of this master's thesis observed that participants are confused with the term 'reliability app and mobile device'. They suggest that it is interrelated with network reliability such as a WI-FI network. Other preferences when using a smart emergency app is elaborated in figure 39. Another important observation relates to cost. Not many participants indicate that cost is an important aspect when choosing smart emergency apps.

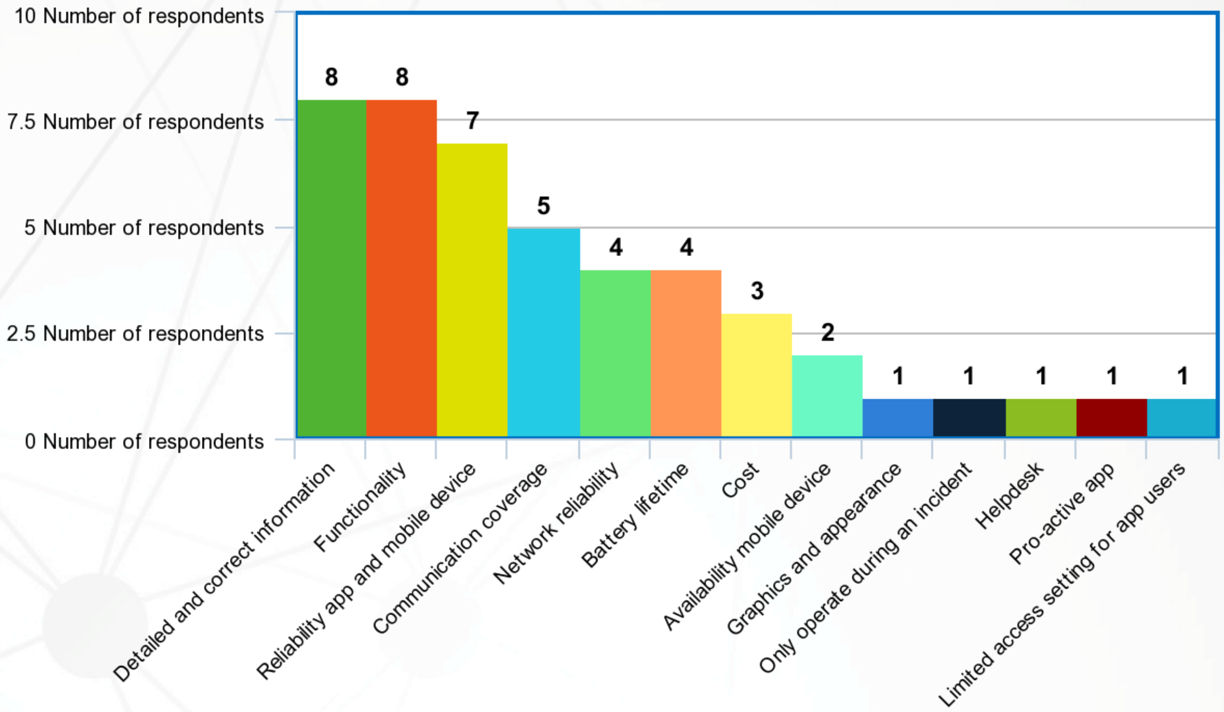
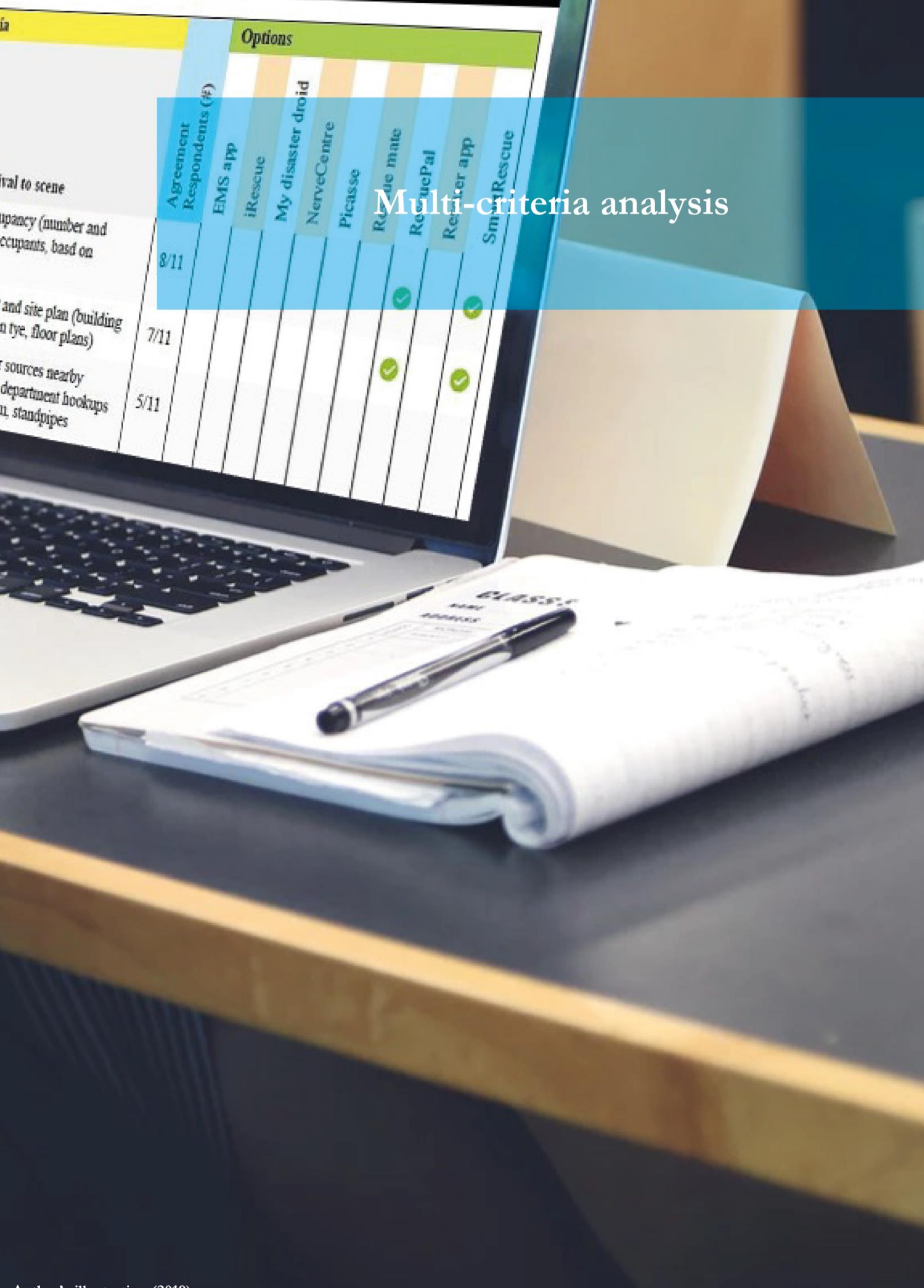


Figure 39 preferences when using a smart emergency app according to the participants (author's illustration, 2019)

11. Conclusion: results empirical research

- A variety of participants with different job title have similar emergency duties as the facility manager;
- The degree of risk acceptance (e.g. subjective data) seems to correspond to the frequency of causes of fire (e.g. objective data);
- Most participants (5/12) from the strategic level are unconvinced regarding the use of emergency apps because participants prefer manpower over technologies and one participant suggest that emergency apps will not increase the situation awareness;
- Participants with a doubtful (3/12) and positive (4/12) opinion about these apps are active at the operational level. They are positive because the use of emergency apps will increase situational awareness;
- Most information items examined by Li et al. (2014) are considered as important to the participants;
- Number of victims in the building is the most important information, which is followed by the cause of fire incident, location of the fire incident, the location of first responders and emergency service;
- Missing information according to the participants refer to numbers of first responders, the arrival time of responding units and the status of victims to name a few.

Multi-criteria analysis



Author's illustration (2019)

12.1 Before arrival to the scene

As discussed earlier, most participants suggest that information items from A1 to A7 are relevant before arrival to the emergency scene. The variety of information items (criteria) are evaluated according to different emergency apps (options) which are examined in the literature study. As shown in figure 40, first responders, emergency managers or facility managers who need information about building occupancy (e.g. the number and identities of occupants) and floorplans, they may opt for RescuePal or SmartRescue. In this respect, RescuePal is able to provide the name and location of the victim while SmartRescue shows the number of victims on a floorplan. Further, they may choose for My Disaster Droid and Rescuer app when they need routing information in and to the building. Both apps have a navigator in their software application and, in particular, My Disaster Droid shows the route to the victims on campus level while Rescuer app provides direction to the victim at the building level. Moreover, 8 out of 11 participants indicate that contact information of building owners, managers and utility contacts (A5) are relevant and essential as well. Therefore, they may opt for EMS app, NerveCentre, and Picasse which stores all relevant contact numbers on the mobile application. Finally, it can be seen that all participants point out that information item 'A6' is essential information. For example, as noted by Dennis Cruyen and Louis van den Berg, it is important to be aware of the presence of asbestos at the building and hazardous substances in lab respectively. However, to date, none of the examined emergency apps provide information item 'A6'.

Criteria			**Options**								
Before arrival to scene	Importance based on Li et al. (2014) (ranking)	Agreement Respondents (#)	EMS app	iRescue	My disaster droid	NerveCentre	Picasse	Rescue mate	RescuePal	Rescuer app	SmartRescue
A1. Building occupancy (number and identities of occupants, based on time of day)	2nd	8/11							✓		✓
A2. Building layout and site plan (building size, construction tye, floor plans)		7/11							✓		✓
A3. Location of water sources nearby (fire hydrants, fire department hookups for sprinkler system, standpipes	3rd	5/11									
A4. Routing information to the building and area map of the neighborhood of the building	1st	7/11			✓					✓	
A5. Contact information of building owners, managers and utility contacts		8/11	✓			✓	✓				
A6. Hazards, location and identification of unusual hazards		11/11									
A7. Location of important objects (facilities, documents, equipment to be saved)		8/11				✓					

Figure 40 Multi-criteria analysis regarding to the phase 'before arrival to scene' (author's illustration, 2019)

12.2 At emergency scene

It can be seen that information item B1 to B6 are considered to be very essential and relevant to the participants when arriving at the emergency scene. In particular, all participants (11/11) agree that the location of the fire in the building, fire size and duration (B1) is considered relevant and necessary. In this respect, facility managers or any other rescuers may opt for NerveCentre, Picasse, Rescuer app, and SmartRescue. However, it must be noted that these smart emergency apps only provide information about the location of the fire in the building and no information about the fire size and duration. Further, the presence and location of occupants in the building is essential information for many participants. In this regard, iRescue, RescuePal, Rescuer app, and SmartRescue helps any rescuer to determine the position of the victim in the building (figure 41). However, none of the emergency apps offer information regarding to sprinkler status (B2), location and condition of smoke (B4), warning of structural collapse (B5) and confidence in the fire being real (B6), while many participants suggest that it is important at the time that they arrive at the emergency scene.

Criteria	Importance based on Li et al. (2014) (ranking)	Agreement Respondents (#)	Options								
At emergency scene			EMS app	iRescue	My disaster droid	NerveCentre	Picasse	Rescue mate	RescuePal	Rescuer app	SmartRescue
B1. Location of fire in the building, fire size, and duration	1st	11/11				✓	✓			✓	✓
B2. Sprinklers' status (number of location of sprinklers that have gone off)		9/11									
B3. Presence and location of occupants in the building	2nd	10/11		✓					✓	✓	✓
B4. Location and condition of smoke	3rd	10/11									
B5. Warnings of structural collapse based on material type, fire location, fire size, and duration		10/11									
B6. Confidence in the fire being real		9/11									

Figure 41 Multi-criteria analysis regarding to the phase 'at emergency scene' (author's illustration, 2019)

12.3 Attack and mitigation

At the time that rescuers need to take action, information items C1 to C6 are used during an emergency response operation at building level (Li et al., 2014). As shown in figure 42, most emergency apps do not offer that information to the rescuers. However, it can be seen that some emergency apps only provide information regarding the location of responding units (C3) including EMS app, NerveCentre, RescueMate or Rescuer app. In relation to the outcome of the interview, participants of the interviews may opt for these emergency apps because most of them stated that information about the location of responding units is important and necessary. It must be noted that these emergency apps only provide updates of first responders' location and not the position of firefighters and police. Therefore, future research and development of emergency apps may focus on integrating the position of firefighters in the software application. In particular, Dennis Cruyen who dealt with the fire incident at the faculty of Architecture in 2008 mentioned that he had a very strong desire to know the position of the firefighters. In contrast to Rob Mulder from Utrecht University, firefighters' position is not necessary information due to the fact that the fire station is located nearby the campus.

Criteria			**Options**								
Attack and mitigation	Importance based on Li et al. (2014) (ranking)	Agreement Respondents (#)	EMS app	iRescue	My disaster droid	NerveCentre	Picasse	Rescue mate	RescuePal	Rescuer app	SmartRescue
C1. Required water flow or foam based on fire condition	2nd	5/11									
C2. Location of available areas of refuge, staging areas	3rd	8/11									
C3. Location and condition of deployed and standing-by responding units	1st	8/11	✓			✓		✓		✓	
C4. Local weather conditions and predictions, wind direction and velocity		5/11									
C5. Locations of building entrance/exit signs		7/11									
C6. Contact information of other emergency agencies		10/11	✓			✓	✓				

Figure 42 Multi-criteria analysis regarding to the phase 'attack and mitigation' (author's illustration, 2019)

12.4 Emergency apps according to the interviewees' most important information

Previous sections reveal that each emergency app can make a contribution in one, two or three phase(s). For example, NerveCentre, Picasse and Rescuer app is beneficial during all three phases while EMS app, Rescue mate and RescuePal is useful in two different phases. Moreover, it can be seen that emergency apps do not offer all the information items. In this respect, this section shows which emergency app can be considered by the facility managers and first responders according to the 5 most important information items. As discussed earlier, many participants suggested that 'the presence of individual and victims in the building' is the most important information. This is followed by the cause and location of the fire incident, location of emergency response officers and, lastly, the position of emergency services. As shown in figure 43, first responders and emergency managers may opt for iRescue, RescuePal, Rescuer app, and SmartRescue which are able to find victims and individuals in the building. Further, it can be seen that 'the location of the fire incident and emergency response officers' is included in several emergency apps. However, other most important information such as the cause of the fire incident and the position of emergency services is not supported by the emergency apps. In conclusion, depending on first responders' and emergency managers' preference, all emergency app can contribute to providing certain important information except for My Disaster Droid.

Criteria		**Options**								
5 ***most important*** **information according to interviewees**	Agreement Respondents (#)	EMS app	iRescue	My disaster droid	NerveCentre	Picasse	Rescue mate	RescuePal	Rescuer app	SmartRescue
The presence of individuals and victims in the building	10/11		✓					✓	✓	✓
Cause of fire incident	8/11									
Location of fire incident	5/11				✓	✓			✓	✓
Location of emergency response officers	5/11	✓			✓		✓		✓	
Position of emergency services (e.g. where are the fire fighters)	5/11									

Figure 43 Multi-criteria analysis regarding to 5 most important information according to the participants (author's illustration, 2019)

12.5 Preliminary recommendations regarding smart emergency apps

Based on the literature study and the results of this research, it seems that information is by far most a crucial aspect during an emergency. In particular, 'detailed and correct information' is necessary when using a smart emergency app according to the participants and, this corresponds with Barrantes et al. (2009) and Van der Meer et al. (2018) in which both authors suggest that information is vital during emergencies in favor of making decisions. In this context, previous sections reveal that different emergency apps provide a variety of information. Therefore, what emergency app, in terms of information provision, can be recommended to the facility managers who need to act during a building fire emergency operation? It must be emphasized that this section provides preliminary recommendations regarding smart emergency apps because most apps such as RescuePal, SmartRescue, and Rescuer app to name a few are still in development.

RescuePal and SmartRescue can be useful and recommended during the 'before arrival to scene' phase because these apps provide the most information compared to other apps. Moreover, it displays information about the 'A1. building occupancy' which is one of the most important information according to Li et al. (2014) and the participants. In addition, both apps show information about the 'A2. building layout and site plan' which is considered as relevant by most participants.

Further, during the phase 'at the emergency scene', it is noted that 'B1. Location of fire in the building, fire size and duration' and 'B3. presence and location of occupants in the building.' are the most important information stated by Li et al. (2014) and the participants. Therefore, the recommendation is given to choose for both Rescuer app and SmartRescue because both emergency apps provide the most and important information (e.g. B1 and B3) compared to other apps.

Finally, during the 'attack and mitigation' phase, facility managers can opt for EMS app or NerveCentre because (1) it shows information about 'C3. Location and condition of deployed and standing-by responding units' which is considered as very important according to Li et al. (2014) and necessary by most participants and, (2) it displays information about 'C6. contact information of other emergencies' is included in both apps which are necessary to most of the participants. (3) Lastly, both apps are able to provide the most and essential information during the concerning phase in comparison to other emergency apps.

However, these recommended emergency apps are based on different phases. When considering the most important information in general, facility managers may opt for a Rescuer app because this emergency app provides three essential information in one single app: (1) the presence of individuals and victims in the building, (2) location of the fire incident and (3) location of emergency response officers.

12.6 Conclusion

To recap the main research question, the intention of this study is to examine the following: *'How can current smart emergency applications, in terms of information provision, contribute to the mitigative barrier in order for the facility managers to improve their situational awareness in building fire emergency response operations?'* The purpose of this section is to evaluate the current smart emergency apps according to a variety of information. Therefore, it can be seen that:

- This multi-criteria analysis shows that all emergency app has a unique information provision whereby emergency apps are useful in one, two or three phase(s);
- No single emergency app provides all information that is examined by Li et al. (2014);
- Some smart emergency apps (e.g. RescuePal and Smart Rescue) are able to provide information about the building occupancy, building layout and the location of the fire in the building;
- The 'strength' of other smart emergency apps is the ability to provide the location of occupants in the building (e.g. iRescue) or provide the location of standing-by responding units (e.g. NerveCentre);
- Information about the cause of the fire incident and the position of emergency services is not integrated yet in any smart emergency apps;
- Other important information such as the victims in the building, location of the fire incident and first responders is widely supported by several smart emergency apps;
- During 'before arrival to scene' phase, facility managers may opt for RescuePal and SmartRescue because these apps are able to provide the most essential information;
- Rescuer app and SmartRescue is recommended during the 'at the emergency scene' phase;
- In the 'attack and mitigation' phase, EMS app or NerveCentre can be chosen because both apps give the most and important information in one single app;
- According to the most important information in general, facility managers may opt for a Rescuer app which is able to provide three essential information in contrast to other apps.

Desired smart emergency app

Author's illustration (2019)

13.1 The ideal emergency app for the Facility Manager

As discussed earlier, the previous section reveals that some emergency apps are recommended during a particular phase in a fire incident. Moreover, it is stated that current emergency apps only provide specific information and do not deliver all information listed by the participants and Li et al. (2014). In this section, the ideal emergency app on a mobile device for the Facility Manager is presented which provide a concept for identifying, inventing, and developing a desirable emergency app. In this regard, the ideal emergency app embodies five aspects: detailed and correct information, functionality, reliability (e.g. network and app), communication coverage and battery lifetime. These aspects are discussed earlier in this research and depicted in figure 39.

It stated that functionalities are important when choosing an emergency app. In this respect, based on the interviews, it is assumed that fire crisis assessment, localization of victims and first responders and victim assessment is considered important during a building fire emergency operation. On top of that, the author of this masters' thesis suggests that direct communication, navigator, and attendance registration is an added value to the future emergency app as well (fig 44). Direct communication through an emergency app enables the facility manager to communicate and report the situation to other emergency managers and first responders during the emergency scene and vice versa. In addition, a real-time walking direction in an emergency app would be beneficial for facility managers who are not familiar with the place (e.g. university campus) (fig 45). Lastly, attendance registration allows facility managers to have an oversight of the capacity of first responders during a fire incident.

Figure 44 the ideal emergency app with the corresponding functionalities (authors' illustration, 2019)

Moreover, the ideal emergency app is based on the assumption that involves the most important information. Therefore, as discussed earlier, it seems that the following information is essential during a building fire emergency operation: (1) the presence of individuals and victims in the building (2) cause of fire incident (3) location of fire incident, fire size and duration (4) location of emergency response officers (5) position of emergency services (6) routing information to the building and area map (7) Location of water sources (8) location and condition of smoke, (9) staging areas and (10) required water flow. It is assumed that this list of information forms a fundamental basis for the ideal emergency apps in order to improve the situational awareness of the facility manager during a fire incident (fig 45).

Figure 45 the desirable emergency app which displays the most important information and real-time walking direction (authors' illustration, 2019)

On top of that, the ideal emergency app should have sufficient communication coverage and battery lifetime and, even more important, be reliable during building fire emergency operations. In the case that these aspects are addressed sufficiently in the future, it is assumed that it will increase and maintain the confidence and satisfaction level of the facility manager in using an emergency app.

Conclusion

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14. Conclusion

The purpose of this research is to add to the existing body of knowledge and increase the understanding of the contribution of current smart emergency applications to the facility manager with the focus on required information during building fire emergency response operations. In this section, the conclusion is drawn for the sub-research questions in the first place and, subsequently, the answer is given to the main research.

Sub-question 1: 'What is the role Corporate Real Estate Management and Facility Management with regard to a safe environment in a university?'

With reference to a safe environment, it is essential to understand Maslow's hierarchy of needs in the first place that is examined by Den Heijer (2011). This is used a basis to align the built environment in order to meet the needs of the individuals and, in the context of this research, the need for safety. In this respect, The General Management domain focusses on the strategic level which involves establishing the long run and overall goals of an organization in strategic plans. This is similar to the role of the crisis manager which determine crisis plan to overcome the crisis situation and support the organization's image. Moreover, this research reveals that the Facility Management domain focusses on offering an efficient working environment with a safe surrounding to the business performance, regardless of the size and scope (Corenet Global, 2015). In particular, facility managers are in charge during catastrophic events. For example, recovering supporting services that will empower the business to operate again, and providing suggestions about crisis-mitigating strategies. Moreover, facility managers must have situational awareness of emergency events, risks, fire safety systems, and combustible materials in favor of their decision-making process. However, creating situational awareness might be difficult for facility managers due to a large amount of information. Therefore, Gheisari et al. (2011) believe that applications and computer technologies can support the activities of the facility manager including managing multiple information for their decision-making process

Sub-question 2: 'What are the typical scenario and acceptable level of risk in a fire emergency event with regard to a BowTie risk assessment method and ALARP?'

In the past twenty years, several fire incidents (e.g. top events) occurred at Dutch universities and, even more important to note, it took place annually at different international universities. With the use of the BowTie risk assessment method, it aims to provide the reader with a visual overview of the accident scenario at these universities. In particular, this method illustrates and examines the causal relationship in a hazardous situation. It provides a clear overview of all conceivable and typical scenarios (threat – top event – consequences) of a particular hazard. In this context, the typical scenario in a fire emergency at Dutch education institution relate to the following: (1) As examined by Statistics Netherlands (Dutch: CBS), main causes at education institution relate to arson, wrong use of a device, work that causes fire, spontaneous combustion, firework and smoking. (2) Thereafter, for example, the top event relates to a fire outbreak at Twente University of Technology in 2002 due to arson. (3) The potential consequences may refer to the impact on business continuity, property loss and loss of human lives to name a few. Whether a risk is acceptable or not it depends on the viewpoint of the society and individuals. Using the ALARP method will increase the understanding of which risk is unacceptable, tolerable or acceptable. Unacceptable risk is considered too high which need to be mitigated. ALARP or tolerable risk is related to the fact that the society and individuals are prepared to live with on the condition that is kept under review and minimized as low as reasonably practicable. Acceptable risk is a negligible risk and where society and individuals live with every day.

Sub-question 3: 'What information items are required and relevant in building fire emergency response operations?'

Information is necessary during an emergency to make decisions in an effective and quick manner and to offer effective and very quick assistance for the victims during a disaster to name a few (Barrantes et al., 2009). However, poor gathering and understanding of information during an emergency may lead to lack of situational awareness which makes the emergency situation more complicated (Li et al., 2014). In this context, Li et al. (2014) examined all necessary information items during a building fire emergency. Specifically, the researchers examined information that is needed in different stages including 'before arrival to the emergency scene', 'at the emergency scene' and 'attack and mitigation'. In particular, the most important information during 'before arrival to the scene' is 'Routing information to the building and area map of the neighborhood of the building. Further, another essential information that is ranked in the first place is 'location of the fire in the building, fire size, and duration' during the phase 'at the emergency scene'. Lastly, during the phase 'attack and mitigation', the information items related to 'location and condition of deployed and standing-by responding units' is considered as the most essential according to Li et al. (2014).

Sub-question 4: 'What current smart emergency applications, in terms of information provision, contribute to building fire emergency response operations?'

Some researchers suggest that applications and computer technologies are able to support the activities of the facility manager in general. In particular, Jiang et al. (2004) think that the use of the sensor, wireless networking, and computing technologies have great potential in gathering information during the event of an emergency. Moreover, Sarshar et al. (2015) suggest that using a smartphone in the emergency event is the most practical solution for raising situational awareness. In addition, Rajalakshmi et al. (2015) point out that using smart emergency applications during an emergency event is advantageous because it provides valuable information to the users. In this respect, this research presents the reader a variety of smart emergency apps which helps the facility and emergency manager during a building fire emergency operation due to their specific information provision: SmartRescue, EMS app, iRescue, My Disaster Droid, NerveCentre, Picasse, RescueMate, RescuePal, and Rescuer app. The contribution of these emergency apps, in terms of information provision, varies from predicting the fire development to finding victims in the building and showing the availability of first responders (Dutch: BHV'ers).

Main research question: 'How can current smart emergency applications, in terms of information provision, contribute to the mitigative barrier in order for the facility managers to improve their situational awareness in building fire emergency response operations?'

This study reveals that current smart emergency apps, with the focus on information provision, have demonstrated a certain degree of contribution to the facility manager amid building fire emergency operation.

Researchers such as Davies et al. (1998), Marchant (2000) and Hassanain (2006) point out that facility managers from the operational level have a variety of responsibilities in a disastrous situation. For example, providing crisis-mitigating strategies and conducting a risk assessment to name few. In this context, the concerning researchers state that facility managers should have situational awareness of emergency events. Continuing on this line, Gheisari et al. (2011) point out that situational awareness in facility management practices, in general, is essential. The reason is that an improved situational awareness can lead to better decision making and performance of the facility manager. In this respect, Gheisari et al. (2011) believe that applications and computer technologies can support the activities of the facility manager including managing multiple information for their decision-making process. In this context, this is particularly relevant during a fire incident in which the facility manager position itself at the mitigative barrier. At this barrier, consequences such as loss of life and property damage need to be mitigated after a fire incident occurs. In this circumstance, the facility manager needs to gather information which is important in disastrous situations and emergencies (Barrantes et al., 2009). Therefore, Li et al. (2014) demonstrated a variety of information that is needed during a building fire emergency operation.

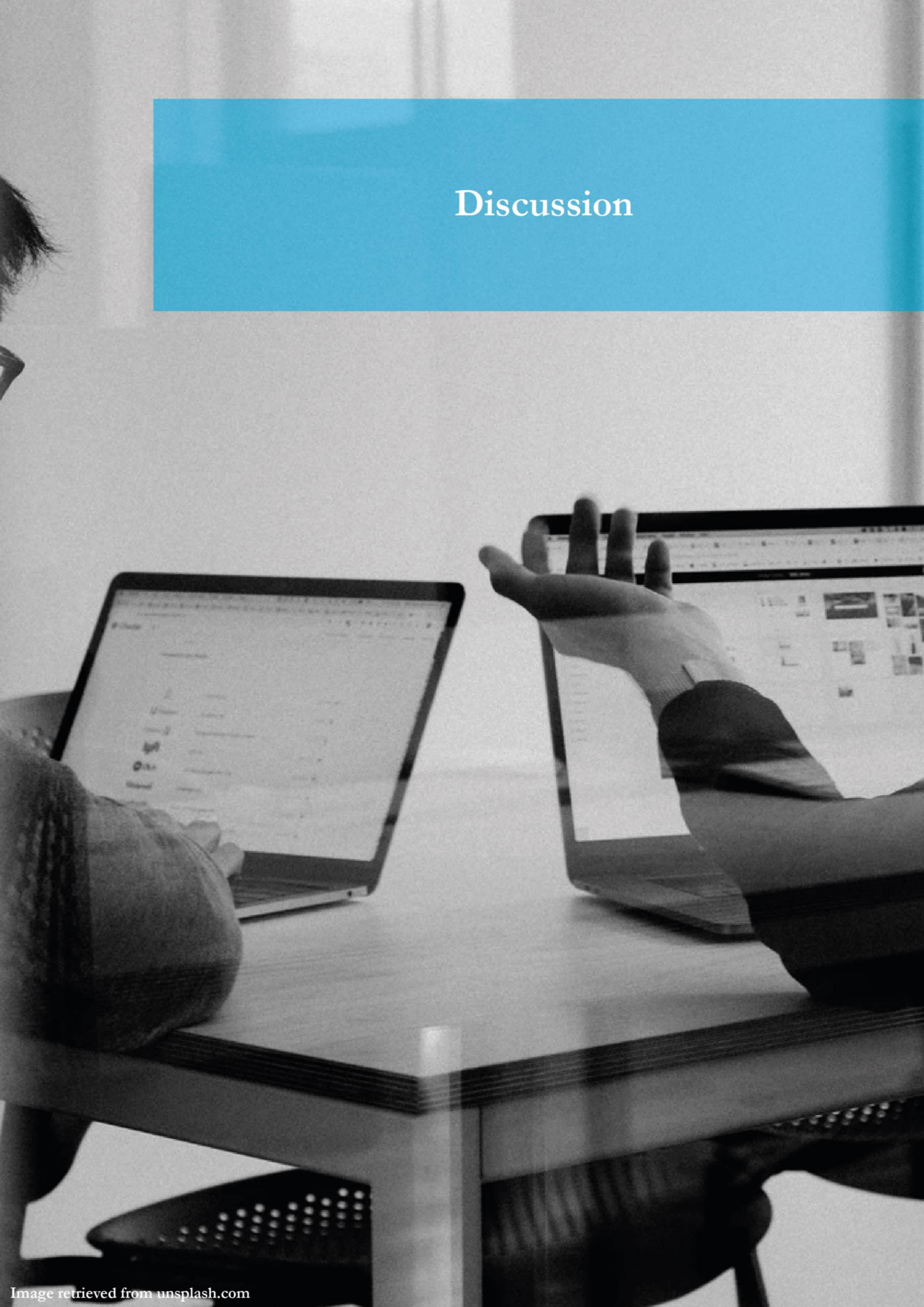
To date, current smart emergency apps are able to provide specific information to the facility manager during a fire incident which seems to correspond with the required information according to Li et al. (2014). In particular, SmartRescue provides information about fire development and the victim's location. EMS app displays information related to indoor and outdoor locations of responding units. iRescue provide facts about the status and location of victims. My Disaster Droid provides information about the location of the victim at the area level. NerveCentre shows the total number of available first responders per location and the indoor and outdoor location of first responders. Picasse provides oversight of the presence and availability of first responders, location of the emergency source, and type of emergency source. RescueMate displays the official procedures for first aid, firefighting, evacuation, acute illnesses, and communication. RescuePal gives insight into the presence and location of occupants in the building and the ID of the victim. Lastly, the Rescuer app shows the location of first responders and victims, the route to the emergency source, type of emergency source and numbers of first responders who are heading to the emergency source.

However, the findings from the interviews and the results of the multi-criteria analysis show that current smart emergency apps contribute to the facility manager to a certain degree. In particular, the multi-criteria analysis in this research shows that the current smart emergency apps have a unique way of contribution during a fire incident. On the one hand, some emergency apps only provide facts about the victim's location, victim's status or the direction to the victim. On the other hand, emergency apps give information about the location and availability of first responders or fire development. In addition, it can be seen that some required information examined by Li et al. (2014) and most important information suggested by the participants are not available in the current smart emergency apps. For instance, to name a few, information items in regard to the cause of the fire incident, the position of emergency services, location and condition of smoke (B4), warnings of structural collapse (B5), sprinkler status (B2), confidence in the fire being real (B6) is not addressed in all current smart emergency apps. Moreover, the results reveal that some emergency apps are useful in 'before arrival to scene', 'at emergency scene', and 'attack and mitigation'. For example, Nervecentre, Picasse and Rescuer app are able to contribute in the concerning phases during. However, another emergency app such as iRescue is beneficial during one phase referring to 'at emergency scene'. Whereas, EMS app, RescueMate and Rescuepal are advantageous in two different phases.

In addition, the findings from the interviews provide valuable insight into whether smart emergency apps contribute to the facility manager who is situated at the mitigative barrier during a fire incident. It shows that some participants agree that the use of smart emergency apps will improve the situational awareness due to receiving facts and relevant information, and even more important, it will help first responders in their activities during a fire incident. This is in line with Gheisari et al. (2011) and these researchers suggest that applications and computer technologies will improve situational awareness in general. However, the results also show that participants are partially convinced about the use of smart emergency apps while others are unconvinced of the relevance of these apps. To be more specific, some are doubtful in using these emergency apps during a fire incident because participants rely more on manpower than on current technologies (e.g. WI-FI). In addition, a participant believes that smart emergency apps will not improve situational awareness because this person needs to see the incident and cause in a real-life context. Surprisingly, most participants are yet unconvinced about the use of smart emergency apps due to the unreliability of measurement techniques such as WI-FI. In addition, they rather see an added value of the current well-trained and skilled first responders than the unreliable ICT network and technology in general.

As stated earlier, the hypothesis of this study is 'the information provision of current smart emergency applications improves the situational awareness of the facility manager by the ability to make right informed decisions in the event of a fire emergency'. It can be seen that the results of this research do support partially the concerning hypothesis. In particular, some participants believe that using smart emergency applications, with the focus on information provision, improves the situational awareness due to receiving relevant fact. In addition, Gheisari et al. (2011) suggest that using computer technologies will enhance the situational awareness of the facility manager as well. At the same time, some participants suggest that they are not or partially convinced yet. However, it is worthwhile to note that most participants in this research do not have experience yet with using smart emergency apps during a building fire emergency operation. Therefore, it is desirable to test the hypothesis in the future to determine whether smart emergency applications improve the situational awareness of the facility manager is likely to be true.

Discussion



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15. Discussion

The purpose of this masters' thesis is to gain an understanding of the contribution of current smart emergency applications to the facility manager with the focus on building fire emergency response and information needs. In this regard, this discussion section provides the reader comprehension of the major findings of the study, the importance and relevance of this research, the relation to previous studies, limitations of the study design and suggestions for further research (Hess, 2004).

The research shows that most facility managers at several Dutch universities are not involved during building emergency response operations, whereas literature study suggests that their responsibility is to offer a safe environment. In practice, internal stakeholders of several universities such as the first responders, emergency managers and head of the emergency response team need to act during a fire incident. However, this research shows that the emergency response duties of the internal stakeholders and facility managers are similar to each other. In other words, the job title differs from the facility manager but the emergency response duties are equivalent to each other.

Moreover, the results of this study confirm that current smart emergency applications, in terms of information provision, contribute to the facility manager's building emergency operation to a certain extent. The findings suggest that the examined smart emergency applications do not provide all required and most important information in the case of facility managers need to act during a fire incident. In this regard, current smart emergency applications focus on providing specific information to the facility and emergency manager. For example, iRescue is able to display the presence of victims in the building, Picasse deliver information about the location of the fire incident, while EMS app present real-time information about the location of first responders. In other words, this research suggests that there is not a single emergency app that is able to deliver all the required information. In this respect, the choice for an emergency app depends on the preference and information priority of the facility and emergency managers.

Further, the research reveals that participants are positive, doubtful and unconvinced about the use of smart emergency apps. It is positive because some participants suggest that smart emergency apps increase their situational awareness during a building fire emergency operation. Several participants are doubting due to the financial investment and, even more important, they prefer to communicate with people rather than using a smart emergency app. Finally, participants who are unconvinced do not think emergency app add value to the situational awareness and current manpower. Moreover, they believe that current technology (e.g. WI-FI) in a fire incident is not trustworthy.

With reference to the importance of this research, the results of this study will contribute to the society and current body of knowledge considering that safety at universities and, smart tools will play an essential role in science and technologies of today and in the near future. Therefore, this empirical research is relevant for readers with specific interest and priorities such as researchers, facility managers, emergency managers, first responders and, even more important, emergency app developers. In particular, facility managers, emergency managers, and first responders will be guided on what emergency app should be selected based on their information preferences. For the app developers, this research forms a fundamental basis for improved performance and information provision of an emergency app. Lastly, this study will help researchers to uncover the capabilities of current emergency apps in relation to a variety of information items that many scientists were not able to examine yet.

In this regard, how do the results extend the findings of previous studies? Most research focuses specifically on the applicability and technical elements of smart emergency apps. For example, Lazreg et al. (2015) aim attention on how to assess the fire development and discover victims in the building with the focus on Bayesian network. Whereas, Yoon et al. (2016) intend to examine how to assess the victim's status on the emergency app with the aid of embedded sensors on the mobile phone. However, less attention has been given to the information provision in relation to the emergency apps with the focus on facility and emergency managers that need to act during building fire emergency operations. Therefore, this empirical research adds to the current body of knowledge by exploring and evaluating relevant emergency apps according to a variety of information items in favor of facility managers. Moreover, it helps the reader to increase the understanding of how facility managers, emergency managers, and first responders perceive the use of smart emergency apps which was not examined yet by many researchers.

However, the limitation of this study relates to the fact that the sample was confined to Dutch universities which involve twelve semi-structured interviews. Moreover, to date, this research was limited to 9 different emergency apps in favor of a facility manager due to the fact that most apps are still in the development phase. In the future, semi-structured interviews should be extended to other international universities and additional future emergency apps should be examined in order to get extended results.

Reflection

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16. Reflection

With a passion for advanced communication technologies, safety management and real estate management, the author of this masters' thesis participated in new experiences during this study. In particular, conducting research activities that are outside of his routine while there is generally a lot of learning going on. In this respect, the purpose of this section is to reflect on the relationship between the master track and graduation topic, the connection between research and design, research instruments that have been used during the study, ethical issues, utilization potential, scientific and societal relevance.

16.1 Relationship between graduation topic and master track

This empirical research is carried out for the completion of the master track Management in the Built Environment (MBE) at Delft University of Technology (TU Delft) in The Netherlands. Up till now, the author gained interesting and new knowledge through this master track including how to manage the construction process and urban development, designing an accommodation strategy to ANZ in the Real Estate Management course, and how to involve all relevant stakeholders in the project 'De Rotterdam' to name a few.

However, the author observed that less attention has been given to the facility management in building fire emergency operations with the focus on smart tools during the master track MBE. In this respect, this subject matter provides the author with a great opportunity to combine knowledge from both the Faculty of Architecture and the Built Environment and Faculty of Technology, Policy and Management at TU Delft. In particular, this graduation project uses the knowledge about Facility Management and Corporate Real Estate Management gained from the master track MBE and, at the same time, it enables the author to focus on the use of smart tools in building fire emergency operations. In this sense, knowledge about safety management from an external faculty of TU Delft, Faculty of Technology, Policy, and Management, is used to support this research. Continuing on this line, it is worthwhile to note that using the studies of Den Heijer (2011), Den Heijer et al. (2016), Valks et al. (2016), and Valks et al. (2018) is very valuable which provide a fundamental basis for this masters' thesis. By doing so, the author believes that this study provides novel knowledge in a specific research domain which can be beneficial for both Faculty of Architecture and the Built Environment and Faculty of Technology, Policy and Management.

16.2 Relationship between research and design

The research design during P2 to P4 is based on empirical research with the focus on multi-criteria analysis and semi-structured interviews. Up till now, the author believes that this is the right approach for this study because the answers to the main research question and sub-research questions are eventually determined sufficiently while keeping the time constraints of the graduation project in mind. However, it must be noted that a case study in favor of this empirical research was taken into consideration during P2. The idea behind it was to gain in-depth knowledge about the role of the facility managers during fire emergency situations and what information items should be needed during a building fire emergency operation. Eventually, after careful consideration, a case study is not included in this research because it does not provide the necessary and extensive data that is needed to answer the sub-research question and, even more important, the main research question.

16.3 Lessons learned from conducting research

The author has gained interesting information during the semi-structured interviews. All interviewees were very enthusiastic about this research and, therefore, willing to provide comprehensive answers to all questions. Moreover, it must be noted that a semi-structured interview is an appropriate method for data collection because it enables the author to gather extensive and valuable knowledge. However, the author experienced a lack of time during all interviews. This led to the fact that the author was not able to (1) ask follow-up questions in favor of data collection and (2) to gain a more in-depth understanding of the subject matter. In this context, the author suggests that multiple-choice questions would be a suitable instrument for future research. In particular, the author believes that this research instrument will enable the interviewer to collect accurate and valuable data within time. For example, the author eventually added a multiple-choice question such as 'Please select the 5 most important preferences to utilize a smart emergency applicant during a fire emergency? Subsequently, the participants were asked to select only the choices offered as a list. This has benefited this research because it enables the author to collect specific data and within time.

Further, the intention to use the ALARP method in this research is useful to demonstrate whether a fire cause belongs to the acceptable, ALARP (tolerable) or unacceptable region. By doing so, particular attention can be devoted to the cause that is unacceptable or tolerable. It was supposed that this result helps the author (1) to determine whether the objective data of CBS (2013) correspond to the subjective data of this research. (2) Evaluate whether emergency apps are presenting the information about the cause of fire to the facility manager and, therefore, improve their situational awareness during a fire incident. However, the author of this masters' thesis has eventually learned that the results of the ALARP method contribute indirectly to the main research question of this study. In addition, using the current ALARP method in this study is not accurate enough. Ultimately, the author would suggest using the 'ALARP risk matrix method' with the corresponding likelihood and impact as depicted in figure 46. By doing so, the author believes that it enables a researcher to compare the subjective data with the objective data of CBS (2013) and examine the degree of risk acceptance in an accurate manner.

Likelihood	Severity			
	catastrophic	critical	marginal	negligible
frequent	A	A	A	A
probable	A	A	A	B
occasional	A	A	B	C
remote	A	B	C	C
improbable	B	C	C	D
incredible	C	C	D	D

Figure 46 the 'ALARP risk matrix method' for future research. Table retrieved from Cook (2008)

Besides, the research in smart tools helps the author to increase the understanding of the usefulness and functionality of the current smart emergency apps. In this regard, the studies of Valks et al. (2016), and Valks et al. (2018) are very helpful to this research. More accurately, these studies provide a direction to the author on how to analyze the current smart tools and, therefore, increasing the understanding of the usefulness and functionality of smart tools. In the future, it is recommended to use the format of Valks et al. (2018) as a fundamental basis for the smart tools' analysis.

16.4 Societal and scientific relevance of the work

With reference to the societal relevance and transferability of the results, the author believes that the findings of this research are valuable for researchers, facility managers, emergency managers, and app developers. In particular, it can be a resource for the researchers for reviewing their smart emergency applications in terms of information provision. Moreover, this study can be a stimulant for the researchers to create novel smart emergency apps through operational research. Additionally, the findings of the research provide constructive feedback to the facility managers. They may use this research to find out which smart emergency applications are advantageous to them according to their required information during an emergency situation. Regarding scientific relevance, most studies focus on the benefits and technical elements of smart tools during emergency situations. However, a need was identified for a detailed study from a distinctive perspective. Hence, the contribution of this research is to add to the current body of knowledge: generating new insight and findings based on the prior available knowledge by doing empirical research with the focus on multi-criteria analysis for supporting the selection of smart emergency application in the facility management.

16.5 Ethical issues

While important and relevant data was gathered for this research, the author also experienced an ethical issue in data collection. In particular, during this research, confidential information about the cost of an emergency app and a script for emergency activities is not included in this study. Permission to publish this confidential information is not granted by the participants. Further, as stated by Kumar (2011), it is unethical to gather information without the consent of the participants. Therefore, this study seeks consent by providing a consent form to the participants of the interview. In this regard, this study uses the consent form that is retrieved from TU Delft. The aim of this informed consent is to make participants aware of the purpose of the research, whether personal information (e.g. real name and job title) of the participant can be used for quotes and for which purpose. In the latter case, it must be noted that all participants give permission to use their real name for quotes.

Recommendations for further research

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17. Recommendations for further research

As discussed earlier, this research was limited to Dutch universities and, additionally, the semi-structured interviews have limited population size due to time constraints. Hence, how well did the author achieved the purpose of this research? In essence, the current results do provide new knowledge and valuable insight into the contribution of smart emergency apps to the facility managers during the fire incident. However, a larger population with the focus on international universities would have allowed for more important data. Therefore, if this research will be conducted again, the following aspects will be taken into account for further research:

- Extension participants population

  The findings of the necessary information analysis in the results section show that the final outcome is minimal. To be more specific, 5 participants agree that the information item *'A3 – Location of water sources nearby'* is necessary and relevant. Whereas, 6 participants believe that this information is not essential for them. The same applies to the information item *'C1 – Required water flow or foam based on fire condition'*. 5 participants agree that this information is essential during a fire incident while 6 participants disagree. Further, another example, 5 participants agree that *'C4 – local weather conditions and predictions, wind direction and velocity'* is important while 5 participants agree and 1 participant considered this information as 'possibly' essential. Therefore, it can be seen that the final outcome is very minimal. In favor of this research, the extension of the participant's population could provide a convincing result whether information items 'A3', 'C1', and 'C4' are important or not.

- Invite participants with experience in the use of smart emergency apps

  This study provides a valuable indication of whether emergency apps are useful to the participants and their situational awareness during a building fire emergency operation. However, it must be noted that most participants do not have experience yet with using smart emergency apps during a fire incident. Therefore, in order to test the hypothesis of this study, it is recommended to invite specific participants who are familiar with the use of emergency apps. By doing so, future research can achieve accurate results and, additionally, determine in more detail whether smart emergency apps improve the situational awareness of the facility manager by the ability to make the right informed decisions in the event of a fire emergency.

- Participants from international universities

  In the future, this research should be extended to participants from international universities to get extensive results. For instance, universities that recently had to face with fire incidents as examined in this study: Carleton University in Canada, Bristol University in England, Tsinghua University in China, Al-Azhar University in Egypt. By doing so, the perspective between participants from the national and international level on necessary information items, their role in emergency situations, acceptable level or risk and the use of smart emergency apps can be determined. Even more important, this could lead to critical thinking and interesting discussion about the subject matter of this study.

- Extend smart emergency apps criteria

  As discussed in chapter 12.5, certain emergency apps are recommended based on one criterion which is the information provision of these apps. However, in order to provide a well-considered recommendation to the facility manager, more criteria should be extended to evaluate the performance of the smart emergency apps. In particular, future research should focus on the following criteria: reliability (e.g. emergency app and network), functionality, communication coverage and battery lifetime.

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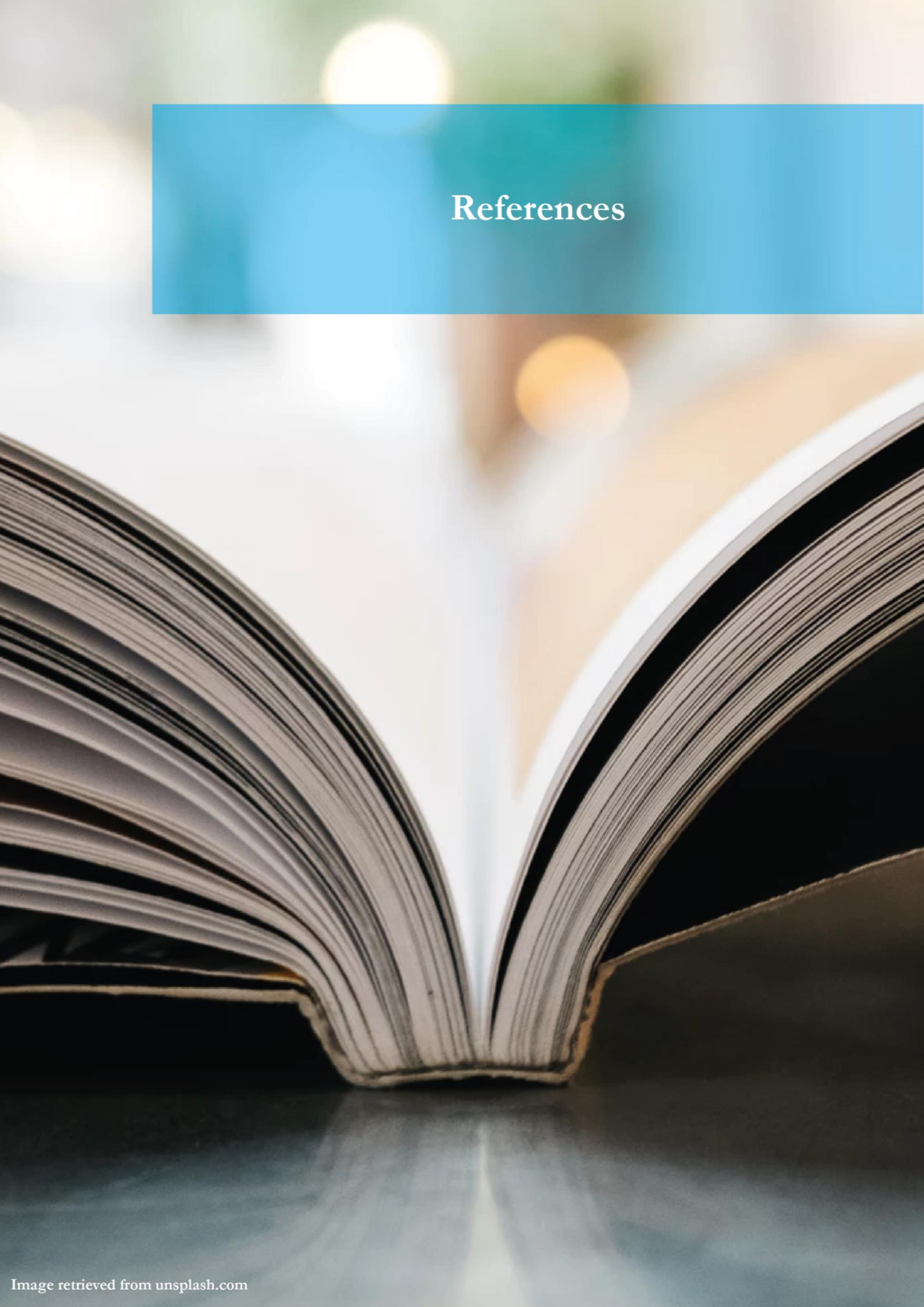

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Appendices

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A. Background of the participant

A1. What is your function at the university?

A2. How long have you been working in the field of fire safety?

A3. To which extent have you been involved in a fire incident and/or fire alarm in a building? If applicable, could you please mention the specific case?

B. The role of participants in emergency situations

B1. What is your role during a fire incident and/or fire alarm?

C. Acceptable level of fire risk

C1 Which fire causes fall under the category ‘acceptable’, ‘tolerable’ (e.g. ALARP region), ‘not acceptable’? Please choose the following causes of fire and categorize.

1. Arson
2. Human error / wrong use of device
3. Smoking
4. Firework
5. Spontaneous combustion
6. Work that causes a fire

D. Information during an emergency situation

D1 Based on the information list of Li et al. (2014), please select the information item(s) which is necessary and relevant during a building fire emergency response operation

D2 On the basis of the information list of Li et al. (2014), what relevant information is, if applicable, *missing* according to you?

D3 What are the 5 most important information that you need to know during a building fire emergency operation?

E. Perceptions of participants in regard to smart emergency apps

E1. To which extent do you believe that smart emergency application, in general, is an added value and improve your situational awareness during a fire emergency? Please motivate.

E2. What are the 5 most important preferences to utilize a smart emergency application during a fire emergency? Please select 5 options below.

1. costs
2. Reliability network
3. Reliability emergency app
4. Reliability mobile device
5. Battery lifetime
6. Functionality
7. Graphic design
8. Communication coverage
9. Correct and detailed information
10. The success ratio of the emergency app
11. Availability of the mobile device
12. Others…

Appendix 2 Information list

Interviewee: .... **University:** ....

Job title: .... **Date:** ....

Before arrival to scene

	Yes	No	Maybe	N/a
A1. Building occupancy (number and identities of occupants, basd on time of day)				
A2. Building layout and site plan (building size, construction tye, floor plans)				
A3. Location of water sources nearby (fire hydrants, fire department hookups for sprinkler system, standpipes				
A4. Routing information to the building and area map of the neighborhood of the building				
A5. Contact information of building owners, managers and utility contacts				
A6. Hazards, location and identification of unusual hazards				
A7. Location of important objects (facilities, documents, equipment to be saved)				

At emergency scene

	Yes	No	Maybe	N/a
B1. Location of fire in the building, fire size, and duration				
B2. Sprinklers' status (number of location of sprinklers that have gone off)				
B3. Presence and location of occupants in the building				
B4. Location and condition of smoke				
B5. Warnings of structural collapse based on material type, fire location, fire size, and duration				
B6. Confidence in the fire being real				

Attack and mitigation

	Yes	No	Maybe	N/a
C1. Required water flow or foam basd on fire condition				
C2. Location of available areas of refuge, staging areas				
C3. Location and condition of deployed and standing-by responding units				
C4. Local weather conditions and predictions, wind direction and velocity				
C5. Locations of building entrance/exit signs				
C6. Contact information of other emergency agencies				

Informed consent form template for research with human participants

Authors: Joost Groot Kormelink, Marta Teperek based on examples provided by UK Data Services
Last edited: 8 May 2018

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1. Note that this is a template to assist researchers in the design of their informed consent forms. It is important to adapt this template to the outline and requirements of your particular study, using the notes and suggestions provided.

2. The informed consent form should be accompanied by an information sheet that describes adequately (for the participants)
   - Purpose of the research
   - Benefits and risks of participating
   - Procedures for withdrawal from the study
   - Whether any personal information about the participant will be collected, processed and how and for what purpose; the right of the participant to request access to and rectification or erasure of personal data
   - Usage of the data during research, safeguarding personal information, maintaining confidentiality and de-identifying (anonymizing) data, controlled access to data, especially in relation to data archiving and reuse, ways of dissemination, data archiving and possible publishing
   - Retention period for the research data, or if that is not possible, criteria used to determine that period
   - Contact details of the researcher (or his/her representative), contact details of the data protection officer, institution, funding source, how to file a complaint.

3. Under the forthcoming General Data Protection Regulation (GDPR), consent needs to be:
   - affirmative
   - granular, seeking consent for different forms of data and for different use purposes

4. In this template:
   - square brackets indicate where specific information is to be inserted
   - black text forms the standard content of a consent form
   - red text is notes to help the researcher finalise the form, not to be included in the consent form.
   - grey text indicates extra optional questions

Consent Form for [*name of study*]

Please tick the appropriate boxes	Yes	No
Taking part in the study		
I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
Separate 'yes/no' tick boxes allow the researcher to make sure that the participant is actively affirming their consent. If the participant wants to tick the no box this allows the researcher to clarify any points the participant is unsure about. If this is not applicable for your study, then remove the 'no' box.		
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
I understand that taking part in the study involves [………………………………………………]	☐	☐
Describe in a few words how information is captured, using the same terms as you used in the information sheet, for example: an audio-recorded interview, a video-recorded focus group, a survey questionnaire completed by the enumerator, ….]		
For interviews, focus groups and observations, specify how the information is recorded (audio, video, written notes)		
For questionnaires, specify whether participant or enumerator completes the form.		
For audio or video recordings, indicate whether these will be transcribed as text, and whether the recording will be destroyed.		
OPTIONAL (delete if not needed):		
Risks associated with participating in the study		
I understand that taking part in the study involves the following risks: [….]	☐	☐
Describe in a few words risks associated with participating in the study, for example: physical or mental discomfort, risk of the participant identity being revealed to close relatives etc.		
Use of the information in the study		
I understand that information I provide will be used for [……………………………………………]	☐	☐
List the planned outputs, e.g. reports, publications, website, video channel, ……, using the same terms as you used in the study information sheet. Consider any secondary use and whether knowledge sharing and benefits sharing needs to be considered, e.g. for indigenous knowledge.		
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	☐	☐

Possible extra questions:

If you want to use quotes in research outputs then add extra question: I agree that my information can be quoted in research outputs ◻ ◻

If you want to use named quotes, then add extra question: I agree that my real name can be used for quotes ◻ ◻

If written information is provided by the participant (e.g. diary) then add extra question: I agree to joint copyright of the [*specify data*] to [*name of researcher*] ◻ ◻

Future use and reuse of the information by others

I give permission for the [*specify the data*] that I provide to be archived in [*name of data repository*] so it can be used for future research and learning. ◻ ◻

Specify in which form the data will be deposited, e.g. anonymized transcripts, audio recording, survey database, etc.; and if needed repeat the statement for each form of data you plan to deposit.

Specify whether deposited data will be anonymized, and how. Make sure to describe this in detail in the information sheet.

Specify whether use or access restrictions will apply to the data in future, e.g. exclude commercial use, apply safeguarded access, etc.; and discuss these restrictions with the repository in advance.

Signatures

______________________ ______________________ ________

Name of participant [printed]

and legal representative If applicable) Signature

Date

For participants unable to sign their name, mark the box instead of sign

I have witnessed the accurate reading of the consent form with the potential participant and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

______________________ ______________________ ________

Name of witness [printed] Signature Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

______________________ ______________________

____

Researcher name [printed] Signature Date

Study contact details for further information: [*Name, phone number, email address*]

Image adapted from www.braaksma-roos.nl/project/bk-city/