Chapter 15

Towards the Development of a Capability Assessment System for Flood Risk Management

Mohammad Hijji, Saad Amin, Wayne Harrop and Rahat Iqbal

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.68784

Abstract

Having in place adequate levels of emergency management capabilities (EMCs) underpins a managed civil emergency response, especially during a flooding event(s). Good EMC is either built on having the right internal capabilities or by exploiting existing emergency capabilities from other responders. In some countries, such as Saudi Arabia, there is a noted lack of decision-making in the Civil Defence (CD) Authority about generating effective mutual-aid requests. Three core areas of EMC include having the right types and levels of response equipment to hand, ensuring sufficient Human Resources, can be maintained throughout a sustained event, and developing adequate Training capabilities. Other factors impacting on Saudi Arabia include both stress and a lack of work experience. In this chapter, we examine the effectiveness of a prototype IT System in the case of Saudi CD Authority as a tool for addressing the availability and adequacy of mutual-aid for EMC, Human Resources (HR), and training capabilities against scalable levels of flood risk event(s). The proposed IT System is built using the 'fuzzy expert system' approach.

Keywords: decision support systems, expert system, emergency management technology, information technology systems, capability preparedness, capability mutual-aid

1. Introduction

In the context of 'decision-making' in 'Flood Risk Management', a lack of decisions related to the required level of preparedness across known EMC within disaster and emergency management organisations could critically increase the likelihood and/or impact of a flood response failure, thus increasing the rate of losses to properties and lives. From a decision-makers' point of view, there are several factors involved; however, factors such as (a) pressure to respond quickly when a flooding alert is given, (b) the lack of experience attributed to decision-making, and (c) a lack of information from other parties [1] could directly affect the timing and quality of decisions [2]. Many studies have agreed that there is a high level of vagueness and uncertainty involved in the decision-making process especially in assessment and determination of needs against current and future flood risk events. In this context, Information Technology (IT) Systems, such as Fuzzy Expert Systems (FES), have created a potential contribution in decision-making for the field of 'Flood Risk Management'.

There are several studies which address the issue of vagueness and uncertainty involved in the decision-making process. For example, Virtual Immersive Reality Training System (VIRTS) is an IT system that trains and assesses emergency responders through visualizing '3D scenarios' [3]. VIRTS enables an end-user to design and modify various risk scenarios, however it does not provide risk scenarios related to natural disasters such as flood and earthquake scenarios. Another study proposed an IT system for detecting and evaluating problems in the equipment capability during operational use [4]. A proposed IT system for mass evacuation [6], which aims to aid decision-makers in understanding complexity within the pre-alert situation and evaluates the adequacy of evacuation plans for areas, however the system has not been tested and validated.

There remains no 'IT system able to evaluate precisely the current preparedness of EMC against scalable levels of flood risk events, and address needed EMC to measure adequate levels of preparedness, as well as adequate 'mutual-aid' requirements. In the case of flooding, areas at risk can be divided into zones (or a ser ies of geographical areas). A EMC zonal assessment can then be undertaken both before and during a flood event, and the assessment can help determined if any active zones need urgent support from other zones (even the wider regional resources) to better manage serve flooding events. **Figure 1** represents a scenario requiring mutual-aid provision.

Figure 1 shows four zones (A, B, C and D), each zone has certain amounts and types of training capabilities (for example skill A), and each zone may be subject to variable levels of flood risk. One of the major issues facing most of the dtecision-makers before a flood event is the ability to assess in context and between zones individual capabilities. Decision-makers often have no rationale model for determining the (re)distribution of limited resources, training, and mutual-aid requirements between zones.

In this chapter, a new prototype and purpose built IT system is presented and examined to determine whether flood response can be optimised using a virtual assessment of 'Capabilities Preparedness' in the context of Saudi Arabian 'Flood Risk Management' scenarios. The IT system performs intelligently by digitalising the process of decision-making in the problem domain. The proposed IT system is called 'The Intelligent Capability Preparedness (ICP) System'. The ICP system focuses on three types of EMC categories: (a) Training; (b) Human Resources (HR), and (c) Equipment. The Effectiveness of using the ICP system has been examined in the case study of Saudi CD Authority, Saudi Arabia. This case study is selected due to

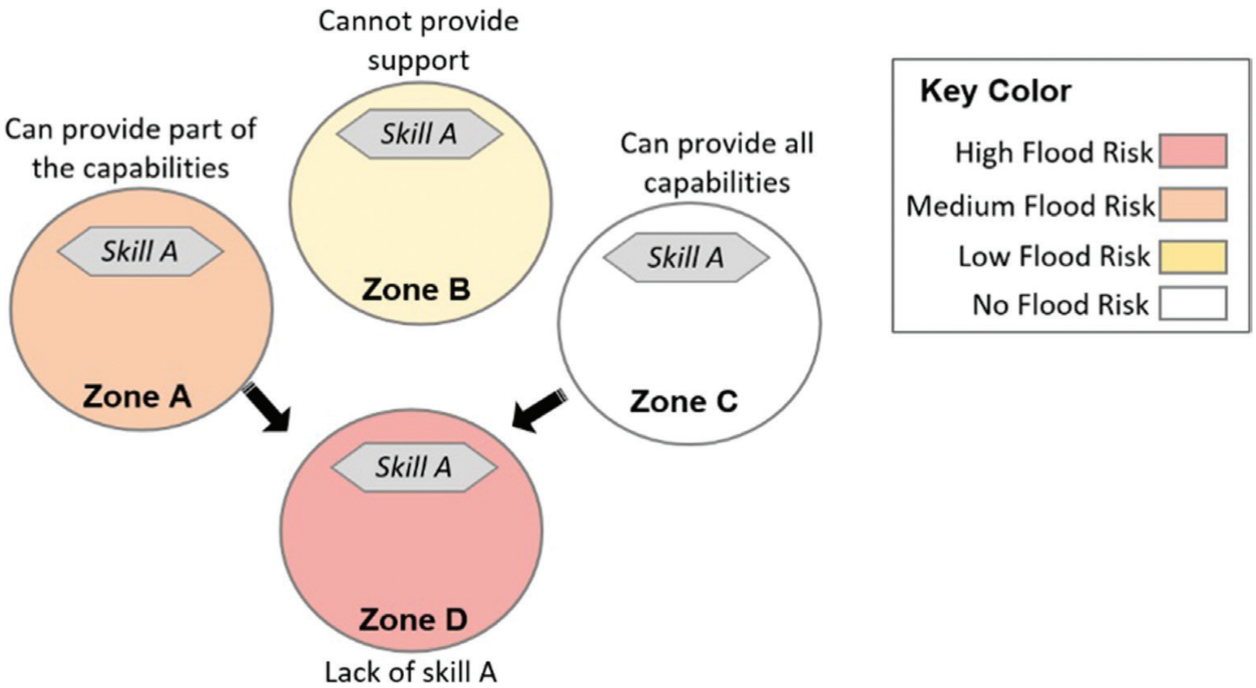

Figure 1. Mutual-aid and flood risk (Source: Authors).

the major problem of flood risk facing the Saudi CD Authority in the city of Jeddah. The chapter is structured as follows. First, a theoretical background on 'what is fuzzy expert systems (FESs) will be presented to understand the principles behind the IT System. Second, an overview of comparable applications like FES is highlighted. Third, the typical methodology of building a FES is highlighted. Fourth, the design of the ICP system is outlined and explained. This is followed by the results of evaluating the effectiveness of the ICP system after consultation and input from the Saudi CD Authority.

2. Saudi Arabian and flash-flooding: background

Saudi Arabia with a population of around '30,770,375' million and an area of approximately '2,149,690 sq. km' is the biggest country in the Middle East [5]. Over the last decade, Saudi Arabia has been marked as one of the foremost countries in the Middle East's facing various kinds of serious disasters, particularly flash-flooding. Flash-flooding is a type of flood which occurs suddenly, as a result of intense rainfall within a short period of time [6].

Generally, flood hazard is considered as the most frequently occurring type of disaster in Saudi Arabia, and over the years, it has been increasing in impact [7], this is mainly because of the nature of the countries' topographical and geographical characteristics as well as the changing global weather [6]. **Table 1** shows a timeline of some of the major flash flooding disasters that have taken place in the country.

City	Year	Killed people	Affected people
Several parts of the country	1964	20	1000
Northwestern	1985	At least 32	5000
Jizan	2004	5	430
Mecca	2005	29	17
Jeddah	2009	163	More than 10,000
Jeddah	2010	More than 122	*Data unavailable
Jeddah	2011	More than 10	144
Tabuk	2013	*Data unavailable	*Data unavailable
Mecca	2014	*Unveiled data	*Data unavailable
Jeddah	2015	*Data unavailable	*Data unavailable
Aseer	2017	*Data unavailable	*Data unavailable

Table 1. Flood-event occurrences in Saudi Arabia [7].

3. Study context and hypothesis

The primary investigation conducted with the Saudi CD Authority in 2013 demonstrated variable flash-flooding capabilities for each of the country's regions. The investigation proposed human resources, training, and equipment capabilities could better incorporate local hazards and vulnerabilities based on a decision-makers experience and perception. Up until this point, it was noted how flash-flooding events had no joined up analysis process or a clear evaluative framework [8].

Furthermore, there were noted concerns by decision-makers about how effective flash-flood response capabilities remained in the face of unequitable access and distribution of flood resources throughout the flooding episode(s). The issues were especially acute about human resources, equipment and appropriate levels of training by first responders. In some cases, the resources were overly committed, or not appropriately allocated across the impacted flooding areas.

Saudi CD Authority is determined to improving the effectiveness of its flood risk management [9]. However, one of the factors hindering it from achieving this objective is the lack of analysis, readiness, and optimized capabilities spanning all flood zones [10]. Therefore, this study aims to develop a new ICP system aimed at better supporting the Saudi CD Authority and its affiliated government sectors manage flash-flooding events.

The proposed ICP system is meant to be used as a reference and a standard for evaluating the level of three types of flood management capabilities (i.e. training, HR and equipment) and to help prepare them to an adequate level. The ICER system can be used as an assistance and assurance tool of the Saudi CD Authority to better assess and prepare its own EMC. It is expected that this will give the Saudi CD Authority confidence and involve other stakeholders against various levels of flood risk (high, medium, low categories of flooding in each geographical/

zonal area). This approach should offer mitigation and preparedness actions against current and future flash-flood risk events. The ICER system will assist the Saudi CD Authority to computerise and share the processes involved in the developed framework. It is envisaged that clear objectives can be established in the framework to unify local hazard and vulnerability data, with optimal resource allocation/capabilities and flood risk forecasting.

4. What is fuzzy expert systems (FESs)?

Fuzzy expert systems (FESs) are a term used to refer to any IT system that works using the principles of 'Fuzzy logic' and 'Expert systems'. Expert systems are an important subset of the Artificial Intelligence (AI) field. They were first introduced by the AI community in the 1960s [11]. Over the years, several definitions of expert systems have been proposed. Some of the most popular definitions include:

a. *'An intelligent computer program that uses knowledge and inference procedures to solve problems that were difficult enough to require significant human expertise for their solutions'* [12].

b. *'A computer program designed to model the problem-solving ability of a human expert.'* [13].

c. *'A system that uses human knowledge captured in a computer to solve problems that ordinarily requires human expertise.'* [11].

On the other hand, Fuzzy Logic is a component of fuzzy expert systems. It is a mathematical approach primarily developed in the 1960's by Lotfi Zadeh to analyse problems that involve a degree of truth or partial truth [14]. The concept of fuzzy logic is based on the assumption that the truth of anything can be expressed as a matter of degrees. For example, beauty, health, or distance – in other words they can be assigned to a sliding scale.

Over the years, several definitions of Fuzzy Logic have been proposed. Among them include:

a. '*…as a set of mathematical principles for knowledge representation based on degrees of membership rather than on crisp membership of classical binary logic*' [15].

b. *'Mathematical technique for dealing with imprecise or incomplete information in a specified scenario'* [16].

The underlying principle of the fuzzy logic approach is based on the fuzzy sets. A fuzzy set can be explained by using the definition of a classical set. A classical set is that which contains every element within a domain or excludes every element within the domain. Simply put, an element X of a universal set U (domain) can either be in two sets, a set A or a set not A. For instance, consider a set of 'old people' as an example. The health organisations in UK define 'old people' as those people that have reached the age of '65'. Therefore, this can be represented by the classical set as shown in **Figure 2**.

Accordingly, any person that is of '65 years' of age can be regarded as 'old'; and any person less than that (64 and less) is 'not old'. In a classical set, an element of any of the sets can

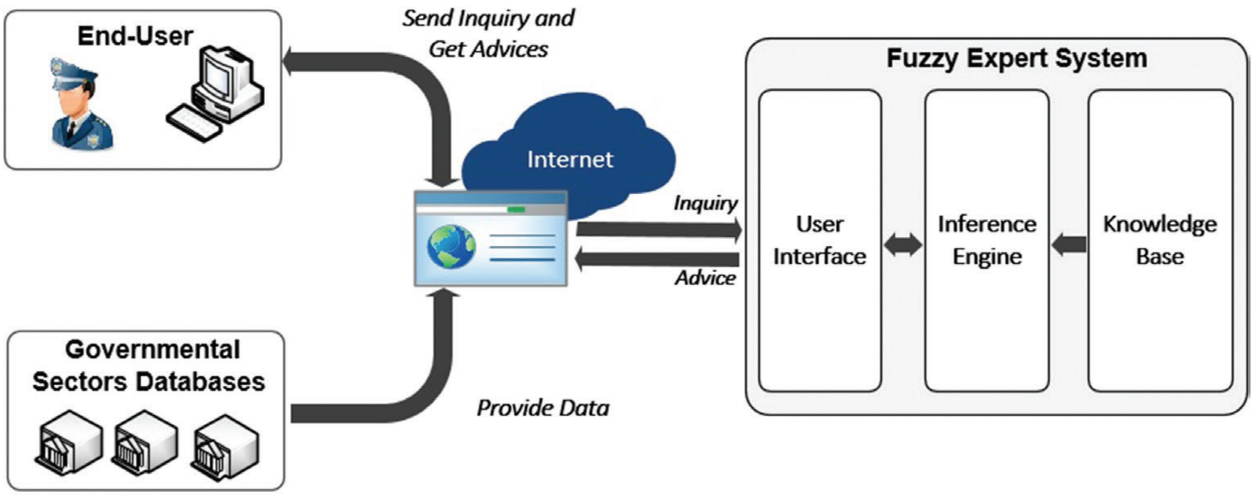

Figure 2. An example of the classical set boundary and fuzzy set boundary for the case of old people.

be categorised as 'yes' or 'no' depending on the boundary of demarcation (which is crisp). However, such boundaries are not clearly defined in reality across all societies. In some societies a person of '55, 65 or 75' can be considered to be old [17–18]. Fuzzy sets make it possible to describe the range of all the possible ages that are considered to make up the 'old peoples' category.

To clearly explain the functioning of the FES, it is best to first understand the architecture of the expert systems, including it various components. The two main components of the FES (as explained previously) are the 'Expert System' and the 'Fuzzy Logic'. Each of the two components also has their own constituent's components. For the typical 'FES, it is made up of six main constituents, these are:

iv. Rule-base

v. Inference

vi. Fuzzification

vii. Defuzzification

viii. User-interface

ix. Users

Figure 3 shows the individual constituents and their relationships. As both components (Expert System and Fuzzy Logic) involve the Rule based and inference, these are only represented once in the fuzzy expert system architecture. The next subsections will give a brief description of the individual components.

4.1. Rule-base

The FES Rule-Base component is that part which holds the pool of rules and facts relating to that specific domain. These are generally presented as a set of fuzzy 'IF-THEN' rules. The information used in developing these rules is derived from experts in that domain of the problem, for

http://dx.doi.org/10.5772/intechopen.68784

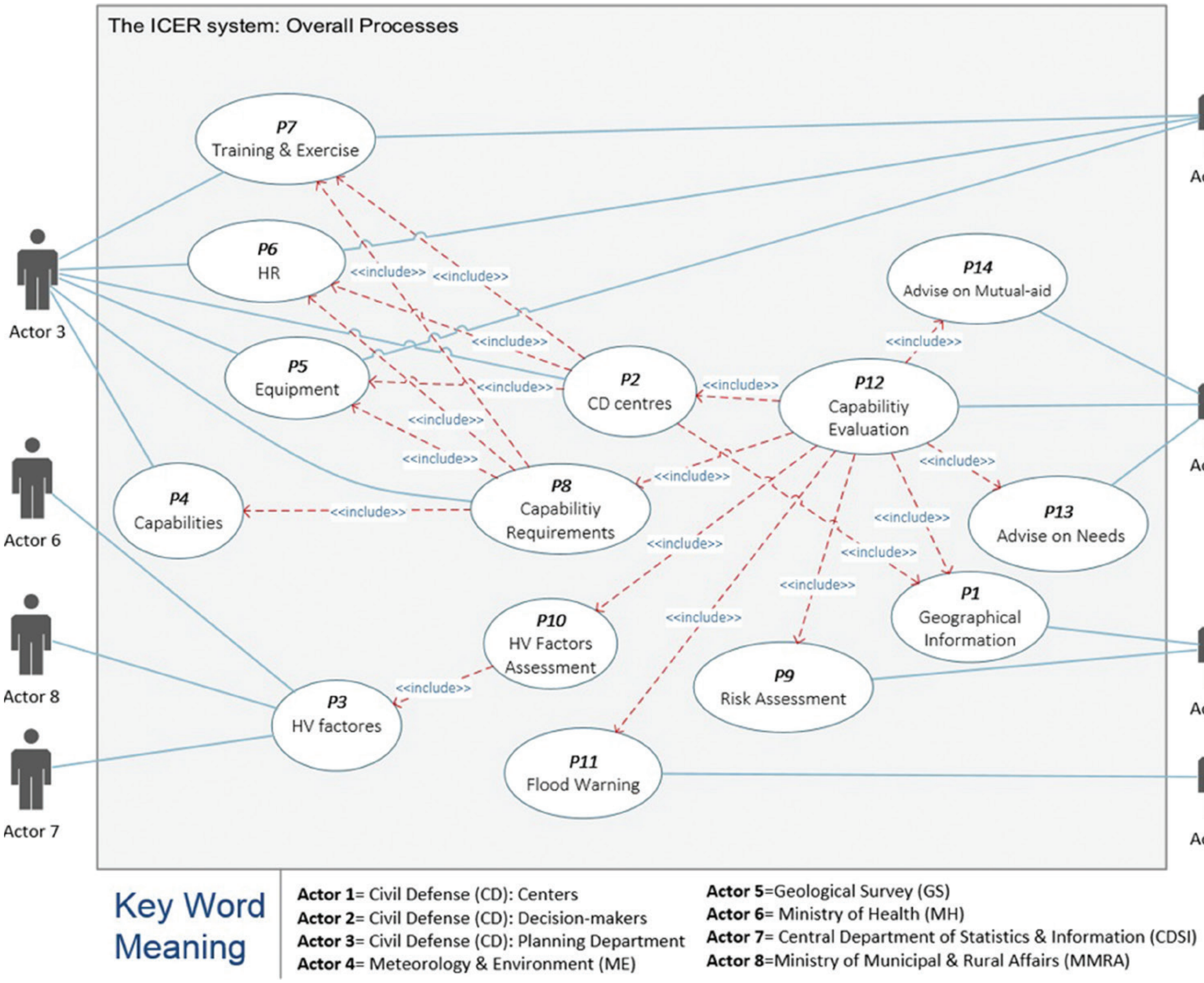

Figure 3. FES complements [12].

example, for the development of an FES relating to 'public awareness campaign'. The contents of such associated rules should typically include issues such as the community location, community size, or campaign schedule. Again, as such rules are continuously evolving and undergoing change, this means that the system should also make a provision to enable these rules to be updated and modified as required. Furthermore, when such input variables, output variables and membership functions have been established, the rule-base needs to be designed in such a way that it will convert the input variables to output variables as represented below [19]:

'IF <Conditions> THEN <Conclusions>'

These rules can be defined subject to the number (and the possible values) of qualitative inputs and outputs. Furthermore, having more rules will also mean a greater degree of reliability from the inferences (even for the same number of variables). Again, it should be noted that, even though rules in general are derived from the expert(s), the whole knowledge does not have to be translated into rules, as in some cases some rules might be irrelevant. One possible approach for designing the rule-base and combinations of inputs is by using the decision matrix. This way the rule-base is interpreted based on the degree of the output's membership by using fuzzy reasoning [11].

4.2. Fuzzification

The fuzzification is the part of the system involved in extracting inputs from the no-fuzzy inputs/outputs, with the use of membership functions. In other words, it is the part used to convert numerical values of every quantitative variable to a qualitative variable with membership functions. Generally, fuzzification is not a strict set of rules or procedure; contrarily, it is an approach that works partly on the basis of insight, experience and analyses of the rules, whereupon it infers a conclusion from the combinations of these inputs. However, for effective operation of the fuzzification, it needs to be calibrated, tested and validated using realistic and accurate inputs and outputs [19].

4.3. Inference

Within the FES, the part that serves as the engine and performs the core problem-solving is the inference. The inference uses both the rule-base as well as the fuzzy set in carrying out the problem-solving. The inference is the engine and core of problem-solving in FES, when mapping out the inputs into outputs. Generally, the two most popular methods used for fuzzy inference include the 'Mamdami technique and the Sugeno technique [21].

In reality, most IT developers commonly used the 'Mamdami' technique compared to the 'Sugeno' technique, and this is mainly because of the fact that the 'Mamdami' technique is closer to human inputs [20]. However the 'Sugeno' technique is appropriate to mathematically analysis [21].

4.4. Defuzzification

The Defuzzification is a similar component to the 'Fuzzification'. This component also involves the conversion of fuzzy inputs to output based on membership functions. These can be achieved by means of various techniques and graphical examples to obtain the final value of the output. The defuzzification method offers a degree of flexibility with which experts can combine their knowledge (with a higher degree of sensibility) on how the results conform to reality. However, the choice of using the defuzzification method will depend on the context of the decision problem [19].

4.5. User-interface

The user inference is the main component for interaction between the end-user and the system. Furthermore, apart from being the main communication link between the system and the user, the success of the whole system (like any other IT system) will depend on the design of the user interface. The simpler and more engaging the user interface, the greater the chances that it will be used by the users [22].

From a user's perspective, the quality of the interface is determined by what the user senses or sees, what the user needs to know to understand the system, and the actions the user needs to take to obtain required results from the system.

The process of providing an interface of the suitable quality is a complex task that requires both technological and psychological factors as well as other associated physical and influencing factors. Some of the important factors that determine the quality of a user interface include [22]:

- The screen design and layout
- The human-machine interaction sequence
- Use of colours
- Information density
- Use icons and symbols
- Information display format

4.6. User-interface

Generally, in the development of an expert system, three main classes of user are considered who directly and indirectly interact with the system. These are the End-Users, Experts and Knowledge Engineers [22]. End-Users are the individuals (non-experts) that make use of the system after it is fully developed. They are the main beneficiary of the system, and whose decision-making processes are aided by using the system. Knowledge Engineers are the professionals that are technically involved in building the advanced underlying logic, and with which the expert system uses to mimic the human decision-making process and high-level cognitive tasks. The knowledge engineers provide the system with all or part of the 'knowledge' that enables its operation. Experts are the individuals that provide the knowledge with which the system use to solve problems within the specific domain. However, other means of obtaining this knowledge are also available in developing the fuzzy expert system [11].

5. Fuzzy expert systems (FES) in other application

Many researchers have worked to identify the most suitable areas or applications for FES implementation. There are several wide-ranging applications. The following are some applications of FES in other areas:

a. Estimating

In this application, FES will ask the user to provide it with the required data to any domain and compare it against the expert knowledge and historical data, for example, ecological characteristics of marine fishes. The FES needs such data to estimate their intrinsic vulnerability to fishing. The rules of such a FES are extracted heuristic rules (expressed in 'IF-THEN' clauses). The rules are describing the relationships between biological characteristics and vulnerability. Input and output variables are defined by fuzzy sets which deal explicitly with the uncertainty associated with qualitative knowledge. Conclusions from different lines of evidence are combined through fuzzy inference and defuzzification processes. This type of FES can be used as a decision support tool in management and marine conservation planning [23].

b. Risk assessment

The FES in this area will ask the user to provide it with the required data to any targeted standard, for example, ISO/IEC Information Security Management System (ISMS) standard, and measure the value of risk based on the risk assessment method and establish a set of FESs. In the meantime, the FES may then provide a recommended acceptable value 'at' or 'of' risk for facilitating and assisting decision-makers through practical aspects [24].

c. Site planning

The FES in this situation would be able to determine the location of equipment for carrying out a certain job, and also location of materials and support facilities at a given site. For example, such a FES could forecast the wind speed at a wind energy conversion system site and the electrical power that will be generated. The FES asks the user to define the forecast horizon, which can range from some minutes up to several hours ahead. The system can make reliable wind speed forecasts in real time [25].

d. Project scheduling

Some of the tasks that would be expected from a FES in this area will include providing the user with information on time or duration of activities. For example, management problems related to the estimated duration of an activity can be solved by using the FES. To implement the FES, various membership functions need to be estimated using good judgement and assisted by experts. One of the downsides of such a system is that it is not sensitive to small variations in the membership values and it can be easily implemented in existing computer programs for project scheduling. This is a very desirable property. However, the method is sensitive to the choice of the fuzzy relations [26].

e. Human resource management

This area is considered as a very important area of consideration when using FES. This type of system aids the user, especially modern and global managers, to meet pressing business challenges. For example, managers are required to possess a set of competencies or multiple intelligences in order to meet pressing business challenges. Hence, expanding global competencies is becoming an important issue. Many scholars and specialists have proposed various competency models containing a list of required competencies. But it is hard for someone to master a broad set of competencies at the same time. Here arises an imperative issue on how to enrich global competencies by way of segmenting a set of competencies into some portions in order to facilitate competency development with a stepwise mode. To solve this issue involving the vagueness of human judgements, good types of FES can be an effective solution [27].

f. Operational problems in constructed facilities

Operational problems can accrue in constructed facilities. FES can solve facilities related problems by giving causes and remedial actions for functional failures such as leaking, poor ventilation, and temperature control. Also it can provide causes and remedial actions for structural failures such as foundation settlement and cracking [28].

g. Training and development

FES can be an excellent tool for inexperienced project staff to improve their project management skills and techniques. It can also form an important part of the training function and can be used as an aid to training programs. The advantage of this would be that the trainee can have access to the expert's knowledge virtually at any time as expert systems can be mounted on desk top PCs. This will give the opportunity 'to' or 'for' trainees to improve on their skills by going through the training expert system within the work environment. Some other areas include constructability evaluation, material management and legal issues [29].

6. How to build a fuzzy expert system (FES)?

In order to build or develop a FES, five key steps need to occur, and **Figure 4** shows each step [22, 19].

Step 1. Specification of the problem and defining the linguistic variables

This is a key step required for determining the input and output variables as well as their ranges. This will involve a critical assessment of the problem as will be described by a 'knowledge engineer'.

Step 2. Determining the fuzzy sets

Fuzzy sets can be represented in various shapes, but most commonly, a triangular or trapezoid shape is enough to represent the expert knowledge, thereby considerably simplifying the computation process.

Step 3. Elicit and construct fuzzy rules

The next step is the development of the fuzzy rules. This can be achieved by getting the expert to make use of the defined fuzzy linguistic variables in describing the problem-solving process. On the other hand, the knowledge engineer will need to do that if the necessary knowledge is to be obtained from other sources like observed human behaviour, computer databases, books or flow charts.

Step 4. Encoding

After the fuzzy sets and fuzzy rules are established, the next step is the 'encoding', which is the actual building of the fuzzy expert system. These can be achieved in two ways:

- Building the system by the use of programming language (e.g. C#, Java or C).
- Applying a fuzzy logic development tool like Fuzzy Knowledge Builder™ or MATLAB Fuzzy Logic Toolbox.

In most cases, experienced developers prefer to use C/C++ programming language as it has more flexibility. On the other hand, when rapid prototyping and development of the fuzzy expert system are required, the fuzzy logic development tool is the best choice because it offers a complete building and testing environment.

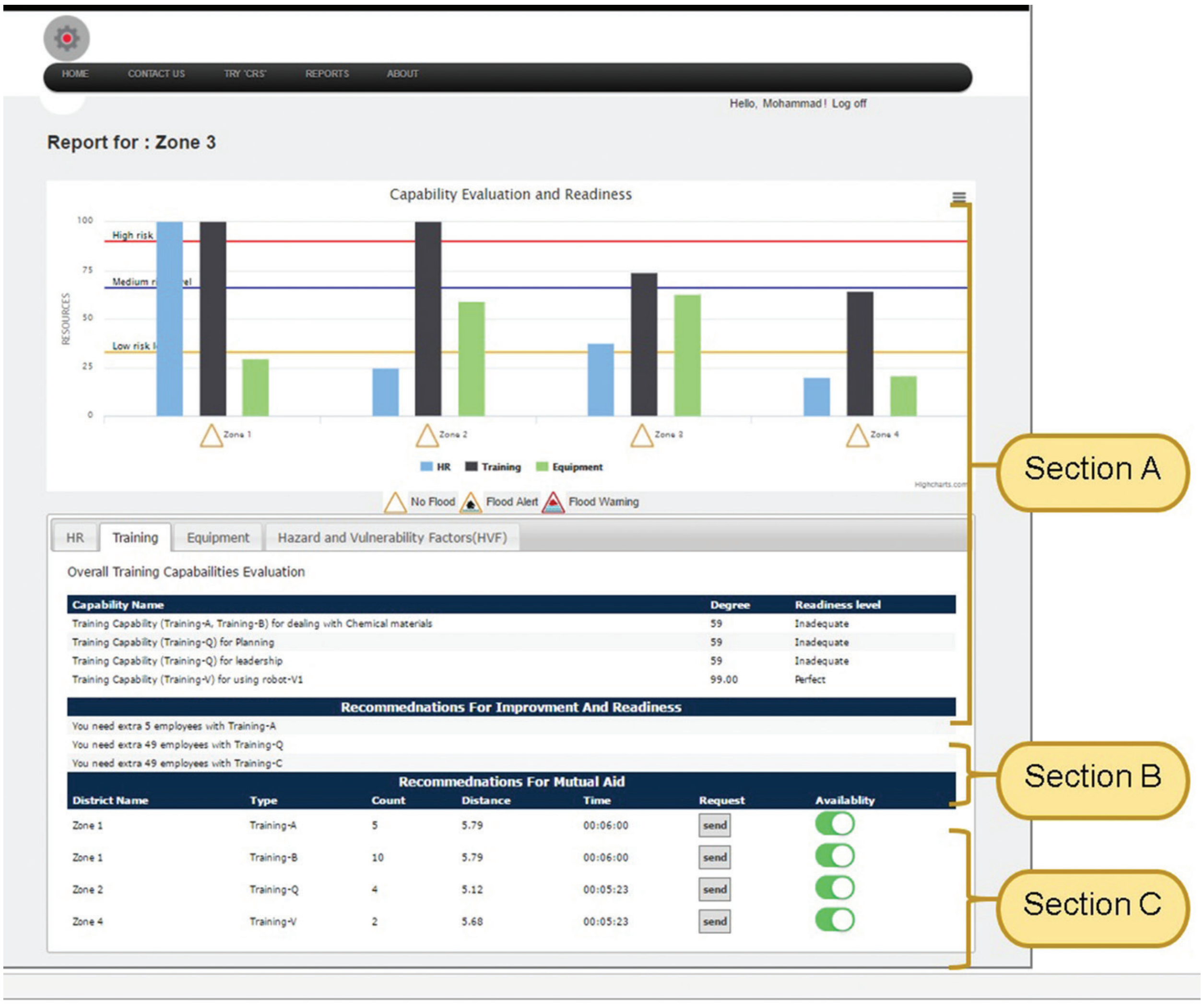

Figure 4. Typical processes of building a FES [19].

Step 5. Evaluating and fine-tuning the system

Finally, the last and most difficult step is the evaluation and fine-tuning of the system. This step determines if the system meets the requirement defined at the beginning of the project. This evaluation or test is generally dependant on the type of variables considered in the development of the system.

After the test, if the developers are not fully satisfied with the performance of the system, it is possible to improve the performance by adding more sets or by extending the rule base according to the FAM (Fuzzy Associative Memory), which is usually referred to as tuning. Generally, to tune an expert system requires much more effort and time than it takes to determine the initial fuzzy sets, and to construct the fuzzy rules. It is always better to successfully develop the solution of the problem on the first trial, with the initial series of fuzzy sets and fuzzy rules.

Another method of implementing FES is by using shells. Shells are defined as 'a software package that facilitates the building of knowledge-based expert systems by providing a knowledge representation scheme and an inference engine' [30]. Therefore, it refers to the software module that contains the (i) interface, (ii) inference engine (iii) and a structured skeleton of a knowledge base (in its empty state) as well as those appropriate facilities for representing the knowledge. Some examples of shell include: CLIPS, EMYCIN, AION-DS and JESS [31].

7. The proposed intelligent capability preparedness (ICP) system

In this section, the Intelligent Capability Preparedness System (ICP) tool is presented, which is constructed based upon the literature review and on data collected via interviews with the domain experts in the Saudi CD Authority. The ICER system is implemented as a 'Prototype' in order to test and evaluate its effectiveness became a fully develop system. The implementation of the ICER system is conducted in 'Visual Studio.net' Framework. The rationale of selecting the '.Net framework' is because its compatibility with the current IT infrastructure used by the Saudi CD Authority; moreover, its flexibility and features are required for implementing such as a system. C Sharp (C#) is the programming language used for coding the system, and also 'Microsoft SQL Server' is used as the database management platform. Furthermore, there are additional tools that are used in the implementation, in order to enhance the functionality and presentation of the results, as well as enhancing the end-user's experience. The following are a brief description and usage of each tool:

- High-Charts: it is an interactive JavaScript charts for web page application. It is free open source java script library for rendering a lot of different types of charts used in the system's reports or outputs.
- Google Maps: it is used to address geographical data such as regions, cities and districts, also it aids in computing the distances between each zone (which is needed in the case of mutual-aid).

7.1. Architecture of ICP system

The architecture of the ICP system is made up of three key components (see **Figure 5**).

Starting on the right-hand side of the diagram, there is the 'fuzzy expert system' component, 'end-user' component and finally 'Governmental sectors' component. The ICP system requires many types of inputs from various location and parties. Therefore, it is necessary to have a worldwide network of computer systems, and for this reason, the Internet is an essential element within the ICP system. Using the Internet will support the ICP system in terms of [32, 33]:

- Providing and obtaining data from the various governmental sectors that are involved in the emergency management.
- Providing the ability to access to the ICP system remotely from any locations, in order to review and discuss the evaluation and recommendations provided by the ICP system.
- Increasing the access to real-time information and up-to-date data relating to flood risk events.

The governmental sectors are the component which will intensively feed the 'Knowledge Base' within the 'Fuzzy Expert System' component, by providing the required input data. The

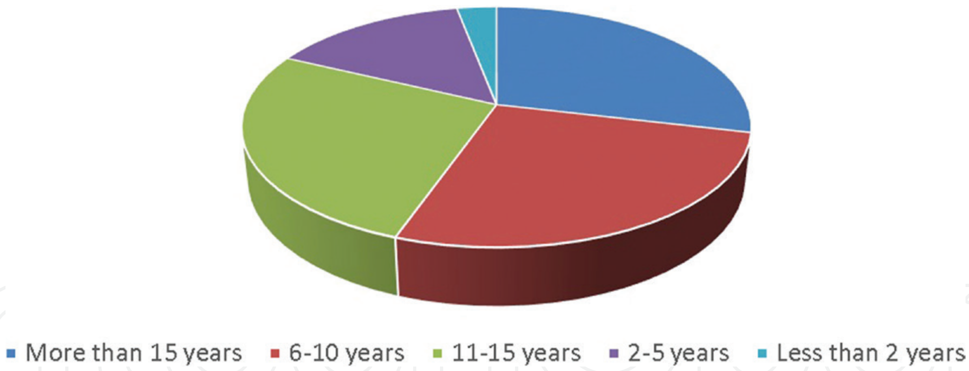

Figure 5. Architecture of the ICP system.

'Knowledge Base' is considered as the warehouse for all the data, information, rules, cases and relationships. The ICP system stores all these types of inputs here, in order to use them to solve the problems in the domain. The 'Knowledge Base' is designed based on the interview conducted with the domain experts in the Saudi CD Authority. The 'Knowledge Base' includes two types of data: (a) facts, and (b) rules. The facts are the part that contains regular inputs such as types of available training, HR and equipment provided, as well as the types and quantity of capabilities within each centre. It also houses the regional information, ID and statue of each emergency responders, and information about Hazard and Vulnerability (HV) factors within each zone. These rules are a more advanced type of input that is provided by experts in the domain to capture their experience. The Fuzzy Expert System includes two types of rules. The first type uses the 'fuzzy set' variables and is called the 'fuzzy rules', for examples, the fuzzy rules, which are used for making decisions relating to capabilities evaluation. The second type of rules does not use 'fuzzy set' variables, for example, which are the capability requirements for flood response missions, and types of exercises required to refresh each training?

A database subsystem is designed within the ICP system to store these inputs or data (see **Figure 6**). The purpose of the designed database subsystem is to organise and manage, systematically, the inputs within the database. As shown in **Figure 6,** the database subsystem comprises of six groups in the model, namely: Geographical Information (T1); Rule and Policy (T2); Flood Risk and HV factors (T3); Training Capability (T4); HR Capability (T5); and Equipment Capability (T6). Although, storing the data in six groups takes more time and effort, it is also very useful to avoid complex data structure. Doing this makes the designed database more professional and allows easy data management.

The end-user will be able to communicate and interact with the ICP system through the 'User-Interface', by sending inquiries and receiving feedback from the ICP system. The design of the 'User-Interface' and how the ICP system should interact with the end-users is a very significant issue, as it influences how efficiently the end-user understands and uses the outcomes as they deal with the problem domain. Therefore, during the process of designing the user-interface of the ICP system, many meetings were conducted with the domain experts in the Saudi CD Authority, as a result, the final design of the main 'User-Interface' for decision-making was developed, which is referred to as the 'Dashboard'.

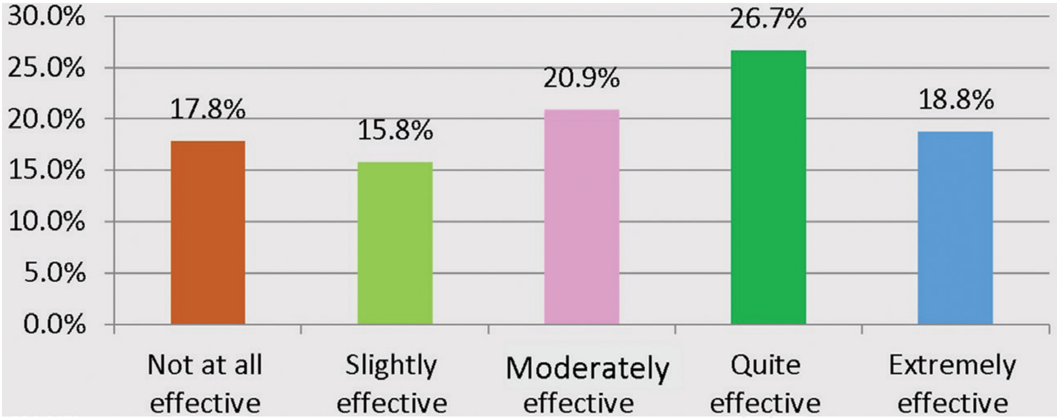

Figure 6. The ICP system's database.

The design of the ICP system involves '14' key processes as shown in the user-case diagram in **Figure 7**. Some of these processes are used for providing inputs data, such as 'P1', 'P2', 'P3', 'P4', 'P5', 'P6', 'P7', 'P8', 'P9' and 'P11'. Some are used for computing and providing outputs, such as 'P12', 'P13' and 'P14'. The use-case diagram shows the interaction between and among the processes. For example, P12 is considered the most complex process in the system; also it interacts with six other major processes. The use-case diagram is also used to clearly show the role of each actor [34, 35].

7.2. ICP system's dashboard for decision-makers

Through the 'Dashboard' interface, decision-makers will be able to communicate and interact with the ICER system, where it displays the needed outputs for decision-making processes. As shown in **Figure 8**, the dashboard of the ICP system comprises three main sections.

- Section 1: This section of the dashboard presents the overall outputs relating to how prepared the current capability is across all zones. The section also provides other significant information such as the up to date flood status, which are presented next to each zone. The details of the capability evaluation for each capability's type are also shown in this section. In addition, it provides outputs relating to the local HV factors for each zone.
- Section 2: This section of the dashboard presents the outputs relating to how prepared the capability need to be. This section of the system provides recommendations on the needed capability for each zone, which should be considered by decision-makers to reach an adequate level of readiness capability across all types of defined capabilities within this zone.
- Section 3: This section of the dashboard presents the outputs relating to the available mutual-aid (or support). This is an important output particularly, when there is major weakness of capability readiness within a zone, and it is under a warning and exposed to flooding. As shown in **Figure 8**, the section provides a list of zones that could provide all/or parts of the missing capabilities; furthermore, it provides other vital information for decision-makers, such as the required time to deliver the support.

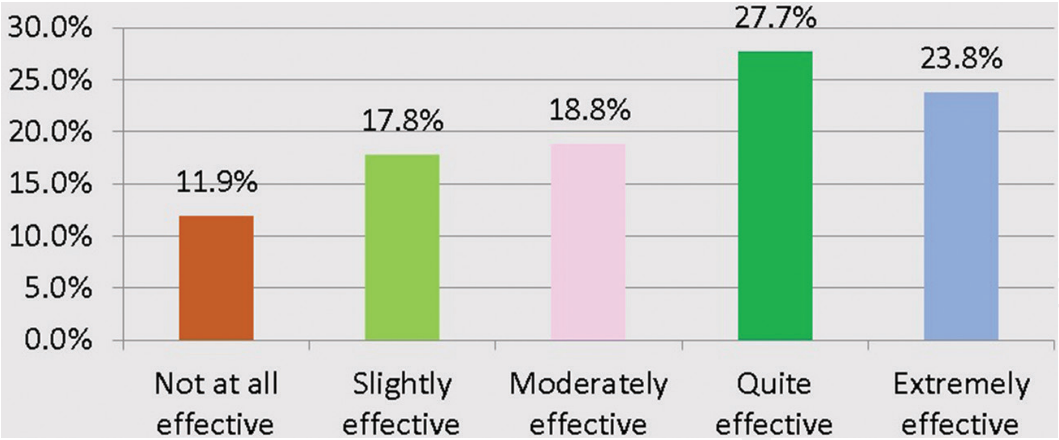

Figure 7. The ICP system's overall processes.

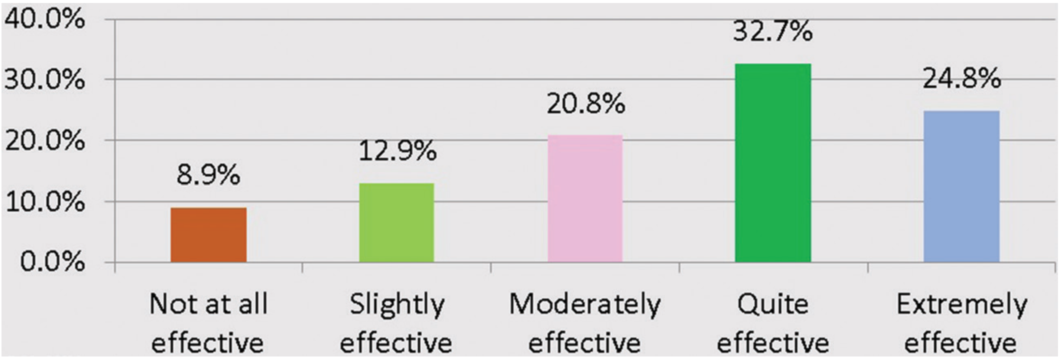

Figure 8. The dashboard of the ICP system.

8. The ICP system V.S EMC preparedness

This section presents the outcome of examining the ICP system in the case study of the CD Authority, Saudi Arabia. The aim of conducting the examination is to evaluate the effectiveness of using such an IT system on the general performance of the Saudi CD Authority, particularly in EMC preparedness for Flood Risk. The examination of ICP system is conducted by using questionnaire and structured-interview. The examination included more than 30 Key Performance Indicators (KPIs); however, only some of them are covered in this section.

It should be mentioned that all the participants who were involved in the questionnaire and structured-interview tested the ICP system before they started the questionnaire and structured-interview. The targeted audience in the structured-interview was focused only on high-level decision-makers in the Saudi CD Authority; however, the questionnaire was targeted at officers and experts. The sample in the questionnaire had '100' participants selected randomly from different locations and '5' participants in the structured-interview. The following subsections describe the analysis and results found via the examination in the field study. **Figure 9** shows the frequency distribution of the participants who were involved in the questionnaire according to their experience. The following subsections describe the analysis and results found via the examination undertaken in the field study.

http://dx.doi.org/10.5772/intechopen.68784

8.1. Evaluation of the ICP system via questionnaire

The following points are some of the questions that were raised in the questionnaire:

1. How effective is the ICP system at evaluating the readiness of the training capabilities?

Figure 10 shows that 17.8% of the respondents think that the system is extremely effective to evaluate the readiness of the training capabilities, 26.7% of the respondents think that the system is quite effective, 20.9% think that the system is moderately effective, while 15.8% of the respondents think that the system is slightly effective. On the other hand, 18.8% of the respondents think that the system is not at all effective to evaluate the readiness of the training capabilities.

2. How effective is the ICP system at evaluating the readiness of the HR capabilities?

As shown in **Figure 11**, the results reveal that 23.8% of the respondents think that it is extremely effective, 27.7% think that it is quite effective, 18.8% think that it is moderately effective, and 17.8% think that it is slightly effective, while 11.9% of the respondents think that the system is not at all effective.

3. How effective is the ICP system at evaluating the readiness of the equipment capabilities? As shown in **Figure 12**, the results reveal that 24.8% think that it is extremely effective, 32.7% think that the system is quite effective, 20.8% think that it is moderately effective, 12.9% think that it is slightly effective, and only 8.9% of the respondents think that the system is not at all effective.

4. How effective is the ICP system at aiding experts in flood preparedness?

As shown in **Figure 13**, the results reveal that 39.6% of the respondents think that the system is extremely helpful to aid experts in flood preparedness, 35.6% think that it is very helpful, 19.8% think that it is moderately helpful, 3.0% think that it is slightly helpful, and only 2.0% of the respondents think that the system is not at all helpful to aid experts in flood preparedness.

5. How helpful is the ICP system at aiding experts in flood response?

As it shown in **Figure 14**, the results reveal that 36.6% of the respondents think that the system is extremely helpful, 34.7% think that it is very helpful, 18.8% think that it is moderately helpful, 8.0% think that it is slightly helpful, and only 1.0% of the respondents think that the system is not at all helpful to aid experts in flood response.

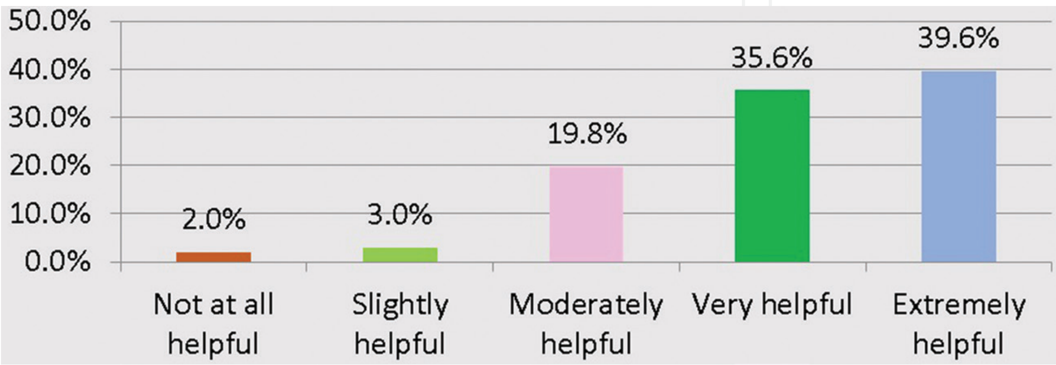

Figure 9. Participants' experience.

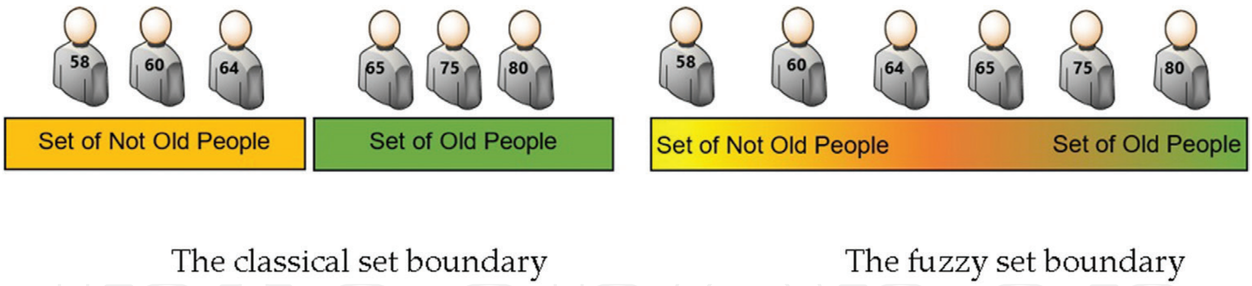

Figure 10. Result for Question 1.

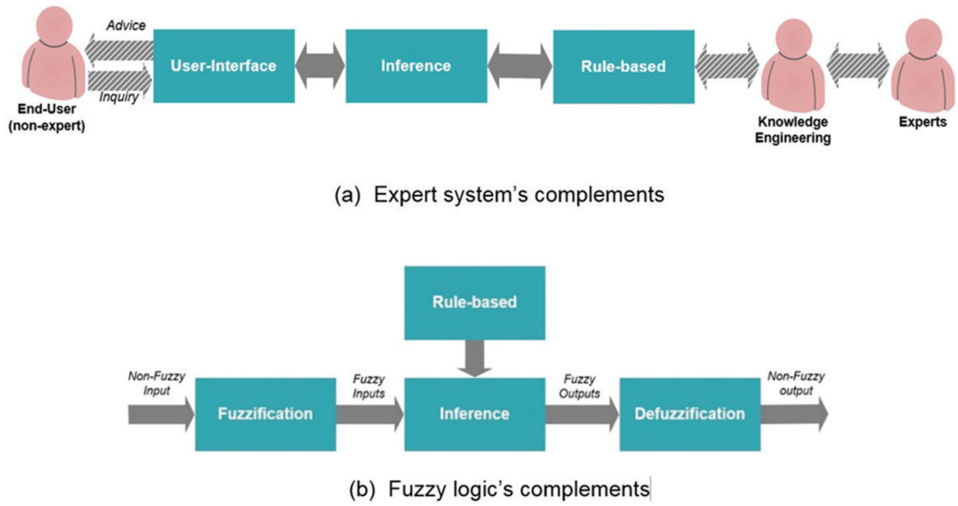

Figure 11. Result for Question 2.

Figure 12. Result for Question 3.

6. How helpful is the ICP system at aiding experts to predict future capabilities needed?

As shown in **Figure 15**, the results reveal that 40.6% of the respondents think that the system is extremely helpful, 34.7% think that it is very helpful, 20.8% think that it is moderately helpful, 3.0% think that it is slightly helpful, and only 1.0% of the respondents think that the system is not at all helpful to aid experts to predict futures needs of capabilities.

8.2. Evaluation of the ICP system via structured-interview

Table 1 presents the results obtained through the structured-interview with five high-level decision-makers. As can be seen from **Table 1**, the ICP system made a marked improvement in all the aspects of the KPIs except for 'viable risk reduction options as identified, evaluated,

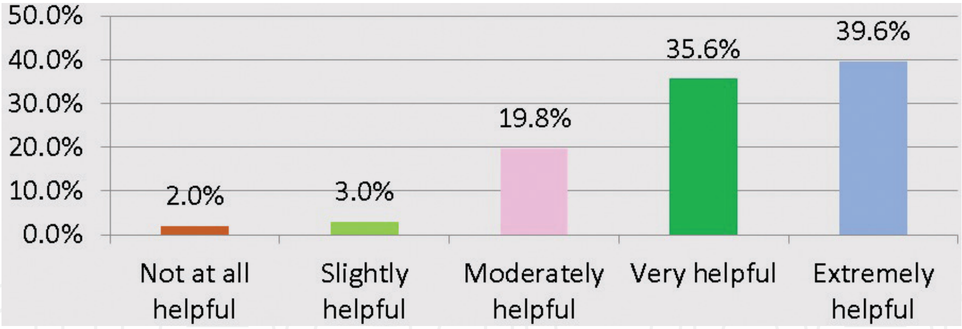

Figure 13. Result for Question 4.

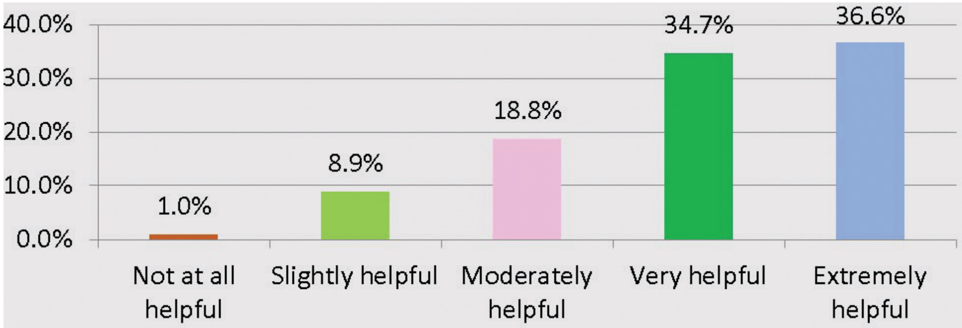

Figure 14. Result for Question 5.

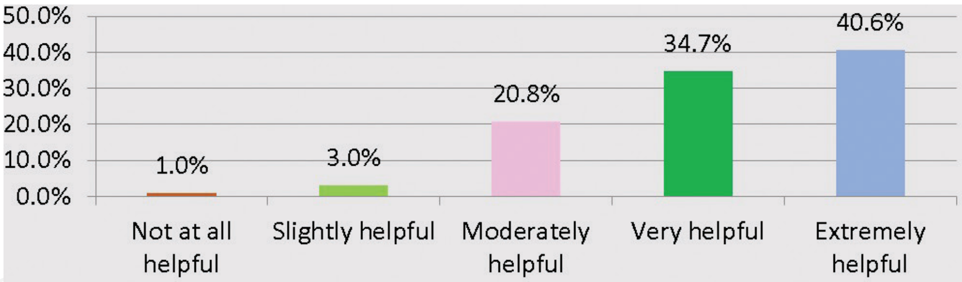

Figure 15. Result for Question 6.

and used to inform planning' and 'warning systems are in place and are maintained and effective', which showed only a slight improvement in performance.

The weak improvement in the first KPI is not surprising, given that, at the moment, the system is designed for the experts to suggest the risk reduction and mitigation options, this will take time to fine tune and improve, and it will also be recommended as a future study to develop a comprehensive data base of response strategies for each identified risk.

Regarding the second weakest area in the KPI improvement (warning systems are in place and are maintained and effective), it is currently out of the scope of this study but it will also be recommended for future studies and development.

The most noticeable improvements included 'Hazard risks are analysed to determine local impact' with the highest score of 92%. This was previously lacking in the system, and it was initially scored at 8%. Given the importance of risk assessment in disaster risk reduction, by using the ICP system, the risk assessment now determines all the subsequent activities of the disaster management requirements. This can be accredited with the general performance improvement across the other key performance areas.

Another significant performance improvement was observed in 'Hazard risk research, and information is collated and stored in a central database or register and is readily available to all stakeholders' this was initially scored as 4% as there was no central system for all the stakeholders to have up-to-date instant information on hazards, risks and vulnerabilities, which is the basis of the planning requirements. The current system now offers a central repository that provides instant, up-to-date, accurate information for all the relevant stakeholders.

Another major performance improvement on the Saudi CD Authority is that the system now allows 'a deliberate correlation between capability development and exercising objectives' this was initially scored at 12% too (this was explained in an earlier interview where previous exercises were just recommended for day to day operations), but this is now scored at 92%.

The above feedback indicates that all these three key performance areas are now in a mature stage of capability readiness. It also highlights visible performance improvements and impacts on all the identified key performance areas. This shows that the system is perceived by end-users to have a significant impact on the flash flood disaster management planning and response in Saudi Arabia (**Table 2**).

KPIs	Effectiveness using current method, average score (%)	Effectiveness using the ICER system, average score (%)	Increased improvement (%)
Emergency Management research is undertaken, assessed, and analysed	16	80	64
Hazard risk research and information is collated and stored in a central database or register and is readily available to all stakeholders	4	88	84
Hazard risks are analysed to determine local impact	8	100	92
Hazards, vulnerabilities, and risks are monitored on an on-going basis	16	68	52
The organisation uses hazard risk information to identify gaps within existing organisational plans, and prioritises planned expenditure	12	72	60
There is a process for monitoring gaps in individual/organisational capability with regard to managing emergency operational functions	8	76	68
Viable risk reduction options are identified, evaluated, and used to inform planning	32	52	20

http://dx.doi.org/10.5772/intechopen.68784

KPIs	Effectiveness using current method, average score (%)	Effectiveness using the ICER system, average score (%)	Increased improvement (%)
Implementation of risk reduction programmes is inclusive and coordinated	16	48	32
Capability development strategy and programs are developed according to organisational needs	16	72	56
The Saudi CD's centres and member work together cooperatively and collaboratively	12	80	68

Table 2. Improvement in KPIs before and after using the ICP system (Source: Authors).

9. Chapter summary

In this chapter, we introduced the FES and discussed the philosophical ideas behind it. Fuzzy logic is a logic that describes fuzziness. As fuzzy logic attempts to model humans' sense of words, decision-making and common sense, it is leading to more human intelligent machines. Fuzzy logic is a set of mathematical principles for knowledge representation based on degrees of membership rather than on the crisp membership of classical binary logic.

This chapter has also discussed and explained the benefits of the ICP system, and how it contributes to the EMC readiness of the Saudi CD Authority in flood risk management (relating to appropriate levels of flash flood equipment, HR and training provisions). The ICER system is implemented in the 'Visual Studio.net' framework because it requires flexible features for implementing the system. The 'dashboard' interface for decision-makers is designed and implemented to display the three types of outputs required for decision-making processes.

Most of the participants in the study considered the ICP system to be effective in aiding experts to improve EMC preparedness and deploy better flood risk responses. Regarding the usefulness of the ICP system to aid in predicting future needs of EMC, the results showed that almost all the respondents found the system easy to use, and only a small minority (less than 5%) considered the system not to be effective. Most importantly, all of the respondents believed that there is a demand for the ICP system in the Saudi CD Authority, and that they would recommend the ICP system to be adopted and used across the CD centres. The most significant recommendation for improvement from the survey was that the system should include other types of EMC and then update the ICP system to aid in management of other disasters. Subsequently, the evaluation of the performance improvement from the use of the system showed that there is significant improvement in almost all the aspects of the identified KPIs compared to the evaluations before deployment of the IT solution.

Author details

Mohammad Hijji*, Saad Amin, Wayne Harrop and Rahat Iqbal

*Address all correspondence to: e-tool@hotmail.com

Faculty of Engineering, Environment and Computing, Coventry University, Coventry, United Kingdom

References

[1] R. H. Flin, P. O'Connor, and M. Crichton, Safety at the sharp end: a guide to non-technical skills: Ashgate Publishing, Ltd., Aldershot, 2008.

[2] J. W. Dean and M. P. Sharfman, Does decision process matter? A study of strategic decision-making effectiveness, Academy of management journal, vol. 39, pp. 368-392, 1996.

[3] X V R. (2013, 29 Sep). Immersive Visualization Systems. Available: http://www.vrmedia.it/en/xvr.html

[4] M. Simões-Marques, R. A. Ribeiro, and A. Gameiro-Marques, A fuzzy decision support system for equipment repair under battle conditions, Fuzzy sets and Systems, vol. 115, pp. 141-157, 2000.

[5] General Authority for Statistics. (2014, 08 May). The total number of the population in 2014 (people). Available: http://www.cdsi.gov.sa/ar/indicators/1

[6] W. Solecki, R. Leichenko, and K. O'Brien, Climate change adaptation strategies and disaster risk reduction in cities: connections, contentions, and synergies, Current Opinion in Environmental Sustainability, vol. 3, pp. 135-141, 2011.

[7] Y. Alamri, Emergency Management in Saudi Arabia: Past, Present and Future, Un. Of Christchurch report, New Zealand, p. 21, 2010

[8] S. Mashael Al, Assessment of flood hazard of Jeddah area 2009, Saudi Arabia, Journal of Water Resource and Protection, vol. 2010, 2010.

[9] S. A. Alshehri, Y. Rezgui, and H. Li, Public perception of the risk of disasters in a developing economy: the case of Saudi Arabia, Natural hazards, vol. 65, pp. 1813-1830, 2013.

[10] N. M. Momani and A. Salmi, Preparedness of schools in the Province of Jeddah to deal with earthquakes risks, Disaster Prevention and Management: An International Journal, vol. 21, pp. 463-473, 2012.

[11] T. Efraim, E. A. Jay, T.-P. Liang, and R. McCarthy, Decision support systems and intelligent systems, Upper Saddle River, NJ, Prentice Hall, 2001.

[12] G. I. Doukidis and R. J. Paul, Research into expert systems to aid simulation model formulation, Journal of the Operational Research Society, pp. 319-325, 1985.

[13] J. Durkin, Expert systems: catalog of applications: Intelligent Computer Systems, 1993.

[14] R. Gelbard and A. Meged, Handling Fuzzy Similarity for Data Classification, ed, 2009.

[15] L. A. Zadeh, Fuzzy sets, Information and control, vol. 8, pp. 338-353, 1965.

[16] K. Kolomvatsos and S. Hadjiefthymiades, Time Constraints for Sellers in Electronic Markets, Encyclopedia of E-Business Development and Management in the Global Economy, p. 265, 2010.

[17] J. Roebuck, When Does Old Age Begin?: The Evolution of the English Definition, Journal of Social History, vol. 12, pp. 416-428, 1979.

[18] M. Gorman, Development and the rights of older people: London: Earthscan Publications Ltd., 1999.

[19] H.-J. Zimmermann, Fuzzy set theory—and its applications: Springer Science & Business Media, New York, 2001.

[20] J. C. Bezdek, A review of probabilistic, fuzzy, and neural models for pattern recognition, Journal of Intelligent & Fuzzy Systems, vol. 1, pp. 1-25, 1993.

[21] H. Ying, The Takagi-Sugeno fuzzy controllers using the simplified linear control rules are nonlinear variable gain controllers, Automatica, vol. 34, pp. 157-167, 1998.

[22] M. G. Helander, Handbook of human-computer interaction: Elsevier. Amsterdam, 2014.

[23] B. M. Ayyub and A. Haldar, Project scheduling using fuzzy set concepts, Journal of Construction Engineering and Management, vol. 110, pp. 189-204, 1984.

[24] T.-P. Hong and C.-Y. Lee, Induction of fuzzy rules and membership functions from training examples, Fuzzy sets and Systems, vol. 84, pp. 33-47, 1996.

[25] J. Liebowitz, The handbook of applied expert systems: cRc Press, 1997.

[26] I. G. Damousis and P. Dokopoulos, A fuzzy expert system for the forecasting of wind speed and power generation in wind farms, in Power Industry Computer Applications, 2001. PICA 2001. Innovative Computing for Power-Electric Energy Meets the Market. 22nd IEEE Power Engineering Society International Conference on, 2001, pp. 63-69.

[27] A. R. Fayek and Z. Sun, A fuzzy expert system for design performance prediction and evaluation, Canadian Journal of Civil Engineering, vol. 28, pp. 1-25, 2001.

[28] W. W. Cheung, T. J. Pitcher, and D. Pauly, A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing, Biological conservation, vol. 124, pp. 97-111, 2005.

[29] M. Hadjimichael, A fuzzy expert system for aviation risk assessment, Expert Systems with Applications, vol. 36, pp. 6512-6519, 2009.

[30] Artificial Intelligence. (2010 18 Feb). WHAT IS EXPERT SYSTEM? Available: http://intelligence.worldofcomputing.net/ai-branches/expert-systems.html#.VsY7_fKLTIU

[31] E. C. Ogu and Y. Adekunle, Basic Concepts of Expert System Shells and an Efficient Model for Knowledge Acquisition, International Journal of Science and Research Volume 2 Issue, vol. 4, pp. 554-559, 2013.

[32] R. Want, B. N. Schilit, and S. Jenson, Enabling the internet of things, Computer, vol. 48, pp. 28-35, 2015.

[33] S. K. Lippert and C. Govindarajulu, Technological, organizational, and environmental antecedents to web services adoption, Communications of the IIMA, vol. 6, p. 14, 2015.

[34] Hijji, M., et al. The Significance of Using Expert System to Assess the Preparedness of Training Capabilities against Different Flash Flood Scenarios. Lecture Notes on Software Engineering 3.3 (2015): 214.

[35] Hijji, Mohammad, et al. A Critical Evaluation of the Rational Need for an IT Management System for Flash Flood Events in Jeddah, Saudi Arabia. Developments in eSystems Engineering (DeSE), 2013 Sixth International Conference on. IEEE, 2013.