Journal of Computer Science 2 (5): 447-454, 2006
ISSN 1549-3636

An Information Management System Model for the Industrial Incidents in Saudi Arabia: A Conceptual Framework Based on SDLC Methodology

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Abstract: The main focus of this study has been on the development of a conceptual framework for improving the current status of industrial accidents' control. The framework is aimed to use of ICT to improve the information exchange between the Civil Defence and Industrial Sector and to provide an information management system model for the Industrial Incidents Administration System (IIAS). The purposed system, designed to highlight the method by which data should be transferred between the Civil Defence and Industrial Sector, as well as other emergency services involved in assessing and controlling industrial accidents. This study used a survey in form of questionnaire and face-to-face interview supplemented by a document analysis of activities relating to those tow sectors and direct observation. This conceptual model based on the traditional System development life cycle methodology (SDLC).Study found that designing an information system network to link the Civil Defence and Industrial Sector in Saudi Arabia to facilitate the exchange of information to control industrial accidents is considered to be important in improving the current situation. As result of this study information management system model was purposed. Such model can be expected to contribute to improving and developing the information exchange system between the tow Sectors.

Key words: Information management system model, disaster management, SDLC methodology, Saudi Arabia

INTRODUCTION

In the last decade, there has been a considerable increase in the number of disasters, including natural, man-made and hybrid types of disaster. A significant increase has been noticed in the man-made category particularly in chemical, transport and nuclear installations[1]. As a direct result of this, there has been an increasing trend of exerting more social, political, legal and economic pressure to create better policies and practices in disaster preparedness, planning, management, mitigation, response and recovery[2]. In the same time, there is a significant advance in computer hardware and software, human-computer interfaces, communications and scientific tools and techniques. It is fair to say that the advances in these areas should help in reducing the vulnerability of humans and the environment to disasters.

In the 21st century, emphasis has shifted towards the communication aspects of information technology, ensuring the continued dominance of information and communication technologies (ICT).Moreover, there is no doubt that (ICT) is becoming increasingly important in every sector. In the context of disaster management, the revolution in (ICT) is changing the nature of economies and societies around the world. Currently, information networks play a major role in controlling and directing the flow of huge amounts of information. Many countries (developed and developing) have now established a series of national computer networks system, which link different sectors with the aim of sharing and exchanging information. Some organisations in Saudi Arabia, have adopted (ICT) to taken full advantage of these new technologies. Civil Defence organisation is one of the most important government organisations that adopted (ICT) and directly involved in disaster management.

The main goal of this study was to develop a model for a proposed information management system for sharing and exchanging information between the Civil Defence and Industrial Sector in Saudi Arabia, in order to control industrial accidents.

MATERIALS AND METHODS

Uses of (ICT) in disaster management those days have attracted considerable attention in an academic and practical setting. Several authors discussed different aspect of such issues from different perspectives. Therefore, literature review will be divided to three parts as follow.

The development of ICT in disaster management in developed countries: ICT has great impact in all aspect of life. ICT are well recognised as tools in disaster management and the effectiveness of ICT for the management of natural, human or technology-induced disasters has been unquestionably established. Hak-

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Su[3] reported that harnessing modern technology and increasing regional cooperation in disaster preparedness could save lives and help prevent property damage. Many lives could be saved and tragedy mitigated, if effective disaster management measures were undertaken. Yodmani and Hollister[4] stated that the role of communication technology has been recognised as integral to disaster management for a long time. In addition, the application of ICT has a role in all the four phases of disaster management. The new ICTs that have emerged over the last two decades lend themselves to greater possibilities of integration into different communication systems. Nowadays major breakthrough of ICT applications in disaster management is the design and development of Geographical Information Systems (GIS) which permit the development of base maps with district boundaries, village locations and their access to critical infrastructure like primary health centres, blood banks, hospitals, police stations, fire brigades, transport depots, etc. This facilitates more efficient decision-making, policy analysis and problem solving both during an emergency and during normal times[5].

Some states and local governments in the USA have used GIS in emergency planning and response. For example, Pennsylvania State developed a GIS database to help in its emergency planning and in Salt Lake City, Utah, GIS has been used to analyse the effect of an earthquake on the response time of fire and rescue squads. By combining information about the road networks, fire stations and the types of soil around the fault line, analysis showed how fast areas within the city could be served, the areas most likely to be affected by accidents or disasters and where the worst damage could be expected. For example, during an earthquake in San Francisco, police and fire department personnel were able to use GIS to create visual images and maps from volumes of disaster reports. This allowed emergency vehicles and repair crews to be dispatched quickly and efficiently around the bay area[6].

The developments on the World Wide Web and the Internet have opened up the possibility of creating Web sites for specialised institutions which work in various domains of disaster management. The potential of the Internet has been tapped by specialised institutions in the developed countries, allowing people to browse the content on their sites. ICT can make a valuable contribution to sustainable disaster management .Its enables a better understanding of issues, such as hazardous materials incidents and helps to monitor ecological conditions so that prevention and mitigation measures can be activated[7]. Moreover, Boppana and Swaminathan[8] indicated that disaster management in the chemical process industries is an integral and essential part of a loss prevention strategy. A good communication system, training and understanding of emergency procedures, regular interaction between government agencies and industries, education of the public and a high level of availability of emergency equipment are the key areas for effective emergency preparedness. Mouginis-Mark *et al.*[9] mentioned that disaster managers are increasingly using satellite observations for the mitigation, response and recovery activities associated with many different types of natural disaster. Kara-Zaitri[2] climes that there are two main barriers those continue to hinder technologies from being transferred to disaster management to cope with disaster reduction and mitigation. These are failure of scientists and engineers to communicate the new tools and failure of disaster management practitioners and decision-makers to take ownership of the new technologies. Moreover, Thorburn and Langdale[10] mentioned that the main barriers to implementing change and to developing disaster management plans are having the people and the skills to do it. Bourn[11] identified the main barriers and incentives for risk taking as follows:

* Lack of expertise in risk management
* Lack of formal systems, processes and procedures for managing risks
* Unclear responsibilities for the management of risks
* Time and funding constraints; and fear of project failure

In the 21st century, emphasis has shifted towards the communication aspects of information technology, ensuring the continued dominance of (ICT). It is indisputable that (ICT) is becoming increasingly important in every sector, but particularly it is becoming one of the most important services in information networks, enabling information to be accessed easily and speedily. The revolution in ICT is changing the nature and work follow in all organisations around the world. In fact, now we are only just catching up with the amazing capabilities of how ICT can affect business.

ICT in disaster management in developing countries: In the Asian region, there is significant disparity in the communication infrastructure across countries and across different kinds of user groups. While there is a good deal of enthusiasm among the scientific and technical community to make use of emerging communication technologies to share real-time information as well as local knowledge and experiences, the decision-makers most responsible for managing disasters have to rely on rather conventional means of communication[4]. While new ICTs have made the sharing of knowledge and information much faster and more reliable, language is going to be a major barrier in the effective application of these technologies in the Asian region. Currently, information system networks play a major role in controlling and directing the flow of huge amounts of information. Many developing countries have now established a series of national computer networks, which link

different public and private sectors with the aim of sharing and exchanging information. Indonesia for example, has developed a program called Disaster Management Information System (SIPBI). The scope of this project includes the development of a computer networking system, a geographic information system (GIS) and a database for disaster management. Under this project, a number of modules are underway on forest fires, earthquakes, tsunami, volcanic eruptions and social unrest, for building a database system in an Internet mode[12].However, in India, the National Natural Disaster Knowledge Network (Nanadisk-Net) is being planned as a "network of networks". The network will act as a digital library service and will facilitate access to global databases and early warning systems in a significant way[13]. Moreover, in the Philippines the National Disaster Coordinating Council (NDCC) started to install an emergency management information system that will link up all their regional centres electronically and make available vital information to the public through the Internet[14]. Moreover, many devolving nations take several steps to build nation network system for disaster management. The 21st century has begun to see the convergence of technologies and the consequent process of globalisation. ICT is a too and it cannot improve conditions or create systems by itself. Its needs a complete life cycle designed for sustainability. People should be trained to be responsible for the proper operation and maintenance of ICT systems.

ICT in Saudi Arabia: Several developed and developing countries have now established a series of national computer networks, which link different sectors with the aim of sharing and exchanging information. Ministry of Planning decided to implement an information network for all government agencies and encourage all organisations to adopt modern technologies, managerial skills and business practices[15,16]. Currently, information system networks play a major role in controlling and directing the flow of huge amounts of information. Therefore, ICT in Saudi is needed for rapid economic development. Today a large number of organisations already make extensive use of ICT[17]. Some organisations for example, are moving towards an integrated computer communication network service.

In fact, Saudi Arabian government has taken steps in the past several years towards diversification and to achieve greater private sector participation in the economy. The number of production factories in Saudi Arabia reached 3,481 by the end of 2001[18]. The possibility of unpredictable industrial disasters is more likely to occur with this increasing number of factories and therefore it becomes imperative to plan and establish information networks. Civil Defence is one of the most important government organisations deal directly in disaster management. One of its functions is to protect the civil population against the effects of hostilities or disasters and assisting them in recovering from the immediate effects of hostilities or disasters. Civil Defence planning and implementation requires extensive information about natural and industrial hazards. Therefore, it should aim to use the most up to date ICT available. Consequently, the establishment of a national information system network, which links both the Civil Defence and the Industrial Sector, has become extremely important for dealing with industrial disasters. This necessitates a study of the dangers that may be initiated and the extent of the impact of such dangers on human lives and property[19].

RESULTS AND DISCUSSION

In order to test these study objectives and obtain rich picture, this study employed 4 complementary assessment tools: the first is 900 staff survey to test the degree of satisfaction with ICT services. The second is an interview conducted with 12 senior managers of each sector. Third is document analysis and fourth is a direct observation. Data collected were coded and analysed using (SPSS). 624 questionnaires were returned, giving a response rate of 69.3%. Descriptive statistics, including cross-tabulations, were used to characterise the responses to each question in the questionnaire, after which an analytical test (χ^2 tests) was used as a test of significance. The purpose of using descriptive analysis is to present the data in an understandable and less complex form

The central theme of this study has been on the development of a conceptual framework for improving the current status of industrial accidents' control. This conceptual framework of the system is designed to facilitate full collaboration and integration among all of the sectors concerned with the control of industrial accidents. It's substantially different from the current system used for exchanging information during industrial accidents in tow ways. First, the design is grounded in Civil Defence tasks, especially for Industrial Fire Brigades (IFB). The aim is to provide them with up to date information about the hazardous materials that are present in the Industrial Sector. Second, this system design is based on a Web-base interface, a set of databases and a GIS application, customised to the requirements of the users that hopefully will facilitate effective data-exchange. The following section aims to discuss the proposed model and the prototype system, as well as evaluating the results. To facilitate effective discussion, use is made of the initial study objectives to give a clear direction while, at the same time, assisting in determining the success or otherwise of the research in relation to these objectives.

ICT services: This study revealed that ICT services in the Industrial Sector were more advanced than those in

the Civil Defence sector. This is because IFB staffs do have insufficient computer skills as well as poor qualifications. The lack of ICT services and the lack of qualified ICT staff in IFBs were seen as major obstacles limiting the benefits that might be gained form the ICT services. The results of the survey indicate that most departments in both sectors have computers. On the availability and use of computers at work for daily tasks, the results show that the majority of the IFB staff never use computers at work (N=190) while the majority of the Industrial Sector staff indicated that they always use computers at work (N=158). The significant differences between these two groups stem from the nature of the duties and responsibilities of the employees of both sectors. While the roles and responsibilities of fire-fighters rarely lend themselves to the use of computers (they are in the field or waiting for an incident to be reported almost all the time), the roles of Industrial Sector employees require constant use of computers.

The Civil Defence Command Centre (CDCC) employees were more advanced than personnel from IFBs in computer utilisation. Despite this, the study revealed that the CDCC still uses manual maps to determine the location of incidents. As was evident in the results of the interview survey, the main reasons for the shortage of ICT services in the CDCC are due to lack of qualified manpower to use ICT effectively, lack of a sophisticated GIS and lack of an infrastructure for digital maps of Saudi Arabia .The results also show that there is no connectivity between the Civil Defence departments and the Industrial Sector. Overall, respondents were dissatisfied with the current situation regarding ICT because the computer applications did not match their information needs; also they asserted that the computers were poorly maintained. Their hope is having more advanced computer systems, advanced applications and networking, all of which could help them to improve their job performance. Here, the management executive should be aware of ICT issues, then, if these are known, the issues can be overcome.

The role of ICT in emergency situations: ICT can increase the speed, volume, quality and transparency of information exchange through faster access to and distribution of, information. ICT also makes possible entirely new procedures, interaction among sectors, information and communications, which were previously impossible because of high cost or unmanageability[20]. ICT can minimise the negative effects of distance and time in terms of emergency management; it can also enhance processes and communications between sectors. Emergency management procedures can be shortened and controlled more precisely and access to information can be shared and data made available in real time, 24 hours a day. Furthermore, ICT will help to improve the co-operation between the sectors since it reduces the negative effects of distance and time, allowing parties to communicate with each other even if they are thousands of miles apart. ICT also allows improved communications between emergency services and assistance agencies.

Because ICT is used only minimally by the two sectors, the call system that is presently in use for emergency situations is the telephone. Concerning the use of ICT for controlling industrial accidents, 88% of the respondents said that they have a warning system to detect and control fire incidents and that this warning system is connected to the control panel to help workers to locate the accident. Regarding using ICT to deal with industrial accidents, that is using an automated directional system to call the fire brigade automatically, the respondents said that they had no automatic directional systems in place but they want to have as this system in future. The study shows that the respondents were keen to have a more advanced emergency management system. The overall opinion of staff within the two sectors is that ICT will facilitate future work in emergency management and accident control. Creating models, simulations and scenarios will contribute to improved emergency management and simplify the forecast of the effect of different planning alternatives on incidents control. Databases from different sectors (Civil Defence departments, the Industrial Sector, other emergency services) can more easily be integrated. Simulation, multimedia, interaction and visualising might even replace traditional plans containing maps and texts. Additionally, ICT might lead to more efficient infrastructure planning and better emergency management. However, to achieve these advantages further ICT education will be necessary.

GISs may represent a useful tool for managing, planning and responding to emergencies[21]. A GIS can present different types of information and such information could be used to provide more accurate estimates of the resources required in dealing with disasters. Stage Three of the SDLC presented the proposed system, which was designed to overcome issues that exist in the current system. The system model for this study provides a solution to these issues. It will improve and enhance the current emergency management situation and will provide up-to-date information for decision-makers helping them to take the right decisions in emergency control. The study has shown that the co-operation between the two sectors is very limited. Stage One of the SDLC identified problems associated with cooperation between Civil Defence departments and the Industrial Sector; this information originates from the primary evidence collected in the questionnaires and interviews. This stage revealed the need to improve information exchange in terms of emergency management. Stage Two identified five fundamental requirements that would help in improving and enhancing the current system. These requirements will help in designing the

proposed system (Stage 3), as well as increasing co-operation and improving information exchange between the two sectors.

Training issues: The main aim of any organisation is to provide sufficient staff training to enable them to use ICT services effectively and efficiently. Despite that, this study shows that the two sectors still fall short of achieving this target. From the questionnaire survey, about 82% of the respondents were not taking any courses in the use of ICT in emergency management. This seems to be a very high percentage and this problem needs to be overcome. Furthermore, both the questionnaire and interview surveys revealed a number of training issues. These issues include:

* The quality of courses was insufficient to improve staff skills in using ICT,
* ICT courses for use in emergency situations were not available,
* There was a lack of management support for providing suitable training courses in how to use ICT in emergency management.

To overcome these issues, provision should be made for advanced training programmes on useful ICT services for dealing with industrial accidents and staff should be encouraged to attend these courses. This would improve the professional efficiency of staff as they will gain knowledge of and be able to organise ICT services; this would, in turn, enable them to use ICT to its full potential. It is also important that both sectors should co-operate with each other to run seminars and workshops in using ICT in emergency management.

It is clear from the findings that training in the two sectors in terms of disaster management still needs to be explored and the benefits of ICT should be harnessed to make training more effective and to prepare workers to meet the changing needs of the future. Both sectors need to evaluate their ICT services in terms of disaster management training by testing out the benefits of these services. To do this, they should consider the views of the users of these facilities. The weaknesses surrounding the use of ICT services needs to be discussed as, the less these facilities are used, the more likely it is they will be scrapped or will never be installed at all. When users evaluate their services to obtain feedback about the shortcomings of what they offer, they often discover that there is a shortage of equipment such as terminals, PCs, etc. or there is a need to upgrade the system. This problem will not be solved if there is insufficient support. The study shows the respondents' attitudes toward ICT: the results were generally positive towards the use of ICT in work. Interestingly, 41% of the respondents who indicated that they have no computers for use in their work highlighted the importance of the use of computers and ICT facilities at work. However, some also raised concerns about the effectiveness of ICT training and the level of management support. The results indicate that change to and use of, ICT are increasingly becoming important for both sectors. This will help in building and increasing the ICT skills of workers, will improve information seeking, expand the use of the Internet and aid in controlling incidents effectively.

ICT problems: The study revealed a number of problems associated with implementing ICT systems within both sectors. These problems were attributed mainly to changes in the organisational structure of both sectors. Respondents expressed their concerns about the lack of funding and difficulties in obtaining financial support from those in management positions. Technical problems, associated with both the quality of services, hardware and software compatibility, a shortage of ICT personnel and low-level training were also identified. Furthermore, some ICT directors expressed concern that senior management might be not adequately informed about the difficulties that might be encountered in establishing any viable system. However, top management support, end-user involvement and the degree of success in getting the system up and running are very difficult to predict. This study revealed that the current mode of information flow is the 'conventional' mode through the exchange of paper forms. Information flow was obviously abundant but the quality of information being disseminated requires improvement. Furthermore, the lack of staff skills concerning the use of certain types of ICT, the lack of ICT training in emergency management and the lack of management support must be considered as the main ICT problems. As a result, there is a need to put more effort into redesigning the information flow between these two sectors, as well as overcoming or improving the above problems.

Benefits of designing an information system network: Developments in ICT mean that both sectors are looking for new ways of upgrading their services. Technology advances offer us more options for delivering and managing services differently and better than before. From the findings, all participants want instant access to information and they require good quality services, especially since electronic products are becoming cheaper and at the same time, are offering better quality. Moreover, an information network connecting these two sectors in terms of disaster management should be designed.There is ample evidence in the literature and from practitioners within the industrial accidents field about the needs and forces that are driving decision-makers and the emergency services to look for better ways to address many of the most intractable problems of incidents concerning hazardous materials. Clearly, improvements need to be made in many areas. Technology-based system designs, such as the proposed model, are superior in many ways to conventional designs.

System model: The aim of this study was to design an information management system model to deal with processes in emergency management. The research employed quantitative and qualitative methods, such as questionnaire surveys, interviews and document analysis, together with an SDLC technique. Feedback from among the participants helped to establish a balanced interpretation while interpretation and modelling formed the pattern for designing an information management system model. The main findings of the study are that both sectors need to support emergency management; they need to increase co-operation and develop information exchange that will allow them to overcome the issues that have been mentioned in this study. As a result, it is important to identify the multiple roles that information plays in emergency management. Figure 1 shows the sequences of model building. The areas in which information systems are expected to enhance emergency situations range from quick response, the quality of services and efficiency in controlling accidents. Nevertheless, little attention has been paid to how integrated administrative and financial support and training should be configured in order to achieve the most efficient and useful model. Co-ordination is informed by and dependent on the documentation of the activities of factories, particularly by monitoring hazardous materials in the Industrial Sector, to help the Civil Defence to be ready for any emergency. Furthermore, such co-ordination relies on information about the quantity and types of hazardous materials. Thus, the co-ordination should provide the Civil Defence with updated information in order to help in emergency management.

Clearly, there is a need for a system that optimises information flow, as well as supporting and developing ICT (hardware and applications). However, the proposed system will provide optimal organisational value for emergency management only if the two sectors support a system model and encourage its implementation in the real world.

The main achievement of SDLC (Stage Three) was the design of the Industrial Incidents Administration System (IIAS) and its successful implementation as a prototype in SDLC (Stage Four). IIAS is a paperless, user-centred, secure method for information exchange able to keep information between the Civil Defence and Industrial Sector in Saudi Arabia up-to-date using electronic sources. The system model consists of online data exchange through the use of the Information Bus; a local database which contains five sub-systems; and the GIS application. Interoperability was an important feature of the proposed system.

The method of prototyping involves developing small sections of the whole system and then demonstrating it to its potential users for evaluation and comment. The main benefit of this method of design is that the users have direct involvement in the design process, thus ensuring that the system fulfils their requirements. It also helps to overcome many of the issues that were mentioned by the respondents.

Appropriateness of the adopted model design: The conceptual model used in this research for linking the Civil Defence and the Industrial Sector to exchange information electronically, provided a useful framework through which a number of related elements were analysed and discussed. The model design was adopted in order to fulfil the aims and objectives of the research. A number of techniques and approaches were used in achieving these objectives. These included quantitative and qualitative techniques of data analysis, a hard systems approach and model system design. These were found to be adequate in designing the proposed system. The conceptual model of this study is presented in Fig. 2.

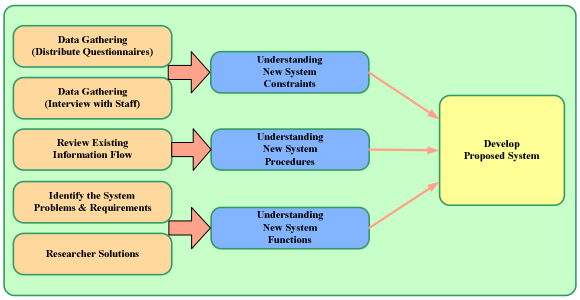

Fig. 1: Sequences of model building

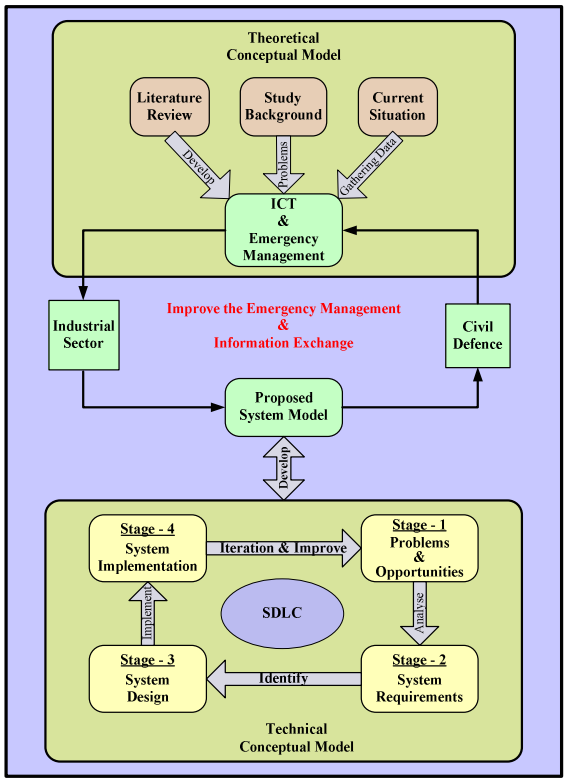

Fig. 2: Conceptual model of this study

There are various categories or types of problem noted in the literature. This research is aimed at exploring a well-structured problem situation with well-defined problems and clear requirements. As found in the literature, the appropriate methodologies for these situations include methodologies based on the traditional Systems Development Life Cycle (SDLC), frequently referred to as the waterfall model. Accurate and timely information is necessary for fire brigades' response, preparedness, recovery and mitigation. Industrial fire brigades need data from factories, such as the types of hazardous material, their quantities and places of storage. It is hoped that the proposed model will help emergency management by coordinating information from a variety of databases and making this information available to the CDCC. It can then provide detailed information to other emergency services or decision-makers when needed.

The model's vision is to produce the right information in the right format, for the right person, in the right time to make the right decision, while the model's mission is to harness information technology to deal effectively with industrial disasters, to save lives and reduce damage to property and the environment resulting from industrial accidents. The model can be expected to contribute to improving and developing the information exchange system between the Civil Defence and Industrial Sector.

Contribution to the knowledge: This study provides the first information system for control of industrial accidents in Saudi Arabia and throughout the GCC region. It draws upon similar studies applied to disaster management in parts of the developed world. The choice of the SDLC model allowed not only an understanding of the issues, but also led to the provision of a proposed system to improve the current situation. The information gathered during the fieldwork was represented in stage one of the SDLC, which identified the problems and opportunities of a proposed information system. Some issues that emerged from this part of the study included a perceived lack of ICT use by the emergency services, a lack of current data about hazardous materials together with no procedures for updating the 'hazards' database and the lack of co-operation and co-ordination between the Industrial and Civil Defence sectors was identified. SDLC stage two defined the principal requirements for the proposed system. The conceptual model produced for this study helped to identify the activities of the proposed system model and in which sequence they should occur. Outputs from SDLC stage three provided the design for the proposed system model (the IIAS). This system comprises three sub-models, web interface, databases and GIS spatial data. The proposed IIAS provides information that has the potential to yield an impact on the management and control of industrial accidents. The information provided is evidence-based to improve the utility of the developed system and delivers a solution required to satisfy the fourth objective of this study. The implementation stage (SDLC stage four) provided the procedures to procure a system prototype and its evaluation. Two evaluation techniques were used for this study to achieve sufficient scope to evaluate the whole system. The heuristic evaluation technique captured Web interface issues and identified the problem themes. The Cognitive Walkthrough technique was used to identify problems that the user may encounter along the information-seeking path.

CONCLUSION

The conceptual model builds to link the Civil Defence and the Industrial Sector to exchange information electronically. A number of techniques and approaches were used in achieving these objectives. These included quantitative and qualitative techniques of data analysis, a hard systems approach (SDLC) and model system design. As a result of this study, a novel information management system model for the Industrial Incidents Administration System (IIAS) has been proposed. The proposed (IIAS) will enable Civil defence to exchange information with industrial sectors electronically. Clearly (IIAS) represents a first attempt to model a system model for disaster management in Saudi. The results provide support for the more recent publications that argue that disaster management is a complex process, comprising many facets and interactions between these facets. Although the system already performs updated information about hazardous materials, it provides recent information for the decision makers. Particular aspects of the system can therefore be further elaborated in future research.

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