Developing a Usable Mobile Expert Support System for Emergency Response Center

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***Abstract*—The emergency response center (ERC) plays a very important role in risk control within the modern semiconductor manufacturing industry. This study develops the fire-detecting expert support system (FDESS) on an intellectual mobile device, as a tutoring and decision-assistance tool that can support the supervisors of ERC in emergency operation control. In order to promote a satisfactory human-computer interaction, the resulting system is based on the application of small-screen design principles, which appears significantly quicker and obtains good performance in fire control, compared to traditional tools. A prototype system illustrating the principles is described.**

***Index Terms*—Expert support system, Intelligent mobile device, Small-screen design.**

I. INTRODUCTION

In the modern semiconductor manufacturing industry, automated control systems are adopted to control the production processes. Under normal situations, the automatic control system maintains the steady operation of the production process. Once abnormal events occur, the automatic control system sends out alert signals and executes a set of pre-set emergency response control actions to protect the safety of personnel and production installations. In the meanwhile the instant and accurate emergency recovery by staff should be the critical factor. Thus, the ability of emergency response center (ERC) plays a very important role in risk control. In 2005, fire broke out at the factory of Advanced Semiconductor Engineering (ASE) in Chungli, Taiwan. The accident caused damage amounting to at least NT$4 billion (US$130 million). By the case, when monitoring the production process of semiconductors, analyzing and diagnosing faults as early as possible will reduce the damages and the losses.

Some incidents and accidental events, such as earthquakes, fire alarm, unstable voltage, chemical gas and chemical liquid leakage may occur. In a real production environment, the time to react is too short for the supervisors to think clearly and thoroughly. Once receiving an incident alarm in the ERC room, one of the supervisors will go to the plant from the ERC as fast as possible, to check the situation at shop flow, and then contact the ERC room via walky-talky to request comments. Furthermore, the supervisors must execute standard operation procedure (SOP) in order to control the emergency situation. However, not much knowledge of emergency operation control has been accumulated in regard to such systems. In order to minimize the predicted losses entailed by an accident, effective collaborative work by the supervisors in the ERC becomes crucial. The purpose of this study is to explore deeper and determine better mechanisms that can support the ERC more effectively and efficiently.

Expert systems (ES) use the expertise of humans in a specific domain, and solve the problems via human expertise. In a specific domain, operators or supervisors accumulate expertise through experience gathered over years, which is heuristic in nature. ES provides a technique to model the reasoning processes of experts and use their knowledge to solve specific problems. Moreover, the use of personal digital assistant (PDA) has increased in the past decade. The display of the PDA is much smaller than that of desktop, and the volume of such intelligent mobile device is smaller and lighter. In addition to supporting a much richer range of interaction styles, advanced interface enables the users to do things they perhaps could only previously imagine. The intelligent presentation of data is required in order to explore the layout of the display and architecture of information of the intelligent mobile device, with minimal loss of information.

This paper focuses on developing a well-interacted fire-detecting expert support system (FDESS) on the PDA, to be used in the ERC for real-time emergency situations; and through experiment, the usability of FDESS is verified.

II. USER INTERFACE DESIGN

Intelligent user interfaces, possibly employing an object-oriented environment, allow efficient interaction with the user. Mobility implies small devices, and unfortunately this size restriction currently limits the display of such devices. This restriction of the PDA has raised numerous issues, and

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subsequent solutions for efficiently designing a PDA interface. The aim is typically to maximize performance, connectivity, and flexibility within the constraints of the available hardware. Graphical user interfaces are in most cases simplified models of scenarios from the real world. In this section, the main focus is on the user interface design of small screens. Some relevant features, such as human-computer interaction, promotion of mobile environment and the features of small display are reviewed.

A. Human Computer Interaction

Human computer interaction (HCI) research has already had a history of thirty or forty years in America and Europe. With the constant development and progress of computer software and hardware, the concepts of user-centered design, designing easy to study and easy to use formats, is the main goal of human-computer interaction. Intelligent HCI promises to support more sophisticated and natural input and output, to enable users to perform potentially complex tasks more quickly, and with greater accuracy as well as increased user satisfaction. In mobile computing scenarios, special considerations for this group of workers include: dynamic user configuration, limited attention capacity, high interaction, and context dependency [17]. The basic premise of the user-centered design approach is that the human advice factor should be integrated with user participation early in the design so that system demands match operator capabilities and the design gains acceptance and the commitment of the workforce [14].

B. Appearance of Mobile Environment

The present evolutionary step in wireless Internet information management involves providing support for tasks. This trend has been brought on partially by the maturation of wireless communications, which is providing many possibilities for mobile workplace scenarios. This means that the information architecture supports the processes of the task, recognizes group interaction, permits users to migrate seamlessly among working spaces and allows these users to stay in touch with the server [22]. The increased capability of these appliances supports applications for tasks that may include a series of activities such as: lookups, selections, comparisons, and data input [3]. Wireless communication tools allow workers to stay in touch with the office. This is very different from the traditional desktop. There are four key elements that define mobile work contexts and explain how they differ from the office setting [15]:

1) Tasks external to the mobile computer are the most important, as opposed to tasks taking place “in the computer” (e.g., a spreadsheet for an office worker).
2) Users’ hands are often used to manipulate physical objects, as opposed to those that are safely and ergonomically placed on the keyboard in the traditional office setting.
3) Users may be involved in tasks (“outside the computer”) that demand a high level of visual attention (to avoid dangers as well as monitor progress), as opposed to the traditional office setting where a large degree of visual attention is usually directed at the computer.
4) Users may be highly mobile during the task, as opposed to those in the office where doing and typing are often separate activities.

As described above, the users of mobile devices face more problems of operation with smaller displays than do the users of traditional desktop. Although these devices have dramatically increased in sophistication, their display size is much smaller than desktop counterparts. Intuitively, as the screen is small, it may become cluttered with information as designers try to cram in as much as possible. This has resulted in constructing devices that are hard to use, with small characters that are hard to read. To study the use of the PDA to support emergency response control, the necessary step requires looking more closely at some important features of small displays.

C. Features of Small-Screens

At a more practical level, with knowledge of the screen and bandwidth constraints of the current devices, one can use them intelligently, along with personal or task preferences to present appropriate data. Some general properties should be considered in the small device [22]:

1) Lines of text should be short.
2) Concise/abbreviated and verbose versions are generated for use as needed.
3) The hierarchy of menu options or data choices is shown, to reflect the aggregate view.
4) Thumbnail sketches may replace full images as default, with full images available by request.
5) Contextual information is included in each screen.
6) Data in tables is filtered at source.

The physical display size affects performance much more than does the complexity of the display. Let us now consider the subject from the effect of screen size on user’s point of view. What is not so widely understood, however, is that small screen users use a very substantial number of scroll activities in completing tasks compared to the large screen users, which may interrupt their primary tasks. Therefore, it is very important to understand the impact that screen reduction has on both task performance and user preference. Previous studies examined the effect of screen size on overall task performance, and they found that the smaller display impeded both focus and less directed search task performance. Moreover, many studies indicated that the effect of the screen size on too much scrolling activity has significant influence on user performance, and indicated that the scrolling can be reduced by the following strategies [11]:

1) Placing navigational features (i.e. menu bars) near the top of displays in a fixed place.
2) Placing key information at the top of displays.
3) Reducing the amount of information on the display, and making the content task focused rather than diffuse.

Previous studies indicated that the main reason for the negative results is that smaller screens make it increasingly more difficult for a user to make good quality judgments about the usefulness of any particular search result or to effectively gain a general overview [10]. Previous studies have shown that smaller screens result in many more page forwards and backwards interactions when subjects were asked to read and summarize text presented in a small window [6]. These studies have shown that semitransparent navigational widgets improved performance on news reading on personal digital assistant (PDA) size screens [12]. The designers will need to make sure that buttons are big enough to press, that icons on a display are clearly and sensibly labeled, and that the task structure does not make excessive demands on people's problem solving abilities [1].

III. Emergency response system

We know that the ES has some defects in the analyzing process, but it is better than others in the following points [8]:

1) Knowledge suppliers can easily modify their experiences to knowledgebase. Analysts can understand the meanings of the outcomes by ES.
2) ES can manage knowledgebase more easily than others.
3) ES knowledge base is smaller than case-based reasoning.

In this study, one case utilized expert support system to create a Fire-Detecting safety inspection and emergency response control. This section describes the two main components of the emergency response system: decision support system (DSS) and ES.

A. Decision Support System

Decision support systems (DSS) have evolved significantly since their early development in the 1970s. DSS is computer technology solutions that can be used to support complex decision-making and problem solving. Previous studies indicated that classic DSS tool design is comprised of components for (1) sophisticated database management capabilities with access to internal and external data, information, and knowledge, (2) powerful modeling functions accessed by a model management system, and (3) powerful simple user interface designs that enable interactive queries, reporting, and graphing functions [21]. In the future, the decision-makers will access electronic services through their PDA or other wireless devices as much as through their desktop computers. The supervisor of ERC needs to go to the site of an accident after receiving an alarm message. The primary purpose of this study is to apply a decision support system for dealing with emergency events by the intellectual mobile device, with the focus on the interface design. Via PDA, the DSS can be used at any time, from anywhere, and under time pressure constraints. The human-computer interface, along with the problem processing subsystem and the knowledge system, is one of decision support systems. The success of a DSS is increasingly judged less by its processing speed and problem size than by its communication capabilities and the interface it provides for the human-computer interaction process.

B. Expert system

When abnormal situations arise in the manufacturing processes, the ES will reason out the causes and propose proper corrective solutions in due time. The reasoning is based on data from the control system and the expertise contained in the knowledge base [19]. An ES is a program which attempts to imitate the human decision-making process by applying inference methods to specific body of knowledge domain. ES generally works with a large number of practical rules and general knowledge from experts in domain. The field of artificial intelligence, which is a type of ES, is concerned with the development of computational programs, which simulate human reasoning. Therefore, the construction of ES will be reviewed first, and then followed by the program evaluation. In recent years, ES has become an increasingly popular computer software approach for solving a wide variety of application problems in a scientific domain that are sufficiently complex as to require significant human expertise for their solutions. ES is more appropriate in solving semi structured or unstructured problems, i.e., problems in which a numerical model does not exist. ES is computer system that advises or helps to solve real world problems which would normally require a human expert's interpretation. Previous studies indicated that a number of characters have been in our minds during the development of the ES. ES for real-time fault diagnosis generally has to meet the following requirements [18]:

1) Contain sufficient domain knowledge and information, especially the large amount of time-varying characters of the system;
2) The system should provide a satisfactory response in a given period of time when faults occur, which require the system to have a highly effective inference machine;
3) The knowledge base should be reasonably structured. This makes the representation of domain knowledge easier and convenient for management of the knowledge base;
4) The system must have strong ability in numerical computation, with new functions easily added.

Such systems work through problems using a computer model of human expert reasoning. Thus, ES is designed to reach the same conclusion that human experts would be expected to reach if faced with a comparable problem. There are several important reasons why organizations are embracing ES technology. The foremost reason is to provide a mechanism for building the institution or corporate memory of the firm. The other important reasons for using ES are as follows [16]:

1) A useful surrogate if expertise is unavailable, scarce or expensive;
2) A helpful device under time and pressure constraints;
3) A way to facilitate training;
4) A vehicle for improving worker productivity, as well as time and cost saving;
5) A tool to help supplement (second check) the decision maker.

Previous studies stated that the knowledge-based system development is simplified by a combination of trees and individual rules to represent the decision-making logic of the system [20]. Then the knowledge is frequently represented in a computer in the form of rules, and the rules that the program used is in IF-THEN-ELSE types. A rule is made up of a list of IF conditions and a list of THEN and ELSE conditions about the probability of particular choice being the appropriate solution of the problem. Then the inference engine could use rules to suggest users' appropriate decisions. In other words, an ES is a decision support tool for helping humans to make decisions more efficiently and effectively. Artificial intelligence approaches, and in particular knowledge-based techniques, have shown to be adequate for supporting this kind of emergency situation and interaction model [5]. Information within the ES may be used efficiently and can be easily modified. Access must be easy and flexible, and the ES must be capable of explaining actions and conclusions [7]. The valid knowledge and quality control aspects are considered as well. In terms of the knowledge base, it is necessary to ensure that it contains the "right" knowledge; that is, these may appear under "evaluation", "verification", and "validation" [13].

IV. Emergency Monitoring and Operation

The tasks of emergency monitoring are aimed at preventing injury, loss of life, and damage or loss to property of the semiconductor industry. In addition, understanding these tasks will help to set the groundwork for restoring an emergency situation back to normal. The problems to be solved should first be defined. The procedure of the fire situation handling is shown in Fig. 1. It starts with a fire alarm, and the fire broadcast will be executed at the same time. The supervisors of ERC will use walky-talkies to notify the patrolmen to make sure the firm alarm has been activated. If the fire alarm is a false alarm, the supervisor will cancel this alarm. When the alarm is genuine, the supervisors have to broadcast the fire message and evacuate operators who are on the site. At the same time, the supervisors have to control the fire and establish the emergency response team (ERT). The function of ERT is to integrate each department into the fire control.

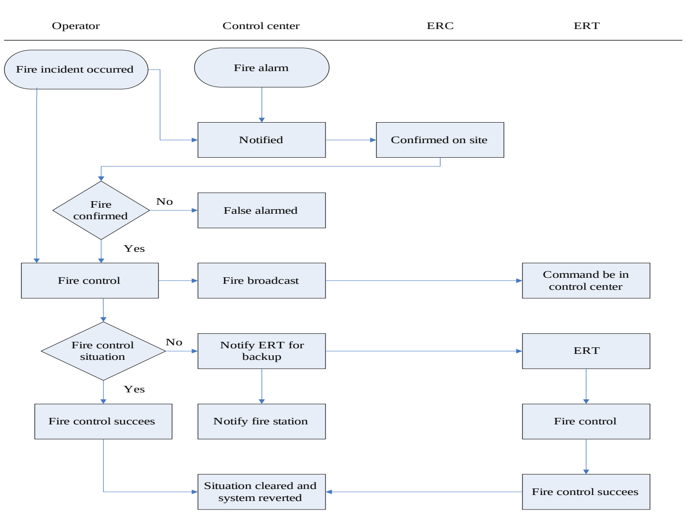

Fig. 1. The flow chart of fire alarm response

Moreover, Fig. 2 shows how the supervisors receive alarm signals and monitor the emergency situation. Operation steps are described as follows:

1) When supervisors become aware of an alarm signal (sound or flashing signal), they go to check the main monitor display.
2) Examine the display to confirm which system is abnormal.
3) Confirm the system alarm, and notify the group members who are outside the control room.
4) The members go to confirm that event on site and report back to the ERC on the event situation: real event or false alarm.

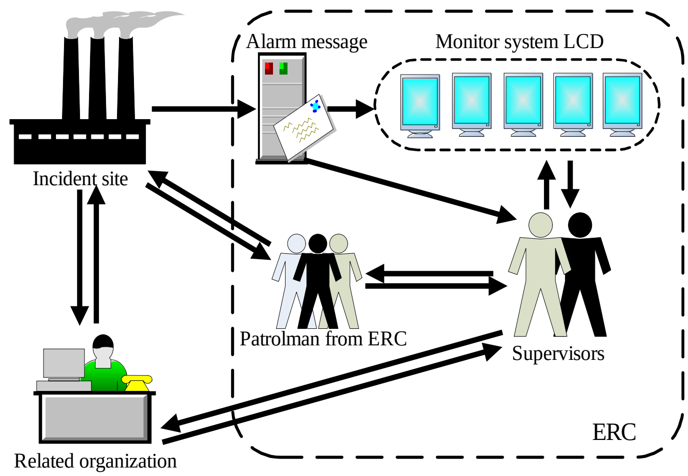

Fig. 2. The response process of the ERC (modified from Chiang, 2003)

The tasks of the ERC in any semiconductor plant have similar characteristics which rely on high vigilance to monitor all kinds of emergency events. The patrolmen use walky-talkies along with the supervisors of the ERC, and this is the only way to communicate with the center. In other words, such relationships cannot immediately interact with one another. Furthermore, the patrolmen need a lot of information to support them in making an appropriate decision for handling emergency events. However, the supervisors and patrolmen only exchange information verbally. The problem that we must consider next is the utility of the device. The modern generation of the PDA offers possibilities that are comparable to computers such as notebooks, and they are much smaller and have much longer battery power supply. Comparably lower prices of the device and the ability to maintain very good parameters, combined with outstanding reliability, encourage supervisors to use solutions based on the PDA. Therefore, the study chose the PDA to substitute for the walky-talky.

Fig. 3 shows the conceptual model of the PDA solution. The PDA can play many roles in different domains. For example, quality medical care depends on prompt, accurate recording, communication, and retrieval of patient data and medical logistics information. In emergency medicine, such information can make the difference between life and death because it enables better planning and scheduling of medical resources. A hospital can assemble the appropriate team of specialists and configuration of equipment so that they are ready as soon as the patient arrives, if medical providers in the field inform the hospital of the patient's condition when they first encounter the patient [9].

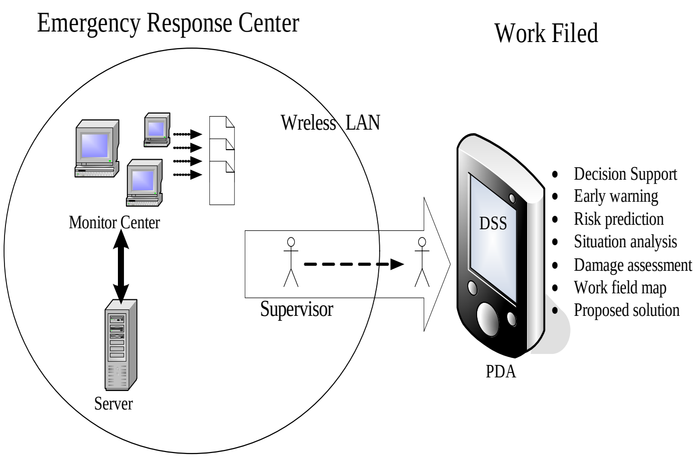

Fig. 3. The conceptual model of PDA solution

V. Development of the Fire-Detecting Expert Support System

The fire-detecting expert support system (FDESS) has its own database that can support supervisors in making an appropriate decision and accumulating the operational processes. Therefore, the FDESS acts as a decision assistance tool that can support the supervisors of the ERC in emergency operation control. Moreover, the database can accumulate cases day by day, to turn them into a knowledge base. Besides, the interface design is based on principles of small display design. Consequently, the FDESS is a well-designed ES in the intellectual mobile device. In the development of FDESS, one may use Microsoft Visual Basic.NET program to establish the system in the PDA.

A. Framework of FDESS

The framework of FDESS has three layers. Fig. 4 shows the construction of FDESS. The first layer is the front page of FDESS. The second layer has two parts: an ES of fire control procedure and safety inspection. The third layer is the contents of the above layers. According to the materials collected, and interviews with supervisors of the ERC, the fire control procedure can be divided into six steps and one support specification: fire alarm, confirmation on site, incident event, primary response, establishing the ERT, recovery system and material safety data sheet (MSDS).

B. Interface Development of FDESS

The interface development of FDESS is shown from Fig. 5 to Fig. 14. Fig. 5 is the front page of the FDESS. The users have to choose the identity for entering the FDESS. Fig. 6 is the flow chart of fire control in the FDESS. There are six steps: fire alarm, confirmation on site, incident event, primary response, establishing the ERT and the recovery system. The six steps can be clicked and selected to enter among them. Fig. 7 to Fig. 12 is the interfaces of ES for fire control procedure.

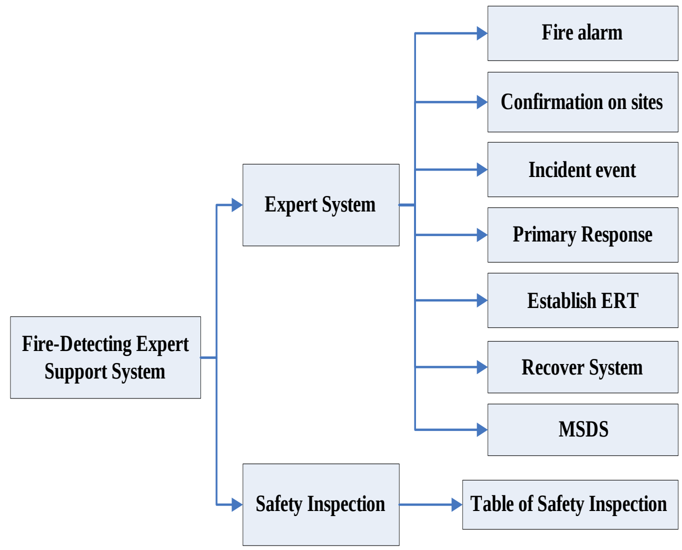

Fig. 4. The framework of the FDESS

Fig. 5. The front page of the FDESS

Fig. 6. The flow chart of fire control in FDESS

The layouts of interfaces contain three locations. Location one is the basic function buttons, such as 'back to index page'. Location two is the flow chart of the fire control procedure.

Location three is the tasks of each fire control procedure. Fig. 7 is the first step in the fire control procedure. The first thing to do in fire control is to determine the type, area and floor of the fire alarm. Therefore, there are three blocks for showing the fire alarm message in location three. Fig. 8 is the second step in the fire control procedure. After reception of the fire alarm message, the supervisors have to confirm, on site, whether it is a true event or a false alarm. Therefore, the checkpoint is the confirmation of fire or smoke on site, and providing a map of the accident site to the supervisors for their understanding of the situation. Fig. 9 is the third step in the fire control procedure. If the fire alarm is a false alarm, the supervisors have to investigate the cause of the incident event, and record it into FDESS. Fig. 10 is the fourth step in the fire control procedure. If the fire alarm is a real alarm, the supervisors must execute the SOP in order to control the emergency situation. In this scenario, the interface will display the important message to support supervisors in their handling of the emergency situation in the primary response. Fig. 11 is the fifth step in the fire control procedure. The function of establishing the ERT is to integrate each department into the emergency fire control. At the same time, the supervisors become assistants of ERT, and continuously supply messages from the location to the ERT. Therefore, the supervisors have to note down state of the plant into the FDESS and deliver the record to the ERT via wireless. Fig. 12 is the final step in the fire control procedure.

Fig. 7. The first fire control procedure of the FDESS (Fire Alarm)

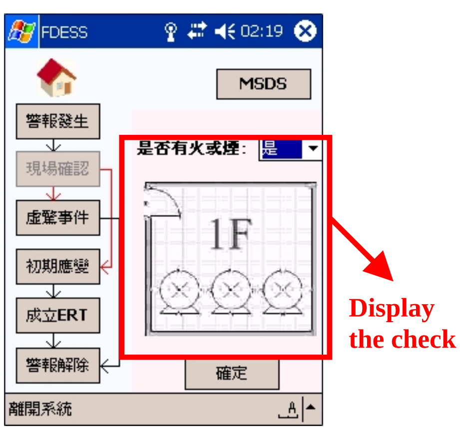

Fig. 8. The second fire control procedure of the FDESS (Confirmation on Sites)

Fig. 9. The third fire control procedure of the FDESS (Incident Event)

Fig. 10. The fourth fire control procedure of the FDESS (Primary Response)

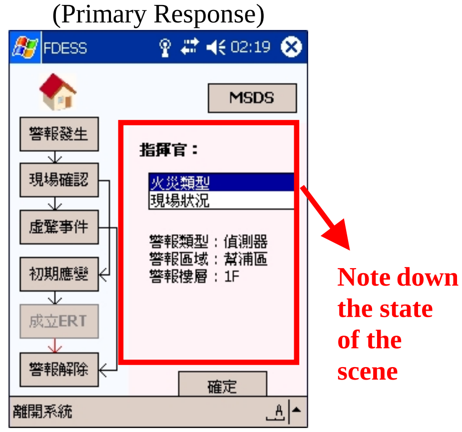

Fig. 11. The fifth fire control procedure of the FDESS (Establish ERT)

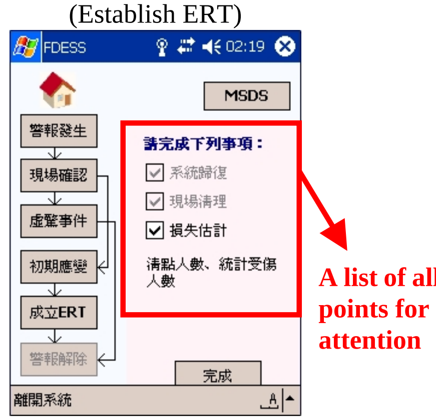

Fig. 12. The final fire control procedure of the FDESS (Recover System)

After fire control, the supervisors have to deal with problems arising from a fire incident. Therefore, they need a list of all the crucial points that require attention, and record the progress of work into the FDESS. Fig. 13 shows the interface of material safety data sheet (MSDS) with the intellectual mobile device. A real fire incident may involve some hazardous materials, and MSDS offers detailed dangers and the technology of precaution-taking information. While the supervisors must understand the information on hazardous materials, there are tens thousands of hazardous materials. For this reason, the MSDS is designed into the system as a support specification. In the FDESS, the MSDS contains four parts: name, characteristics of hazardous materials, personal protective equipment and cautions. When supervisors select the name of hazardous materials, then the other items will be displayed at fixed locations. Fig. 14 shows the interface of safety inspection with the intellectual mobile device. Routine safety inspections played an important role in preventing accidents. Therefore, the costs of any factory damage will be lower when the routine safety inspections have been properly handled. For this reason, safety inspection must be put into the FDESS. Moreover, the intellectual mobile device can record the results of safety inspections into the database, and, via statistics analysis, discover some potential factors. The interface of safety inspection contains six parts: inspection items, the interpretation of inspection key points, recording the status of items, description of status, as well as looking up the inspection specifications and illustration of each item.

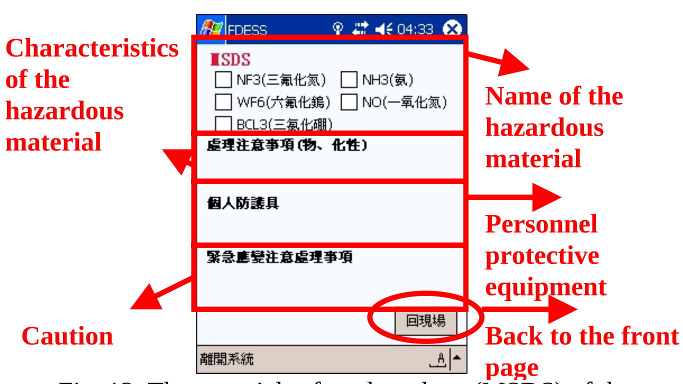

Fig. 13. The material safety data sheet (MSDS) of the FDESS

Fig. 14. The safety inspection of the FDESS

The development of the interface is based on principles of small screen design [4] [11] [22], and is summarized as follows:

- Perceptual principles: as shown in Fig. 6, top-down processing was used to arrange the procedure of fire control.
- Mental model principle: as shown in Fig. 14, the realistic illustration was used to support the supervisors in the safety inspection.
- Principle based on attention: as shown in Fig. 7 to Fig. 12, the proximity compatibility principle was used, because all of these six interfaces constitute the fire control procedure.
- Memory principle: as shown in Fig. 10, predictive aiding was used to list the notice information, so that this design could reduce the memory loading by supervisors.
- Lines of text should be short: the longest line of text was 7 characters in all of the small screen interface design.
- Concise/abbreviated and verbose versions are generated for use as needed: there were four parts in Fig. 13, with information generated in each part.
- The hierarchy of menu options or data choices is shown to reflect the aggregate view, as shown in Fig. 6; the flow chart was used to reflect the aggregate view, and these six procedures can be clicked and selected to enter the system among them.
- Thumbnail sketches may replace full images as default, with full images by request, as shown in Fig. 14; the small illustration (96x80 pixels) was used to support the supervisors in the safety inspection.
- Contextual information is included in each screen, as shown in Fig. 7 to Fig. 12; the fixed location for fire control was used in the left area, because all of these six interfaces involve the procedure of fire control, so that the supervisors can to understand the fire condition through the contextual information.
- Placing key information at the top of displays, as shown in Fig. 7 to Fig. 12, the MSDS was put in to support the supervisors, because the supervisors must understand the information about any hazardous materials anytime and anywhere.

VI. Design of Experiment

There are two methods in the experiment to support inspection tasks as shown in Fig. 15; the traditional method means participants use manuals to learn about the routine safety inspection and emergency response control. In Fig. 16, the PDA device not only allows supervisors to communicate with the ERC but also provides user information about the procedures for operating the emergency events, and the PDA (HP iPAQ rx3715) with a 3.5 inches screen, resolution of 240*320 pixels, a touch-screen pen interface, and an on-screen keyboard used with a pen.

A. *Experimental subjects*

Twenty graduate students of the Industrial Engineering and Engineering Management Department of National Tsing-Hua

University participated in the experiment and each of participants was paid NT200 dollars after the experiment. The background of participants was similar to that of the supervisors of the ERC who have master's degrees. Hence, we assumed that the variance of different groups were equal. Each of the participants was randomly assigned into one of two groups, the control group or the experiment group. The control group used a manual to learn about the tasks of safety inspection and emergency response control, whereas the experiment group used the PDA device to learn about the tasks of safety inspection and emergency response control.

Fig. 15. The traditional method (Manual Learning)

Fig. 16. The intellectual mobile device method (HP iPAQ rx3715)

B. *Experimental variables*

The independent variable of this experiment is the inspection support method: with manual or with the PDA, to execute the task of safety inspection and emergency response control. The dependent variables are training time, safety inspection time, number of errors, and the performance of procedure examination.

- Training time: time for learning the tasks of safety inspection and fire control procedure.
- Safety inspection time: the time interval from the beginning to the end of the safety inspection.
- Error frequency: the frequency of making a mistake when doing safety inspection.
- Test scores: A written test on procedure of fire control. For example, if the correct answer was "A-B-C-D-E", and the answer of the subject was "A-B-D-C-E", then one can translate the answer to "1(correct)" or "0", and thus we can derive the result of "1-1-0-0-1". This test of emergency response control was dependent on the standard operation procedure. For instance, if the action "A" was not executed at first but action "B" was executed instead, then the earlier procedures should weigh more in determining the scores than would the later procedures. Therefore, the score of this example is 10 points (1x5+1x4+0x3+0x2+1x1=10).

C. *Experimental Procedure*

All the subjects were told that the goal of the study is to test new application of the intellectual mobile device in emergency situation. The study was conducted in one room where all apparatus were setup, and the subjects were assigned to one of two groups (10 in each group):

- One group learned the procedure of fire control using the manual (Fig. 15)
- The other group learned the procedure of fire control using the FDESS (Fig. 16)

After subjects understood the purpose of the experiment, the formal experiment began. Subjects started the formal experiment for learning about the contents of safety inspection and emergency response control. Each subject took a short rest after finishing the learning stage. Both groups were required to complete two tasks: safety inspection and a written examination about the procedure of fire control.

VII. Experimental Results and Discussion

A. *Experimental results*

In this study, the performance of all participants was evaluated by these four indicators: training time, safety inspection time, error frequency and test scores. Table 1 shows the raw data of the experiment for each participant.

Table 1 The raw data of experimental for each participant

Group	**No**	**Training time (Sec)**	**Inspection time(Sec)**	**Error Frequency**	**Test scores**
PDA	1	927	367.8	0	210
	2	738.6	315	1	420
	3	1057.8	399.6	0	130
	4	650.4	309.6	0	220
	5	1447.2	292.8	1	290
	6	1377.6	506.4	1	420
	7	1273.8	339	0	320
	8	1014	261	2	300
	9	851.4	423.6	1	400
	10	1244.4	342	0	60
Manual	11	876	216	1	90
	12	1656	356.4	1	100
	13	1525.2	355.2	2	200
	14	1080	319.2	0	170
	15	1780.8	271.8	1	80
	16	1135.8	393	1	120
	17	1305.6	221.4	0	40
	18	1285.2	250.2	3	130
	19	1179	268.8	1	10
	20	1864.8	229.8	1	90

As shown in Table 2, training time when using the PDA is significantly different from that of the traditional method ($p<.05$). From the sample means for the two groups, one can see that the PDA group spent significantly less training time than did the traditional group.

Table 2 The t-test for average training time of independent populations (α =0.05)

Dependent Variable	**Training Time**	
Independent Variable	**PDA Group**	**Traditional Group**
Mean	1058.22	1368.84
Standard Deviation	271.80	324.94
Sample Size	10	10
Degree of Freedom	18	
T-value	-2.319	
P-value	0.032*	

As shown in Table 3, the safety inspection time when using the PDA is significantly different from that of the traditional method (p<.05). From the sample means for the two groups, one can see that the PDA group spent significantly more safety inspection time than did the traditional group.

Table 3 The t-test for average safety inspection time of independent populations (α =0.05)

Dependent Variable	**Safety Inspection Time**	
Independent Variable	**PDA Group**	**Traditional Group**
Mean	355.68	288.18
Standard Deviation	71.93	63.47
Sample Size	10	10
Degree of Freedom	18	
T-value	2.225	
P-value	0.039*	

As shown in Table 4, there is no significant difference in error frequency when using the PDA versus the traditional method.

Table 4 The Mann-Whitney U for average error frequency of independent populations (α =0.05)

Dependent Variable	**Error frequency**	
Independent Variable	**PDA Group**	**Traditional Group**
Mean Rank	8.85	12.15
Sum of Ranks	88.5	121.5
Sample Size	10	10
Mann-Whitney U	33.500	
P-value	0.172	

As shown in Table 5, the test scores when using PDA are significantly different from those of the traditional method (p<.001). From the sample means for the two groups, one can see that the PDA group got significantly higher test scores than did the traditional group.

Table 5 The t-test for average test scores of independent populations (α =0.05)

Dependent Variable	**Test Scores**	
Independent Variable	**PDA Group**	**Traditional Group**
Mean	277	103
Standard Deviation	122.48	56.18
Sample Size	10	10
Degree of Freedom	18	
T-value	4.083	
P-value	0.001**	

B. Discussion

In this study, we found that the method of handling the emergency response control significantly influences performance in fire control; the PDA group spent significantly less time and got significantly higher test scores in fire control than did the traditional group. However, contrary to our predictions, the PDA group spent significantly more safety inspection time than did the traditional group. The reasons may be due to the safety inspection items and sample size. The safety inspection items might be too small (only contained 16 items) to test the real effect in the experiment and the sample size was insufficient to reveal the effect between two methods. The result of error frequency was not significant, which may be due to the smaller number of safety inspection items. Previous studies described the process and methodology of designing and developing a mobile support system for triaging abdominal pain in the emergency room of hospitals [23]. Previous studies have addressed this issue by implementing the DSS in mobile platform, such as the handheld Palm. This creates a "DSS in a pocket" model, allowing a decision-maker to get support irrespective of location and decision-making environment. In addition, the analysis of observation records revealed that the subjects of the manual group spent more time learning the procedure than did the FDESS group. However, from the results of this experiment, we can see the advantages of small screen design, and that the FDESS in an intellectual mobile device is a useful application that can support emergency response control.

VIII. CONCLUSIONS

A. Contributions

This research is based on developing an FDESS for routine safety inspection and emergency response control. A well-designed human-computer interface may help users to control such devices instinctively. The development of the FDESS is an important advancement for the emergency response center. The development of the FDESS in this study offers some contributions as follows:

- With the FDESS, the supervisors can quickly understand the whole fire situation as well as complete the fire control quickly, to prevent the losses resulting from slow response and/or faulty diagnosis. Moreover, it can guarantee the normal production process in the semiconductor manufacturing industry.
- The FDESS can respond to emergency response control inquiries with expert experience, and can be used in the education and training of novice.
- Via this intellectual mobile device, the collaboration of supervisors and ERC can be improved, such as exchanging information more effectively and efficiently in collaboration.
- The safety inspection function in the FDESS has its own database that can store the data from routine safety inspections. In addition, it benefits the ERC to accumulate the records data for future predictions of probability faults.

B. Future studies

Some follow-up researches are proposed as follows:

- In the study, the major purpose is to design an FDESS and to compare it with the traditional system. Therefore, future studies can test the performance of different small interface designs to determine some potential factors.
- The FDESS only contains fire conditions but there are other emergency events in the semiconductor manufacturing industry, such as earthquakes, unstable voltage, chemical gas and chemical liquid leaks etc… Hence, future studies can add other emergency situations to extend the system.
- In order to achieve the purpose of risk management, future studies can add more routine safety inspection topics and items into the system, and test the effect of predicting the faults that may cause fire.
- The route of the semiconductor manufacturing industry was very complex, and the plant map played an important role in helping the supervisors get to the correct site. Therefore, future studies can add the plant map into the system and try to design an easy to use interface on such a small display.

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