An Innovation Design for Hazardous Chemical/Gases Disaster Detection and Analysis Equipment by Using Cross-Cultural User Scenarios and Service Design

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Abstract. Unexpected releases of toxic, reactive, or flammable liquids and gases in processes involving highly hazardous chemicals or gas explosions have been reported for many years. The recent incident happened in Taiwan at 31st July, 2014 shows that a series of gas explosions occurred in the Cianjhen and Lingya districts of Kaohsiung in Taiwan, following reports of gas leaks earlier that night claimed 31 lives and injured other 309 people. In this study, we organized an interdisciplinary team that contains scholars from university, leaders from firefighter department, high rank officers from disaster management agencies, researchers and project managers from research institute and gases detector manufacture company and product designers to work together to propose an innovation design for hazardous chemicals/gases detection and analysis equipment. Based on the QFD analysis, operation for air detection is the most important feature. The results shown in the QFD Matrix, was further analyzed using a questionnaire that polled 6 inter-disciplinary experts in order to collect the pair-wise comparison results in AHP. The top 3 feature from the AHP are similar to the QFD weight: Air Type (20.05 %), Air Concentration (19.71 %), and Air Detection (17.44 %) The results of this research point out that the innovation product design should also include the design of service mechanism in order to meet users' requirement. For cross-cultural user scenarios perspective, design thinking method that use diagram and pictures for providing info-graphic results and the usability of user interface (UI) are two major factors should be included in the design process. The conclusions of this study suggest that the integration of product design and service design, and the co-working

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mechanism among interdisciplinary team play very important role in the innovation design for hazardous chemicals/gases detection and analysis equipment.

Keywords: Service design · Cross-Cultural scenarios · Usability · Hazardous chemical/gases · Disaster management

1 Introduction

Unexpected releases of toxic, reactive, or flammable liquids and gases in processes involving highly hazardous chemicals or gas explosions have been reported for many years. Incidents continue to occur in various industries that use highly hazardous chemicals/gases, which may be toxic, reactive, flammable, or explosive, or may exhibit a combination of these properties. The recent incident happened in Taiwan at 31st July, 2014 shows that a series of gas explosions occurred in the Cianjhen and Lingya districts of Kaohsiung in Taiwan, following reports of gas leaks earlier that night claimed 31 lives and injured other 309 people. Eyewitness reported that smell of gas and white smoke was coming out from manholes over three hours prior to the incident. Although the firefighter rushed to the scene immediately after receiving 911 call and setup the alert zone, they could not prevent the explosion since the failure on identifying the type of leaking gas. The importance of related equipment design that can be used to detect and analyze the hazardous chemicals/gases in the disaster management cycle is aroused after this catastrophic incident.

In this study, we organized an interdisciplinary team that contains scholars from university, leaders from firefighter department, high rank officers from disaster management agencies, researchers and project managers from research institute and gases detector manufacture company and product designers to work together to propose an innovation design for hazardous chemicals/gases detection and analysis equipment. In order to integrating coworkers to work on creating the operation procedure and mechanism of the designed equipment, we hosted two workshops by using service design approach for interdisciplinary integrating. We also used cross-cultural user scenarios to ensure the design results can fulfill the international standard, such as standard for process safety management of highly hazardous chemicals (Occupational Safety and Health Administration in the United States 2011), the Clean Air Act Amendments (CAAA) (United States Environmental Protection Agency 2014).

Unlike follow the principles of traditional product design that is focused on "perfect-form" with "multiple-functions" based on well-organized design method, the innovation design for hazardous chemicals/gases detection and analysis equipment should follow the requirements proposed in the disaster management cycle as well as the operation mechanism of firefighters, and the decision making procedures of disaster management agencies.

Thus, this research begins from the exploration of hazardous chemicals/gases disaster management cycle by interviewing several research scholars in university and high rank officers of disaster management agencies to build up the scope of managing hazardous chemicals/gases disaster in Taiwan. Then, meetings with the firefighter who had experiences on responding to the hazardous chemicals/gases disaster are arranged to know the operation procedures and the scenarios of using hazardous chemicals/gases detectors. Thirdly, service design workshops with interdisciplinary team work together to propose the Quality Function Deployment (QFD) matrix and cross-cultural user scenarios of the innovation design for hazardous chemicals/gases disaster detection and analysis equipment. Thereafter, the product designer will follow the results from the workshop to design and produce the equipment prototype. Finally, World Cafe and Analytic Hierarchy Process (AHP) are implemented to review the prototype and user experiences.

2 Literature Review

The response time for the emergency response team to react is very short when facing chemical/gases leakage and spillage. In order to reduce the casualties, how to efficiently detect chemical/gases leakage and spillage is very pivotal when activating emergency response plan. According to the emergency management domain from several countries such as: the United States (Emergency Management Institute 2015), Canada (Canadian Environmental Assessment Agency (CEAA) 2013), and Japan (ASIAN DISASTER REDUCTION CENTER 2011), the mission statement basically includes four missions: (1) Prepare for emergency plan, (2) Respond to emergency center, (3) Recover the place, and (4) Mitigate the disaster. For more detailed measures and complicated situations, re-prepare for unpredictable disasters in the future is also important in the statement as shown in Fig. 1.

Based on this review, how to design hazardous chemicals/gases detection and analysis equipment should put emphasis not just multiple-function, to meet the user requirements would be the first target for the motivations. In this study, in-depth interviews with scholars from university, leaders from firefighter department, and high rank officers from disaster management agencies would put forward for "how and what to detect on site" when chemical/gases leakage and spillage disaster occurred. Moreover, the recent gas explosions incident timeline happened in Taiwan was the basic analysis and research scenario event (Fig. 2). If hazardous chemicals/gases detection can start when or even before the fire starts, the casualties would be reduced.

Fig. 1. Emergency management mission statement

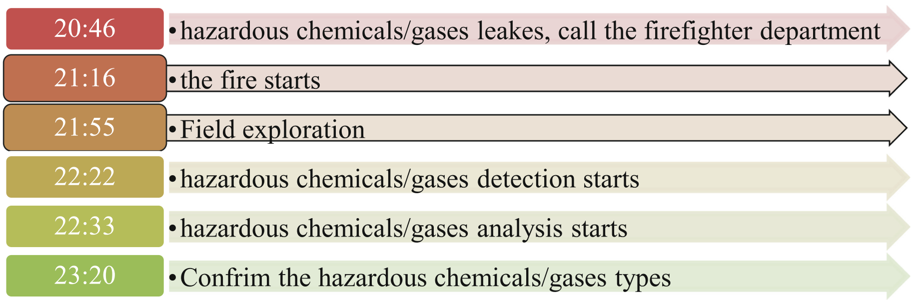

Fig. 2. Timeline for the recent gas explosions incident timeline in Taiwan (2014)

After first contacting and interviewing with the interviewees, no matter the profession language, working patterns, and even the focus were totally different. Service design is a method for transferring traditional product design and interface design to the commercial service in the society (Birgit 2006). It includes the environment for providing service, the serving process, and even the training for these service personnel (Koskinen 2008). It is a permanent feedback that requests and constantly updating process, in which the response of the users are continually being observed and monitored. Moggridge asserted that “service design is the design of intangible experiences that reach people through many different touch-points”. That is, service design is a process of continual updates based on the cross-cultural responses of users who are observed and monitored.

In addition to the service design approach, the QFD Matrix and AHP are also been used simultaneously to systematically evaluated the classes and features derived from service design. QFD is a systematic approach to design, based on a close awareness of customer desires, coupled with the integration of corporate functional groups. The ultimate goal of QFD is to translate subjective quality criteria into objective ones that can be quantified and measured and which can then be used to design and manufacture the product. However, this simple point scale system used by the QFD Matrix has two weaknesses: the first one is it does not prioritize the customer requirements; the second one is the weights are of subjective value and depend on the consensus of the panel experts.

To address the above-inherited weaknesses, several researchers and practitioners have advocated using AHP to determine the weights of customer requirements (CRs). AHP is a structured technique for dealing with complex decisions (Saaty 1990; Saaty and Vargas 2012). The combined AHP-QFD approach has been used successfully to assess customer needs based on a multiple-choice decision analysis (Gupta et al. 2011) review the combination of QFD-AHP for the evaluation and selection methodology for an innovative product design concept.

The methodology combining QFD-AHP was mainly used as a multi-criteria decision method for evaluating user requirements. By considering the hazardous chemicals/gases detection and analysis of service design, this work uses this methodology to evaluate the development of hazardous chemicals/gases detection and analysis equipment.

3 Methodology

This work integrates design thinking with technology development process for developing a concept design for hazardous chemicals/gases detection and analysis equipment. As for Fig. 3, the process starts with a service design workshop that moves through macro environment analysis, product opportunity gap analysis, product and service description, and empathy map and character map analyses. This work invited scholars from university, leaders from firefighter department, high rank officers from disaster management agencies, researchers and project managers from research institute, gases detector manufacturing company and product designers to brainstorm at a 2-day workshop, with the goal of defining the features of hazardous chemicals/gases detection and analysis equipment using the service design approach. The features selected from service design results are further analyzed and used to compose the QFD matrix. The AHP is then used to prioritize and weight each criterion. A process of delivering ideas to define the features of hazardous chemicals/gases detection and analysis equipment starts by cross-cultural profession experts in a brainstorming process. The process of investigating service design is used to simplify discussions. Sticky notes were used, as "IDEO" favors this method as it helps cross-disciplinary team members describe their innovations.

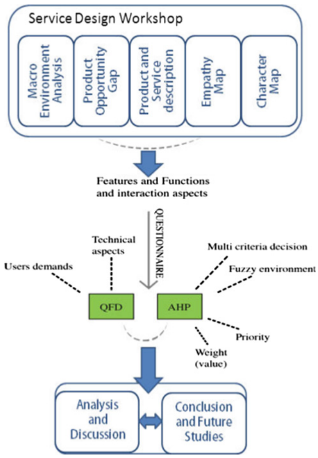

Fig. 3. Implementation processes

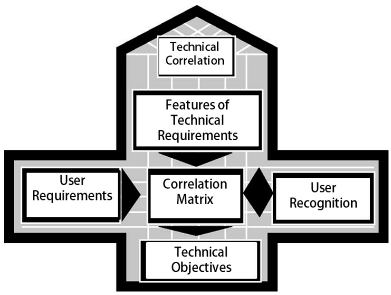

Fig. 4. Conceptual diagram of quality function deployment.

All features derived from the workshop are listed in a QFD matrix. Figure 4 presents the conceptual diagram of the QFD.

The QFD matrix shows the importance of each feature via correlation analysis of user requirements and features of technical requirements. It also shows user recognition by describing their experiences to competitors by giving a value to their importance. The importance range is 1–5 and their thinking is limited to strong, moderate, or poor. This method tells us how strongly the features (product characteristics) are related to user requirements and reflects the strengths of existing products. This work uses the QFD matrix to systematically list the features of the hazardous chemicals/gases detection and analysis equipment design.

The three basic AHP steps in this research are as follows.

1. Describe a complex decision-making problem as a hierarchy.
2. Use pairwise comparison techniques to estimate the relative priority of various elements on each level of the hierarchy.
3. Integrate these priorities to develop an overall evaluation of decision alternatives.

4 Result and Discussion

For the interdisciplinary team that contains scholars from university, leaders from firefighter department, high rank officers from disaster management agencies, researchers and project managers from research institute and gases detector manufacturing company and product designers to work together in this project, service design workshops were to propose an innovation design for hazardous chemicals/gases detection and analysis equipment. In Figs. 5 and 6, an interdisciplinary team that contains scholars from university, leaders from firefighter department, high rank officers from disaster management agencies, researchers and project managers from research institute and gases detector manufacture company and product designers to worked together for brainstorming workshop and created a sticky notes idea map.

Fig. 5. Brainstorming workshop

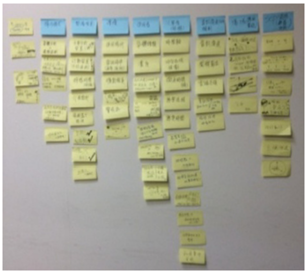

Fig. 6. Sticky notes idea map from cross-disciplinary team.

Following the conclusion of the brainstorming workshop, Fig. 7 shows the QFD Matrix results of hazardous chemicals/gases disaster detection and analysis equipment. Based on the QFD analysis, operation for air detection is the most important feature. SOP, user, and director are the second important features. In comparison to the technical features, air degree, data records, and auto-save are highly demanded by the respondents. The results shown in the QFD Matrix, was further analyzed using a

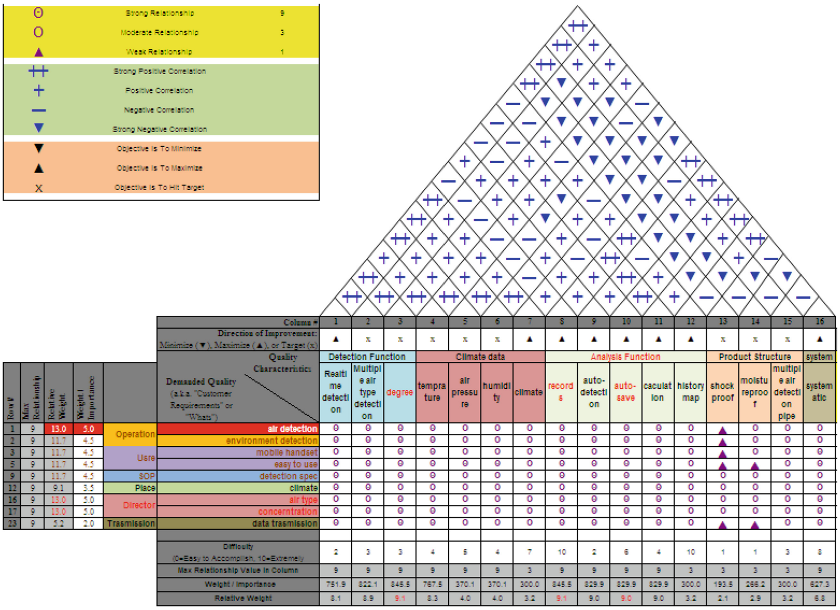

Fig. 7. QFD matrix result

questionnaire that polled 6 inter-disciplinary experts in order to collect the pair-wise comparison results. The AHP template was used to analyze the results and generate the weights and priorities of each feature.

As shown in Table 1, there is a correlation between the QFD Matrix's weight scale and the weights and ranking from AHP method. The most demanded features of hazardous chemicals/gases disaster detection and analysis equipment is *Operation*

Table 1. The QFD-AHP comparison table

Class	Features	AHP percentage	AHP priority	QFD	QFD priority
Operation 26.07 %	Air Detection	17.44 %	3	5.62	1
	Environment	8.63 %	5	5.06	2
User 3.19 %	Mobile Handset	3.19 %	9	5.06	2
	Easy to Use	7.97 %	6	5.06	2
SOP 6.91 %	Detection Spec	6.91 %	7	5.06	2
Place 3.05 %	Climate	3.05 %	10	3.93	4
Director 3.95 %	Diffusion	3.95 %	8	4.49	3
	Air Type	20.05 %	1	5.62	1
	Air Concentration	19.71 %	2	5.62	1
Transmission 9.10 %	Response Time	9.10 %	4	3.93	4

(26.07 %) and then *Transmission (9.10 %)*. There are not much difference between the *Director (22 %), User (3.19 %) and Place (3.05 %)*. The top 3 design priority for hazardous chemicals/gases disaster detection and analysis equipment are: *Air Type (20.05 %)*, *Air Concentration (19.71 %)*, and *Air Detection (17.44 %)*.

The top 3 feature from the AHP are similar to the QFD weight. Further more than the research, the user scenario and concept design was implemented then. In Fig. 8, combining with the QFD and AHP matrix results with deep interview with firefighters, the user scenario was visualized for described the operation situation and behaviors. For detection the air type, air concentration, and efficiently detected, "plug-and-play" is the core for operating this hazardous chemicals/gases disaster detection and analysis equipment. Also, cooperated and integrated with the firefighter on site working process, all the operations were related to the original firefighter on site working process. In Fig. 9, the concept images were purposed to the features and user scenario visualization.

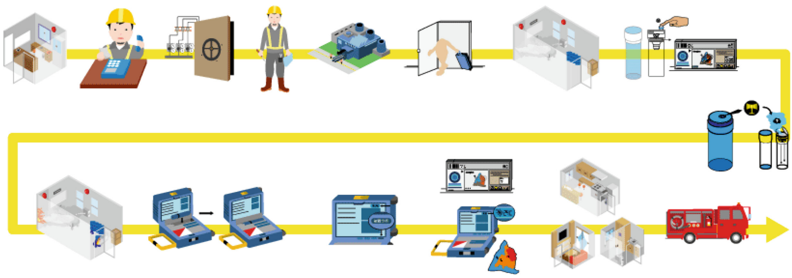

Fig. 8. User scenario visualization

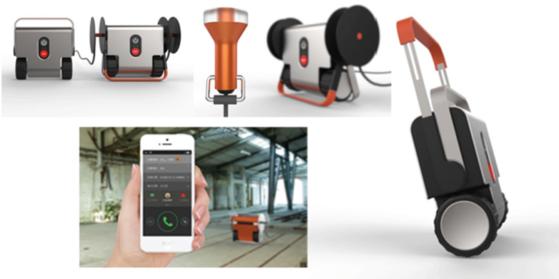

Fig. 9. Concept images

5 Conclusion and Future Works

The results of this research point out that the innovation product design should also include the design of service mechanism in order to meet users' requirement. To solve the problems with how to design a propriety product with required service, service design provides a practical and flexible method for concept design. For cross-cultural user scenarios perspective, design thinking method that use diagram and pictures for providing info-graphic results and the usability of user interface (UI) are two major factors should be included in the design process. Furthermore, the ideas and scenario pictures generated from the co-work brainstorming in the service design workshop could not only provide the analysis on the functions and techniques details that product designer can be used for prototype implementation, but also can be used to develop applications and procedure plans that can be included in the hazardous chemicals/gases disaster management cycle. Finally, the results from the World Café and AHP, which integrates the opinions and suggestions from domain experts, provide the priority and importance of the factors and problems, such as operation efficiency, mobility, visual communication interface, requirement of heterogeneous display device for analysis results, and cross-cultural user experiences evaluation. The results also provide a mechanism for verifying the prototype of product design. The conclusions of this study suggest that the integration of product design and service design, and the co-working mechanism among interdisciplinary team play very important role in the innovation design for hazardous chemicals/gases detection and analysis equipment.

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