Asking Users: A Continuous Usability Evaluation on a System Used in the Main Control Room of an Oil Refinery Plant

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ABSTRACT

This paper presents a case study that observes usability issues of a system currently used in the main control room of an oil refinery plant. Poor usability may lead to poor decision makings on a system, which in turn put thousands of lives at risk, and contributes to production loss, environmental impact and millions dollar revenue loss. Thus, a continuous usability evaluation on an existing system is necessary to ensure meeting users' expectation when they interact with the system. Seeking users' subjective opinions on the usability of a system could capture rich information and complement the respective quantitative data on how well the system is in supporting an intended activity, as well as to be used for system improvement. The objective of this survey work is to identify if there are any usability design issues in the systems used in the main control room at the plant. A set of survey questions was distributed to the control operators of the plant in which 31 operators responded. In general, results from the quantitative data suggest that respondents were pleased with the existing system. In specific, it was found that the experienced operators are more concerned with the technical functionality of the system, while the lesser experienced are towards the system interface. The respondents' subjective feedback provides evidences that strengthen the findings. These two concerns however, formed part of the overall usability requirements. Therefore, to continuously improve the usability of the systems, we strongly suggest that the system be embedded with these usability aspects into its design requirements.

Keywords: usability, evaluation, continuous improvement, decision making.

1. INTRODUCTION

Issues pertaining to user interface design are not new. It started as early as the 1960s and has evolved ever since. However, designing a user interface especially for systems in a control room is still a challenging task. Having an appropriate user interface design that includes the display and control design, console layout, communications, and most importantly, the usability of the system to be addressed by and made to help users is important in control room systems [1]. A huge amount of information needs to be presented on the screen in order for the users to monitor the system. Therefore, designers need to be careful as not to impose a cognitive workload to the users when interacting with the system. A continuous assessment on the users' performances may help in determining if such an issue exists [2]. In this case, understanding the users' subjective experience interacting with the existing system in order to capture qualitative information is necessary [3] in order to decide if any improvements are needed; hence, ensuring the usability of the system.

One important preparation before evaluating an existing system is addressing the question of what to evaluate from the system. The phrase usability and functionality as two sides of the same coin could possibly provide an answer to this issue. The usability of the system and, the requirements analysis on the functionality are two aspects in the system development lifecycle that need to be emphasized [4,5]. The evaluation should focus on a thorough approach that provides a balance between the meaning of the visualization elements that conform to the mental model of an operation, and what lies beneath these visual representations i.e. functionality from a technical engineering perspectives.

This paper attempts to examine operators' opinions when interacting with an interface design of systems used in a control room of an oil refinery. The intention is to provide a case study that emphasises on the importance of a continuous assessment. The paper includes a section on related work and follows with a survey study conducted to elicit users' opinions on the user interface design. The survey study uses both quantitative [6] and qualitative data [7,8] in evaluating an existing system [9,10]. The evaluation involves assessing the technical functionality and usability of the systems. A claim based on the study findings is suggested and discussed at the end of the paper.

2. RELATED WORK

Studies that involve evaluation of user interface design in various control room environments such as in the steel manufacturing industry [11], transportation [12], power plant [13], and refineries [12,13,14,15] have frequently been reported. Even though there are many challenges involved in the evaluation process, there is still a pattern in terms of the study focuses that could be found. Two main focuses from these studies are: those pertaining to designing for an interactive control room user interface, and applying various types of interface design into industrial applications.

Designing the user interface for control rooms is the most common topic found. In most cases, the new design is an enhancement based on existing systems after seeking for users' feedback [2]. The methods and procedures for developing the graphical user interfaces of a process control room in a steel manufacturing company have been described in Han et al.'s [11]. A phase-based approach was used in the study after modifying the existing software development procedures to emphasize the differences between the desktop tasks and control room tasks. With GUI-based human computer interface method, the users were able to monitor and control the manufacturing processes. A more explicit explanation that details out the approach when designing the user interface could be found in Begg et al.'s [13]. A combination of techniques i.e. questionnaires, interviews, knowledge elicitation techniques, familiarization with standard operating procedures, and human factors checklist was used in order to obtain the user requirements for the control system. Similar to Begg et al.'s [13] approach, Chen et al. [16] included an initial study that consists of several techniques to gather information for the user requirements. Chen et al's work is more extensive in which it involves a development and an evaluation of a user interface suitable for an Incident Management System. Although Guerlain et al. [12] mainly described how several design principles could be applied to represent data into hierarchical data layers, interviews and observations on the operators using the controllers were still conducted. A common feature found in all studies reported here is the users' subjective experience sought in order to improve the user interface design of the system.

Applying various types of interface design into industrial applications [14] is another area in user interface design for control room environments. The work reported involves applying an ecological interface design into the system, aiming towards providing information about higher-level process functions. However, the work did not involve eliciting user subjective experience as it was not within the scope of study.

Despite many enhancements on the user interface designs done based upon evaluation of the existing systems, those reported work [11,12,13,16] lacks attention on summative evaluation [17]. Such a pattern could result in lesser emphasis given on the evaluation of the whole system development life cycle; hence, not fully meeting the goal of a summative evaluation that is judging the extent to which the system met its stated goals and objectives and the extent to which its accomplishments are the result of the activities provided. In order to ensure that the usability of the system is in place, a continuous evaluation even after the deployment of a system to the company is needed. Rather than checking only on certain features of the system, such an evaluation should involve assessing the functionality as well as the usability of the interface design. Thus, summative evaluation should be performed even after beta testing and perhaps beyond the product released stage.

Recently, the way in which usability evaluation is performed by the HCI communities has been heavily criticized because at times the choice of evaluation methods is not appropriate to the situations being studied. Such a choice could be too rigid that hinders software designers from being creative in expressing their ideas; hence the designs [18]. Greenberg and Buxton in [18] suggest for a balance between objectivity and subjectivity in an evaluation. By being objective, one is seeking for assurance on the usability of the system through quantitative empirical evaluations while being subjective focuses on qualitative data that is based on users' expressed opinions. A similar argument of objectivity over subjectivity has also been raised in other design disciplines as noted in Snodgrass and Coyne [19]. The issue raised signals for a need to incorporate both quantitative and qualitative approaches during the summative evaluation.

3. SURVEY STUDY

The pattern from reported work presented in the earlier section indicates that a new system is usually developed based on the limitations found in the system currently being used. These limitations could be identified when evaluations that include some forms of a qualitative approach are used. Based on this pattern, a survey was conducted at an oil refinery in Malaysia.

The objective of the survey was to identify if there are any usability issues in the systems used in the main control room at the plant. The idea is to ensure usability and user experience goals [13] are maintained throughout the system life cycle. By asking users through a survey, an example on how both quantitative and qualitative data could complement one another could be demonstrated; hence, assisting in achieving the objective.

The target group for the survey was the panel operators at the plant. 31 operators responded to the survey. The survey questions could be divided into three parts, in which a mixture of both quantitative and qualitative questions was used to benefit from the study. Part 1 covers demographic questions regarding the panel operator's background working in the plant. Part 2 involves seeking quantitative data from the users. It investigates the usefulness of the system(s) to the panel operators (users). The questions in this part could be divided into two groups i.e.

those pertaining to the technical functionalities and, that on the usability of the system. Finally, Part 3 involves those that elicit their subjective experience when interacting with the user interface of the system(s) used in the control room.

4. RESULTS AND ANALYSIS

For easy referencing and clarity purposes, the study findings presented in this paper will follow the sequence of parts as described in Section 3. In this case, the results and analysis of findings in Part 1 that covers the demographic questions will be described in Section 4.1. Similarly, quantitative data collected from Part 2 will be presented in Section 4.2. Likewise, the qualitative data obtained in Part 3 will be discussed in Section 4.3. These findings are primarily used as a basis to justify and complement those found in Part 2.

4.1 Findings on the respondents' background

All 31 respondents were male. The average age was between 31 to 40 years old. Most of them have been working at the company for more than 10 years (Figure 1) but majority has only 1-3 years experience as panel operator (Figure 2). From this finding, 2 groups of panel operators are formed: more experienced and less experienced to represent the former and latter groups, respectively. These groupings will be analysed and referred to frequently in this paper.

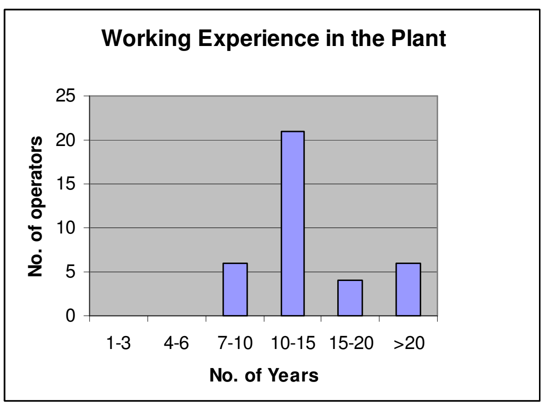

FIGURE 1: No. of years working in a plant

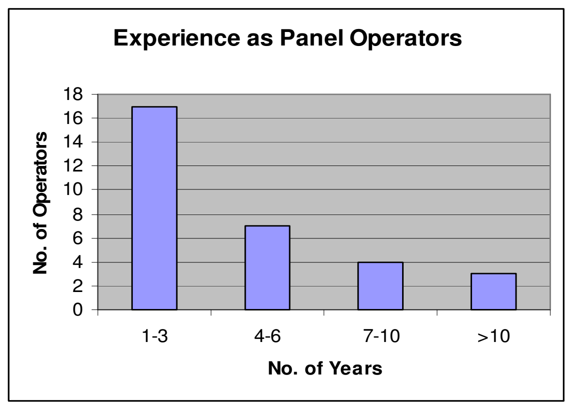

FIGURE 2: Experience as a panel operator

There are two main systems currently used to control the processes in the plant: Plant Information System (PI) and Distributed Control System (DCS). Based on the survey findings, about 90% of the respondents interact frequently with DCS while the rest with PI system.

4.2 Checking the usefulness of the existing systems – quantitative data

The usefulness of the system, mainly the DCS was initially determined based on the quantitative data collected. Each usability feature was rated by the respondents using a 5 ranking scale i.e. '1' indicates 'never', '2' is for 'almost never', '3' means 'sometimes', '4' is 'often', and '5' indicates 'always', accordingly. The study findings reveal that none of the respondents rated 'never' and very few rated 'almost never' in the survey, indicating that overall the respondents are happy with the existing system. One possible reason could be due to their familiarity interacting with the applications. This may be the only systems that they have been exposed to when working as a panel operator. Quite a number of responses were received for the 'Sometimes' category but these are not very interesting to be analysed further as they may signal a neutral view from the respondents. In this case, only those rated for 'Often' and 'Always' categories are being analysed in this study as they imply definite responses from the respondents. The summary of findings is presented in Table 1.

Element	**Usability Features**	**Frequency of rating according to years of experience**									
		Never		Almost Never		Sometimes		Often		Always	
		Less experienced	More experienced	Less experienced	More experienced	Less experienced	More experienced	Less experienced	More experienced	Less experienced	More experienced
Technical Functionality	The system provides info I was hoping for	0	0	2	1	1	3	8	6	6	4
	The system provides sufficient content for me	0	0	1	0		2	13	8	3	4
	The content of the system is presented in a useful format	0	0	1	0	1	3	9	6	6	3
							Average	**10**	**6.7**	**6.3**	**3.7**
Usability of the System	The content presentation is clear	0	0	1	1	3	1	10	9	3	3
	The system is user friendly	0	0	1	0	1	1	13	7	2	6
	The system is easy to use	0	0	1	0	1	2	10	6	4	6
	It is easy to navigate around the system	0	0	1	0	3	3	9	7	4	3
	I can easily determine where I am in the system at any given time	0	0	2	2	3	2	9	7	3	3
	The system uses consistent terms	0	0	2	1	2	1	8	8	5	4
	The system uses consistent graphics	0	0	2	1	1	2	9	8	5	3
							Average	**10**	**7.4**	**3.7**	**4**

TABLE 1: Quantitative Data Analysed

Table 1 shows the frequency of each usability feature being rated based on the respective ranking i.e. from ‘never’ until ‘always’. For each rank, a further grouping is provided to cater for respondents who have experience working as a panel operator for less than 3 years and, those that have more.

As our main concerns are on those who rated for the ‘Often’ and ‘Always’ categories, so only the highlighted columns in Table 1 will be discussed. The average values for category ‘Often’ are higher than that for ‘Always’ in both experienced and less experienced panel operators. This indicates that although the operators are satisfied with the current system, there are still some features that require improvement.

Comparing the average values in the ‘Technical Functionality’ element for experienced operators with less experience (i.e. 10 and 6.7 for ‘Often’ and ‘6.3 and ‘3.7’ for ‘Always’), we could conclude that with regards to the technical functionality of the system, those who have more experience tend to feel that the technical content is not adequate as compared to those have less experience. This is when the average values for experienced operators are lesser than the less experienced in both categories. However, this is not the case in the ‘Usability of the System’ group whereby the more experienced operators rank slightly higher (average = 4) than the less experienced (average = 3.7) in the ‘Always’ category. This could signal that the more experienced operators felt that the usability of the system is more important as compared to the lesser experienced operators. One possible reason for this pattern could be due to the familiarity aspect whereby the more experienced operators are more familiar with the system and looking for more usefulness features of the system as compared to those with lesser experienced.

When comparing the 'Often' and 'Always' columns to examine the 'Technical Functionality' and 'Usability of the System' elements, the findings from the 'Always' columns indicate that the experienced group is more concerned with the technical functionality of the system while the less experienced is on the usability of the interface. This is derived from the average value that shows a slightly lesser value for more experienced as compared to the less experienced in the 'Technical Functionality' section and vice-versa for the 'Usability of the System'.

4.3 User Subjective Experience on the Usability of the Existing Systems

The qualitative data collected from the survey is used to strengthen and provide justifications for the findings presented in Section 4.2. The subjective data were compiled, analysed, and grouped according to the common related themes. These groupings are presented as categories shown in Table 2.

Categories	*Details*
Ease of use	The current systems have met usability principles that include: • user friendly (Respondent Nos. 5, 6, 7, 12, 15, 20, 21, 24, 25, 26) • easy to learn (Respondent No. 12) • easy to control (Respondent Nos. 6, 7, 8, 13, 15, 16, 17, 18, 20, 22) • and effective (Respondent No. 14)
Interaction Styles	The touch screen provides a convenient way of interacting with the systems (Respondent Nos. 15, 17, 24).
User Requirements	The systems are functioning well and following the specifications. *"Parameters of the system is (are) mostly accurate"* (Respondent No. 14). Thus, resulted in *"achieve (achieving) greater process stability, improved product specifications and yield and to increase efficiency."* (Respondent No. 10)
Information Format	The information has been well presented in the systems. Most of the process parameters are displayed at DCS (Respondent No. 11).The users have positive feeling towards the visual information displayed on the screen. They are pleased with the trending system (Respondent Nos. 7, 21, 24), graphics (Respondent Nos. 3, 27), colour that differentiates gas, hydrocarbon, water etc. (Respondent Nos. 8, 13, 14).

TABLE 2: Subjective responses on the positive aspects

Table 2 shows four main categories that were identified from the subjective responses regarding the existing systems. The 'Ease of Use' category that refers to the usability principles and the 'Interaction Styles', mainly about interacting with the system, should be able to support the positive feedback given for the user interface design element presented in Section 4.2. On the other hand, both the 'User Requirements' and 'Information Format' categories could be a reason why the operators are happy with the content provided in the system.

4.4 Improvement for the current system

The subjective user feedback from the survey could also be used to explain the reasons for the slight differences between the more experienced operators and those with less experienced. From the previous section, it has been indicated that overall, the more experienced operators have some reservations towards the content of the system. Based on the data compiled as mentioned in Section 4.3, the subjective findings pertaining to issues raised by the respondents were analysed and categorised. These categories and their details are presented in Table 3.

Categories	*Details*
Information representation	The current systems may not be able to provide adequate information to the users; hence, they require input from other resources. *"Receive less feedback or information compared to my senior panelman."* - (Respondent No. 18) *"I receive less feedback and information compared to my senior panelman."*- (Respondent No. 5) *"Not 100% but can access at other source."*- (Respondent No. 7) Several respondents expressed their opinions to improve the information representation. Respondent No. 15 said: *"Need extra coaching about the system"* while Respondent No. 11 commented: *"During upset condition, we need SP, PU and OP trending. Add (link) PI system to DCS".*
Trending	Trend information is used to assist panel operators to monitor and control the processes in the plant. Feedbacks received pertaining to this issue are *"no trending of output in History Module of Honeywell DCS*" (Respondent #11) and the *"need to learn how to do the graphic"* (Respondent No. 15).

TABLE 3: Subjective responses on the content

From Table 3, both categories presented are related to the content of the system. With the exception of Respondent No. 5, the rest of the respondents who commented on the content have less than 3 years experience being a panel operator. This could imply that overall, majority of the respondents in the survey feel that additional features should be made available in the existing system in order to increase their work performances.

Similarly, several issues were also raised by the panel operators when interacting with the system's user interface design. The qualitative data that reveals this information is presented in Table 4.

Categories	*Details*
System Display	The black background color of the current system interfaces is causing discomfort to the users (Respondent Nos. 20, 21, 24, 25). Some of the discomfort reported includes glaring and eye fatigue. Such background color drowns down the information on the screen such as the font and color of the texts. Improvement to adjust the contrast setting (Respondent No. 24) and to *"change the screen background color"* (Respondent No. 13) are proposed.
System Design	With respect to the system design, the most frequent comments were on managing alarms (Respondent Nos. 2, 6, 10, 17, 22, 28). Whenever there are too many alarm signals, the alarm management system will malfunction (Respondent Nos. 2, 17). Users expressed their frustration when this happens (Respondent No. 10). One main concern arises when interacting with PI and DCS systems is *"so many alarms and how to manage alarm"* (Respondent No. 28). This is strengthened by another claim that says *"cannot handle repeatability alarm"* (Respondent No. 6).

TABLE 4: Subjective responses on the user interface design

Table 4 consists of 'System Display' and 'System Design' categories that are identified from comments made by a balanced mixture of panel operators from the more experienced and less experienced groups. The comments made on the user interface design in the system are mainly pertaining to the screens and interface elements (e.g. colour and font of the text). This corresponds to Ketchel and Naser [1] findings to emphasize on the importance of choosing the right color and font size for information presentation. Managing the alarm system is also an issue raised in this category. The frequency of the alarms frustrates the operators especially when the warnings are of minor importance. This issue needs addressing in order to reduce operators' cognitive workload in an oil refinery plant.

Besides the feedback received pertaining to the content, and user interface design, another important issue raised by the panel operators is mainly on the working environment. The current situation could affect the performance of the workers. Respondent No. 27 commented on the *"contrast; lack (of) light"* in the control room. Improvement on the system may be able to reduce the workers' negative moods. *"As panel man, you (are) always in (a) positive mood; you must put yourself in (a) happy/cool/strategic when you face a problem"* (Respondent No. 14). He added that so far the system is good but an improved version would be better still as panel operators could get bored if they have to interact with the same thing each time.

5. CONCLUSIONS & FUTURE WORK

The main aim of this paper is to emphasise that a continuous assessment on existing systems is necessary to maintain the system usability and at the same time examine if any improvements are required. This has been demonstrated in a case study that uses a survey to elicit comments from a group of panel operators from the main control room of an oil refinery plant. In doing so, the capability of both quantitative and qualitative data have been utilised. The combination of these two approaches benefits evaluation activities as findings from each complement the other.

The study result has suggested that although in general the panel operators are happy with the existing system in terms of its technical functionality and user interface design, there are still enhancement to be made on the system. While the more experienced panel operators are more concern about the technical functionality issues of the system, the less experienced tend to focus on the system interface. It could be argued that should both concerns are addressed the overall user requirements could be better met. This is supported from the fact that usability and functionality are two elements of equal importance in a system.

A future work could be suggested based on the issues raised from the study findings. Users' feedback indicates that "automation" of knowledge based on previous experience is necessary to assist them in their work. This could be made available by having an expert system and should be made accessible to all panel operators. Such a system may be necessary especially when most respondents in the survey have less than 3 years experience working as a panel operator. In developing the expert system, collective opinions from both experienced and lesser experienced operators is required in order to obtain a more complete set of design requirements.

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