SAFEFORM: Usability analysis of a safety-based knowledge management system

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Abstract. Globally, the prevention of falls in construction is always challenging to contracting organizations. A web-based safety knowledge management (KM) system, SAFEFORM, was developed to prevent falls during vertical formwork operations in Indian construction projects. The purpose of this study was to conduct a usability analysis for SAFEFORM using a system usability scale (SUS). Fifteen potential end users were targeted to evaluate the SAFEFORM. The results indicated that the respondents considered SAFEFORM excellent and acceptable. It is expected that the SAFEFORM could assist users in preventing falls during vertical formwork operations in Indian CPs and enhance overall safety performance.

1 Introduction

Fall from height (FFH) accounts for many accidents and injuries in the construction industry (CI; [1]). In many countries, including India [2], Malaysia [3] and Saudi Arabia [4], FFH fatalities were reported more than half of the overall construction accidents. Such accident rates result in work loss and delays in construction projects (CPs) and cause serious financial damage to the construction environment and individuals [5].

Globally, in CI, enhancing safety performance through achieving zero accidents is the current mantra [6]. Therefore, many researchers (e.g., [7]) proposed different approaches to prevent falls, but the fall rates continue to impact the CI [8]. Sanni-Anibire et al. [9] indicated that these methods were too complicated to implement in practice; hence, a straightforward, comprehensive, and practical approach is still lacking to enhance the safety performance of CI. This could be achieved by the fall risk assessment (RA) approach. RA is the critical process in CI, and all other procedures will likely fail if the RA method fails [10].

Safety planning entails recognizing and evaluating safety risks involved in construction activities and selecting effective control measures to control the impact of risks [11]. According to Celik and Gul [12], RA is a core of safety planning and needs proper planning and monitoring. In any CPs, RA is essential and usually performed by safety managers/heads [13]. An effective RA approach could reduce the number of accidents/injuries [14].

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Nevertheless, users face significant challenges, including recognizing hazards/causes of accidents, identifying the sequence of accidents, and having insufficient time to conduct the RA process [15].

Incorporating knowledge management (KM) into safety planning could eliminate the challenges related to safety in CPs [16]. According to Kamardeen [17], utilizing and transforming knowledge from different sources for continuous corporate improvement is the strategy of KM. KM is viewed to improve organizations' efficiency and competitiveness [16]. In the same line, Hallowell [18] pointed out that an effective safety KM could enhance the performance of safety in CI. India is a developing country like other regions, and CI contributes to poor safety performance [19]. The CI in India also faces challenges such as insufficient medical facilities, poor accident reporting methods, poor safety culture, and lack of implementation of safety regulation all of which contribute to the industry's poor safety culture [19]. Given the above, a web-based safety KM system, SAFEFORM, was developed for the RA process in Indian CPs to prevent falls during vertical formwork activities.

SAFEFORM is a safety-based KM tool where users can access the safety knowledge for the fall RA process focusing on preventing falls during vertical formwork operations in India. SAFEFORM contains the breakdown of formwork activities into sub-activities, risks involved in each sub-activity, causes of falls/hazards, and individuals at risk, and control measures for each sub-activity to prevent fall risks. The development of SAFEFORM can be found in [20].

One of the essential aspects that SAFEFORM must consider is user experience (UX) while interacting with the system. UX is subjective because it depends on everyone's views and opinions [21]. According to ISO ((International Organization for Standardization; [22]), UX describes the satisfaction of the users and their pleasure with a product or service as they use, see and experience it. The main goal of website creation is to provide users with a positive experience by effectively displaying useful information. This paper presents and discusses the usability analysis carried out for SAFEFORM. To answer the question of what impact the usability of SAFEFORM has from the respondents' point of view, the author proposed using the system usability scale (SUS) to evaluate SAFEFORM's usefulness.

2 Materials and methods

The usability of SAFEFORM was measured using the SUS questionnaire in the CPs in southern India.

2.1 Research object

In this study, the authors chose a web-based safety KM system, SAFEFORM, that the authors developed to prevent fall accidents/injuries during vertical formwork operations in Indian CPs. The SAFEFORM was developed using the PHP programming language. Fig. 1 shows the front end of the SAFEFORM.

In the front end, the SAFEFORM describes the overview of the system, publications related to SAFEFORM, safety regulations and safety practices for vertical formwork operations, how to use SAFEFORM, and accident statistics of formwork activities. The user can start performing the fall RA by clicking the assess risk tab on the front end. The user should start performing the fall RA by entering the project details and mail IDs (see Fig. 2)
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![Fig. 2. The page display of fall RA.](image2)

![Fig. 3. The page display of trade (wall/column) for vertical formwork activities.](image3)
Once the users enter the RA page, they can start selecting the trade for which they want to perform fall RA. At this stage, the user can select the activity involved in any trade. For instance, Fig. 3 shows the vertical formwork activity "panel erection" under the trade "column." Once the activity is selected, the causes of falls/hazards involved will be visualized along with the individuals who might be harmed during that activity. The user must choose the height of work to be carried out and select the appropriate control measures from the list that will be already visualized in SAFEFORM. Once the user finishes performing RA, the entire result will be displayed on the final page (see Fig. 4). Here the user can modify the list of activities by adding or rejecting them. The user can finally generate the worksheet and printing option and forward it to the management team for approval.

Fig. 4. The page display of RA results.

2.2 Questionnaire design

In 1986, John Brooke developed SUS, which has been used to measure usability in many studies [23] due to its effectiveness. SUS is a questionnaire with ten statements on a Likert scale that provides views on the usability of the products or services.

2.3 Target users and participants

To measure the usability of SAFEFORM, 20 random potential end-users were contacted. Among these, 15 were accepted to participate in the study, which was an adequate sample as recommended by [17] for the usability study. The users carried out a live demonstration and they were asked to fill out the SUS questionnaire in which they would be able to express their thoughts on various systems aspects. Along with this, users were also asked to indicate their designation, experience in construction safety, and educational background. Safety managers/heads were targeted as they are the ones who perform fall RA in CPs.

2.4 Data analysis and processing

Once the data was collected, data were analyzed according to SUS rules as follows [24]:

a. For odd number statements, each question score is calculated by subtracting one from the user score.
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a. For odd number statements, each question score is calculated by subtracting one from the user score.

b. For even number statements, each question final score is calculated by deducting its user score from 5.

c. To determine the SUS score, the outcome of each question's score addition is multiplied by 2.5.

\[
\text{SUS score} = ((Q1-1) + (5-Q2) + (Q3-1) + (5-Q4) + (Q5-1) + (5-Q6) + (Q7-1) + (5-Q8) + (Q9-1) + (5-Q10)) \times 2.5
\]

The category of the final SUS score was determined in the evaluation process using the SUS score scale (see Fig. 5). Following the final SUS score calculation, the SUS score scale will show whether the system falls inside the acceptable category or not based on percentile ranks, grades, adjectives, acceptability, and promoters and detractors [25]. Overall, the system is acceptable if the mean score of SUS is higher than 70 [26].

3 Results and discussion

3.1 Respondents' characteristics

Table 3 shows the complete participant's background. Out of 15 respondents, most of them were safety heads (60%), followed by safety managers (27%) and safety officers (13%). Most of the respondents were undergraduate degree holders (47%), and all the respondents' experience in RA ranges from ten to twenty-four. The participant's level of safety competency in Table 1 indicates that they had sufficient knowledge and expertise to evaluate the proposed system.
Table 1. User’s characteristics.

<table>
<thead>
<tr>
<th>Study variables</th>
<th>Highest level of qualification</th>
<th>Work experience (in years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Undergraduate degree</td>
<td>Postgraduate degree</td>
</tr>
<tr>
<td></td>
<td>7 (47%)</td>
<td>3 (20%)</td>
</tr>
<tr>
<td></td>
<td>Diploma</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 (33%)</td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>15.2 (4.2)</td>
<td>Range</td>
</tr>
<tr>
<td>Range</td>
<td>10-24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Safety manager</td>
<td>Safety officer</td>
</tr>
<tr>
<td></td>
<td>4 (27%)</td>
<td>2 (13%)</td>
</tr>
<tr>
<td></td>
<td>Safety head</td>
<td>9 (60%)</td>
</tr>
</tbody>
</table>

3.2 SUS score for SAFEFORM

Usability testing was carried out in this study to determine how effective, efficient, and satisfied the users were with SAFEFORM. This test aimed to measure users' satisfaction with the systems' use. Usability testing could assist designers in determining if the designed system or product is in line with users' demands or not [27].

SUS is a comprehensive evaluation of usability factors (effectiveness, efficiency, and satisfaction) as users subjectively feel them. The SUS score could indicate the user's acceptability range. Brook [26] states that a mean SUS score greater than 70 is deemed acceptable. The average SUS score obtained for SAFEFORM was 82.16 after calculating the data according to the rules of calculating SUS score. The SUS score for SAFEFORM is indicated in the SUS scale (see Fig. 6).

![SUS score for SAFEFORM](image)

Fig. 6. SUS score for SAFEFORM.

Sauro [25] described the SUS score category. The SUS score can be interpreted in five ways: percentile ranks, grade, adjectives, acceptability, and promoters and detractors.

The obtained SUS score was converted into grades and percentile ranks. The grade reflects the usability rate from A+ (superior performance) to F (failed performance). In contrast, percentile ranks visualize the usability rate as a percentage (%) [28]. The SAFEFORMs' SUS score, i.e., 82.16, was compared with the grade scale, and the grade score was in grade A. The SUS score that falls within the percentile range is the percentile score. Accordingly, a SUS score above 68 is considered above average, whereas a score below 68 is considered below normal [25]. According to the SAFEFORMs' SUS score, the percentile range was between 90 to 95. The obtained SUS score was above average in both grade and percentile ranks.

The adjective scale includes best imaginable – excellent – good – ok – poor - worst imaginable. According to Sauro [25], a SUS score above 80.7 is excellent. As SAFEFORMs' SUS score was more than 80.7, the usability of SAFEFORM, according to respondents, was
excellent. Acceptability is the fourth way of describing SUS. The SUS score is categorized as acceptable if the SUS score is greater than 71 [29]. The SUS score for SAFEFORM was higher than 71 and categorized as acceptable.

SUS and Net Promoter Score (NPS) are strongly and consistently correlated. The range between 30% and 50% in users' likelihood to suggest the application is described by the average SUS. According to Sauro [25], the NPS classifies recommenders into three categories: promoter (if SUS score is higher than 78.8), passive (if the SUS score is above 62.6), and detractor (if SUS score ranges between 0 and 62.6). The relationship between NPS and SUS is shown in Fig. 6, and it is evident that the SAFEFORMs' SUS score, 82, falls into the promoter category. The detractor classification is less likely to recommend a system or product to a friend and the promoter classification is more likely to do so (Derisma, 2020). As a result, the study's respondents were recognized as some of the first to promote the SAFEFORM.

4 Conclusion

A web-based KM system, SAFEFORM, was developed to improve safety performance to prevent falls during vertical formwork operations in Indian CPs. This study conducted the usability analysis using a SUS for SAFEFORM with fifteen potential end-users. The results show that the average SUS score for SAFEFORM was 82.16. The interpretation of the results indicated that the obtained SUS score was in grade A and the percentile range was between 90 and 95. These findings show that the respondents believed the SAFEFORM was excellent and acceptable. Respondents also act as early promoters when seen in the context of the NPS category. Overall, it is expected that the SAFEFORM could assist users in preventing falls during vertical formwork operations and enhance the overall safety performance of construction organizations.

References


