

A Hybrid Approach to User Interface Design: Integrating DT and QFD with Usability Evaluation in a Detection-Based Classification System for the Sugarcane Industry

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ABSTRACT

Quality User Interface (UI) and User Experience (UX) design are crucial for web system success, as poor design can hinder information retrieval and cause miscommunication. To address this challenge within a specific industrial setting, this study presents a detailed case study on the design and development of an intranet web system for a sugarcane processing company. A combined methodology of Design Thinking (DT) and Quality Function Deployment (QFD) was applied to capture user needs and translate them into a functional, user-centered UI/UX design. The design process involved iterative prototyping and continuous user feedback. Evaluation of the prototype using the System Usability Scale (SUS) resulted in a score of 85, classified as "excellent". These findings demonstrate that integrating DT and QFD substantially enhances UI/UX design effectiveness. The findings from this case study offer practical blueprints and valuable insights for practitioners aiming to implement similar user-centered design projects, particularly within the agroindustry sector or other comparable contexts.

Keywords-user interface; user experience; Design Thinking (DT); Quality Function Deployment (QFD); System Usability Scale (SUS); usability

I. INTRODUCTION

User Interface (UI) and User Experience (UX) are fundamental components of front-end web services. A well-designed UI that provides a clear and effective UX is increasingly regarded as a critical dimension of software quality and a key determinant of application success [1, 2]. Consequently, effective UI development must prioritize UX by thoroughly analyzing and addressing user needs and perspectives.

The Design Thinking (DT) approach has emerged as a widely adopted and effective method in UI/UX development [3]. As a user-centered methodology, it places users at the core of the system development process [4], helping design teams empathize with users, define existing problems, and engage in ideation to generate creative solutions tailored to real user needs [5]. Authors in [6] demonstrated that applying DT in UI development enables more accurate identification of user needs and supports prototype testing aligned with software quality standards.

Authors in [7] attempted to enhance this process by integrating Quality Function Deployment (QFD) with DT, thereby improving system effectiveness. QFD can translate user desires and expectations into measurable design elements, reducing design errors and increasing user satisfaction [8, 9]. Authors in [9] emphasized the role of QFD in systematically mapping user requirements to UI elements, while authors in [10] showed that implementing QFD in the UI design of digital twin Prognostics and Health Management (PHM) systems improved interaction quality and delivered a more intuitive UX.

As the quality of UI design directly affects system usability and overall success [11], failure to meet UI requirements often results in difficulties in information retrieval and miscommunication among users [12]. In the sugarcane processing industry, for example, inefficiencies in classification processes have arisen due to the lack of user-friendly interfaces, as operators face challenges when recording and classifying data, when the interface fails to present real-time information across workers. These problems are compounded by reliance on manual reporting, which frequently leads to miscommunication between operators, particularly in suboptimal working environments. Previous studies have shown that similar challenges in other industries have been successfully addressed using DT to improve comfort, efficiency, visual appeal, functionality, and overall user-friendliness [13, 14].

In response to these challenges, this study focuses on designing a website-based intranet sugarcane detection system UI/UX, combining DT as the foundation for user needs analysis with QFD to reinforce the ideation process and ensure systematic translation into design specifications. This integration aims to produce a UI/UX that enables accurate, efficient, and effective sugarcane classification, while improving communication among field operators. To evaluate whether the UI/UX meets user expectations, the System Usability Scale (SUS) was applied. The SUS is a widely used standardized instrument for measuring perceived usability [15,

16] and has been validated as a reliable tool for assessing product and system quality [17, 18].

According to previous studies, employing only QFD [19] often fails to produce highly usable designs due to the lack of early user requirement analysis. Similarly, approaches that rely solely on SUS for evaluation [11, 15, 18, 20] emphasize quantitative usability metrics but often neglect deeper insights into user needs. While the combined use of DT and SUS has been reported frequently [14, 21, 22] and shown potential for producing user-centered designs, further improvements are possible by incorporating a structured and measurable method such as QFD. Based on the literature review (Table I), no prior studies have fully integrated DT, QFD, and SUS in a single framework to improve UI/UX usability. Therefore, this study aimed to bridge this gap.

II. METHODOLOGY AND RESULTS

This study adopts a methodological framework that integrates DT with QFD and employs the SUS for evaluation, as illustrated in Figure 1. DT emphasizes a user-centered perspective, providing a solution-oriented framework to address user-related issues. The method encompasses five stages: empathizing, defining, ideating, prototyping, and testing. During the ideation stage, a QFD approach was incorporated to identify user requirements comprehensively, combining qualitative insights from the defining stage with quantitative analysis derived from the House of Quality (HoQ). In the testing phase, the SUS was applied to evaluate whether the developed prototype adequately addressed user needs.

A. Empathize

Data collection was conducted through in-depth interviews with five respondents, comprising three system operators and two management representatives. The collected data were used to develop user personas, which served as the foundation for designing the sugarcane detection system interface within the DT methodology.

Interview results revealed the respondents' problems, experiences, and expectations, which were synthesized into two user personas representing operator and management perspectives. User Persona 1 emphasizes the need for a simple, efficient, and highly user-friendly UI/UX with intuitive access and clear data visualization to support rapid and accurate field operations. User Persona 2 highlights the need for quick and efficient data access and comprehension. Collectively, both personas underscore the importance of an efficient, accessible, and easy-to-use UI/UX design.

B. Define

In this phase, the problems identified during the empathize stage were analyzed using empathy mapping, which considers what users say (Says), think (Think), do (Do), and feel (Feel) when addressing challenges in sugarcane quality classification [23]. The mapping was conducted twice, corresponding to the number of predefined respondents.

From the "Say" and "Think" mapping, users indicated the need for a clear, simple, and visually appealing interface that employs easily understandable icons and color schemes. For

accessibility, users emphasized the importance of quick, real-time data retrieval, including access to historical data and the ability to export reports in PDF or Excel format. They also

stressed the need for seamless data integration between operators and management to prevent discrepancies.

TABLE I. OVERVIEW OF RELATED UI/UX STUDIES

Ref.	Description	Method	Limitation
[11]	Usability testing of an e-Health application, with 31% of users reporting improvements through iterative SUS-based development.	SUS	Without DT integration, early user needs were insufficiently captured, reducing UI/UX effectiveness.
[13]	UI/UX design for a financial application using DT to ensure alignment with user needs and preferences.	DT	DT was applied, but the approach lacked measurable and clearly defined technical specifications.
[14]	UI/UX design for a company's official website to produce an attractive and user-friendly site, evaluated using SUS.	DT, SUS	DT lacks a systematic method to translate user needs into technical specifications.
[15]	Development and testing of inclusive and adaptive UI/UX to enhance UX and satisfaction.	Adaptive UI based on Semantic Technology, SUS	Evaluation focused on usability but lacked early-stage user needs analysis.
[18]	Usability testing in the educational context is employed to maintain system quality and enhance user satisfaction.	SUS	The study has only conducted system evaluation and has not yet undertaken development using a user-centered approach.
[19]	Quality improvement study using QFD in a ceramic tile factory case to enhance product quality and sales.	QFD	QFD was applied without early identification of user needs, limiting its effectiveness in UI/UX improvement.
[20]	Usability testing in health informatics highlights the need for valid and effective evaluation methods.	SUS	Evaluation emphasized quantitative usability but lacked qualitative insights into user needs and specifications.
[21]	UI/UX design for an e-learning application using DT and SUS to measure user satisfaction.	DT, SUS	Although DT helped identify user needs, it was not supported by a structured translation into technical design, potentially limiting the quality of the results.
[22]	DT applied as an innovative method to address user needs and health sector problems.	DT	Lacked a systematic approach to translate user needs into measurable design specifications, especially regarding usability.

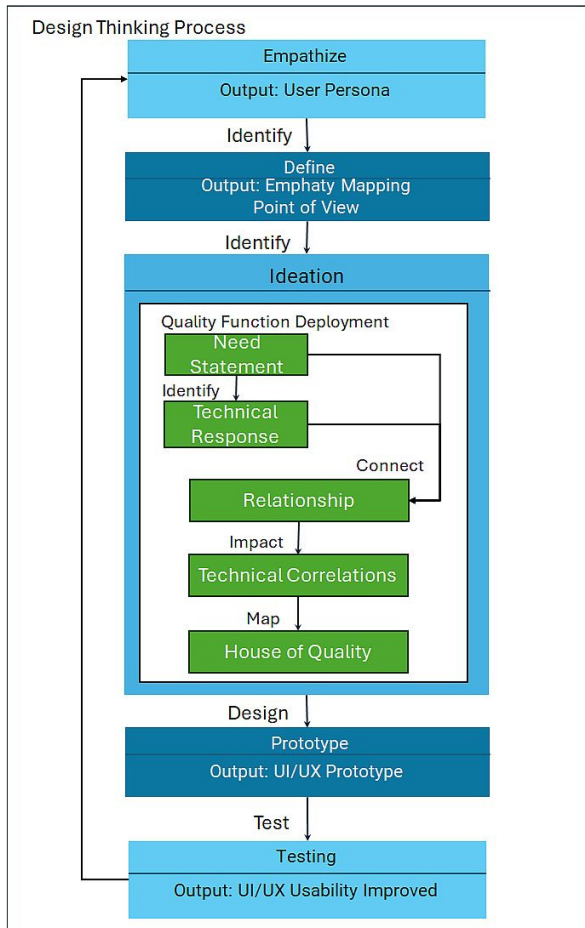


Fig. 1. Combined DT and QFD process for UI/UX improvement.

From the "Do" mapping, users were found to frequently perform product quality classification, consult colleagues or supervisors in uncertain cases, and monitor classification results for evaluation and auditing. Finally, the "Feel" mapping revealed user frustration and confusion when classification criteria lacked visual clarity or when data were difficult to access. Conversely, users reported satisfaction when the system presented data quickly, clearly, and intuitively. After data classification, conclusions were drawn to identify pain points and personal gains (Table II). The pain points revealed issues with the existing UI/UX, while the gains highlighted desired improvements, forming the foundation for development.

TABLE II. PAINS AND GAINS IDENTIFICATION

Pain (Existing UI/UX)	Gain (Suggested improvements)
Absence of visual indicators such as icons or quality labels.	Availability of visual indicators and a simple interface with large buttons, contrasting colors, and clear fonts.
Non-user-friendly interface; small fonts and complex layout.	Easy-to-read, user-friendly interface enabling faster classification.
Operators must guess sugarcane quality due to a lack of reference indicators.	Availability of visual criteria supporting classification and supervision.
Difficulty accessing scattered, non-integrated data.	Integrated, easily accessible historical data, viewable and downloadable.
Dense, text-heavy, and unattractive interface.	Clear, structured display with icons that enhance usability.
Classification errors due to a lack of visual references.	System-assisted classification through visual indicators.

Based on this analysis, a point of view (POV) was derived to map user needs in detail and ensure relevant solutions. Operators required visual quality labels with large buttons, contrasting colors, and legible fonts, as they often work in field environments where speed and accuracy are critical. They also

required searchable, downloadable historical records to track sugarcane quality over time, and real-time data synchronization to minimize errors caused by unsynchronized information.

Management required a display that integrates the entire classification process, including visual labels, graphical results, and downloadable historical data. They also needed structured real-time access with limited access rights to preserve data integrity. Visual indicators are equally essential to ensure a shared classification framework between operators and management, reducing miscommunication and improving quality management effectiveness.

C. Ideate

At this stage, researchers formulated design solutions based on the problems identified in the define phase. QFD was used to systematically translate user needs into technical specifications through the following five steps:

1) Identification of Needs Statement

Need statements were extracted from interviews and empathy mapping and are presented in Table III.

TABLE III. NEED STATEMENT IDENTIFICATION

Variable	Need Statement
V1	The website includes visual quality label display.
V2	The website uses large buttons.
V3	The website applies contrasting colors.
V4	The website uses readable fonts.
V5	The website is easy to operate.
V6	The website provides historical data storage.
V7	The website allows data download.
V8	Website synchronizes data.
V9	The website includes input fields.
V10	The website provides real-time access.
V11	The website includes access control features.
V12	The website displays graphical results.
V13	The website supports Closed-Circuit Television (CCTV) display.

2) Create Technical Response

Technical responses with measurable parameters were defined to explain how product attributes could be fulfilled. At this stage, the researcher relied on both literature review findings and direct observations. The resulting technical responses are presented in Table IV.

3) Determine Relationship

The next step involved mapping the relationships between product attributes and technical responses and assigning values to reflect the strength of each relationship.

As illustrated in Figure 2, the use of a readable font (V4) shows a strong relationship with the implementation of sans-serif fonts. This choice significantly improves text readability. A moderate relationship was identified between historical data storage (V6) and export features (Excel and PDF). Although data export is a distinct function, it directly enhances the usability and management of stored data. Conversely, the ease of operation (V5) demonstrated only a weak relationship with color-contrast ratios, suggesting that while contrast contributes

to visual comfort and navigation, it is not a primary determinant of overall usability.

TABLE IV. CONNECTING USER NEEDS TO TECHNICAL RESPONSES IN UI/UX DESIGN

Need Statement	Technical Response
The website includes visual quality label display.	Sugarcane quality criteria (from in-depth interview).
The website uses large buttons.	The appropriate button size [24].
The website applies contrasting colors.	The use of the right color contrast ratio [25].
The website uses readable fonts.	Use of sans-serif font [26].
The website is easy to operate.	Organized webpage layout [27]; attractive and user-friendly design [28]; appropriate button size [24]; sans-serif font [26].
The website provides historical data storage.	Storing classified data with timestamps [29].
The website allows data download.	Excel and PDF export features (in-depth interview).
Website synchronizes data.	Synchronized web (in-depth interview).
The website includes input fields.	Availability of input forms [30].
The website provides real-time access.	Live update feature (in-depth interview).
The website includes access control features.	Use of authentication [31]; login via email [32].
The website displays graphical results.	Visualization using a chart [33].
The website supports CCTV display.	The availability of CCTV display (in-depth interview).

4) Determine Technical Correlations

Figure 2 also illustrates the technical correlations derived from systematically linking user needs to technical responses. The results indicate that combining sans-serif fonts with an orderly webpage layout provides a moderate positive effect: sans-serif fonts enhance text clarity, while layout consistency improves visual organization. However, the impact of layout organization alone was found to be strongly positive, as a structured and consistent design greatly enhances intuitiveness, navigation, and visual appeal. Thus, webpage layout organization was identified as a primary determinant of both usability and aesthetic quality.

5) House of Quality (HoQ)

At this stage, the HoQ is created by integrating product attributes, technical responses, relationships, and technical correlations to determine the priority of the specifications that serve as the main focus in designing the interface of the sugarcane detection system. The planning matrix was intentionally omitted, as the study focused on fulfilling the needs of the company’s internal users rather than benchmarking against competitors. This decision aligns with the study in [34], which emphasized that QFD is adaptable to project-specific contexts. By concentrating on internal user requirements, the HoQ eliminated the need for priority weighting based on external benchmarking. Instead, it directly prioritized specifications derived from user needs and technical responses. These specifications then served as the foundation for developing the prototype of the sugarcane detection system interface.

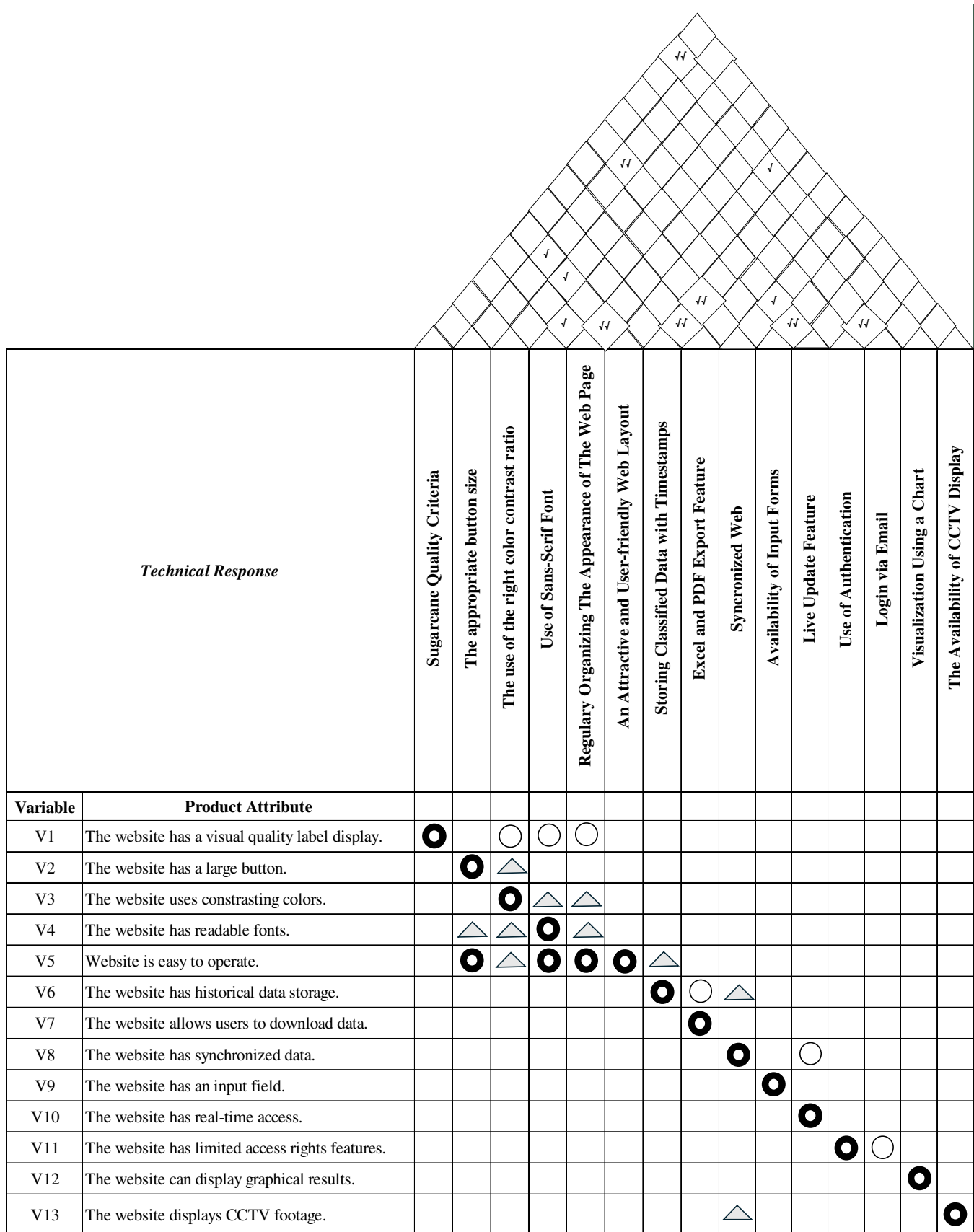


Fig. 2. HoQ: A matrix of product attributes, technical responses, and their correlations.

D. Prototype

In the design stage of the sugarcane detection system, the prototype was developed to align with the identified needs and preferences of end-users. The design process followed a structured sequence beginning with the delineation of user flow, followed by the construction of wireframes, and culminating in the creation of high-fidelity prototypes. Figma was employed as the primary tool for both low- and high-fidelity designs.

1) Wireframe (Low-Fidelity Prototype)

The wireframe represents an initial schematic design of the website, outlining the page layout and core functional elements in accordance with the defined product attributes. Figure 3 illustrates an example of a wireframe presented to management, which incorporates key features such as graphical data visualization, historical data summaries, and options for downloading and exporting reports.

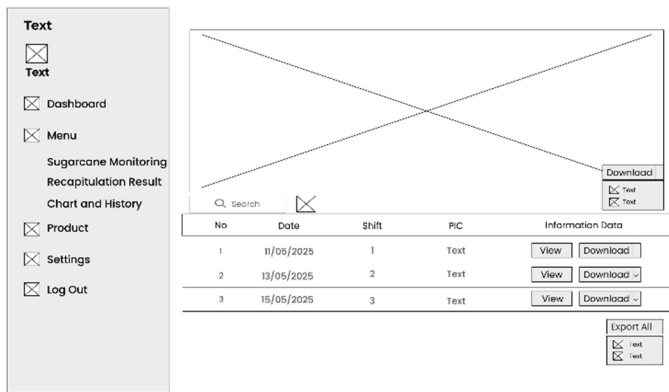


Fig. 3. Low-fidelity wireframe concept.

2) High-Fidelity Prototype

The high-fidelity prototype extends the wireframe by integrating design elements such as colors, typography, and graphical details to illustrate the intended final interface. Figure 4 presents an example of the high-fidelity prototype, showing a page that includes a trend graph of sugarcane quality over time as well as a tabular summary of historical classification data input by operators.

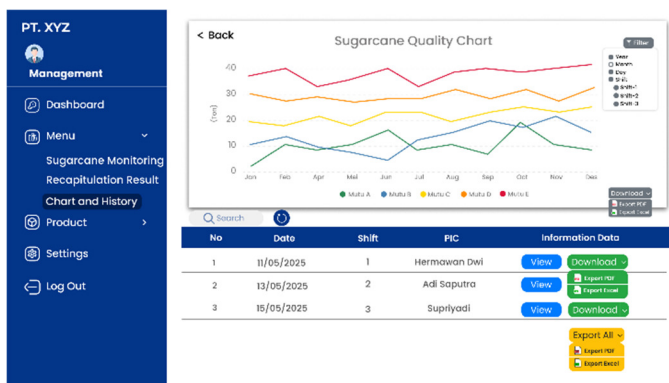


Fig. 4. High-fidelity wireframe concept.

E. Testing

The prototype was verified and evaluated to determine its usability and alignment with user requirements. Verification was conducted by ensuring that the defined product attributes were incorporated into the prototype. For instance, Figure 5 demonstrates the implementation of the attribute "large buttons," integrated into the dashboard interface to enhance ease of use.

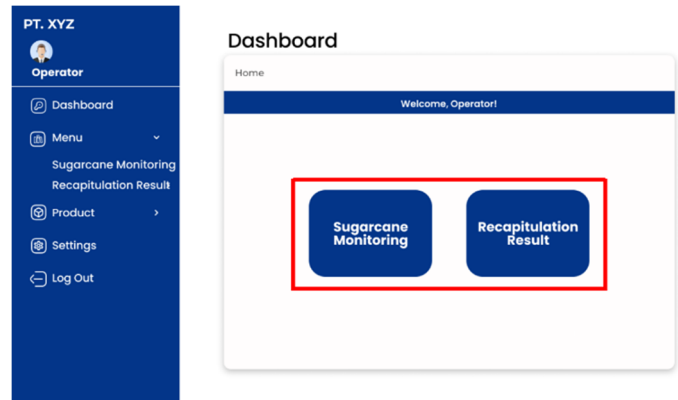


Fig. 5. The sugarcane detection system interface proof-of-concept.

Subsequently, usability evaluation was conducted with expert involvement. In this study, an expert was defined as an individual between the ages of 21 and 55 with experience in UI/UX design or formal certification in the field. To strengthen validity, the evaluation also included representative end-users of the system. Following the sampling strategy proposed in [35], four participants were recruited: two expert evaluators and two intended system users.

The evaluation employed the SUS, a widely recognized standardized instrument for measuring perceived usability [36, 37]. A questionnaire consisting of 10 items was distributed, and participants rated their level of agreement using a 5-point Likert scale. The study received approval from the Research Committee of Telkom University (Approval No. 374/LIT06/PPM-LIT/2024). Written informed consent was obtained from all participants before data collection, and participation was entirely voluntary with full disclosure of the research objectives and procedures.

TABLE V. SUS SCORES AND FINAL EVALUATION

Question	R1	R2	R3	R4
Q1	5	4	5	5
Q2	1	1	2	1
Q3	5	5	5	4
Q4	2	1	2	1
Q5	4	4	4	5
Q6	3	1	1	2
Q7	4	4	3	4
Q8	1	2	1	1
Q9	5	4	4	5
Q10	2	1	2	1
Raw Score	34	35	33	37
Final Score	85	87.5	82.5	92.5
Mean SUS Score	86.88			

The resulting mean SUS score was 86.88, corresponding to the "excellent" category (Category B) as classified by authors in [38]. This outcome demonstrates that the prototype meets high usability standards and effectively addresses the needs of both operators and management.

It is important to note that the scope of this study was limited to the UI design of the sugarcane detection system. The research did not include the development of backend data processing algorithms or full-scale implementation. Furthermore, no competitive benchmarking analysis was performed, as the primary objective was to address specific user challenges within the organization.

III. CONCLUSION

This study demonstrates that the integration of Design Thinking (DT) and Quality Function Deployment (QFD) offers a systematic and user-centered approach to User Interface/User Experience (UI/UX) development, particularly within the context of an intranet web system for a sugarcane processing company. By combining DT's ability to capture deep insights into user needs with QFD's structured translation of these needs into technical specifications, the design process ensured that usability was prioritized throughout the prototype development cycle.

The evaluation results, as measured by the System Usability Scale (SUS), yielded a mean score of 86.88, which is categorized as "excellent". This outcome confirms that the designed prototype successfully addressed the usability challenges identified during the requirement analysis phase. Moreover, the results validate the effectiveness of employing DT and QFD in tandem, not only for understanding user perspectives but also for systematically translating them into actionable design attributes.

The contribution of this study lies in providing a practical blueprint for enhancing UI/UX usability within organizational environments, particularly in the agroindustry sector. The findings extend beyond the specific case study by offering valuable methodological insights for researchers and practitioners who aim to implement user-centered design strategies in similar contexts. Future work may expand this research by incorporating backend system development, comparative benchmarking with alternative design approaches, and larger-scale usability testing to further validate the generalizability of the results.

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