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Design solution for weighbridge application system using user-centered design toward green digital transformation

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Abstract
Digital transformation in the palm oil industry requires reliable and user-friendly systems to ensure accurate data recording and efficient operational workflows. As a critical control point within the supply chain, the weighbridge system plays a central role in verifying Tandan Buah Segar (TBS) transactions and maintaining traceable production data. However, the desktop-based weighbridge system that has been in use since 2012 still faces several usability limitations, including non-adaptive input fields, inconsistent navigation, and manual calculations that increase the risk of operational errors. Therefore, this study aims to redesign and evaluate the weighbridge system interface to improve input accuracy, reduce operator cognitive load, and support sustainable digital operations. This research applies the User-Centered Design (UCD) methodology to redesign the weighbridge system interface through four iterative stages: identifying user needs, designing alternatives, developing interactive prototypes, and evaluating usability. Data were collected through field observations, interviews, document analysis, and questionnaires. The redesigned interface resulted in a prototype capable of presenting contextual input fields, automating the calculation of average bunch weight (BJR), and streamlining workflow processes. The prototype was evaluated using Nielsen's Heuristic Evaluation method and achieved a usability score of 89.89%, categorized as Very Attractive. Which means that the majority of evaluators have a positive view of the mobile-based weighbridge system prototype design. The results indicate that UCD effectively enhances efficiency, reduces user errors, and supports sustainable digital operations by minimizing paper-based processes and process optimization.

Keywords
User-Centered Design (UCD), Weighbridge application system, Heuristic evaluation, Green digital, Design solution

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Introduction

Digital transformation has become a major focus of research across various industrial sectors, including plantation and agricultural industries. In the palm oil sector, the integration of digital technologies is regarded as a key driver for enhancing operational transparency, data accuracy, and the implementation of sustainable production practices. One of the most critical components in the palm oil supply chain is the weighbridge system, which functions to verify incoming and outgoing load volumes while simultaneously providing integrated data for production and distribution processes. Accurate data management at these critical points in the supply chain is fundamental to the success of digitalization in the palm oil industry [1].

In practical operations, weighbridge systems are used to ensure that Fresh Fruit Bunch/ Tandan Buah Segar (TBS) harvest data are recorded accurately and can be seamlessly integrated into the company's information system. Modern weighbridge systems are designed to support automated data management to reduce manual recording errors and enable data-driven decision-making. Despite the adoption of digital technologies, several challenges remain in field implementation. This is evident in the desktop-based weighbridge system used by PT Hasnur Informasi Teknologi since 2012, where the weighing process is often performed manually due to weighbridge hardware that does not always operate optimally. This condition increases the risk of recording errors, particularly in input forms that lack flexibility in accommodating various product categories, as well as the potential for inaccurate BJR (Berat jenjang rata-rata/ Average Bunch Weight) calculations when operators forget to click the "Hitung" button to update the BJR values.

Previous studies have attempted to modernize weighbridge systems, with many focusing on developing IoT-based automation to improve measurement accuracy and reduce manual interaction [2]. Other studies have emphasized secure and verified systems, evolving from unattended weighbridge systems that rely heavily on precise automated data [3]. While these approaches contribute to improving technical performance, most research pays limited attention to user experience (UX), even though operational interfaces play a significant role in the success of industrial digitalization [4]. Moreover, weighbridge systems that overlook human interaction aspects tend to result in operational errors, even when equipped with advanced sensor technologies [5].

In weighbridge environments, operators must input data quickly, accurately, and repeatedly, often under non-ideal environmental conditions. Workflow complexity, variations in product categories, and unintuitive interface designs can increase operators' cognitive load and trigger operational errors. Valentini et al. highlight that industrial interface designs that ignore user context often lead to low system adoption and degraded data quality [6].

Until now, research addressing comprehensive interface design aspects in palm oil weighbridge systems remains very limited. Most studies focus on sensors or automation technologies without understanding the needs and behavior of operators as primary users. This creates a significant research gap: the need for a design approach that not only improves system functionality but also ensures that interfaces genuinely support fast, accurate, and low-error field operations. To address this need, this study applies the User-Centered Design (UCD) method to redesign the digital weighbridge system interface in the palm oil industry. UCD enables contextual identification of user needs, followed by the development of interactive prototypes and heuristic evaluation to validate the resulting design. This method ensures that the designed interface meets user needs [7] while improving the effectiveness and efficiency [8] of the weighbridge system. Designing for frontline operators is crucial to ensure that the system adapts to varying work conditions, enhances system acceptance, and minimizes operational errors. Beyond improving usability, this approach aligns with digital sustainability goals, including improve resource efficiency, and reduce waste through optimized processes and digital traceability [9] as part of green digital transformation.

The main objective of this study is to redesign and evaluate a weighbridge system interface that can improve input accuracy, reduce operator cognitive load, and support sustainable digital operations. Through the application of UCD and empirical validation, this research is expected to provide tangible contributions to improving the quality of information systems in the palm oil industry while addressing gaps in prior research that have not fully integrated human-centered and sustainability considerations into weighbridge system design.

Method

This research was conducted at PT Hasnur Informasi Teknologi (HIT), located in Banjarbaru Indonesia, an IT consulting company established on 2011. One of the services offered by HIT is the development of a Weighbridge System Program. This system has been developed since 2012 using a traditional desktop-based conceptual design and still faces several operational limitations in real field conditions. The method used in this study is the User-Centered Design (UCD) approach to redesign the digital weighbridge system interface for the palm oil industry. UCD was selected because it places users at the core of the design process, enabling the development of solutions that align with operational needs, fieldwork patterns, and contextual challenges faced by operators. The UCD process in this study consists of four iterative stages: (1) identifying requirements, (2) designing alternatives, (3) making prototypes, and (4) evaluating. Each stage is detailed to ensure that the resulting design truly aligns with user needs and the operational context, as described below:

1. Identifying requirements. The first stage begins by understanding the system's usage context. Several techniques were used for data collection, including direct observation at the weighbridge area, interviews with HIT's Functional Analyst,

document analysis, and questionnaires. Observations involved examining inbound and outbound weighing workflows, user interactions with both software and hardware, environmental conditions, and any barriers affecting data entry speed and accuracy. The interviews provided deeper insights into user interaction patterns, difficulties experienced with the previous interface, and efficiency needs within the weighing process. Document analysis supported the investigation by reviewing materials such as error correction requests sent via email, data correction reports, and other operational records. Questionnaires were used to evaluate the current system and conduct usability testing of the proposed prototype. This stage yielded a complete list of user needs, task analysis, and success criteria that formed the foundation for the interface redesign.

2. Designing alternatives. In this stage, interface designs were developed based on the identified requirements. The process involved ideation sessions with operators and the technical team to generate potential design solutions, such as simplifying workflows, optimizing input form layouts, grouping information based on product categories, and reducing manual input requirements such as through automated BJR calculation. These alternative designs were then translated into user flows and wireframes to map out navigation and interactions more clearly. At this point, an initial design system was also created, including interface components, layouts, color schemes, and iconography to ensure visual consistency and accessibility.
3. Making prototypes. The third stage focused on developing interactive prototypes with increasing levels of fidelity. Low-fidelity prototypes were created first to test workflow structure, conditional display logic, input validation, and automated mechanisms such as BJR calculation. After receiving initial feedback, a high-fidelity prototype was developed using realistic data, near-final visual design, and simulations of field conditions such as network disruptions or sensor reading errors. These prototypes enabled more accurate testing of the designed interface and helped the technical team visualize implementation specifications.
4. Evaluating. The final stage involved evaluating the design using the heuristic evaluation method to quantitatively assess its effectiveness. The heuristic evaluation was conducted by usability experts using Nielsen's ten usability principles to identify major interface issues. Heuristic Evaluation is recognized as an effective and efficient usability evaluation method within UCD, as it can identify numerous interface issues before the system is tested by actual users. Systematic use of Heuristic Evaluation in UI/UX design can predict potential usability problems and support the development of designs that better meet user needs [10]. The evaluation was carried out by distributing questionnaires containing statements related to the ten heuristic principles.

To validate the redesigned system is greener than the conventional system, this research proposes quantifiable sustainability indicators aligned with Green transformation for sustainable information systems principles [11], namely:

1. Error minimization is assessed through the decrease in documented input errors and data correction reports, which reduces administrative waste and redundant processing.
2. Transaction efficiency is evaluated by comparing the average weighing processing time before and after redesign, as shorter processing time contributes to lower vehicle idle duration and indirect energy savings.
3. Process optimization is measured by the reduction in repeated transactions caused by inaccurate data entry

These indicators provide a structured validation framework demonstrating that the UCD-based redesign contributes not only to usability improvement but also to measurable environmental sustainability outcomes consistent with Green IT principles.

Results and Discussion

Identifying requirements

The requirements identification stage was carried out to understand the operational challenges of the weighbridge system that has been used since 2012. The interface of existing weighbridge system is shown in Figure 1.

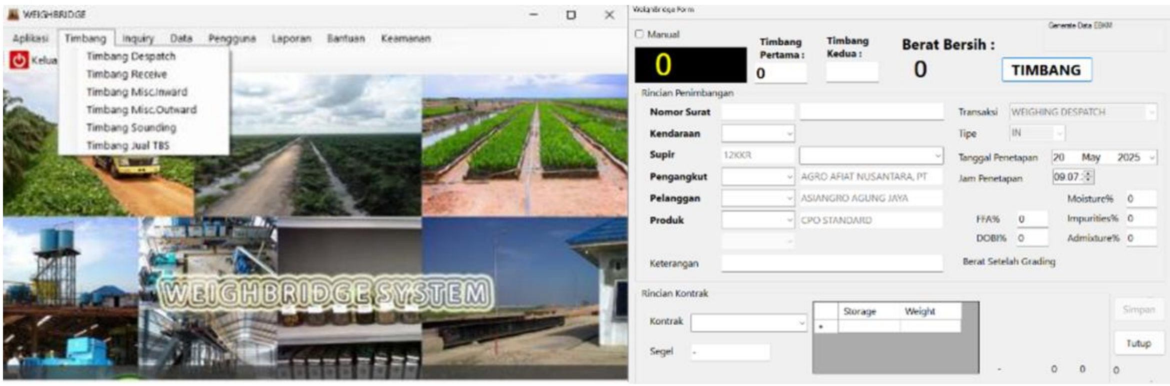

Figure 1. Weighing Menu Interface in Existing System

The results of observations, interviews, and document analysis indicated that the data recording process still contains a high risk of error due to an inflexible interface and strong dependence on manual user input. This is evident from findings showing that the input form cannot restrict field visibility based on product categories, allowing users to enter irrelevant or incorrect data. In addition, the calculation of the Berat Janjang Rata-rata (BJR) still requires operators to manually click the "Hitung" button, potentially leading to data inconsistencies if the operator forgets to perform this step. Beyond identifying functional requirements, this stage also mapped end-user needs. Based on the analysis of operator tasks, users require an interface that can: 1) Display contextual input fields that appear according to product category, 2) Automate BJR calculations to minimize errors, 3) Provide clearer and more consistent navigation, 4) Accelerate access to regional reports, including the need for mobile device access.

A questionnaire was distributed through Google Forms to three evaluators two Functional Analysts and one System Developer at HIT. The questionnaire was constructed using the Heuristic Evaluation method based on Nielsen's ten usability principles, rated using a 1–5 Likert Scale. Table 1 shows the evaluation results from the requirements-gathering stage.

Table 1. Requirements gathering evaluation results

Aspect	Percentage	Interface Quality and Usability Average
Visibility of System Status	64.00%	54.39%
Match between System and the Real World	73.33%	
User Control and Freedom	45.00%	
Consistency and Standards	57.33%	
Error Prevention	51.87%	
Recognition Rather than Recall	51.13%	
Flexibility and Efficiency of Use	40.00%	
Aesthetic and Minimalist Design	53.33%	
Help Users Recognize, Diagnose, and Recover from Errors	56.67%	
Help and Documentation	48.87%	

Based on the questionnaire score of 54.39%, the current system interface falls into the "Fair" category and needs improvement to achieve an optimal level of usability. This requirements identification aligns with studies on UCD that emphasize the importance of contextual inquiry and task analysis in designing complex operational systems. Shneiderman asserts that the success of interactive design is determined by a deep understanding of user workflows in real contexts [10].

Designing alternatives

After identifying requirements, the next step was to design alternative solutions through the development of user flows, sitemaps, and a design system. This stage aimed to produce a more logical and efficient interaction structure before moving to the visual design phase. The user flow was refined to ensure that the weighing process followed a simpler sequence and minimized redundant steps. Each scenario including dispatch, receive, inward, and outward weighing was remodeled to identify navigation bottlenecks in the existing system. The results showed that several processes previously required multiple clicks to achieve the intended action, so the new design streamlined these navigation patterns.

The redesign of the sitemap aimed to improve menu visibility and reduce inconsistencies in page structure. A clear information structure can reduce cognitive load and improve interaction accuracy [12], which is essential for operators working in fast-paced and repetitive environments. Figure 2 shows the sitemap of the redesigned weighbridge system website.

Design system was developed to ensure consistency in visual elements and interaction patterns across all pages. Its components include color schemes, iconography, typography, and navigation patterns. Design systems enhance development efficiency, facilitate collaboration among design teams, and maintain interface consistency [13]. Accordingly, the resulting design alternatives not only improve the visual appearance but also support minimalist design and error prevention principles, as outlined in Nielsen's heuristics. Figure 3 presents the design system of the weighbridge system.

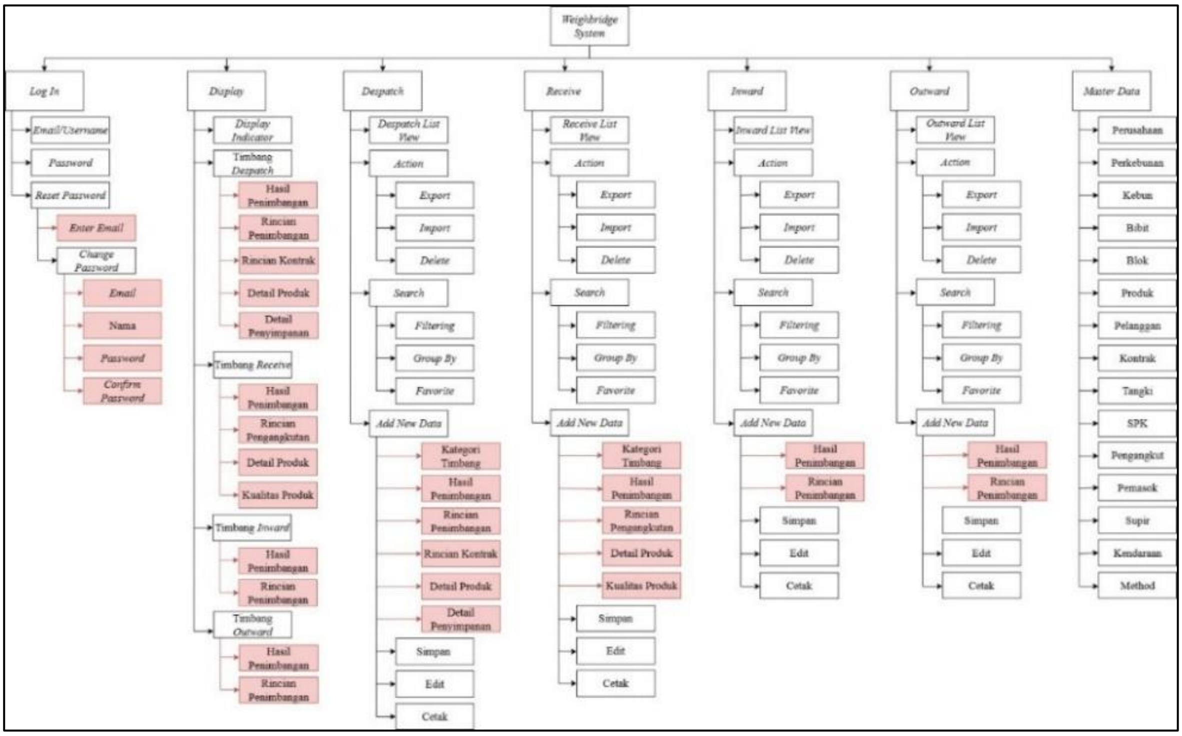

Figure 2. Sitemap of the Weighbridge System Website

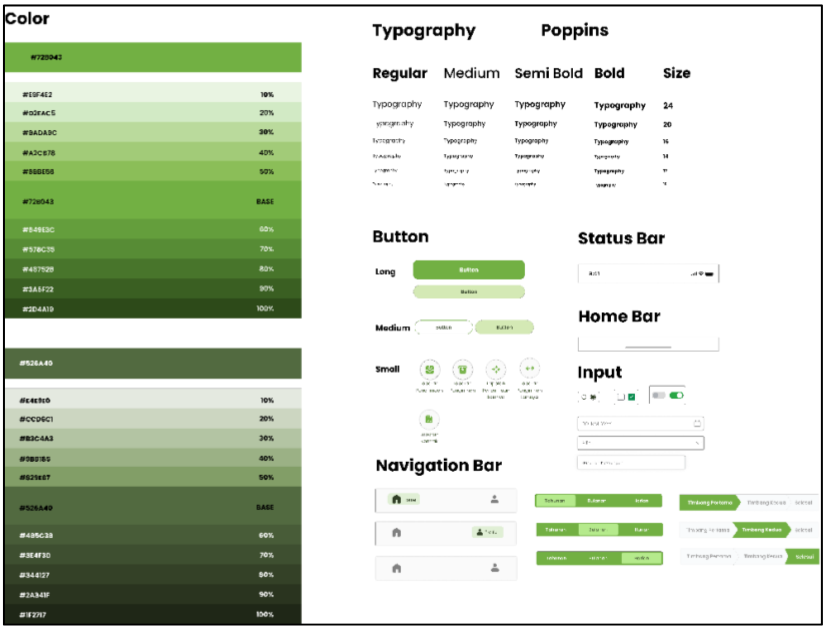

Figure 3. Design system of the weighbridge system

Prototyping

The next stage involved creating low-fidelity and high-fidelity prototypes using Figma. The low-fidelity prototype was used to validate basic workflow structures, while the high-fidelity prototype provided a more realistic simulation of the interface for evaluator testing. Key features developed in the new prototype include:

1. Dynamic fields that appear only according to product category.
2. Automatic BJR calculation without manual clicking.
3. Simplified navigation with consistent icons and layout.
4. Mobile interface integration for field access needs.
5. Improved visibility of system status through weighing indicators, invalid-input notifications, and visual loaders.

One example of a designed prototype, the Dispatch Weighing interface, is shown in Figure 4. High-fidelity prototypes were highly effective in providing realistic user experience simulations, enabling more representative evaluations.

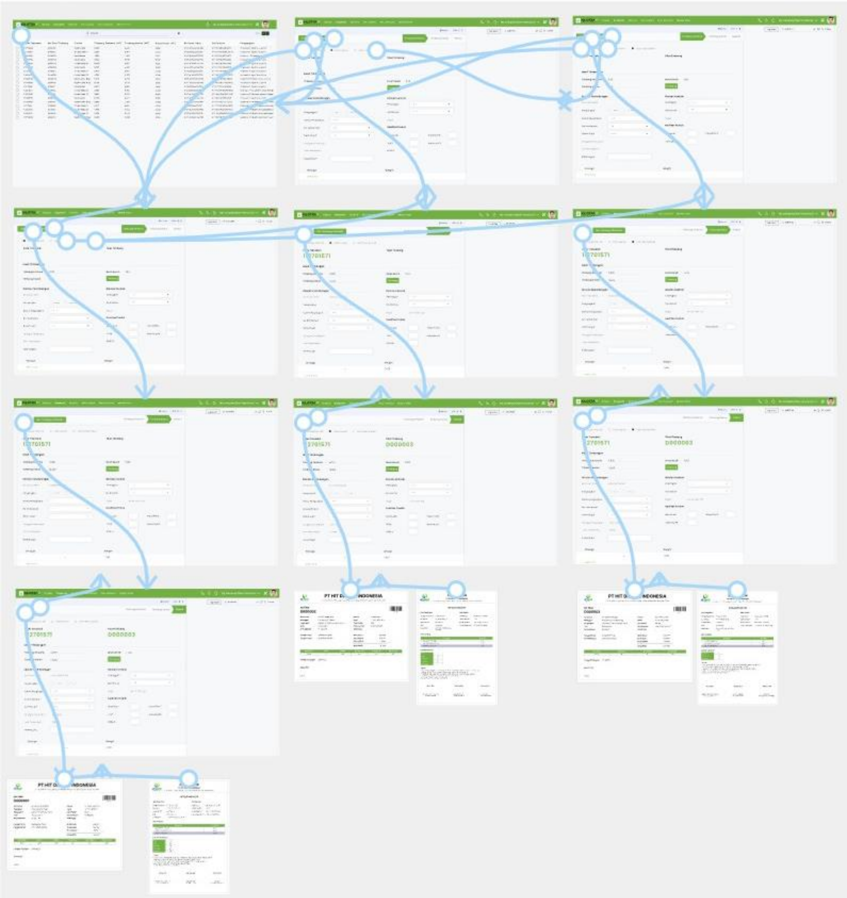

Figure 4. Dispatch weighing prototype

Evaluation

The evaluation was conducted using the Heuristic Evaluation method based on Nielsen's principles. The questionnaire instrument consisted of 51 questions rated on a 1–5 Likert Scale to identify usability issues in the proposed prototype. Three evaluators: two Developers and one Functional Analyst assessed the prototype via Google Forms. The results showed significant improvement across all usability categories compared to the existing system. The proposed prototype achieved a score of 89.89%, indicating a substantial increase from the existing system's score of 54.39%. This result places the new interface in the "Very Attractive" category. This means that the majority of evaluators have a positive view of the mobile-based weighbridge system prototype design. Table 2 provides a comparison of the heuristic evaluation results.

Table 2. Comparison of prototype heuristic evaluation results

Aspect	Existing System	Proposed prototype
Visibility of System Status	64.00%	88,00%
Match between System and the Real World	73.33%	88,33%
User Control and Freedom	45.00%	83,33%
Consistency and Standards	57.33%	93,33%
Error Prevention	51.87%	90,40%
Recognition Rather than Recall	51.13%	95,53%
Flexibility and Efficiency of Use	40.00%	90,00%
Aesthetic and Minimalist Design	53.33%	86,67%
Help Users Recognize, Diagnose, and Recover from Errors	56.67%	90,00%
Help and Documentation	48.87%	93,33%
Average	**54.39%**	**89,89%**

Based on the scores in Table 2, the highest improvements were in the aspects of "Recognition rather than Recall" (51.13% → 95.53%) and "Consistency & Standards" (57.33% → 93.33%), showing that the new design successfully simplified user interaction by presenting relevant and consistent information. Meanwhile, significant increases in "Error Prevention" (51.87% → 90.40%) and "Efficiency of Use" (40.00% → 90.00%) demonstrate that the new design is not only visually improved but also functionally effective in reducing errors and accelerating workflows. Overall, the developed prototype not only enhances the interface appearance but also significantly improves operator work quality, weighing accuracy, and supports more sustainable digital transformation within the palm oil industry.

Beyond usability enhancement, these quantified improvements provide measurable implications for green digital transformation through three sustainability indicators. First, error minimization, reflected in the significant increase in "Error Prevention", reduces documented input errors and correction reports. This reduces administrative waste, redundant data processing, and reliance on printed correction forms. Such process accuracy improvements are consistent with recent findings that digital transformation enhances environmental performance by reducing material waste and improving operational precision [14]. Second, transaction efficiency indicated by the improvement in "Efficiency of Use", reflected in shorter processing times, contributes to reduced vehicle idle duration at the weighbridge station, which indirectly supports fuel savings and lower emissions. Empirical studies confirm that digital process optimization contributes to energy efficiency and carbon reduction at the operational level [15]. Third, process optimization demonstrated through improvements in "Recognition Rather than Recall" and "Consistency & Standards", achieved through automatic BJR calculation and contextual field validation, minimizes repeated transactions caused by inaccurate entries and inconsistent workflows. This aligns with contemporary research highlighting that integrating digital transformation with environmental innovation enables resource optimization and sustainable operational outcomes [16].

These evaluation results indicate that the proposed prototype has a high level of usability aligned with Nielsen's ten principles. This achievement confirms that UCD-based design iterations significantly improve efficiency, error prevention, user control, and visual clarity compared to the existing system. Moreover, the new interface design supports sustainable operational practices by reducing reliance on paper-based documentation, minimizing redundant processing, and optimizing digital workflows in the weighing process. Therefore, this research not only demonstrates the effectiveness of UCD in designing complex industrial systems but also provides valuable contributions to green digital transformation within the palm oil sector.

Conclusion

This study demonstrates that the systematic application of User-Centered Design (UCD) effectively enables the redesign of a digital weighbridge system interface to be more efficient and user-friendly within the operational context of the palm oil industry. All stages of UCD from requirements identification, designing alternative, prototyping, to evaluation show that the new design successfully addresses the issues present in the existing system. The resulting prototype resolves problems related to mismatched input fields, complex navigation, and potential errors in BJR calculation. The evaluation using the Heuristic Evaluation method produced a score of 89.89%, confirming a significant improvement in usability and aligning with the research objective of developing a more intuitive interface that supports a more sustainable digital workflow.

These findings reinforce the importance of UCD in developing complex industrial operational systems and demonstrate that interface improvements can positively impact data quality and the efficiency of weighing processes. For future research, it is recommended to conduct task-based usability testing in real operational environments, integrate the system with sensors and IoT devices to enhance automation, and perform long-term evaluations of the impact of digitalization on operational efficiency and sustainability.

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