

A Usability Evaluation of an E-Commerce Checkout System Using SUS and Usability Testing

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ABSTRACT

This study focuses on evaluating and improving the usability of the XYZ Checkout System, which previously exhibited several issues that negatively affected transaction completion, including unclear information hierarchy, inconsistent interface behaviour, and inefficient checkout flows. To address these challenges, the research adopted a User-Centered Design (UCD) approach supported by a mixed-method evaluation strategy, combining the System Usability Scale (SUS), usability testing, and open-ended questions. A between-subject research design was employed, involving two independent groups of participants. The initial *as-is* evaluation was conducted with 35 users and produced an average SUS score of 69.57, indicating marginal usability and the presence of notable interaction barriers. Based on the findings, a high-fidelity *to-be* prototype was designed using established usability heuristics and UCD principles. The redesigned interface was subsequently evaluated by a different group of 35 users, resulting in a significantly improved average SUS score of 96.64, classified as Excellent with high acceptability. Overall, the results demonstrate that the proposed design improvements successfully enhanced interface consistency, clarity of interaction, and checkout efficiency, emphasizing the critical role of systematic usability evaluation in optimizing e-commerce checkout systems.

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1. INTRODUCTION

The rapid development of digital technology in Indonesia has significantly accelerated the growth of e-commerce and online transactions [1]. E-commerce adoption continues to rise, reflected in increasing gross merchandise value and a growing number of users annually [2]. Consumer demand is particularly strong in product categories such as fashion, beauty, and food and beverages [3]. Existing studies have indicated that convenience and ease of use represent the primary factors influencing consumers in selecting e-commerce platforms, followed by payment flexibility, security perceptions, and promotional incentives [4], [5], [6]. However, despite this rapid expansion, e-commerce platforms in Indonesia face persistent challenges, especially during the checkout stage. High cart abandonment rates are frequently linked to usability issues, perceived transaction risks, emotional uncertainty, and increasing transaction costs, particularly in mobile shopping environments [7], [8]. Consumer trust and data security are crucial for e-commerce growth, requiring stronger laws and better user protection [25], [26]. Additionally, ease of access and price promotions strongly influence Indonesian consumers, emphasizing the importance of user experience optimization for platform competitiveness [27].

XYZ is a technology startup offering a universal checkout system integrating payments, couriers, and rewards across merchant platforms. Since launching in 2022, it has gained 200,000 users and 50 merchant partners. However, its actual performance falls below expectations. Although the company targeted a monthly GMV of IDR 500 million and a 35% conversion rate, it only achieved 11% on average. A gap analysis revealed usability issues, including complexity, unclear information, and system instability. Moreover, root cause analysis using Ishikawa's fishbone model identified the lack of a formal usability evaluation as a key process factor [9]. Given the critical role of usability in ensuring effective and efficient online transactions, systematic usability evaluation is necessary to assess system effectiveness and improve user experience via methods such as heuristic evaluation and usability testing [10]. Within the context of these issues, this study addresses the following research questions:

RQ1: What is the current usability level of the XYZ Checkout System?

RQ2: What improvements can enhance the system's interface usability?

RQ3: How effective is the redesigned interface compared to the existing one?

This research used a mixed-method user-centered design (UCD) approach involving usability testing, heuristic evaluation, and the system usability scale (SUS). The findings aim to improve XYZ's system and contribute to human-computer interaction studies. Notably, similar methods have effectively identified usability barriers and enhanced user satisfaction in other contexts [28].

2. RESEARCH METHOD

The present research applied a structured process to identify usability issues and propose improvements for the XYZ Checkout System. As shown in Figure 1, it began with problem identification and a literature review, followed by usability evaluation using quantitative and qualitative methods. The findings were then analyzed to produce conclusions and design recommendations within a mixed-methods evaluative case study framework. This study employed a between-subject design, where the as-is and to-be evaluations were conducted with two independent groups of participants. This approach was selected to minimize learning effects and recall bias during usability assessment.

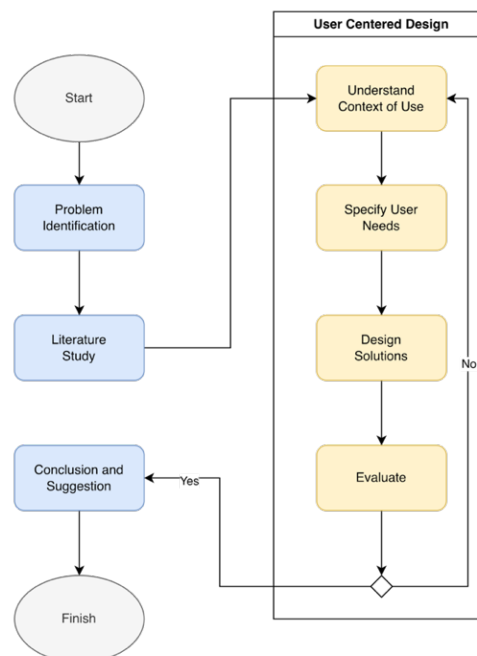


Figure 1. Research Flow Diagram

Table 1. Research Design

Component	Description
Classification	Mixed methods
Category	Case study
Paradigm	Evaluation
Purpose	Understand system usability from shoppers who already transact using the XYZ Checkout System
Result	Proposed design recommendation for the XYZ Checkout System
Data collection	System usability scale, open-ended questions, usability testing
Sampling strategy	Purposive sampling

2.1. User-Centered Design

This study adopted a UCD approach, which emphasizes understanding users' needs, characteristics, and limitations to produce relevant and usable solutions [11], [12]. UCD is iterative and involves user participation through design and evaluation activities, comprising four stages: understanding context; specifying requirements; designing solutions; evaluating usability [13], [14].

2.2. Usability Testing

Usability testing evaluates system performance by observing users completing predefined tasks to identify barriers, errors, and efficiency issues [24]. It employs realistic scenarios and records behaviors such as navigation, completion time, and mistakes to reveal non-intuitive elements [13]. In the present study, structured task scenarios simulated real shopping and checkout interactions in the XYZ Checkout System, which are summarized in Table 2.

Table 2. Task Case Scenario

Task	Goals	Scenario	Code Task
Find product	Enable shoppers to find products on the merchant's website	Shopper searches for an item on the merchant's website.	TCSF-01
Select variant product and add to cart	Enable shoppers to select variant of product on the merchant's website	Shopper select variant of product and add to cart on the merchant's website	TCSF-02
Checkout the product	Allow shoppers to initiate checkout from the merchant website	Shopper proceeds to checkout from the seller/merchant website.	TCSF-03
Login/register	Support login/registration-based checkout	Shopper performs checkout using their account (login/register).	TCSF-04
Input OTP, email, and name	Verify user identity and collect personal information	Shopper fills in OTP verification, email, and full name.	TCSF-05
Fill in detailed shipping address information	Collect complete and accurate shipping information	Shopper fills in detailed and complete shipping address information.	TCSF-06
Select courier or shipping	Allow selection of courier/shipping options	Shopper selects a courier service for shipping.	TCSF-07
Select payment method	Allow selection of preferred payment method	Shopper selects a payment method.	TCSF-08
Access and input voucher	Provide a way to apply vouchers or promotions	Shopper enters and selects a voucher.	TCSF-09
Click the "Pay Now" button	Complete the payment process	Shopper clicks the "Pay Now" button to finalize the transaction.	TCSF-10

2.3. System Usability Scale

The SUS was used to quantitatively measure users perceived usability of the XYZ Checkout System through a standardized 10-item questionnaire rated on a 1–5 Likert scale [16]. A total of 35 respondents completed the SUS survey (separate from usability testing participants) along with demographic questions. The SUS instrument is widely recognized for its reliability and efficiency across digital systems. The SUS questions used in this study are presented in Table 3.

Table 3. SUS Questions

No.	Questions
1	I think I would use this system again.
2	I find this system unnecessarily complex.
3	I find this system easy to use.
4	I think I would need help from another person or technician to use this system.
5	I find the features of this system function as intended.
6	I find that there are many inconsistencies in this system.
7	I think most people would learn to use this system very quickly.
8	I find this system confusing.
9	I feel confident using this system.
10	I need to learn a lot of things before I can get going with this system.

2.4. Shneiderman's Eight Golden Rules of Interface Design

In designing an intuitive and efficient checkout system for an e-commerce platform, applying Shneiderman's eight golden rules of interface design is essential for enhancing user satisfaction and reducing cognitive load. These principles help create interfaces that are predictable, easy to navigate, and supportive of user goals [17]. The core principles of these rules are presented in Table 4.

Table 4. Shneiderman's Eight Golden Rules of Interface Design

No.	Principle	Description
1	Strive for consistency	Maintain consistent layout, colors, terminology, and element placement across all pages.
2	Cater to universal usability	Ensure accessibility and ease of use for all users, while allowing experienced users to utilize shortcuts.
3	Offer informative feedback	Provide clear and immediate feedback for every user action to support understanding and control.
4	Design dialogs to yield closure	Present clear completion signals, such as confirmation messages, to guide users through interaction stages.
5	Offer simple error handling	Display helpful, non-technical error messages that assist users in correcting mistakes.
6	Permit easy reversal of actions	Allow users to undo or backtrack actions easily to reduce anxiety and support exploration.
7	Support internal locus of control	Give users a sense of control by enabling predictable navigation and responsive system behavior.
8	Reduce short-term memory load	Minimize cognitive burden by presenting essential information directly on screen and avoiding unnecessary memorization.

2.5. Heuristic Evaluation

Heuristic evaluation is a usability inspection method in which experienced evaluators assess an interface using established heuristic principles to identify potential usability issues [11], [12]. This study applied Nielsen's 10 usability heuristics, which provide guidelines for evaluating clarity, consistency, error handling, and overall user experience. These principles help reveal usability problems early and support the creation of intuitive system interactions [15]. The 10 usability heuristics are presented in Table 5.

Table 5. Heuristic Evaluation

No.	Heuristics Principle	Description
1	Visibility of system status	The system should provide timely and clear feedback so users always know what is happening.
2	Match between the system and the real world	Use language and concepts familiar to users, aligned with real-world conventions.
3	User control and freedom	Allow users to undo or redo actions easily without restrictions.
4	Consistency and standards	Maintain consistent terminology, layout, and rules to reduce confusion.
5	Error prevention	Prevent errors through confirmations, constraints, and clear instructions.
6	Recognition rather than recall	Display necessary information so users do not need to remember anything across screens.
7	Flexibility and efficiency of use	Support different user skill levels, including shortcuts for experienced users.
8	Aesthetic and minimalist design	Keep the interface clean and uncluttered, with only essential information provided.
9	Help users recognize, diagnose, and recover from errors	Provide clear error messages and guidance for resolving issues.
10	Help and documentation	Offer accessible help materials for situations where assistance is needed.

2.6. Data Collection

User-centered data collection helps identify usability challenges and improve interaction design quality [29]. The mixed-method approach used in this study combined quantitative and qualitative instruments, including demographics, the SUS, and open-ended questions. A total of 70 participants were involved in this study across two evaluation phases. The as-is evaluation included 35 participants who completed the SUS questionnaire and open-ended questions, with 5 of them additionally participating in usability testing. The to-be evaluation was conducted with a different group of 35 participants using the same instruments, including SUS, open-ended questions, and usability testing with 5 participants. The separation of participant groups ensured independent assessments between the two interface conditions. Mixed-method studies have effectively been used to reveal system inefficiencies and support interface improvements in e-commerce platforms [30].

2.7. Data Analysis

The data were analyzed using qualitative and quantitative techniques to evaluate usability performance. Qualitative data from testing and open-ended questions were processed through reduction, categorization, and thematic analysis approach. Identified usability issues were grouped based on similarity and frequency through iterative categorization conducted by the researcher. The integration of qualitative findings with quantitative SUS results enabled triangulation across methods, strengthening the validity of the identified usability problems and design recommendations. [18],[19]. Quantitative analysis used the SUS to convert Likert responses into standardized scores [20]. Notably, scores below 68 indicated usability problems impacting efficiency and user satisfaction [21]. This mixed approach enabled evidence-based conclusions on the usability of the XYZ Checkout System.

3. RESULTS AND DISCUSSION

This section presents the results of the usability evaluation conducted using the UCD approach. A total of 35 respondents completed the SUS and open-ended questions between October 17 and 24, 2025, while 5 participated in usability testing. The redesigned *to-be* interface was re-evaluated between November 24 and December 1, 2025, using the same methods. Combined findings provide the basis for analyzing usability improvements and remaining issues.

3.1. Analysis of System Usability Scale Results

The SUS results for the current XYZ Checkout System, based on responses from 35 users, show substantial variation in perceived usability. Scores ranged from very low values (25–30), indicating notable usability issues, to very high values (95–97.5), reflecting highly positive experiences. This disparity suggests that while the checkout flow was clear for some users, others encountered difficulties in steps such as shipping selection, voucher validation, and address completion. Detailed SUS scores are presented in Table

Table 6. SUS Results for the Current XYZ Checkout System

Respondent	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS Score
R 1	2	2	4	1	5	4	4	1	4	1	75
R 2	4	4	4	2	3	2	5	2	5	3	70
R 3	4	1	4	1	5	2	3	2	4	1	82.5
R 4	3	2	4	4	4	3	4	2	4	3	62.5
R 5	4	1	5	1	5	1	4	1	5	2	92.5
R 6	4	1	4	1	5	1	5	1	5	1	95
R 7	5	3	4	2	4	3	4	3	4	4	65
...	...	...	...	...	...	...	...	...	...	...	...
R 35	4	1	5	1	5	1	5	1	5	1	97.5
Average											69.57

The current XYZ Checkout System achieved an average SUS score of 69.57, indicating marginal usability with notable issues in efficiency and interaction clarity [22]. The SUS results showed high variability ($SD = 19.45$), suggesting inconsistent usability experiences among participants. Furthermore, the 95% confidence interval ranged from 63.13 to 76.01, indicating that a substantial portion of users perceived usability below the acceptable benchmark. Qualitative responses support these findings, highlighting accessibility and compatibility as primary concerns, followed by issues related to page layout, navigation, and text presentation.

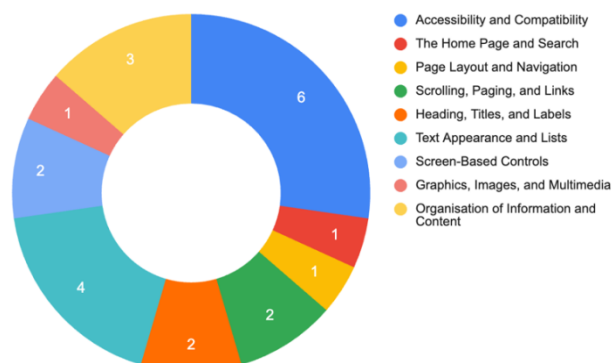


Figure 2. Categorized Results of Open-Ended Responses

3.2. Analysis of Usability Testing Results

The usability testing process conducted with five users revealed that several task scenarios continued to generate notable difficulties. Table 7 presents 11 test case scenarios (TCSFs). Notably, TCSF-04 (checkout with login) and TCSF-06 (completing the shipping address form) were the most problematic, with each occurring in 80% of participants. These repeated issues indicate that authentication and data-entry flows remained major sources of friction in the current checkout experience.

Table 7. Usability Testing Results for the Current XYZ Checkout System

Scenario/ Respondent	R1	R2	R3	R4	R5	Total	Freq.
TCSF-01							0%
TCSF-02							0%
TCSF-03		✓	✓	✓	✓	4	80%
TCSF-04							0%
TCSF-05		✓	✓	✓	✓	4	80%
TCSF-06							0%
TCSF-07	✓		✓			2	40%
TCSF-08				✓	✓	2	40%
TCSF-09							0%
TCSF-10							0%

After obtaining the frequency data from Table 8 and following the categorization proposed by Sauro and Lewis [23], the researcher classified and mapped each issue into four problem-severity levels: low ($\leq 10\%$), mid (11–50%), high (51–89%), and very high ($\geq 90\%$). This classification helps prioritize which tasks require immediate redesign. The detailed grouping of identified usability problems is presented in Table 8.

Table 8. Problems in Usability Testing (As-Is Condition)

Level	Category	Frequency Range	Scenario
1	Low	$\leq 10\%$	
2	Mid	11 – 50%	TCSF-08, TCSF-09
3	High	51 – 89%	TCSF-04, TCSF-06
4	Very High	$\geq 90\%$	

The overall distribution of issue types (see Figure 3) suggests that most usability problems fall under screen-based controls, page layout and navigation, and the organization of information and content. These patterns indicate the need for improvements in layout clarity, the consistency of interface elements, and the structuring of information to better support efficient task completion.

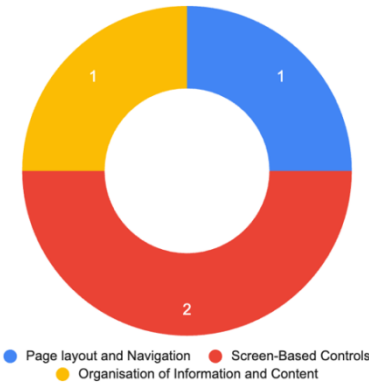


Figure 3. Categorized Usability Testing Results

3.5. Identification of Usability Issues

Findings from the SUS, open-ended questions, and usability testing were integrated to identify key issues in the XYZ Checkout System. SUS measured overall perception, while qualitative insights revealed task challenges. Figure 4 and Table 9 summarize the identified problems and corresponding evaluation methods.

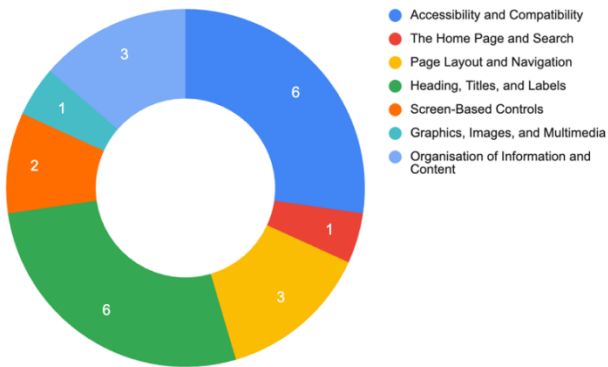


Figure 4. Summary of Usability Issues in the Current XYZ Checkout System

Table 9. Comparison of Usability Issues by Evaluation Method

No.	Category	Usability Testing	Open-Ended Questions
1	Accessibility and compatibility		✓
2	Home page and search		✓
3	Page layout and navigation	✓	✓
4	Heading, titles, and labels		✓
5	Screen-based controls	✓	✓
6	Graphics, images, and multimedia		✓
7	Organization of information content	✓	✓

The consolidated results reveal recurring usability challenges related to accessibility and compatibility, page layout and navigation, and information organization, indicating weaknesses in clarity and structure. Other issues, including screen-based controls and labeling, appeared less frequently but still affected user flow. Notably, these findings guided the prioritization of design improvements.

3.6. Design Solutions and Validation Results

This subsection presents design solutions derived from usability issues identified through the SUS, open-ended feedback, and usability testing. Each issue was translated into targeted recommendations aligned with interface design principles and implemented in a redesigned prototype. The mapping of problems, solutions, and design rules to support evaluation is summarized in Table 10.

Table 10. Categorized Results of Usability Testing

Function	Problem Description	Solution Description	Shneiderman’s Eight Golden Rules of Interface Design
User information form	Login/registration only allows phone number; users expect more options.	Add login alternatives such as Google or email-based authentication.	Enable frequent users to use shortcuts

Function	Problem Description	Solution Description	Shneiderman's Eight Golden Rules of Interface Design
	Input instructions unclear, causing incorrect data format.	Add explicit placeholders and example formats for each input field.	Offer error prevention and simple error handling
	Users confused by presence of both "Login" and "Guest Checkout" buttons.	Simplify flow: merge or contextualize login vs. guest options.	Strive for consistency
Product review and navigation	Users struggle to return to product pages after entering checkout.	Add shortcut links or CTA buttons back to product details.	Reduce short-term memory load
Address form	Form feels too long and confusing; province/zip code not auto-detected.	Enable auto-detection for province, district, and postal codes.	Enable frequent users to use shortcuts
	Important information (price, delivery) not visually emphasized.	Increase font size and improve visual hierarchy.	Strive for consistency
	Users find address input too long; lack autosuggestions.	Enable auto-complete for province/subdistrict/zip code fields.	Enable frequent users to use shortcuts
Shipping method	Additional shipping cost not shown early in the process.	Show estimated shipping cost earlier during checkout.	Offer informative feedback
Voucher input	Voucher code field difficult to find; confirmation unclear.	Make the voucher input field more visible and provide clear validation feedback.	Offer informative feedback
	Voucher input unclear; no confirmation message after applying.	Display clear success/failure and reason messages.	Offer informative feedback
	Payment method orders unclear; additional fees not shown.	Reorganize payment list and display extra fees in real time.	Offer informative feedback
	Extra admin fee not visible until after selection.	Show additional cost per method upfront in real time.	Offer informative feedback
	General (all scenarios)	Typography inconsistent across screens.	Standardize typography and spacing across all pages.
	Button/field labels not consistent or descriptive enough.	Harmonize labels and naming conventions.	Strive for consistency
	Low text-background contrast affects readability.	Improve color contrast for better visibility.	Aesthetic and minimalist design
System status visibility	Price/discount information not sufficiently highlighted.	Increase visual emphasis for price/discount changes.	Offer informative feedback
	No loading/progress indicators; system feels unresponsive.	Add responsive loading indicators.	Offer informative feedback
	Help and guidance	No short explanation for new users about checkout steps.	Provide short contextual guidance or tooltips.
	Instruction language too technical; not user-friendly.	Rewrite text using simpler, more familiar terms.	Strive for consistency

Based on Table 10, each usability issue was mapped to its corresponding interface element to illustrate how the redesign addresses user pain points. One key issue, confusion caused by the presence of both *Login* and *Guest Checkout* options, was consistently identified across all evaluation methods and is illustrated in the *as-is* design presented in Figure 5.

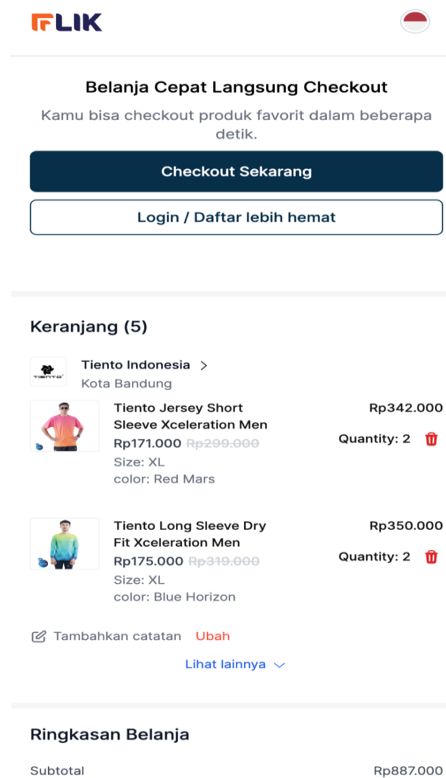


Figure 5. Current XYZ Checkout System User Interface

To resolve this inconsistency, the redesigned *to-be* interface merges and contextualizes login-related actions, making the user journey more streamlined and predictable. This refinement aligns with the usability principle *Strive for Consistency* and reduces unnecessary cognitive effort. The improved design is illustrated in Figure 6.

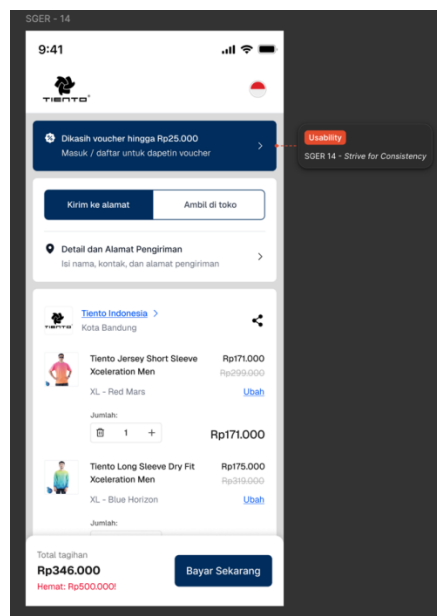


Figure 6. Design Solution for the XYZ Checkout System

After implementing the design improvements, the redesigned interface was re-evaluated using the SUS, open-ended questions, and usability testing. The SUS questionnaire was administered first

to measure the perceived usability of the updated design. The results are presented in Table 11 as the primary indicator of usability improvement.

Table 11. SUS Results for the XYZ Checkout System Design Solution

Respondent	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS Score
R 1	5	1	5	2	5	1	5	1	5	1	97.5
R 2	5	2	4	1	5	3	5	1	5	1	90
R 3	4	1	5	1	5	1	5	1	5	1	97.5
R 4	5	1	5	1	4	3	4	2	5	1	87.5
R 5	5	1	5	1	5	1	5	1	5	1	100
R 6	4	1	4	1	4	1	4	1	4	1	90
R 7	4	1	5	1	4	1	5	1	5	2	90
...	...	...	...	...	...	...	...	...	...	...	...
R 35	5	1	5	1	5	1	5	1	5	1	100
Average											96.64

Based on the SUS responses from 35 participants, the redesigned XYZ Checkout System demonstrated a substantial usability improvement. The average SUS score increased from 69.57 in the as-is condition to 96.64 in the to-be condition, placing the system in the Excellent category with high acceptability [22]. Although the average SUS score is considerably high, the results show low variability ($SD = 3.69$), indicating consistent positive usability perceptions among participants. Furthermore, the 95% confidence interval ranged from 95.42 to 97.86, confirming that the observed usability improvement was not driven by extreme individual ratings but reflected a broadly shared user experience. This result exceeds industry benchmarks, thereby reinforcing the effectiveness of the implemented design improvements (Table 12).

Table 12. Comparison of SUS Scores for the As-Is and To-Be User Interfaces

Average SUS Score (As-Is)	Average SUS Score (To-Be)	Average SUS Benchmark
69.57	96.64	70.14

Following the SUS evaluation, an open-ended question assessment was conducted to capture users' qualitative feedback and deeper insights regarding the redesigned user interface. This method complements the quantitative SUS results by revealing user perceptions, remaining friction points, and the overall experiential impact of the design improvements. The analysis of open-ended responses is presented in Table 13.

Table 13. Results of Open-Ended Questions for the To-Be XYZ Checkout System

No.	User Impression Summary	Theme
1	The redesigned XYZ Checkout System is perceived as easy to use, clear, and suitable for first-time users.	Easy, simple, friendly for new users
2	Ease of use, speed, and efficiency emerged as the most dominant positive aspects.	Fast, practical, responsive, efficient
3	The interface is considered clean, comfortable, and visually supportive of user tasks.	Clean and pleasant user interface design
4	Features such as automatic courier selection, QR payment, and voucher reminders are highly appreciated.	Supporting features
5	The checkout flow is viewed as clear and consistent, with smooth login navigation.	Login, navigation, and clear system flow
6	Instructions and tutorials help users understand the checkout process.	Informative guidance for new users

No.	User Impression Summary	Theme
7	Only minor improvement suggestions were mentioned, with no significant usability issues reported.	Improvement expectations
8	Overall experience is perceived as positive, safe, comfortable, and satisfying, with very few complaints.	Positive perception

Open-ended responses show a positive shift in user experience following the redesign, particularly in terms of flow clarity, interaction efficiency, and visual comfort. Supporting features reduced cognitive load, while clearer navigation resolved prior issues. Remaining suggestions involve minor refinements. To further validate these improvements, usability testing results for the redesigned interface are presented in Table 14.

Table 14. Usability Testing Results for the To-Be XYZ Checkout System

Scenario/ Respondent	R1	R2	R3	R4	R5	Total	Freq.
TCSF-01						0	0%
TCSF-02						0	0%
TCSF-03		✓				1	20%
TCSF-04						0	0%
TCSF-05						1	20%
TCSF-06						0	0%
TCSF-07						0	0%
TCSF-08			✓			0	0%
TCSF-09						0	0%
TCSF-10						0	0%

The usability testing results for the to-be user interface indicate a significant reduction in problem frequency across scenarios. Only two scenarios, TCSF-04 and TCSF-09, were encountered by a single respondent (20%). All other scenarios recorded 0% issue frequency, indicating that the redesign effectively minimized the major interaction problems previously observed in the *as-is* condition. The detailed grouping of usability problems identified in design solutions is presented in Table 15.

Table 15. Problems in Usability Testing (To-Be Condition)

Level	Category	Frequency Range	Scenario
1	Low	$\leq 10\%$	
2	Mid	11 – 50%	TCSF-04, TCSF-09
3	High	51 – 89%	
4	Very High	$\geq 90\%$	

All identified usability issues in the redesigned system fall within the *Medium* category, with none reaching high severity. This indicates substantial improvement since prior issues were addressed through clearer navigation, improved layouts, and better system feedback. Overall, usability testing confirms the effectiveness of the design solutions, supporting the positive SUS and open-ended question results.

4. CONCLUSION

This study evaluated and improved the usability of the XYZ Checkout System using the SUS, open-ended questions, and usability testing. The initial *as-is* evaluation produced an average SUS score of 69.57, revealing issues related to navigation clarity, visual hierarchy, cognitive load, and system feedback. Guided by UCD principles and heuristic guidelines, a redesigned *to-be* prototype was developed. Re-evaluation showed a significant usability improvement, with the SUS score increasing to 96.64 (*Excellent*). Usability testing and qualitative feedback confirmed smoother interactions and fewer errors. Future work could include broader user validation, accessibility improvements, and long-term evaluation to support continued system refinement. Although this study employed a between-subject design to reduce learning effects, future research could apply a within-subject design with counterbalancing to enable direct individual-level comparisons between interface versions.

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