SinkrOn
JURNAL & PENELITIAN TEKNIK INFORMATIKA

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 10, Issue 1, Januari 2026
DOI : https://doi.org/10.33395/sinkron.v10i1.15792

e-ISSN : 2541-2019
p-ISSN : 2541-044X

From Monitoring to Reliability Analytics: Designing a Reliability Information System for Data Centers Using DT and QFD

Hikam Adziyak[1)*], Erfan Nugroho[2)], Rizki Permadi Putra[3)], Niniek Fajar Puspita[4)], Jani Rahardjo [5)]
[1,2,3,4,5)] Interdisciplinary School of Management and Technology, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
[1)4)5)]6047251006@student.its.ac.id , [2)]6047251017@student.its.ac.id, [3)]6047251002@student.its.ac.id

Submitted :Jan 7, 2026 | **Accepted** : Feb 22, 2026 | **Published** : Feb 23, 2026

Abstract: Equipment reliability is critical to ensuring service continuity in data centers as strategic digital infrastructure. However, existing operational information systems remain largely alarm-oriented and do not adequately distinguish warning notifications from actual equipment failures. Key reliability indicators such as time to repair (TTR), repair cost, and annual failure rate (AFR) are often unavailable in an integrated historical format, limiting data-driven maintenance decision-making. This study proposes the design of an equipment reliability information system using an integrated Design Thinking (DT) and Quality Function Deployment (QFD) approach. The research was conducted in an operational data center through semi-structured interviews with six key stakeholders, including maintenance technicians and management. DT was applied across the empathize, define, ideate, prototype, and test stages, while QFD translated user needs into prioritized technical features. Validation was performed through prototype testing using historical maintenance and failure data. The results indicate that prioritized features include work order tracking, equipment-level maintenance history, asset data management, and reliability analysis modules. The proposed DT–QFD framework offers a replicable approach for designing reliability information systems in data centers and other critical infrastructure environments.

Keywords: Data center, Design Thinking, Quality Function Deployment, equipment reliability, time to repair, annual failure rate, Maintenance strategy.

INTRODUCTION

Data centers constitute critical infrastructure that underpins digital services across public and commercial sectors. High equipment availability and reliability are therefore essential to ensure service continuity. Despite substantial investments in monitoring technologies, recent industry surveys report that operational disruptions in data centers remain frequent and costly, indicating that improved monitoring alone does not necessarily translate into effective reliability management (Sembiring, 2021).

Existing research and industrial practices largely emphasize real-time monitoring, alarm handling, and availability reporting. While these approaches enhance operational awareness, they primarily support reactive maintenance actions. In parallel, reliability engineering studies provide analytical models for failure rates, repair time, and maintenance cost optimization. However, these studies are often developed independently of operational information systems and rarely consider how reliability indicators are embedded into daily maintenance workflows. As a result, a disconnect persists between reliability analysis as a technical discipline and its practical application within data center operational dashboards.

This disconnect constitutes a key scientific conflict: although reliability metrics are widely recognized as essential for maintenance optimization, they are seldom operationalized within user-oriented information systems. Existing dashboards typically remain alarm-centric and do not systematically integrate historical reliability indicators such as Annual Failure Rate (AFR), time to repair, and repair cost into decision-support functionalities. Consequently, maintenance decisions continue to rely heavily on operator experience rather than structured reliability evidence.

Based on this conflict, the explicit research gap addressed in this study is the lack of a structured design framework that integrates user-centered system design with quantitative reliability indicators in data center

*name of corresponding author

information systems. To address this gap, this study poses the following research question: How can an equipment reliability information system for data centers be systematically designed to translate user needs into reliability-oriented analytical features that support maintenance decision-making? To answer this question, this study integrates Design Thinking as a user-centered design approach with Quality Function Deployment as a structured requirement translation method. The academic contribution of this work lies in proposing and validating an integrated DT–QFD framework that bridges the gap between qualitative user requirements and quantitative reliability metrics (Ahmad, 2019). The proposed framework offers a replicable methodological reference for future research on reliability-oriented decision-support systems in data centers and other critical infrastructure domains.

LITERATURE REVIEW

Operational Monitoring Systems versus Reliability-Oriented Information Systems

Existing studies on data center operations predominantly focus on operational monitoring systems that emphasize real-time status visualization, alarm handling, and availability reporting. Such systems are effective in supporting rapid response to abnormal operating conditions and short-term fault isolation. However, prior research consistently notes that alarm-centric dashboards tend to reinforce reactive maintenance behavior, as they provide limited historical context and insufficient analytical capability for evaluating long-term equipment reliability (O'Connor, 2021).

In contrast, reliability-oriented studies emphasize quantitative performance indicators—such as Annual Failure Rate (AFR), mean or time to repair, and maintenance cost analysis—as essential inputs for maintenance optimization and asset lifecycle management (Ahmad & Kamaruddin, 2019). While these indicators are analytically robust, they are commonly applied as standalone analyses or retrospective evaluations rather than being embedded within operational information systems. As a result, a gap persists between operational monitoring practices and reliability-based maintenance decision-making.

Reliability Engineering Approaches and Their Practical Limitations

Reliability engineering literature has made significant advances in modeling failure behavior, repair processes, and maintenance cost optimization. These approaches provide valuable theoretical foundations for risk-based maintenance and asset prioritization. However, comparative studies suggest that such models are often detached from the socio-technical realities of maintenance operations, where decisions are constrained by workflow complexity, information availability, and user interpretation.

Moreover, reliability models typically assume structured and complete historical data, an assumption that does not always hold in operational data center environments. This mismatch limits the practical adoption of reliability analytics in daily maintenance planning and reinforces reliance on experience-based decision-making rather than evidence-based strategies (Zio, 2022).

User-Centered Design Approaches in Maintenance Systems

User-centered design methodologies, particularly Design Thinking, have been increasingly applied to engineering and maintenance systems to address usability, workflow alignment, and stakeholder engagement. Studies demonstrate that Design Thinking is effective in capturing tacit knowledge from technicians and operations managers, thereby improving system acceptance and usability (Curedale, 2019) (Dam, 2023). However, comparative analyses reveal that many Design Thinking applications in industrial contexts prioritize interface design and functional completeness, while offering limited mechanisms for ensuring that user-defined needs are translated into analytically rigorous system outputs. Consequently, systems developed using purely user-centered approaches may improve user experience but fail to enhance reliability analysis capability or decision quality. This research is based on the design thinking framework shown in Figure 1.

Figure 1 Design Thinking Framework

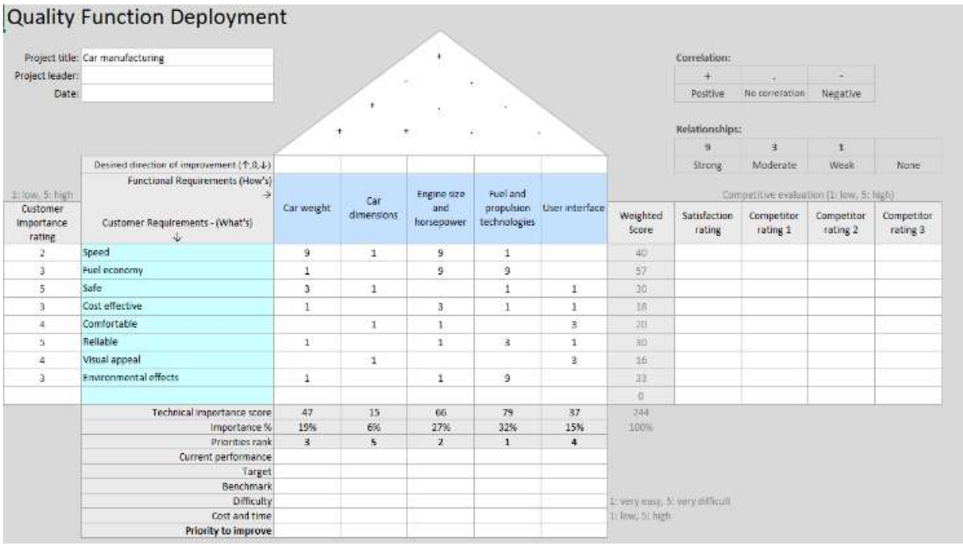
*name of corresponding author

SinkrOn
JURNAL & PENELITIAN TEKNIK INFORMATIKA
Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 10, Issue 1, Januari 2026
DOI : https://doi.org/10.33395/sinkron.v10i1.15792
e-ISSN : 2541-2019
p-ISSN : 2541-044X

Requirement Translation and the Role of Quality Function Deployment

Quality Function Deployment (QFD) provides a structured method for translating customer or user requirements into technical specifications, enabling traceability between stakeholder needs and system features (Mazur, 2020) (Franceschini, 2022). In engineering design, QFD has been shown to improve prioritization and reduce feature redundancy.

Despite these strengths, existing applications of QFD are largely concentrated on product development and manufacturing system design. Limited studies apply QFD to information systems for maintenance or reliability management, and even fewer explicitly link QFD outputs to quantitative reliability indicators. As a result, requirement translation processes often prioritize functional features without systematically embedding reliability metrics as core analytical outputs. QFD worksheet can be seen in Figure 2.



Quality Function Deployment

Project title: Car manufacturing
Project leader:
Date:

Correlation: + Positive; . No correlation; - Negative

Relationships: 9 Strong; 3 Moderate; 1 Weak; None

Customer Importance rating (1: low, 5: high)	Customer Requirements - (What's) ↓ / Functional Requirements (How's) →	Car weight	Car dimensions	Engine size and horsepower	Fuel and propulsion technologies	User interface	Weighted Score	Satisfaction rating	Competitor rating 1	Competitor rating 2	Competitor rating 3
	Desired direction of improvement (↑,0,↓)							Competitive evaluation (1: low, 5: high)			
2	Speed	9	1	9	1		40				
3	Fuel economy	1		9	9		57				
5	Safe	3	1		1	1	30				
3	Cost effective	1		3	1	1	18				
4	Comfortable		1	1		3	20				
5	Reliable	1		1	3	1	30				
4	Visual appeal		1			3	16				
3	Environmental effects	1		1	9		33				
							0				
	Technical importance score	47	15	66	79	37	244				
	Importance %	19%	6%	27%	32%	15%	100%				
	Priorities rank	3	5	2	1	4					
	Current performance										
	Target										
	Benchmark										
	Difficulty						1: very easy, 5: very difficult				
	Cost and time						1: low, 5: high				
	Priority to improve										

Figure 2 Quality Function Deployment

Synthesis and Identified Research Gap

The reviewed literature reveals a clear fragmentation among three research streams: (1) alarm-oriented operational monitoring systems, (2) analytically rigorous but operationally detached reliability engineering models, and (3) user-centered design approaches with limited analytical integration. While each stream addresses important aspects of maintenance management, their separation has hindered the development of information systems that are simultaneously user-oriented and reliability-driven.

Specifically, there is a lack of structured frameworks that integrate user-centered design methodologies with formal requirement translation techniques to embed quantitative reliability indicators—such as AFR, time to repair, and repair cost—directly into operational information systems. This gap indicates the need for an integrated design approach capable of bridging usability, operational relevance, and reliability analytics within data center maintenance decision support systems.

METHOD

Research Design

This study adopts a qualitative design-oriented research methodology integrating Design Thinking (DT) and Quality Function Deployment (QFD) to develop an equipment reliability information system for a data center environment. The methodological framework is designed to ensure traceability between user needs, system features, and reliability indicators, including Annual Failure Rate (AFR), time to repair, and repair cost. The overall research process is illustrated in Figure 3.

Participant Selection and Data Collection

Participants were selected using purposive sampling to ensure representation of key operational roles directly involved in data center maintenance and decision-making processes. Six participants were involved, consisting of maintenance technicians, an operational supervisor, an engineering manager, and an operations manager. The selection criteria were based on participants' direct responsibility for equipment operation, maintenance planning, and reliability-related decision-making. Data collection was conducted through semi-structured interviews, supported by direct observation of maintenance workflows and system usage. Interviews focused on current

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 10, Issue 1, Januari 2026
DOI : https://doi.org/10.33395/sinkron.v10i1.15792
e-ISSN : 2541-2019
p-ISSN : 2541-044X

system limitations, information needs related to reliability indicators, and challenges in maintenance decision-making.

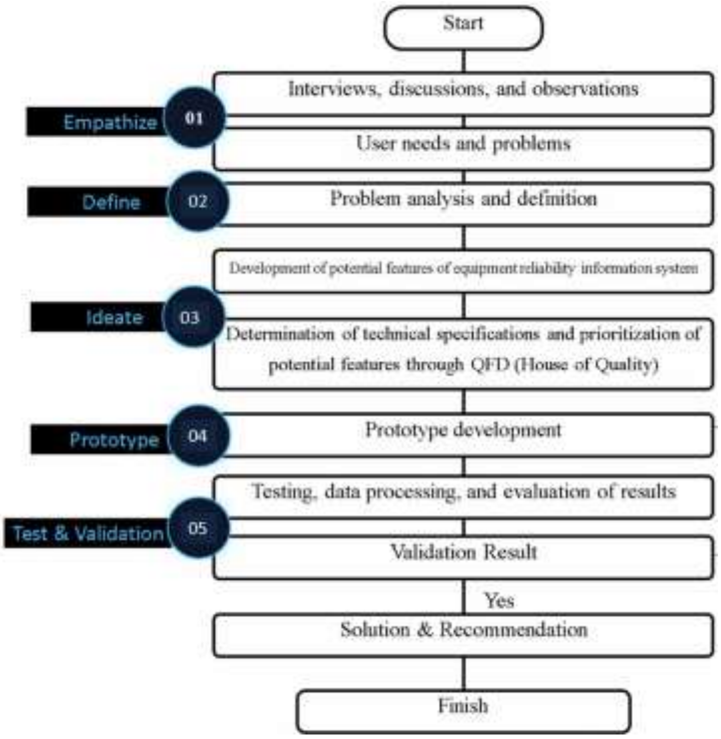


Figure 3 A design thinking-based research methodology integrated with Quality Function Deployment (QFD) in developing an information system for equipment reliability in data centers.

Define Stage: Problem Structuring and User Personas
Findings from the thematic analysis were synthesized into structured problem statements and categorized into three primary user personas: operators/technicians, operational supervisors, and maintenance planners. These personas represent distinct decision-making levels and were used to contextualize user requirements during system design.

Ideate Stage: Requirement Translation Using QFD
The Ideate stage integrates DT with QFD to translate user requirements into prioritized technical specifications. User requirements derived from thematic analysis were treated as customer requirements within the House of Quality. Each requirement was assigned an importance weight based on frequency of occurrence and perceived operational impact. Relationships between user requirements and technical features were evaluated using standard QFD relationship scales (strong, moderate, weak). This process resulted in prioritized system features explicitly linked to reliability indicators.

Prototype Development
A high-fidelity prototype was developed based on prioritized QFD outputs. The prototype represents core system functionalities, including work order tracking, maintenance history databases, asset master data management, and visualization of reliability indicators such as AFR, *time to repair*, and *repair cost*. The prototype was designed to reflect realistic operational workflows.

Validation and Evaluation Framework
System validation was conducted through a two-layer evaluation framework. First, usability testing was performed with participants using scenario-based tasks representing typical maintenance and decision-making activities. User feedback focused on clarity of information, relevance of reliability indicators, and ease of interpretation. Second, expert validation was conducted through structured review sessions with senior engineering and operations personnel to assess the logical consistency of reliability indicators, feature relevance, and alignment with maintenance objectives.

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 10, Issue 1, Januari 2026
DOI : https://doi.org/10.33395/sinkron.v10i1.15792
e-ISSN : 2541-2019
p-ISSN : 2541-044X

Credibility of qualitative findings was enhanced through triangulation between interview data, observational findings, and prototype evaluation results. This multi-step validation approach strengthens the methodological rigor and supports the reliability of the proposed system design.

RESULT

Empathize

This section discusses the results of an exploration of user needs for equipment reliability information systems in data centers. The analysis was conducted through interviews with key stakeholders directly involved in equipment operation and maintenance to identify critical information needs and the limitations of existing information systems in supporting reliability-based maintenance strategies.

To gain a comprehensive understanding of user needs for equipment reliability information systems, this study conducted interviews with key stakeholders in the data center environment: three maintenance technicians, one operations manager, one engineering manager, and one operations director. The interviews focused on two main aspects: identifying critical features and information needed to support maintenance strategies, both existing and planned, and evaluating the limitations of existing information systems. The interviews showed that existing systems are generally still oriented toward status and alarm monitoring, with constraints in providing historical reliability indicators, failure analysis, and support for long-term maintenance planning. These limitations make it difficult for the engineering and maintenance teams to formulate maintenance priorities, evaluate the effectiveness of preventive maintenance, and make strategic decisions based on reliability data. These findings form the basis for formulating user requirements and developing a more analytical and decision-oriented equipment reliability information system.

Define

Based on the results of interviews during the Empathize phase, the Define phase focused on formulating user requirements and identifying key issues with the existing information system. The analysis revealed that the requirements for an equipment reliability information system focused on several key aspects: a complete asset list, reminders for preventive and corrective maintenance (PM/CM) activities, monitoring work status (start, pause, pending), a follow-up mechanism for field findings, a maintenance schedule calendar, maintenance work order compliance, maintenance activity history (PM and CM), and failure rate analysis capabilities. These requirements reflect user demands for a system that not only functions as a monitoring tool but also supports strategic decision-making for reliability-based maintenance.

However, the current information system has several significant limitations. The existing system does not provide reminders for PM/CM plans, does not offer a history of maintenance activities for each piece of equipment, and does not support data on failure rates and repair costs. This lack of information hinders the evaluation of historical equipment reliability performance, complicates the analysis of maintenance program effectiveness, and limits management's ability to prioritize maintenance based on risk and cost.

Therefore, the primary problem addressed in this study is the need for an integrated equipment reliability information system capable of presenting historical data and reliability analytics and supporting more systematic, data-driven maintenance decision-making.

Ideate

The primary input for implementing QFD at the Ideate stage comes from the results of the Empathize and Define stages, which are formulated as customer requirements. These requirements include a complete asset list, PM/CM reminders, maintenance work status, follow-up on findings, a maintenance schedule calendar, work order compliance, maintenance history (PM and CM), failure rate analysis, and repair costs. Each user requirement is weighted by importance on a scale of 1–5 to reflect its level of influence on the maintenance strategy's effectiveness and equipment reliability. Based on these needs, several potential technical features (design requirements) for an equipment reliability information system were formulated, including asset master data management, interactive calendar and schedule automation, work order status recording and completion, integration with a ticketing system, a per-equipment maintenance and repair history database, and a reliability and failure analysis module, as presented in Figure 4.

*name of corresponding author

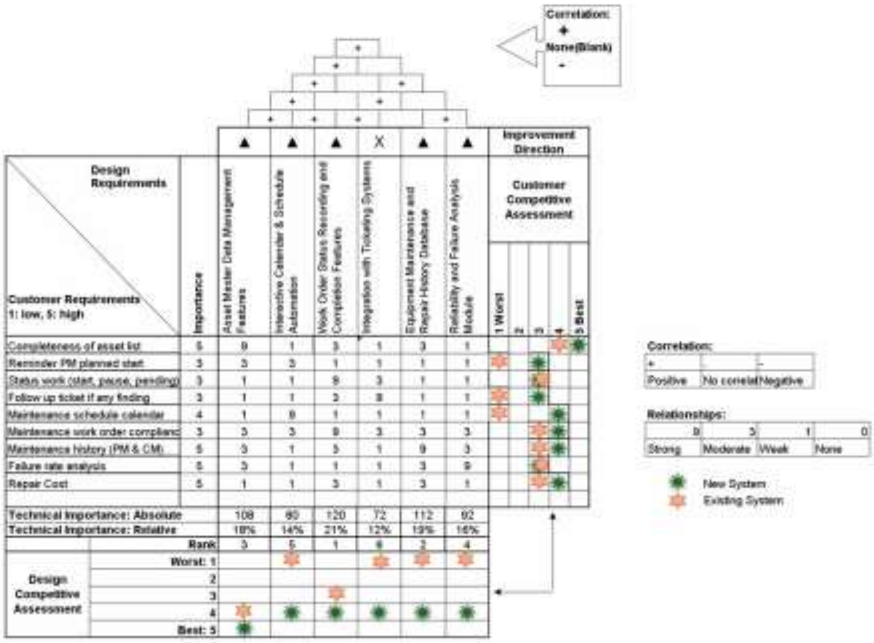


Figure 4 Quality Function Deployment (QFD) Matrix for System Feature Prioritization Equipment Reliability Information

On the left side of the matrix (customer requirements), user requirements derived from the Empathize and Define stages are defined, such as completeness of asset lists, PM/CM reminders, work status, follow-up on findings, maintenance schedules, work order compliance, maintenance history, failure rate analysis, and repair costs. Each user requirement is weighted by importance (scale 1–5), which reflects the user's perception of its impact on the effectiveness of maintenance strategies and equipment reliability.

At the top of the matrix (design requirements), technical features of the information system are formulated that have the potential to address these needs, including asset master data management, interactive calendar and schedule automation, work order status recording and completion features, integration with a ticketing system, a maintenance and repair history database for each piece of equipment, and a reliability and failure analysis module. The relationship between user needs and technical features is assessed using the QFD relationship scale (strong = 9, moderate = 3, weak = 1, and no relationship = 0), demonstrating the extent to which each feature contributes to meeting user needs.

Technical importance is calculated by multiplying the importance weight of each user requirement by the relationship value in each matrix cell, then summing the values for each technical feature. The results of this calculation yield absolute and relative importance values that serve as the basis for determining feature development priorities. Furthermore, the roof section of the House of Quality is used to identify correlations among technical features, allowing potential synergies and conflicts to be considered during the design phase.

Based on the QFD results, the top priorities for developing equipment reliability information system features are: (1) a feature for recording work order status and completion, (2) a database for maintenance and repair history per piece of equipment, (3) an asset master data management feature, and (4) a reliability and failure analysis module. These priorities indicate that users place transparency of the maintenance process, availability of historical data per piece of equipment, and reliability analytics capabilities as key elements in supporting a data-driven maintenance strategy. Thus, QFD plays a crucial role in bridging user needs and technical solutions, ensuring that the ideation process yields solutions that are relevant, measurable, and focused on improving equipment reliability.

Prototype

As shown in Figure 5, the Prototype stage in this research was conducted by developing a supplementary system in the form of an equipment reliability information system that can be used as a benchmarking tool against existing information systems in the data center. This prototype was not designed to replace the existing system, but rather to complement and evaluate its capabilities for providing historical data, asset traceability, and equipment reliability analytics.

According to Figure 5, the prototype integrates four main features prioritized in the Ideate stage using QFD: (1) a feature for recording status and completing work orders, (2) a database of maintenance and repair history per piece of equipment, (3) an asset master data management feature, and (4) a reliability and failure analysis module.

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 10, Issue 1, Januari 2026
DOI : https://doi.org/10.33395/sinkron.v10i1.15792
e-ISSN : 2541-2019
p-ISSN : 2541-044X

These four features are represented in a single, interconnected data structure, enabling end-to-end tracking of outage and maintenance information, from asset identification to repair results (Chen, 2021).

The work order status and completion feature, as shown on the left side of Figure 5, records critical information related to the outage management cycle, including ticket opening and closing times, repair times, and job status. A database of maintenance and repair history per piece of equipment
enables structured storage of PM and CM history, allowing historical analysis of each asset's reliability performance. The asset master data management feature serves as the primary reference linking data on location, system, subsystem, and equipment type. Meanwhile, the reliability and failure analysis module, shown on the right side of Figure 5, is designed to process this historical data into reliability indicators such as failure frequency and Annual Failure Rate (AFR).

Figure 5 Implementation of Equipment Reliability Information System Prototype

Referring to Figure 5, this prototype demonstrates how integrating operational and maintenance data can improve visibility into equipment reliability compared to the existing system. This supplementary system approach enables a realistic evaluation of the benefits of the proposed features before full implementation. It strengthens the design justification for the equipment reliability information system developed in this study.

Test & Validation

In the Test and Validation phase, the equipment reliability information system prototype was tested and validated with users to assess the system's ability to support data-driven strategic maintenance decisions. Testing was conducted using historical outage and maintenance data that represented data center operational conditions, ensuring that the evaluation results reflected realistic usage scenarios.

As shown in Figure 6, the prototype presented failure frequency per piece of equipment in an annual failure visualization. Through this display, users could quickly identify the equipment experiencing the most frequent outages across both electrical and mechanical systems, without manual data processing. This information served as the initial basis for determining maintenance priorities and evaluating the effectiveness of the ongoing preventive maintenance program.

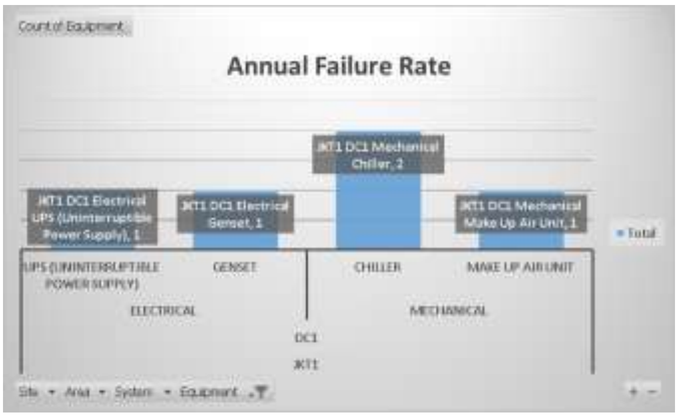


Figure 6 Failure frequency per equipment (annual historical data).

Furthermore, Figure 7 shows a visualization of repair costs per piece of equipment, allowing users to identify which assets contribute the most to repair costs. With structured and integrated repair cost data available, engineering and maintenance teams can conduct more objective cost analyses, including determining the focus for cost control and justifying the procurement of supporting components or equipment.

*name of corresponding author

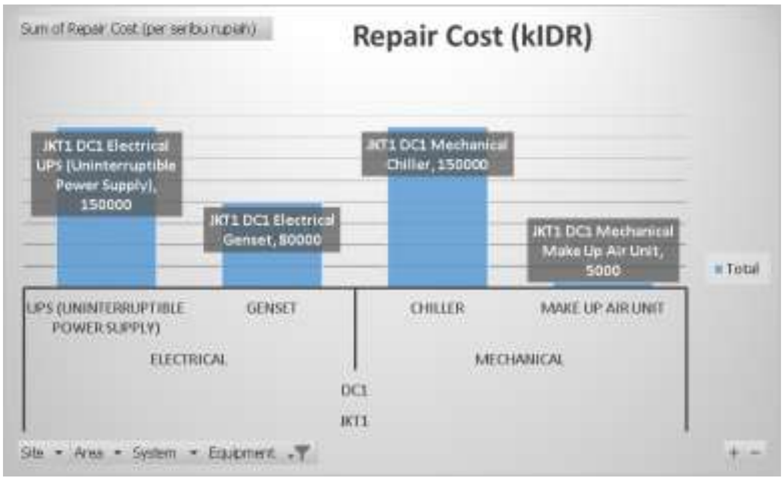


Figure 7 Visualization of repair costs per piece of equipment as a basis for analyzing maintenance cost contributions.

Regarding repair duration, Figure 8 presents the average time to repair per piece of equipment. This information provides an overview of the equipment that takes the longest time to repair when a disruption occurs. Based on this data, users can analyze the need for critical spare parts to expedite repairs and reduce potential downtime that impacts data center availability.

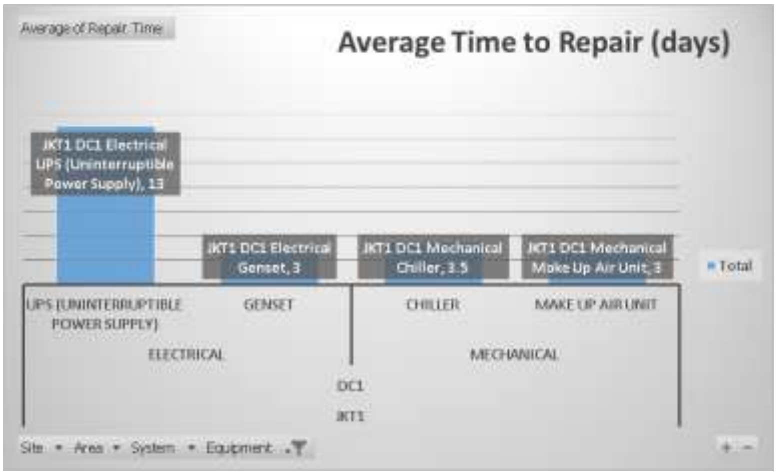


Figure 8 Visualization of the average time to repair per piece of equipment to evaluate the duration of outage handling.

Overall, the test results demonstrated that the prototype could integrate outage, cost, and repair-time data into a single analytical system that users easily interpreted. By leveraging the QFD results prioritization features, users could conduct reliability analysis and evaluate maintenance programs without relying on manual data processing. Furthermore, the resulting failure analysis data supported the formulation of more data-driven advanced maintenance strategies to reduce equipment failure rates and sustainably improve system reliability.

The Test and Validation are also conducted with usability evaluation, efficiency gain, decision accuracy. Participants completed the 10-item System Usability Scale (SUS) questionnaire after interacting with the prototype with score result 82.5. It is indicate excellent usability. With the efficiency gain for task completion, from 1 month (160 hours) evaluation become only 1 day (40 hours) evaluation. Overall average task time reduction is 75% efficiency gain.

DISCUSSIONS

The findings of this study contribute to the ongoing discourse on maintenance digitalization and reliability-centered maintenance (RCM) by demonstrating that the primary limitation in many data center environments is not the absence of monitoring technology, but the lack of analytical integration between operational data and reliability metrics. Prior studies on maintenance information systems predominantly emphasize real-time monitoring, fault detection, and alarm management. However, such approaches often reinforce reactive

*name of corresponding author

maintenance behavior rather than enabling strategic reliability optimization. The present study extends this body of knowledge by empirically illustrating how the integration of Design Thinking and Quality Function Deployment (QFD) can structurally align user-centered system design with reliability engineering principles.

Theoretically, this research bridges two domains that are typically treated separately: human-centered system design and quantitative reliability analysis. While Design Thinking literature emphasizes empathy and iterative prototyping, it rarely formalizes the translation of qualitative user insights into measurable technical reliability parameters. Conversely, reliability engineering research focuses on metrics such as Annual Failure Rate (AFR), repair time, and cost modeling, often without incorporating structured user requirement prioritization. By integrating QFD into the Design Thinking framework, this study proposes a traceable transformation mechanism—from stakeholder needs to reliability indicators—thereby contributing a methodological linkage between socio-technical system design and asset performance analytics.

Furthermore, the empirical evaluation demonstrates improvements in usability, efficiency, and decision accuracy supports the argument that reliability intelligence must be operationally interpretable to generate organizational impact. This reinforces socio-technical system theory, which posits that technological capability alone does not improve performance unless aligned with human workflow and decision structures. The findings suggest that maintenance digitalization maturity depends not merely on data availability, but on structured integration of reliability metrics into decision workflows.

From a theoretical standpoint, the study contributes in three keyways:

1. It reframes maintenance information systems as reliability intelligence platforms, extending beyond monitoring-centric paradigms.
2. It introduces an integrated DT–QFD framework as a replicable design methodology for reliability-oriented system development.
3. It empirically demonstrates that structured alignment between user requirements and reliability metrics can measurably improve decision-support performance.

Thus, the contribution of this paper lies not only in the development of a prototype, but in proposing and validating a methodological model that connects human-centered design with reliability engineering analytics in critical infrastructure environments. Future research may further examine long-term operational impacts, such as downtime reduction and lifecycle cost optimization, to extend the theoretical model toward predictive and prescriptive maintenance domains.

CONCLUSION

This study provides empirical evidence that the effectiveness of maintenance digitalization in data center environments depends not merely on monitoring capability, but on the integration of reliability analytics into decision-making workflows. The findings demonstrate that aligning user-centered design processes with structured reliability metrics significantly improves decision-support performance, as reflected in measurable gains in usability, analytical efficiency, and prioritization accuracy. These results suggest that the transformation from reactive monitoring systems toward reliability intelligence platforms requires methodological integration between socio-technical design approaches and quantitative reliability engineering.

The primary scientific contribution of this research lies in the development and validation of an integrated Design Thinking–QFD framework that establishes traceable linkage between stakeholder requirements and reliability indicators such as failure rate, repair cost, and average time to repair. This integration advances existing literature by bridging human-centered system design and reliability analytics within a unified methodological structure applicable to critical infrastructure contexts.

However, several limitations must be acknowledged. First, the evaluation was conducted within a single organizational setting, limiting generalizability. Second, the empirical assessment focused on short-term decision-support performance rather than long-term operational outcomes such as downtime reduction or lifecycle cost improvement. Third, the sample size for usability and decision testing was relatively limited.

Future research should therefore examine longitudinal implementation effects, incorporate multi-site validation, and explore integration with predictive and prescriptive maintenance models. Extending the framework toward advanced analytics and AI-based failure prediction would further strengthen its theoretical and practical relevance in reliability-centered asset management.

e-ISSN : 2541-2019
p-ISSN : 2541-044X

REFERENCES

Sembiring, F. a. (2021). IMPLEMENTASI PENJADWALAN PREVENTIVE MAINTENANCE SISTEM INFORMASI DENGAN METODE RCM DI PT PRATAMA ABADI INDUSTRI (JX). Jurnal Riset Sistem Informasi dan Teknologi Informasi (JURSISTEKNI), 25-35.

Basanta, F. a. (2017). erancangan Aplikasi Analisis RCM (Reliability Centered Maintenance) Dan RCS (Reliability Centered Spares) Dalam Menentukan Kebijakan Maintenance Dan Persediaan Spare Part. *eProceedings of Engineering.*

Gunawan, A. S. (2017). Perancangan Maintenance Management Informastion System untuk Unit Pemadam Kebakaran (Studi Kasus: PERUSAHAAN X). *Jurnal Nasional Teknologi Dan Sistem Informasi, 3(2)*, 219-224.

Kurniasari, S. S. (2018). Evaluasi Kebutuhan Fungsional Sistem Informasi Pelaporan Kegiatan Menggunakan Metode Quality Function Deployment di BNN Kota Malang. *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer, 2(12)*, 7331-7337.

Akao, Y. &. (2020). *Quality Function Deployment: Integrating Customer Requirements into Product Design.* New York: Productivity Press.

Brown, T. &. (2023). *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation (Revised ed.).* Harper Business.

Chen, L. H. (2021). Fuzzy Quality Function Deployment for maintenance strategy selection in critical infrastructure. *Fuzzy Quality Function Deployment for maintenance strategy selection in critical infrastructure. Journal of Quality in Maintenance Engineering, 27(4)*, 812-830.

Rodriguez, M. &. (2024). Bridging the gap: Integrated frameworks for reliability analysis and system design in data centers. . *International Journal of Information Technology & Decision Making*, 45-68.

Tan, K. C. (2022). Integrating Design Thinking into Quality Function Deployment: A structured framework for digital transformation. *Journal of Engineering and Technology Management*, 101-118.

Dam, R. F. (2023). *Design Thinking: Get Started with the Empathy Map. Interaction Design Foundation. Curedale, R.* Interaction Design Foundation.

Curedale, R. (2019). *Design Thinking: Process and Methods Guide.* Design Community College Inc.

Veldman, J. &. (2024). Maintenance strategy selection under uncertainty: A systematic review. *Journal of Manufacturing Systems*, 115-132.

Zio, E. (2022). Prognostics and Health Management (PHM): Where are we and where are we going? Reliability Engineering & System Safety.

Mazur, G. H. (2020). Quality Function Deployment (QFD) for Systems Engineering. *International Journal of Quality & Reliability Management*, 37.

Franceschini, F. G. (2022). *anagement by Measurement: Designing Key Performance Indicators and Performance Measurement Systems.* Springer Nature.

Ahmad, R. &. (2019). An overview of time-based and condition-based maintenance in ndustrial application. *Computers & Industrial Engineering,*, 681-690.

O'Connor, P. D. (2021). *Practical Reliability Engineering (6th ed.).* Wiley.

*name of corresponding author