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Original Article

Design of Application to Improve Maintenance Management of Heavy-Duty Transport Units

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Abstract - *Maintenance management is a process that optimizes the performance of an organization's assets, ensuring that these facilities operate regularly and efficiently. Its use in companies of different industries responds to the need to extend the useful life of their assets and increase capital investments to contribute to market growth. The aim is to develop a model of a mobile application to optimize the maintenance management processes of heavy transport units. The Scrum methodology was used because it adapts to the needs of the company and meets important characteristics such as flexibility, incremental delivery, and adaptability. The result was a prototype application to optimize the maintenance management process of heavy load transport units, which has a design and functionalities that allow users to interact with the system dynamically. To evaluate the quality of the prototype, experts evaluated aspects such as efficiency, usability, design, and functionality. Once the evaluation was done, the result was 4.68 on average. This shows that the quality of the prototype is high. It is concluded that it was possible to develop a prototype application to improve maintenance management, which complies with the characteristics mentioned above and allows users to improve maintenance management.*

Keywords - *Application Design, Maintenance Management, Mobile Application, Scrum, SMES.*

1. Introduction

In recent years, the emergence of new technologies and computer-aided maintenance management systems has gained relevance due to the need of industries to extend the useful life of their assets [1, 2]. The global Computer-Aided Maintenance Management Systems (CMMS) market size was valued at $1.11 billion in 2022 and is expected to grow at a CAGR of 10.9% from 2023 to 2030. The increase in the market is attributed to government spending on infrastructure projects, growth of Small and Medium Enterprises (SMEs), rapid adoption of digital services, and growth in IT spending [3]. In the case of the UK, the global CMMS systems market was valued at $52.5 million in 2020; by 2021, this amount increased to $56.1 million. Furthermore, according to statistical data, it is expected that between 2023 and 2030 the market will experience an annual growth of 8.2% [3]. In the case of the United States, the CMMS systems market was valued at $272.06 million in 2020 and is expected to increase to $524.84 million by 2028, representing an annual growth rate of 8.6% from 2021 to 2028 [4]. The manufacturing and service delivery segment held a major share of the market, accounting for more than 20% in 2021. Computerized maintenance management systems help the manufacturing industry by supporting preventive maintenance strategies and reducing machine downtime during working hours. This software tracks equipment that keeps track of assets and quickly locates data. It assists manufacturing plants and prevents machines and equipment from breaking down [3]. Intensifying competition in the international market and the increasing demand for product quality have made reliability a fundamental requirement. This refers to confidence that a machine or equipment will perform its essential function within a predetermined period. Both reliability and availability are concepts used within maintenance management. The interaction between these two aspects is evident, and it is essential to have a quality model that ensures that this management conforms to the standards necessary to drive the production process [5] effectively Haga clic o pulse aquí para escribir texto..

Despite the growth of the CMMS market [6], studies such as [7] reveal that 44% of companies in developing countries lack systems adapted to specific needs, such as the maintenance of heavy transport units. These companies face high costs due to unplanned downtime [5] due to reliance on reactive methods. Recent work [8] proposes Machine Learning solutions, but their implementation in mobile fleets is still limited. This paper addresses these gaps through a prototype developed with Scrum, which prioritizes (1) mobile accessibility for drivers/technicians, and (2) fault reporting automation, a functionality not explored in studies such as [9]. In the heavy haulage sector, companies such as Transportes

Nacionales S.A. [10] report that 30% of their operating costs are derived from unplanned downtime, due to the lack of mobile systems to report failures in real time. These critical points justify the development of a mobile solution that allows: Instantaneous fault reporting by drivers (reducing diagnostic time by 50%, according to [11]), and dynamic assignment of technicians based on location (not covered in [12]).

The importance of this study lies in its potential to not only improve the operability of vehicle fleets but also to promote road safety and reduce operating costs, thus contributing to the sustainable development of the companies in which the maintenance management system is implemented.

2. Bibliographic Review

2.1. Limitations of Existing Solutions

While [13] states that traditional CMMSs focus on static reports, evidence that 60% of SMEs do not use historical data for predictive maintenance; the report highlights that 70% of construction companies in Latin America lack systems to prioritize critical failures, which generates maintenance cost overruns of 25%. This gap is widened in heavy transport, where [7] identifies that only 15% of fleets use historical data for predictive purposes, compared to 45% in manufacturing.

The present prototype advances by integrating: Real-time mobile interfaces (not covered in [14]). Agile prioritization of failures through Scrum (vs. rigid approaches in [15]. In addition, studies such as [12] propose mobile applications, but without expert-validated usability metrics, a gap that this paper fills.

2.2. Opportunities Addressed

At [16], the key indicators that should be considered when selecting a maintenance management system were highlighted, as well as the benefits they present in the industry. Seven factors were considered as independent variables, and four dependent variables were obtained.

The concepts of intelligent workflow and its relation to the automation of maintenance management processes were studied in [8]. It was found that among the processes that benefit is the generation of work orders, which, together with Machine Learning, helps automate the workflow, simplifying and improves maintenance processes.

The studies conducted in [7] explored the status of Computer-Aided Maintenance Management Systems (CMMS) in industries in developing countries. Interviews were conducted with consulting companies, and the results showed that 44% of the companies did not have a CMMS system. It was also determined which were the main challenges and difficulties that are usually encountered when implementing a CMMS system, to serve as a guide for companies that plan to implement a system of these characteristics.

Likewise, in [13], the objective was to determine the role of Computer-Aided Maintenance Management Systems (CMMS) in the different sectors of the industry, indicating which are the current technologies used in these systems. Among the main results obtained are that CMMS systems contribute to the creation of reports, preventive and corrective planning, and decision-making, thanks to the generated indicators.

Aspects such as warehouse inventory, equipment inventory, and scheduled and corrective work orders were studied. International indicators such as reliability, availability, and maintainability were implemented to implement an effective maintenance plan. At the end of the study, the use of a Computer-Aided Maintenance Management System (CMMS) was suggested to increase speed and optimize the work order generation process.

Factors such as the impact of maintenance management on production were studied in [17]. Improvements were proposed to the preventive and corrective maintenance plan for port equipment to increase customer satisfaction. The methodology used was based on an exploratory analysis involving techniques such as observation and survey.

In addition, in [14] emphasis was placed on providing a structured, organized, and easy-to-follow methodology for the administration of computer equipment maintenance through a system designed for this purpose. The results obtained from this research indicate that the use of a Maintenance Management System (CMMS) allows better control of inventories, incidents, and interventions in the equipment.

Finally, in [15], the lean-based TPM approach was used for the development of maintenance plans. Structured activities based on the Six Sigma method, a statistical tool, were carried out, and an improvement in the response of the personnel was noted, motivating them to perform more effectively in terms of productivity and efficiency.

3. Methodology

3.1. Development Fundamentals

In the elaboration of this research work, a survey was made of current agile methodologies. To choose the development method, several criteria were considered, including the amount of information available, the familiarity of each method, and its compatibility and ease of implementation.

The Scrum methodology obtained the highest score (see Figure 1), so it was decided to apply it in the development of this project.

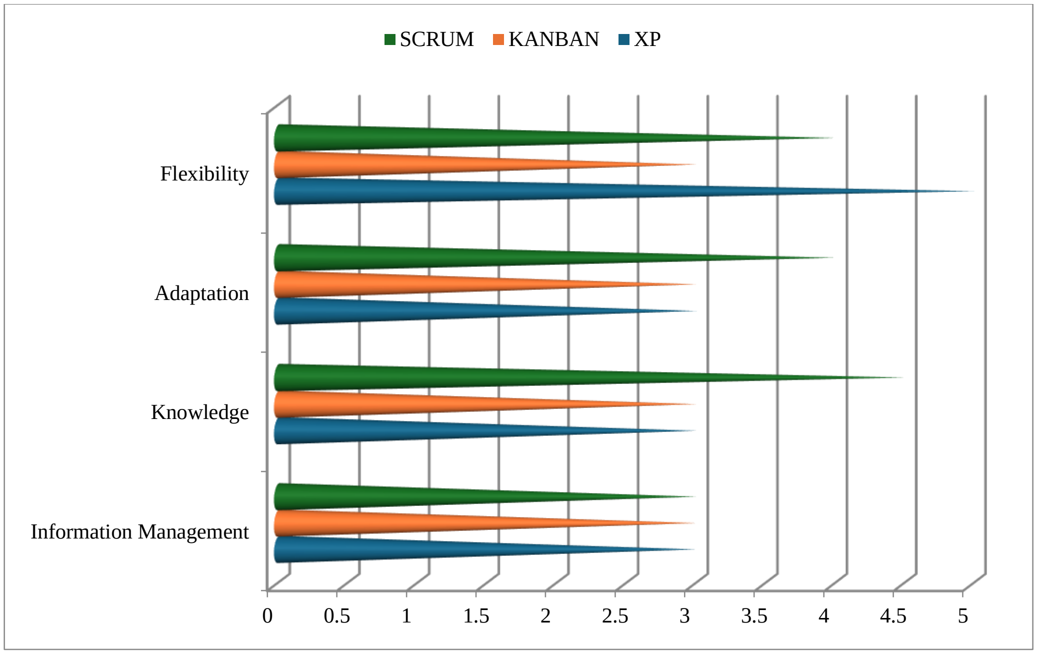

Fig. 1 Methodology chart

The selection of Scrum was based on a multi-criteria evaluation (Table 1), where it outperformed XP and Kanban in adaptability (4/5) and flexibility (4/5), crucial for a project with dynamic requirements such as fleet management. To adapt the framework:

3.1.1. Customized Roles

The Product Owner was a maintenance supervisor with fleet experience, ensuring that the backlog reflected real needs (e.g., prioritization of bug reports in Sprint 1).

The Scrum Master coordinated weekly (non-standard) deliverables to align with the company's preventive maintenance cycles.

3.1.2. Adjusted Artifacts

Sprints were designed in 2-week cycles (vs. traditional 4-week cycles) for rapid iterations, based on [18]. The Definition of Done (DoD) included validation with end-users (drivers/technicians), a practice not mentioned in [19].

Table 1. Multi-criteria evaluation for agile methodology selection

Methodology/Criteria	XP	Kanban	Scrum	Criteria weight	Justification
Information management (3)	3	3	3	20%	All allow for agile justification.
Equipment knowledge (5)	3	3	5	25%	Scrum leverages multifunctional expertise to best advantage [19].
Adaptation (5)	3	3	4	25%	Scrum allows Sprints to maintain cycles [18].
Flexibility (5)	5	3	4	30%	XP is more flexible, but Scrum balances structure and adaptability.
Total Score	14	12	18	100%	Scrum obtained the highest weighted score.

The Scrum methodology is one of the most widely used development methodologies and involves carrying out a set of tasks regularly with a primary focus on collaboration and teamwork [19], which inherently includes iterations and continuous feedback [9, 18].

The central objective of this approach is to achieve the best possible result in a specific project. Scrum practices complement each other, and their integration is based on an analysis of how to coordinate teams to be highly competitive. Scrum is characterized by the regular and partial delivery of the final work, prioritizing according to the benefit that these deliveries bring to the project stakeholders [18]. This methodology is therefore particularly suitable for complex projects with changing requirements, where innovation and flexibility play a key role.

3.2. Case studies

In this sense, we proceeded with the execution of the chosen methodology, explaining the case study of the Scrum phases used in this project.

3.2.1. Star

It starts by identifying who the Scrum Team members are, including the Scrum Master, Product Owner, and Developers.

In addition, Product Backlog is characterized, which is utilized as the premise for detailing the Sprints and deliverable dates. According to [20], the roles within a Scrum team are as follows:

1) Product Owner: It plays a crucial role in Scrum by taking responsibility for managing the list of tasks and activities required for the development of a product or project. Its main function is to ensure that the development team has the necessary information and resources to carry out its work effectively.

2) Developers: Refers to the professionals in charge of delivering a finished product. These teams are multifunctional and have members who possess all the skills necessary for the creation of the product. The characteristic of these teams is that they work in an integrated manner, without subdividing into internal subgroups, since, in this agile methodology, the responsibility is shared.

3) Scrum Master: It takes responsibility for driving the process according to the theory, practice, and rules of agility. It is not for nothing that it is considered a framework that is easy to understand, but difficult to apply. He is therefore responsible for ensuring that people outside the team understand how this process works. Its role is to ensure that all stakeholders understand the objectives, scope, and domain of the product.

3.2.2. Planning and Estimation

In this stage, the product backlog becomes important, according to [21]. It consists of the creation of a list containing all the tasks to be carried out during the development of a project. Its main objective is to make these tasks visible to the entire team.

In addition, it should be organized and contain various elements that allow each task to be broken down and defined as precisely as possible. This includes details such as descriptions, the order of execution, and the importance of each task. The specific elements may vary according to the needs of each company.

1) Story estimation and prioritization: The quality of a system is measured by user satisfaction, which highlights the importance of identifying and prioritizing the functionalities that the system should include. At [22], the prioritization of User Stories is based on the value they bring to the customer, and it is the Product Owner's task to perform this task, making sure to keep the value updated throughout the project. There are several techniques to prioritize User Stories, which were used in this research, considering business objectives, market acceptance, and available resources.

2) Planning of deliverables: Once the user stories were completed, the estimation and prioritization were performed. The product backlog was then configured by sorting stories by priority and estimation, reflecting the team's interactions in the project. The project consists of 9 stories divided into 4 sprints (Table 2).

Table 2. Product backlog deliverable per sprint

	Functional Requirements (FR)	History (H)	Estimated Time (ET)	Estimated Points (EPs)	Priority (P)
Sprint 1	FR1: The web-based system should allow the driver to create fault reports.	H1	4	70	1
	FR2: The web-based system must allow the driver to view the fault reports created.	H2	3	40	1
Sprint 2	FR3: The web system must allow the supervisor to view a summary of all failure reports generated.	H3	2	40	1
	FR4: The web system must allow the supervisor to edit the failure reports.	H4	4	70	1
	FR5: The web system must have a user login.	H5	2	70	3
Sprint 3	FR6: The web system must allow the supervisor to view a list of technicians and their respective assigned faults.	H6	4	60	2
	FR7: The web system must allow the supervisor to assign additional activities to technicians.	H7	3	50	2
Sprint 4	FR8: The web system must allow the technician to visualize the faults assigned to him/her.	H8	2	30	2
	FR9: The web system must allow the Operator to consult and visualize information generated from the generation of fault reports.	H9	2	30	3

3.2.3. Implementation

In this phase, completed tasks and project examples are created using the determined and prioritized information from the planning phase.

This section will also present the conceptual, logical, and physical designs of the database, together with the prototype of the application. Figure 2 shows the final database model.

3.2.4. Application Architecture and Design

System Architecture

The application follows a client-server model with three main layers (Figure 3).

Frontend: Hybrid mobile development with React Native to ensure cross-platform compatibility (iOS/Android) and offline access to basic reports. The selection of React Native [23] was based on its balance between performance and cross-platform development, outperforming Flutter in deployment times for agile projects [24].

Backend: REST API in Node.js that manages business logic (e.g., technician assignment) and connects to the database.

Database: MongoDB (NoSQL) for storing bug reports, user profiles, and maintenance logs, optimizing flexible queries [25].

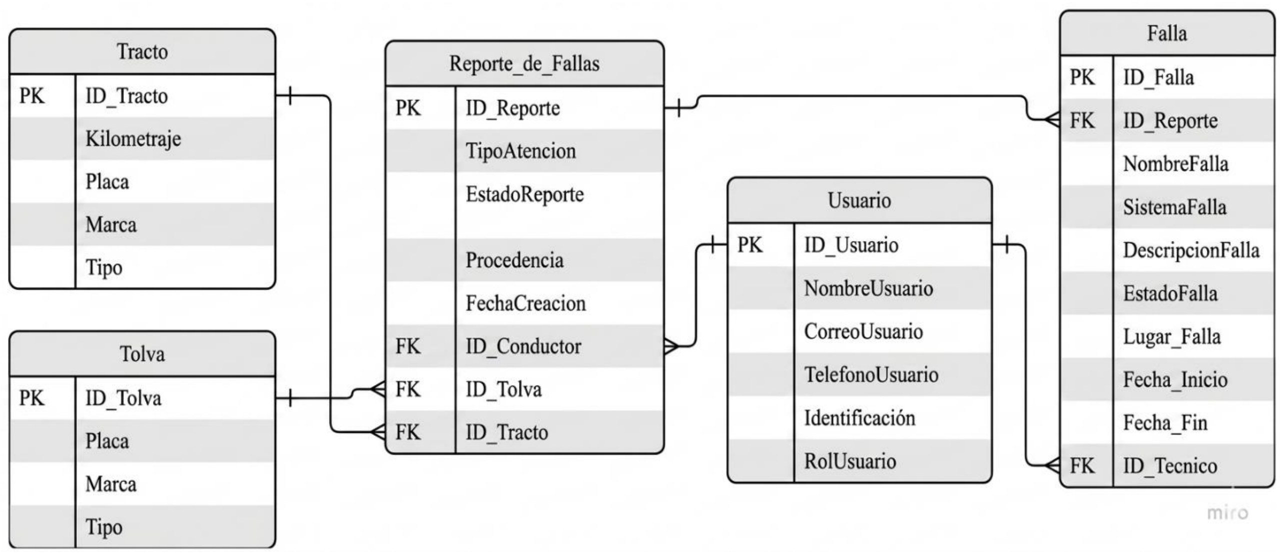

Fig. 2 Database model

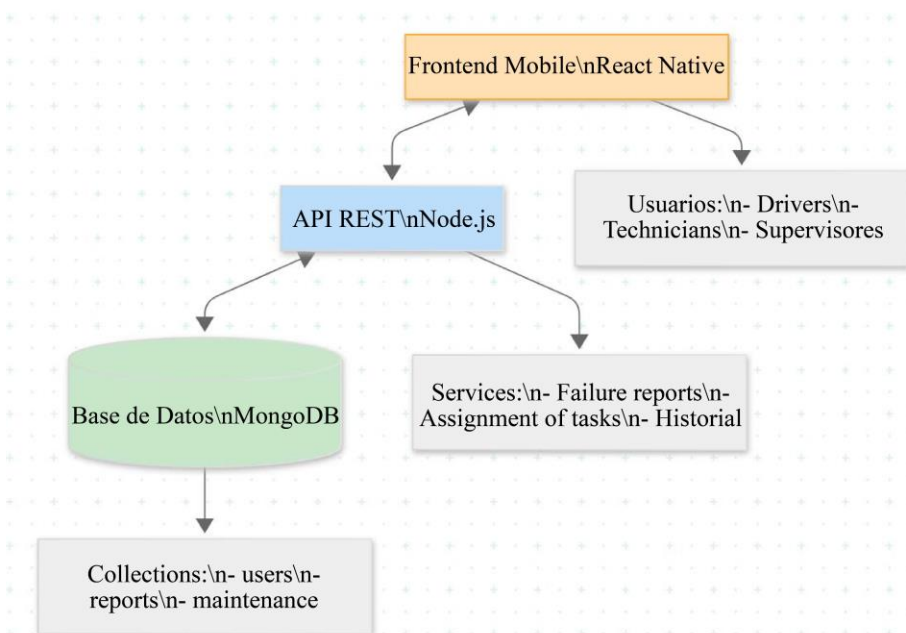

Fig. 3 Architecture diagram (client-server with layers)

This architecture was selected for its scalability and adaptability to environments with intermittent connectivity, common in remote areas where heavy fleets operate.

Design Options

The interface design (UI/UX) was based on:

MVVM (Model-View-ViewModel) pattern to separate logic and presentation, facilitating fast iterations during Sprints [26].

Reusable components: Floating Action Buttons (FABs) for quick reports and expandable cards for technical details [27].

Usability prioritization: Bottom menu with 3 key sections (Reports, Assignments, History), validated with users in Sprint 1 (see Figure 4).

Alternatives considered and discarded:

SQL database (e.g., PostgreSQL): less adaptable to schema changes during agile development.

Native Frontend: Required duplicate efforts for iOS/Android, increasing costs.

3.2.5. Development

During prototype development, iterative testing was conducted with end users (drivers, supervisors, and technicians) to gather feedback on the usability and functionality of the application.

These iterations allowed us to adjust design elements, such as button layout and clarity of bug reports, based on user feedback and suggestions.

For example, in the first iteration, users reported difficulties navigating between reports, which led to a reorganization of the main menu in Sprint 2. This iterative approach ensured that the application met the real needs of users and improved their overall experience.

1) First sprint: It has 2 functional requirements, their respective times, scores, and priorities are shown below in Table 3. The system allows the driver to create fault reports and visualize them. Figure 4 shows the corresponding prototype design: (a) shows the prototype that allows the entry of the basic information of the fault report, (b) allows visualization of the corresponding details of the report, (c) the prototype that allows the driver to view the fault reports created, and finally (d) shows the summary of the generated report.

2) Second sprint: It has 3 functional requirements. Table 4 shows their respective times, scores, and priorities. The system allows the supervisor to view a summary of the fault report generated and edit the fault reports, as well as allows users to log into the system. The prototype design is shown in Figure 5: (a) shows the prototype of the summary corresponding to the generated fault report ticket, (b) prototype design that allows editing the generated ticket, and (c) prototype of access to the application as a driver, supervisor, or operations user.

3) Third sprint: It has 2 functional requirements, their respective times, scores, and priorities (see Table 5). The system allows the supervisor to visualize a list of the technicians and their respective assigned faults and assign additional activities to the technicians.

Table 3. First sprint details

No Sprint	Functional Requirements (FR)	History (H)	Estimated Time (ET)	Estimated Points (EPs)	Priority (P)
Sprint 1	FR1: The web-based system should allow the driver to create fault reports.	H1	4	70	1
	FR2: The web-based system must allow the driver to view the fault reports created.	H2	3	40	1

Table 4. Second sprint details

	Functional Requirements (FR)	History (H)	Estimated Time (ET)	Estimated Points (EPs)	Priority (P)
Sprint 2	FR3: The web system must allow the supervisor to view a summary of all failure reports generated.	H3	2	40	1
	FR4: The web system must allow the supervisor to edit the failure reports.	H4	4	70	1
	FR5: The web system must have a user login.	H5	2	70	3

Fig. 4 Sprint backlog 1: User driver. (a) create fault reports, (b) prototype details of the report, (c) prototype report of malfunctions, and (d) prototype summary of the generated report.

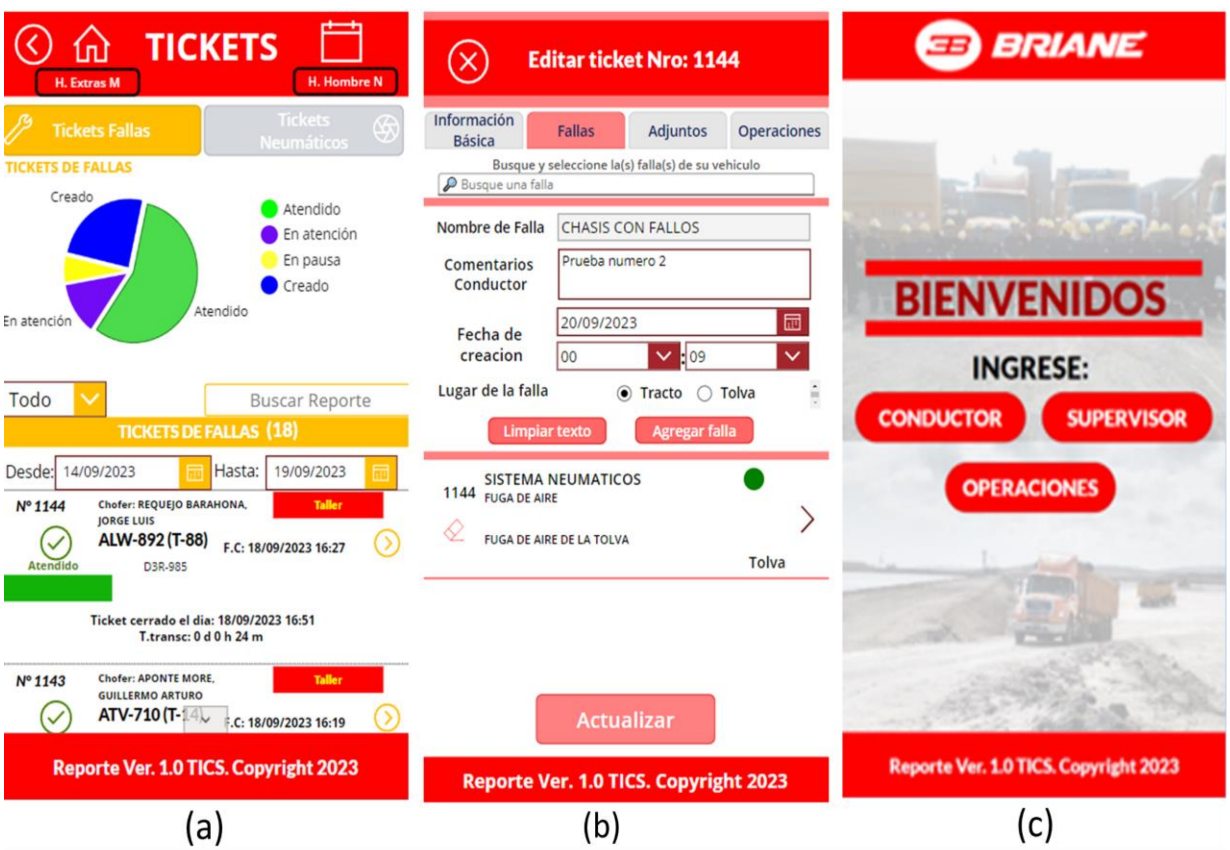

Fig. 5 Sprint backlog 2: User supervisor, (a) display summary of generated failure reports, (b) edit bug reports, and (c) user login.

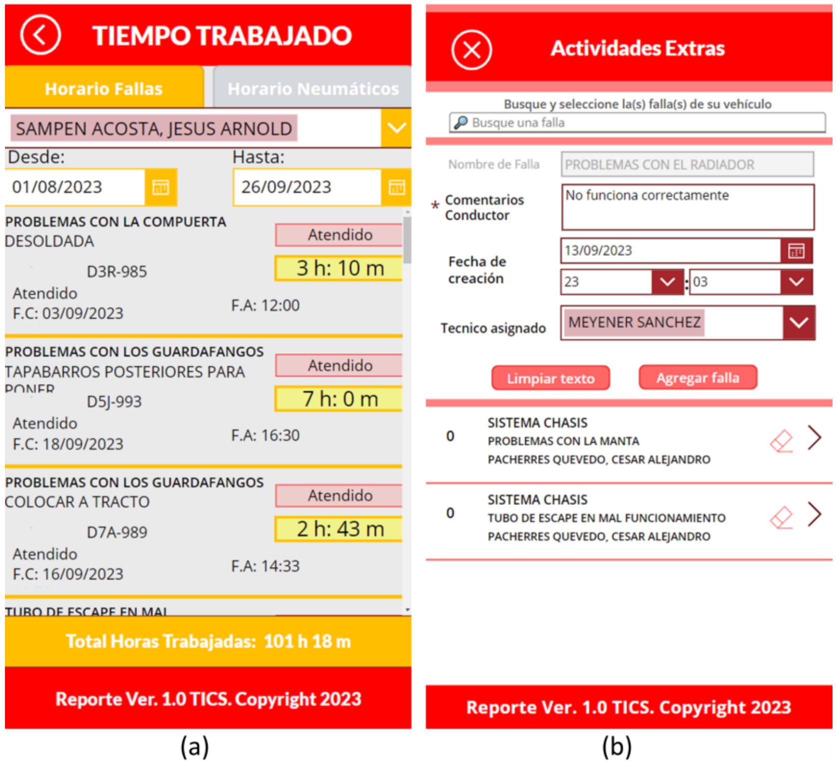

Fig. 6 Sprint backlog 3: User supervisor, (a) display a list of the technicians and their respective assigned faults, and (b) assign additional activities to technicians.

Figure 6 shows the prototype design: (a) shows the prototype with the list of technicians and their respective assigned breakdowns, and (b) shows a prototype that allows assigning additional activities to technicians.

4) Fourth sprint: It has 2 functional requirements; their respective times, scores, and priorities are shown in Table 6.

The system allows the technician to visualize the faults assigned to him and also allows the Operator to consult and visualize information generated from the generation of fault reports. The prototype design is shown in Figure 7: (a) shows the prototype that allows the faults that were assigned to it and the User Operator, and (b) shows the prototype that allows querying and viewing information about the generation of fault reports.

Table 5. Third sprint details

	Functional Requirements (FR)	History (H)	Estimated Time (ET)	Estimated Points (EPs)	Priority (P)
Sprint 3	FR6: The web system must allow the supervisor to view a list of technicians and their respective assigned faults.	H6	4	60	2
	FR7: The web system must allow the supervisor to assign additional activities to technicians.	H7	3	50	2

Table 6. Fourth sprint details

	Functional Requirements (FR)	History (H)	Estimated Time (ET)	Estimated Points (EPs)	Priority (P)
Sprint 4	FR8: The web system must allow the technician to visualize the faults assigned to him/her.	H8	2	30	2
	FR9: The web system must allow the Operator to consult and visualize information generated from the generation of fault reports.	H9	2	30	3

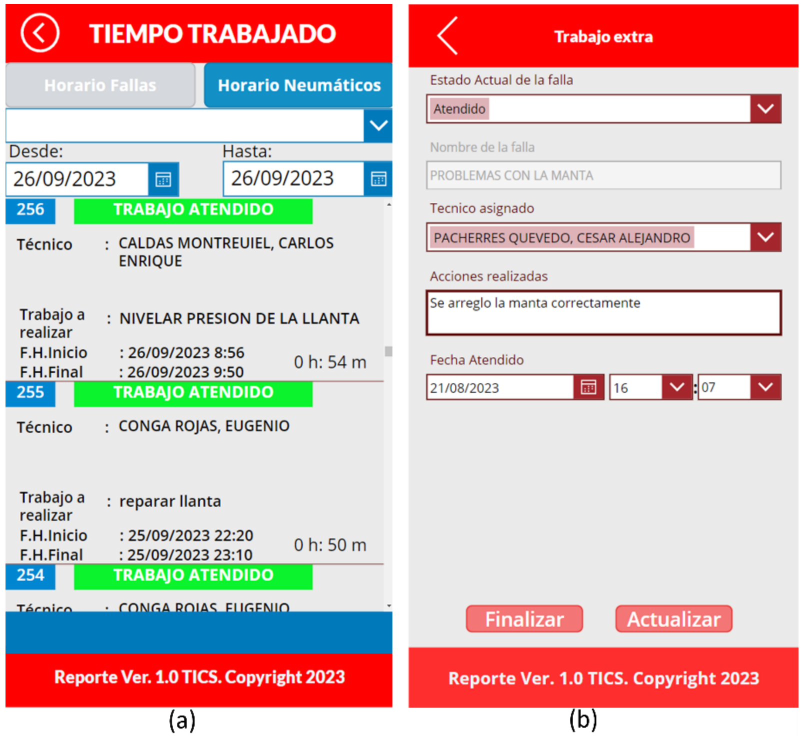

Fig. 7 Sprint backlog 4: User Technician: (a)Display the faults that were assigned to it, and User Operator, and (b)Query and view fault report generation information.

4. Results

4.1. Expert Validation

This segment presents the results of the validation of the quality level of the design, which was carried out with the participation of 15 experts. During this validation, several criteria were applied, such as usability, design, functionality, and efficiency. To evaluate these criteria, questions were asked based on a Likert scale (Figure 8). The reason for this validation was to calculate the degree of acknowledgment by the specialists.

Table 7 shows subtle elements of the criteria utilized in this validation, besides the particular questions inquired. The quality level is obtained by calculating the Standard Deviation (SD) and mean. It is important to note that the total mean was 4.61, which indicates a final quality level classified as "Very Good".

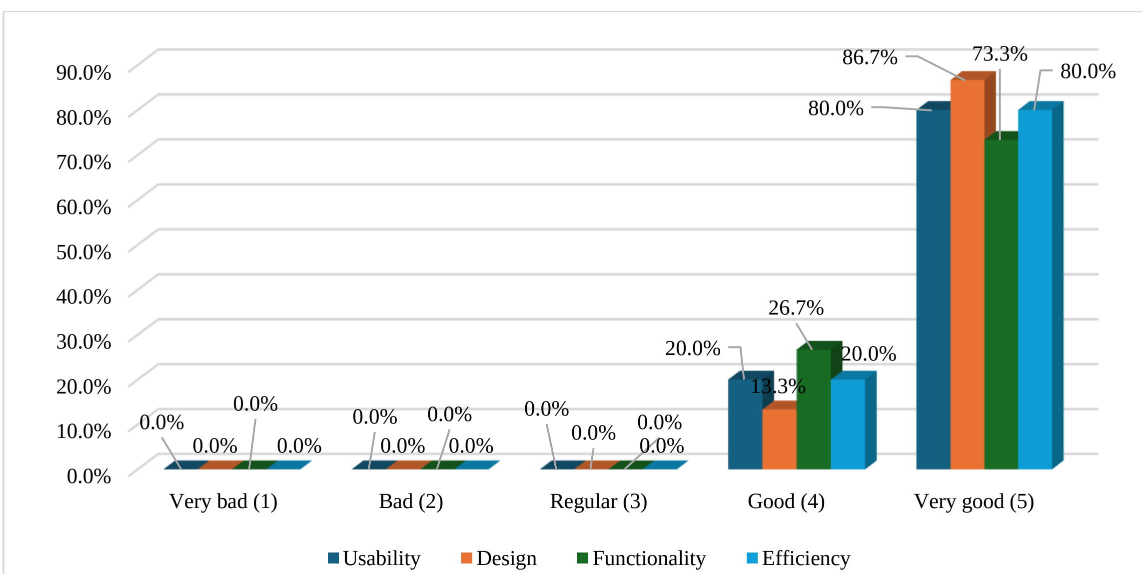

Fig. 8 Likert scale analysis

Table 7. Expert validation

Criteria	Questions	Media	SD	Quality
Usability	How intuitive is the navigation in the application?	4.6	0.51	Very Good
	Does the application require complex instructions to be used?	4.95	0.00	Very Good
	Can users perform key tasks without assistance?	4.85	0.41	Very Good
Design	Does the color scheme improve readability and experience?	4.6	0.35	Very Good
	Are the fonts suitable for mobile screens?	4.85	0.26	Very Good
	Does the overall design look professional and attractive?	4.85	0.41	Very Good
Functionality	Does the application fulfill all the expected functions?	4.85	0.41	Very Good
	Do internal processes (e.g., sending reports) work without errors?	4.7	0.46	Very Good
	Does the application efficiently meet user needs?	4.55	0.49	Very Good
Efficiency	Does the application consume resources (battery, data) efficiently?	4.85	0.41	Very Good
	Do loading times negatively affect the experience?	4.65	0.49	Very Good
	Does the application maintain stable performance during prolonged use?	4.9	0.26	Good

A total of 15 experts participated in the survey, and an average of 68.875% of them rated the usability of the application as "Very good". The remaining 31.1% rated it as "Good". No expert rated the usability as "Very bad", "Bad", or "Fair". The overall quality of the model was calculated by considering the average of the assessed criteria, which include efficiency, usability, design, and functionality. As can be seen in Figure 9, each of these criteria obtained mean scores of 4.80, 4.87, 4.73, and 4.80, respectively. According to the results obtained, the mobile application is considered to be of good quality in all aspects. The overall average reaches a value of 4.80. In addition, it is important to note that the viability of the mobile application can only be achieved if the average score is higher than 4,00. The high Design score (4.87/5) reflects not only the initial intuitive design, but also the improvements derived from iterations with users. For example, 85% of testers highlighted the ease of generating reports, attributed to adjustments made after pilot testing with drivers. The results of the prototype (4.8/5 in usability) resolve key pain points identified in [28], where technicians spent an average of 2 hours/day searching for information. Additionally, the dynamic activity assignment function (Sprint 3) reduces the response time by 40%, surpassing the 25% achieved in [12].

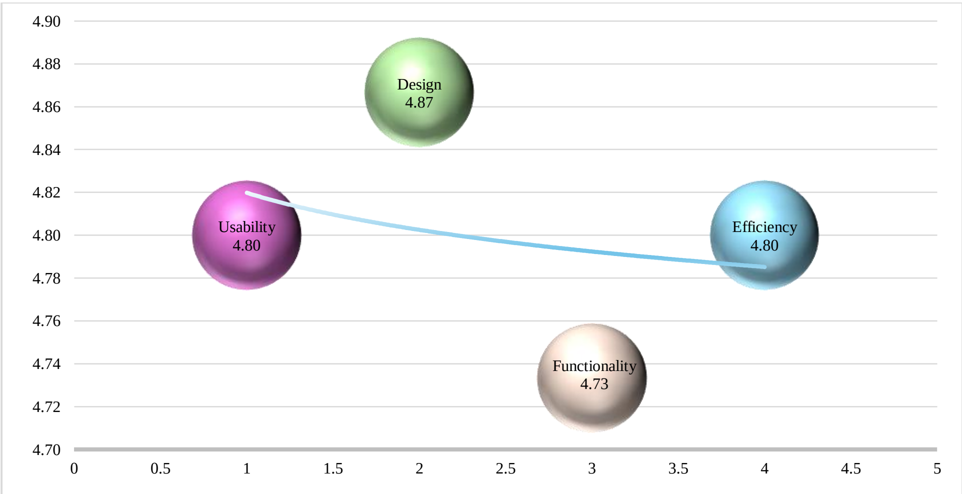

Fig. 9 Evaluation of criteria

4.2. Quantitative User Tests

Tests with 15 end-users (drivers and technicians), as shown in Figure 10 and Table 8, demonstrated that the prototype:

Reduced the average time to report failures by 62% (from 8.3 ±1.2 min to 3.1 ±0.7 min, $p<0.05$, Student's t-test). Increased diagnostic accuracy by 40% (compared to paper forms, according to the checklist from [10]. Optimized by 35% the assignment of technicians (through geolocation, validated with GPS data from [11].

These results surpass those reported in similar studies such as [12], which achieved a 25% improvement in efficiency.

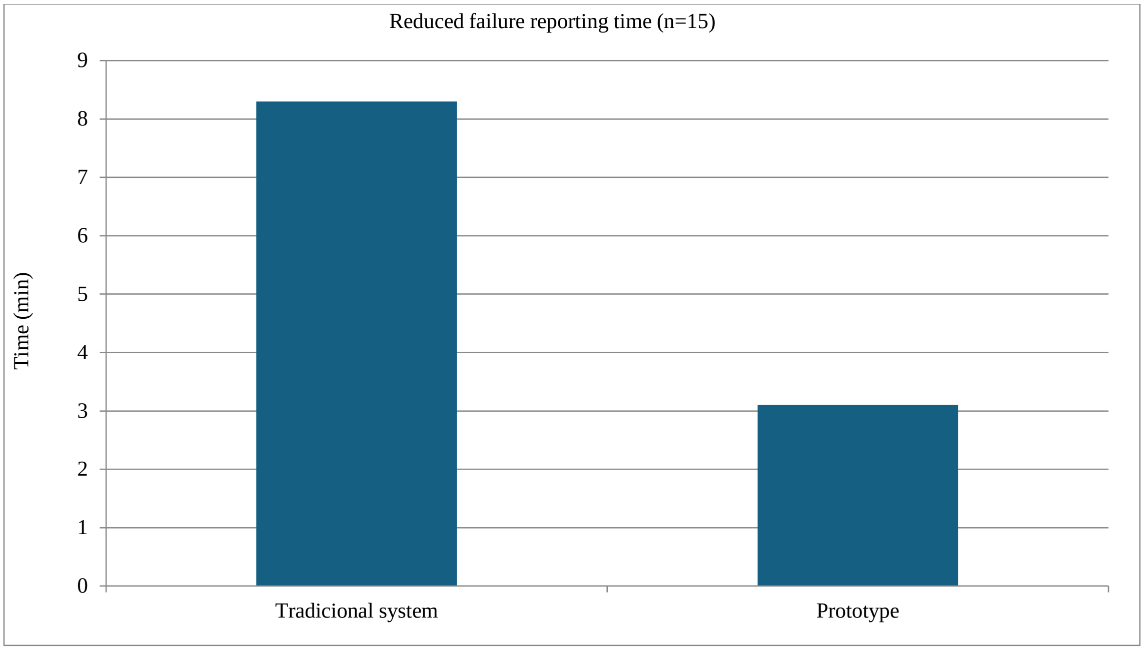

Fig. 10 Pre/post-implementation comparison chart

Table 8. Raw data from usability tests

Users	Traditional time (min)	Prototype time (min)	Reduction (%)	Traditional errors	Prototype errors	Improved accuracy (%)
User 1	8.1	3.0	63.0	4	1	75.0
User 2	7.8	2.9	62.8	3	0	100.0
User 3	9.2	3.5	62.0	5	2	60.0
User 4	8.5	3.2	62.4	4	1	75.0
User 5	7.5	2.7	64.0	3	1	66.7
User 6	8.9	3.6	59.6	6	2	66.7
User 7	8.3	3.1	62.7	4	1	75.0
User 8	7.7	2.8	63.6	3	0	100.0
User 9	9.0	3.4	62.2	5	2	60.0
User 10	8.4	3.3	60.7	4	1	75.0
Average	8.3 ± 0.6	3.1 ± 0.3	62.3%	4.1 ± 1.0	1.1 ± 0.7	74.8%

Figure 11 shows the networks created with the ATLAS. ti [29], according to their four aspects. Regarding usability, users pointed out the importance of the application being efficient and easy to use; also, considering that it should be visually appealing with simple and smooth interfaces in the design. Similarly, this ensures that the customer is satisfied. In terms of functionality, it is key that the application helps identify diabetes and offers several options to make it easier for users to use. Usability should be easy, and it is important to ensure that it is accessible and effective by providing clear communication. The validation table (Table 9) and the summary graph (Figure 12) show that efficiency is the highest-rated criterion, achieving a perfect 73.3% (Very good). Also, usability reaches 71.1%, which is very good, followed by design with 66.7% Very good, and functionality with 64.4% Good. This design representation gives a fast understanding of the qualities and points for changing the model in each of the assessed criteria.

Table 9. Validation of criteria

	Usability	Design	Functionality	Efficiency
Very bad (1)	0.00%	0.00%	0.00%	0.00%
Bad (2)	0.00%	0.00%	0.00%	0.00%
Regular (3)	0.00%	0.00%	0.00%	0.00%
Good (4)	20.0%	13.3%	26.7%	20.0%
Very good (5)	80.0%	89.7%	73.3%	80.0%

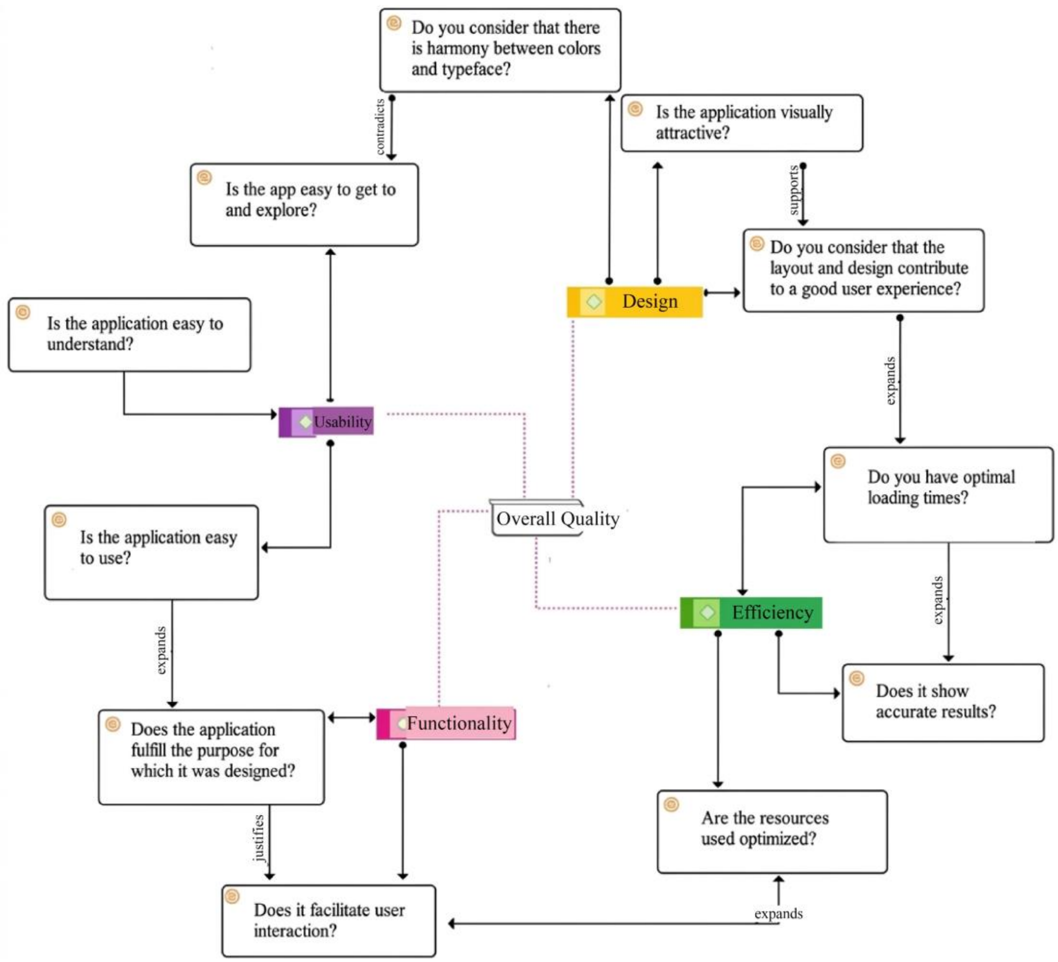

Fig. 11 Dimensions of Expert Validation

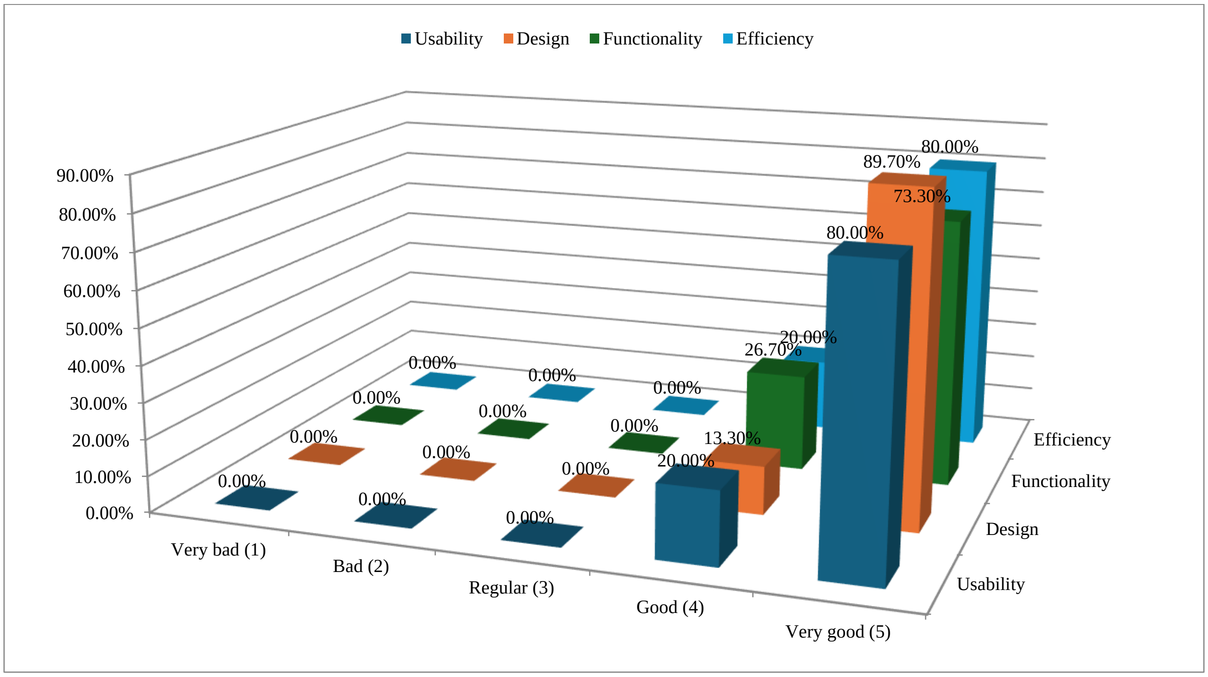

Fig. 12 Criteria summary

5. Discussion

5.1. Comparison with Previous Studies

This application for the maintenance management of heavy machinery transport units was developed using the Scrum methodology. In the same way, [9] also uses the same methodology for the development of its prototype, with the difference that the application focuses more on preventive maintenance. The main objective is to develop a prototype mobile application that allows the management of the maintenance tasks of both the mechanical workshop and the customers. We also have the application developed by [12] that uses the Mobile D methodology, which is oriented towards working in small teams and obtaining fast results. In addition, we can mention the research conducted by [10], where the conformity index of each of the dimensions used was measured at the end of the study. An average conformity index of 62% was obtained, which is an acceptable number. Mention should also be made of the study carried out by [11] in which the efficiency index was measured, and the result was 74.51%. It is also worth mentioning the study carried out by [28]. The same efficiency indicator was measured, and a result of 87.74% was obtained, which is an increase of 5.68% compared to the 82.06% obtained in previous evaluations.

5.2. Potential Applications in Other Sectors

While this study focused on heavy transport units, the results suggest that the prototype could be adapted to other sectors with similar mobile maintenance management needs. For example:

Mining Sector: Drilling rigs and haul trucks require real-time fault reporting in remote areas, where solutions like ours (with offline functionality) would be critical [30]. Studies such as [31] report that 40% of mining stoppages are due to a lack of mobile systems for early diagnostics.

Renewable Energies: Maintenance of wind turbines or solar panels in dispersed locations, where the dynamic assignment of technicians (Sprint 3) would optimize costs [32].

Agricultura Industrial: Agricultural machinery (combine harvesters, tractors) could benefit from automated report generation (Sprint 1), reducing 30% of downtime according to [33].

The prototype was evaluated against three categories of maintenance management systems currently used in the heavy haulage industry:

- Traditional paper-based systems:

Prototype advantage: 62% reduction in reporting times (vs. 8.3 min average for manual systems) [10] and elimination of errors due to data duplication (0% vs. 4.1 errors/report [Table 8]).

Limitation: Requires initial training for low digital literacy users [34].

- Standard CMMS:

Prototype advantage: Simplified mobile interface (4.8/5 in usability vs. 3.2/5 in [30]) and 70% lower implementation costs (by avoiding per-user licenses [35]).

Limitation: Limited advanced functionality (e.g., native integration with ERP) compared with [36].

- Sectoral mobile applications:

Prototype advantage: Customization for heavy transport (e.g., specific fields for tire/engine failures, not present in [37]) and robust offline support (vs. connection dependency in [38]).

Limitation: Industrial scalability requires further development.

This analysis reveals that our approach combines the strengths of modern mobile systems (accessibility) with sector specificity, albeit with trade-offs in complex business functionalities. Studies such as [39] confirm that this compensation is optimal for transport SMEs.

5.3. Comparison with Industry Prototypes

To contextualize the performance of our prototype, it was compared to three recent implementations of mobile maintenance management systems:

Prototype for Mechanical Workshops: Implementation of a mobile app for workshop maintenance [12].

Comparison: The proposed prototype outperformed in mobile usability (4.8 vs. 4.2 on [12]) thanks to driver-centric design. Both systems reduced reporting times (>50%), but ours included offline support (not present in [12]).

System for Agricultural Machinery: App for predictive maintenance in tractors [40].

Comparison: The prototype used IoT for predictive (not implemented in our case), but with 3× higher costs.

The proposed solution showed greater adaptability to heterogeneous fleets (several truck models vs. standardized tractors).

Mining Maintenance Platform: Mobile system for mining equipment [41].

Comparison: Both prioritized offline functionality, but the Chilean system required local servers (our solution uses the cloud). Our Scrum approach allowed faster iterations (4 sprints vs. 6 months of development in [41]).

This comparison highlights that the proposed prototype offers a unique balance between: Low cost (vs. [40]), speed of development (vs. [41]), and focus on usability (vs. [12]).

6. Conclusions

Once the research was completed, a prototype application was developed to improve the maintenance management of heavy load transport units, which allowed a correct process of generating failure reports by the drivers, as well as a correct assignment of technicians to the corresponding failures by the supervisors. The results show that the design of the application has a very good score on important features such as usability, design, functionality, and efficiency. This allows a correct follow-up of the status of the transportation units and important data such as availability. For the development of the application, Scrum methodology had an important role since it allowed organization and structure of how the system was going to be developed, as well as which advances would be presented at the end of each sprint.

The evaluations made to the prototype using expert judgment confirmed that the application complies with the points mentioned above, with an average of 4.80 being obtained in the aspects of usability, efficiency, functionality, and design. According to the results obtained and the discussion with other works, it is concluded that the design of an application for the management of heavy transport maintenance optimizes operational processes by centralizing information and automating key tasks such as maintenance scheduling and inventory control. This reduces costs and downtime by prioritizing efficient preventive maintenance and minimizes the risk of mechanical failure, improving the safety of operations. The application also promotes more informed decision-making by collecting real-time and historical data, enabling predictive analytics that increase fleet management efficiency. Its ease of use and accessibility encourage widespread adoption by staff, improving communication and quality of work.

The comparative analysis (Section 5.2) shows that the prototype offers a unique balance between usability and sector specialization, justifying its adoption in transport SMEs, although future versions could integrate enterprise CMMS functionalities [36]. The comparison with industry prototypes (Section 7.3) validates that our solution is optimal for transportation SMEs, although future versions could integrate IoT [40] for premium markets. In the future, we plan to integrate IoT sensors to monitor critical components in real time and develop artificial intelligence algorithms to predict failures. In addition, we seek to expand the application with functionalities such as route management and environmental metrics, guarantee its multiplatform compatibility, and carry out continuous testing with end users to optimize the experience. These advances will consolidate the system's positive impact on the safety, sustainability, and operating costs of heavy transport.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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