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Design of website-based Preventive Maintenance Checklist Smart System (PMCSS) to support the operation of ARFF vehicles at I Gusti Ngurah Rai Airport

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ABSTRACT

This design aims to increase the preparedness of Airport Rescue and Fire Fighting (ARFF) vehicles in supporting operations at I Gusti Ngurah Rai Airport by creating a website-based preventive maintenance application. This research was based on initial observations on the effectiveness level of preventive maintenance systems for operational vehicles that still apply conventional systems so that they are prone to human error. The research and development method was used in this study, including stages namely potential issues, information gathering, product design, product validation, product repair, product trial, and product revision. This study shows that the validation carried out obtained an average percentage of 81.5% with a very decent category. Based on the research results and discussion, it can be concluded that the website-based PMCSS application is effective in supporting ARFF operational vehicles at I Gusti Ngurah Rai Airport.

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1. Introduction

In the era of Society 5.0, the integration of big data technology through the Internet of Things (IoT) promises significant operational efficiency. IoT is what humans use to facilitate work [1], [2]. The effectiveness of android-based digital media in optimizing the learning experience within the Diploma 3 Program in Aviation Rescue and Firefighting at the Palembang Aviation Polytechnic has been investigated [3], [4]. Information Technology is basically created to facilitate human activities [5], [6]. Of course, it must be utilized as much as possible in the field of ARFFS, which are units that must be provided by airport operators [7], [8]. Along with the rapid development of technology, all work should be completed quickly, smoothly, and efficiently. The smooth and preparedness of operational activities of ARFF unit personnel will affect aircraft flight safety which is a matter of great concern in the aviation world.

During observation and work implementation, it is evident that the maintenance aspect is a critical factor that demands attention from all personnel involved in the upkeep of Aircraft Rescue and Firefighting (ARFF) service facilities [9], [10]. Recognizing the pivotal role of maintenance in ensuring

the preparedness of ARFF unit vehicles and equipment, the necessity for well-defined operation and maintenance guidelines, along with effective reporting systems, became apparent. Initial observations and interviews with ARFF personnel at I Gusti Ngurah Rai Airport revealed that the current vehicle maintenance checklist system is carried out conventionally, potentially leading to human errors. This echoes findings in related research, such as Lukiana et al's examination on the ARFF vehicle maintenance at Hang Nadim-Batam Airport [11]. In a similar vein, Safitri et al explored the maintenance system for ARFF facilities at airports [12]. Fauzan et al focused on the design of vehicle maintenance information systems and fire extinguisher operations for PT. Angkasa Pura II in their research [13]. This study aims to build upon these investigations by undertaking the design of a more effective and streamlined product for ARFF vehicle maintenance checklist systems, to minimize human errors and enhance overall operational efficiency. These errors include incomplete or inaccurate recording of maintenance tasks, inconsistent inspection practices, and delays in identifying and addressing maintenance issues, all of which can compromise the readiness and effectiveness of ARFF vehicles and equipment.

To facilitate the work of ARFF personnel in carrying out tasks in the field of vehicle and equipment maintenance, it is necessary to plan more effective maintenance checking methods to maintain maximum operating performance and not damage or reduce the performance of ARFF personnel, vehicles and equipment. In preparing for the era of digital society 5.0, activities that were originally carried out manually have turned digital because they have safer and easier data storage, in general, website-based systems affect performance in completing a job and assessing the role of the website in helping to improve work efficiency, then the assigned work can be completed in less time [14]. Implementation of web-based systems revolutionizes maintenance processes across various industries. For instance, companies optimized their maintenance management by digitizing workflows, resulting in decreased downtime and heightened productivity. Likewise, an aviation maintenance company streamlined aircraft upkeep through real-time tracking and efficient scheduling using web-based software. Similarly, a property management firm enhanced building maintenance by deploying a facility management portal, enabling swift issue resolution and improved tenant satisfaction.

The planned application to support maintenance activities that only utilize the internet network can help with the daily activities of application users without worrying about space and time anywhere and anytime. In addition, it can manage vehicle engine maintenance data that has not been checked or repaired to a maximum [15]. The application will provide real-time monitoring and tracking capabilities for vehicle engine maintenance tasks. Users will be able to access up-to-date information on maintenance schedules, pending tasks, and completed repairs, enabling proactive management of maintenance activities. The application will include automated reminders and notifications to alert users of upcoming maintenance tasks or overdue inspections. This feature will help ensure timely and thorough maintenance, minimizing the risk of equipment failures or breakdowns during critical operations. Furthermore, the application will offer comprehensive reporting and analysis tools to help users identify trends, patterns, and areas for improvement in maintenance practices. By analyzing historical maintenance data, users can make informed decisions to optimize maintenance workflows and enhance operational efficiency. Overall, the planned application will serve as a valuable tool for ARFF operations, providing users with the necessary support to effectively manage vehicle engine maintenance tasks and maximize the readiness and reliability of their equipment.

2. Method

Borg and Gall's Research and Development (R&D) model was adapted into seven stages [16], [17], better suited to the present study. Recognizing the need for agility, the traditional ten-step model to fit dynamic research methodologies was tailored [18], [19]. Fig. 1 outlines the conceptual framework, starting with identifying ARFF service facility maintenance challenges. Then, comprehensive data was collected and an improved maintenance checklist system was conceptualized. Rigorous validation and iterative design ensure effectiveness, followed by product testing for functionality and necessary revisions for continuous improvement. This streamlined approach aligns with Borg & Gall principles, addressing specific ARFF maintenance challenges.

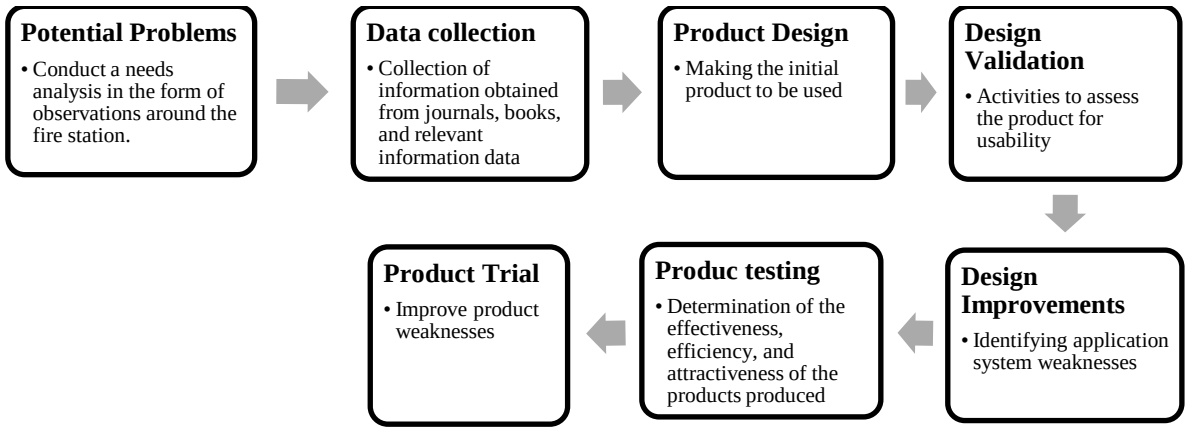

Fig. 1. Conceptual framework

An assessment from design experts, IT experts and ARFF unit *maintenance* experts by using a *Likert scale* of 1-5 was used to collect product quality data. PMCSS application assessment criteria for design experts are appearance, colouring, fonts, images and menus. While assessment criteria for IT experts are appearance, ease of use, language, and implementation. Then, the assessment criteria for ARFF unit maintenance experts are functional requirements, security, compatibility and performance monitoring.

The score display is used to identify the feasibility level of a product resulting from development research. The decision-making criteria for Android-based learning media validation are listed in Table 1.

Table 1. Product eligibility percentage [22]

Score	Criterion
$80\% < P \leq 100\%$	Very Worth It
$60\% < P \leq 80\%$	Proper
$40\% < P \leq 60\%$	Pretty Decent
$20\% < P \leq 40\%$	Less Decent
$0\% \leq P \leq 20\%$	Very Less Feasible

Table 1 outlines the score display used to evaluate the feasibility of products resulting from development research. It provides criteria for Android-based learning media validation, ranging from "Very Worth It" to "Very Less Feasible" based on score ranges.

Theoretical Basics

Website

Website is the entire website pages contained in a domain that contains information. Website is usually built on many website pages that are easily connected [20]–[22]. JavaScript is a programming language in the form of a collection of scripts that run on a Hypertext Markup Language (HTML) document [23], [24]. HTML serves as the foundation or structure of the website and becomes the programming language of PHP (Hypertext Preprocessor) and JavaScript [12], while CSS (Cascading Style Sheet) is a rule to adjust the appearance of the website so that the appearance of the website is more structured. The function of CSS is to provide more complete settings so that the website structure made with HTML looks neater and more elegant [25].

Smart Application System

A smart application system is an application system capable of automatic analysis, data processing, and decision-making using artificial intelligence (AI) [15]. In general, applications are computer programs or software designed to perform certain tasks or provide specific services to users. They are created to facilitate or increase efficiency in carrying out daily activities [26]. In addition, they can be interpreted as a program in the form of software that runs on a certain system that is useful for helping various activities carried out by humans [27]. In other words, a smart application system is a software program or software used to facilitate certain jobs and tasks.

ARFF Operations

ARFF is an emergency management unit at airports, following PR 30 of 2022 it is stated that the ARFF unit has main tasks [28], [29]. The main tasks of ARFF are to save lives and property from emergencies at the airport and its surroundings. The main tasks are divided into 3, namely: 1) *Operation* is an administrative activity, standby to ensure personnel are on standby, carrying out *rescue*, prevention, and blackout. 2) *Training* aims to improve safety, improve coordination, evaluate and improve systems, acquire the necessary knowledge and skills, and prepare for mental preparedness in the face of emergencies. 3) *Maintenance* aims to ensure vehicles and operating equipment are ready for use.

Every airport operator is required to carry out *vehicle maintenance* activities and ARFF operational support equipment to create maximum preparedness for ARFF vehicles and equipment following the ARFF service category at the airport [7], [8], [27]. ARFF vehicles and equipment must be maintained and maintained regularly under existing guidelines [28], [30].

3. Results and Discussion

In determining potential problems, observations were made at I Gusti Ngurah Rai Airport from October 2022 to June 2023. Fig. 2. illustrates the stages of problem-solving. During the information collection stage, the author observed personnel in each main and supporting vehicle at the ARFF unit of I Gusti Ngurah Rai Airport. Initial data collection includes needs analysis, literature studies, or surveys targeting users [31]. From these observations, it was noted that the ARFF unit comprised 2 fire stations, 1 launching pad, and 2 maintenance rooms. Additionally, there were a total of 16 ARFF vehicles, consisting of 3 main vehicles, 3 backup vehicles, and 10 support vehicles. The results of the design phase include a system flowchart and a display of PMCSS design development.

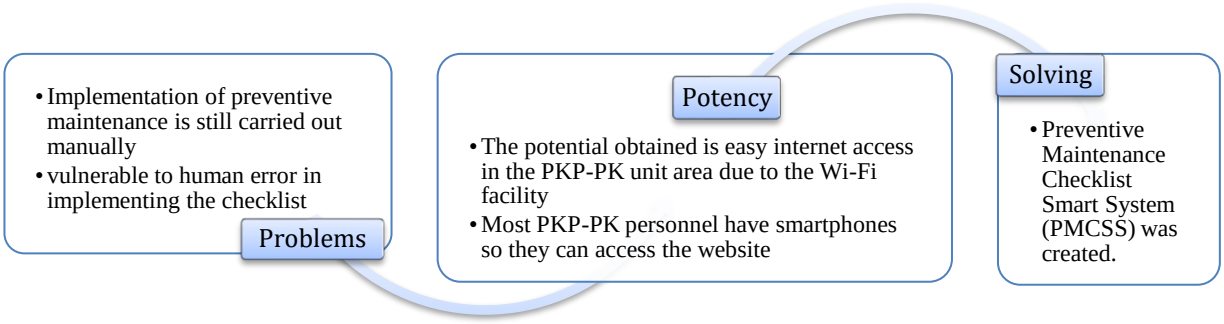

Fig. 2. Stages of problems solving

As illustrated by the flowchart in Fig. 3, user actions begin with opening the browser, entering the website, and scanning the barcode system. The system then displays the website. Subsequently, the user selects the feature and completes the checklist. The system responds accordingly and the checklist is validated by the Maintenance Squad Leader, marking the task as finished.

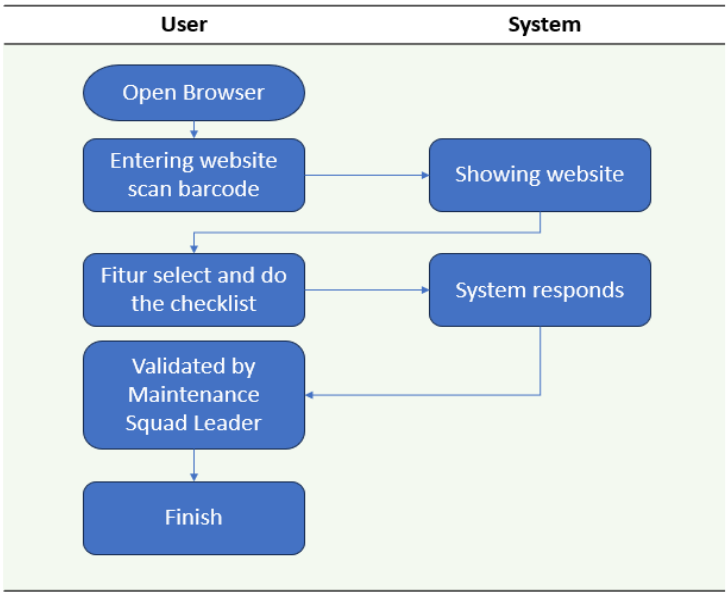

Fig. 3. Flowchart of user and system interaction

In this stage, the author designs a *website* system that includes the main appearance and display model of menus and sub-menus in the system to be developed. Design selection is tailored to the needs of the information system. The menu and sub-menu of the application (PMCSS) displayed on desktop and smartphone are shown in Fig. 4 and Fig. 5, respectively. PMCSS application has four features, namely: a) *Plan* that contains the work program of *ARFF* personnel arranged by the *maintenance supervisor*. b) *Inspection* which contains a *checklist* of vehicles that have been adjusted by KP 04 Year 2013. c) *Performance* which contains vehicle performance visualized in the form of a graphic *dashboard. d) Specification* which contains the specifications of ARFF operational vehicles.

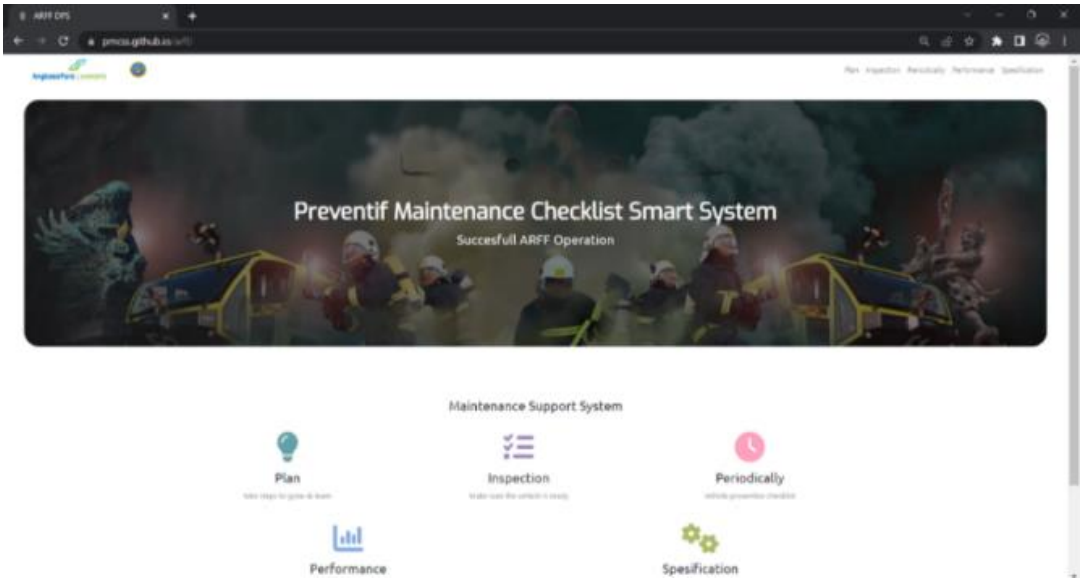

Fig. 4. Application display on the desktop

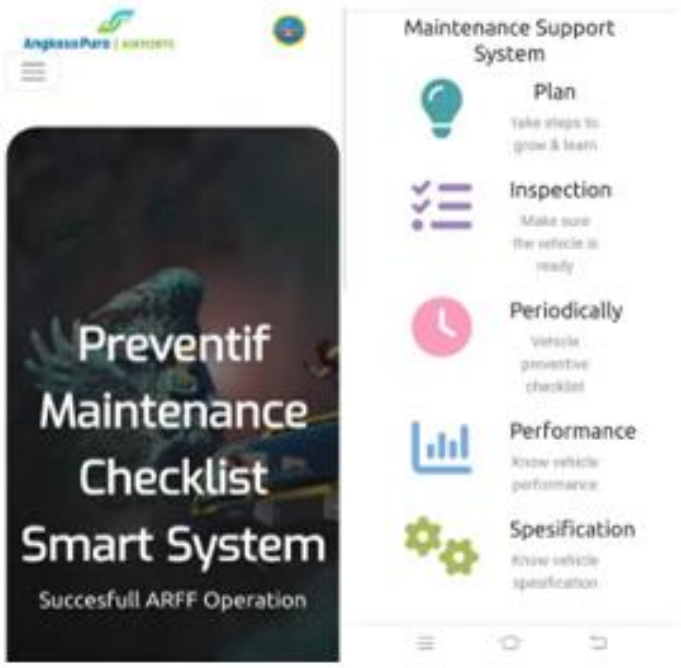

Fig. 5. Application display on smartphone

The next stage is product validation, this stage is an activity to assess the application system that has been made before the media is tested on respondents. Validation is carried out by design experts, IT experts and ARFF maintenance experts. The assessment data from the three experts can be seen in Fig 6, Fig.7, and Fig. 8.

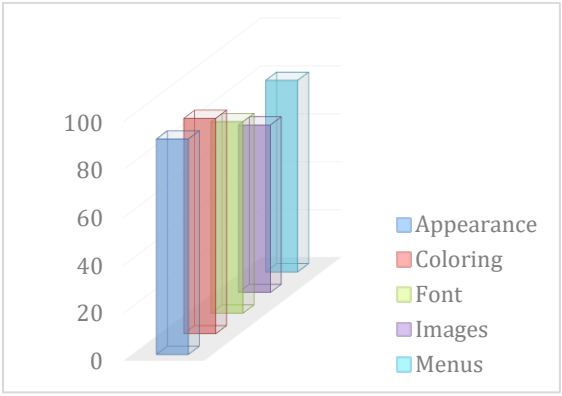

Fig. 6. Design expert validation

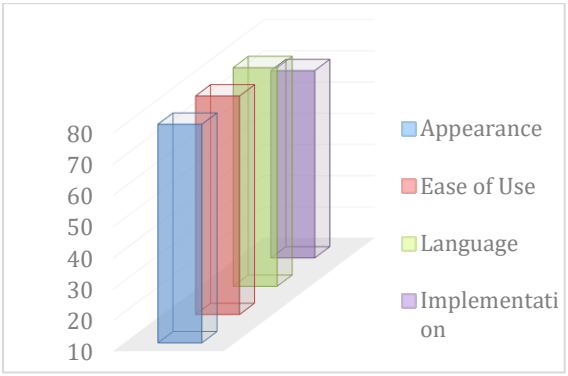

Fig. 7. IT expert validation

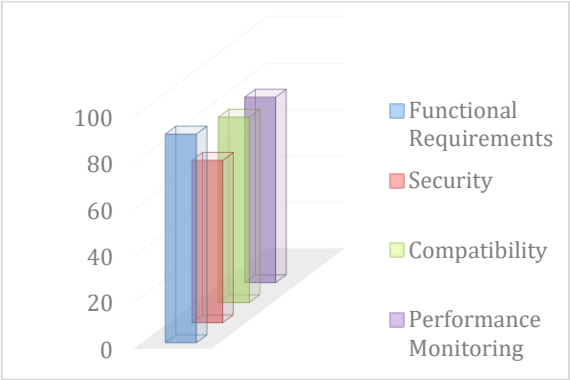

Fig. 8. ARFF maintenance expert validation

Based on the validation results conducted by experts, product improvements were achieved with an average assessment percentage of 79.25%, categorized as "proper," indicating that they were satisfactory or appropriate. Two criticisms and suggestions were provided by IT experts: adding icons to facilitate the introduction of features and functions, and creating barcodes to simplify access to the application via smartphones.

After validation is carried out then proceed to the product improvement stage. This stage aims to improve the application. By the criticisms and suggestions given by expert validators to the PMCSS application, the author revised and corrected the errors and shortcomings contained in the website-based application system. The results of revisions made by the author can be seen in Table 2.

Table 2. Revision Results

No	Revision	Before	After
1	The features provided are added icons to facilitate the introduction of features	The feature is still not equipped with a pointer icon	Add an icon for each feature on the homepage
2	Barcode generation that goes to the app	None	Available
3	Added periodic checking feature	None	Available

Based on the revision, revalidation was carried out from IT experts to get a more optimal product. The IT expert validation are presented in Fig. 9. The product initially received high praise from IT experts, with an average assessment score of 82.5%, falling within the "Very Worth It" category. This indicates its exceptional performance across all four aspects assessed, highlighting its effectiveness and suitability for its intended purpose. Despite a slight decrease to 81.5% after repair and revalidation, the product was classified as "Very Worth It." This suggests that the minor adjustments made during the process did not significantly impact its overall quality or perceived value. Potential reasons for the slight decrease could include changes during the repair process, variations in assessor expertise, or inherent limitations in assessment methodology.

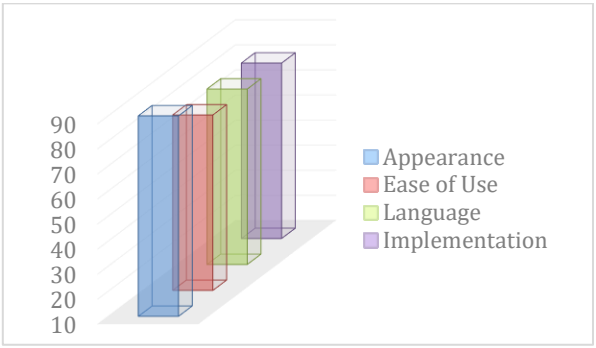

Fig. 9. IT expert revalidation

The product trial phase marks the culmination of Borg & Gall's R&D writing model [2], [4]. At this stage, data was collected from opinions and suggestions offered by ARFF personnel at I Gusti Ngurah Rai Airport, providing insights into the product's enhancements. The trial encompasses four squads, each comprising a minimum of 30 individuals, and has been sanctioned by both the maintenance supervisor and personnel representatives of each team. Data acquisition was executed through questionnaires, with opinions and suggestions from ARFF unit personnel being randomly selected and outlined in Table 3.

Table 3. App test score results

NO	Respond	Score	Criticism & Suggestions
1	Squad A	88 %	There is a feature update in the change of monthly work program.
2	Squad B	92 %	More developed for its features and pays attention to security and privacy.
3	Squad C	80 %	The relationship of *performance* features with *inspection* features**.**
4	Squad D	88 %	Our suggestion is to make *a barcode* sticker so that it is more accessible.
Total		87 %	

The assessment questionnaire of satisfaction with the PMCSS, which categorized users as "Very Worth It" with an average score of 87%, utilized specific instruments or tools to measure effectiveness, efficiency, and attractiveness. Through this assessment, users provided feedback on various aspects of the application's performance, usability, and appeal. The results indicate that users found the PMCSS to be highly effective in fulfilling their needs, efficient in its functionality, and attractive in its design and presentation.

The product revision stage was the last carried out after product trials were done. From some criticisms and suggestions obtained from the trial stage, the author only revised as shown in Table 4.

Table 4. Application revision results

No	Revision	Before	After
1.	Added *barcodes* for app access	None	There is a *barcode* connected to the application, testing is carried out using a *smartphone* device

The revision of the PMCSS application aims at performance optimization. The result is the addition of *barcodes* in the PMCSS application to make it easier to access the application and increase response speed, reduce loading time, and reduce crashes or *bugs.* After revision, the product was tested again, in this case, the trial was carried out by the author to find out if the application runs well or still needs improvement. System testing was done by running *software* to determine whether the system meets the requirements and operates as planned. Testing is done by testing each process and possible *bugs* in each process.

In a related context, the challenges encountered in the aircraft production and maintenance process, specifically regarding data collection and documentation, led to the development digital-based maintenance recording system [32]. The application design, tested using the R&D research method, demonstrated web-based specifications suitable for computer devices and smartphones. The successful implementation of this electronic-based maintenance recording application signifies a positive outcome and high satisfaction in testing.

Similarly, in educational development, the research focuses on using interactive multimedia in Android-based learning. Following the Borg & Gall development model, the study emphasizes adapting to educational advancements. This approach aims to enhance the quality of education, particularly in vocational schools like SMK, where staying abreast of technological developments is crucial [33]. The research underscores the significance of effective learning processes and the utilization of interactive multimedia to improve students' creativity and engagement in the ever-evolving educational landscape.

The research on the design of the PMCSS website also emphasizes the use of real-time monitoring, predictive maintenance, and priority scheduling algorithms. The utilization of IoT devices such as Arduino Wemos-D1 and PLC for machine status monitoring was also integrated into the study [34]. However, there are differences in the focus and development methods between the present study and those of PT. Beta Pharmacon study. The present study emphasizes the use of interactive multimedia in Android-based learning, while the PT. Beta Pharmacon study focuses on developing a web-based preventive maintenance system with priority scheduling algorithms. Nonetheless, both studies aim to improve the efficiency and effectiveness of specific processes in industry and management, albeit through different approaches.

Based on the PMCSS research stage using reliability assessment, PMCSS has passed three testing steps for continuing development and implementation. First, the *product validation* carried out by design experts, IT experts, and ARFF maintenance experts achieved an average assessment percentage of 79.25%, categorized as "proper," and has two corrections to improve provided by IT experts: 1) adding icons to facilitate the introduction of features and functions, and 2) creating barcodes to simplify access to the application via smartphones. Second, *product revision* has received high praise from IT experts, with an average assessment score of 82.5%, falling within the "Very Worth It" category. This result indicates its exceptional performance across all four aspects assessed, highlighting its effectiveness and suitability for its intended purpose and suggesting that the minor adjustments made during the process did not significantly impact its overall quality or perceived value. Potential reasons for the slight decrease could include changes during the repair process, variations in assessor expertise, or inherent limitations in assessment methodology. Third, the assessment questionnaire of satisfaction with the PMCSS, which categorized users as "Very Worth It" with an average score of 87%, utilized specific instruments or tools to measure effectiveness, efficiency, and attractiveness.

4. Conclusion

The research was initiated by observations on the effectiveness of the preventive maintenance system for operational vehicles that still apply conventional systems so that they are prone to human error. This research provides a solution by developing an interactive learning multimedia designed to increase ARFF vehicles' preparedness to support operations at I Gusti Ngurah Rai Airport by creating a website-based preventive maintenance application. The adapted Borg and Gall methodology was used, starting with potential issues, information gathering, product design, product validation, product repair, product trial, and product revision. The validation results obtained a very decent category so it can be concluded that the PMCSS application is practical in supporting ARFF operational vehicles. The results of validation by experts show that the PMCSS application is very feasible to use to support ARFF vehicle operations at I Gusti Ngurah Rai Airport. This product has been implemented to date at ARFF I Gusti Ngurah Rai Airport and has successfully increased vehicle operational productivity.

Recommendation

The recommendation is to continue using the PMCSS application in ARFF vehicle maintenance operations at I Gusti Ngurah Rai Airport to enhance efficiency and operational effectiveness. To maintain the application’s quality, regular evaluations should be conducted to ensure alignment with user needs and anticipate potential operational challenges. Intensive training and socialization sessions

for ARFF personnel are crucial for a comprehensive understanding of the application's features, promoting effective use in daily tasks. In the ongoing development process, involving experts and considering input from other users is advised to enhance the application's quality and functionality continually. Finally, there is hope for expanding PMCSS applications to other airports or similar operational contexts, fostering widespread benefits and improvements in ARFF vehicle maintenance practices.

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