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Innovative Mobile Solutions for Elevating Restroom Maintenance in Malaysian Shopping Malls

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ABSTRACT

Public toilets, crucial for our basic physiological needs, are often plagued by inadequate maintenance and poor hygiene, further exacerbated by their communal nature, which increases the risk of pathogen contamination, including SARS-CoV-2. Restroom hygiene significantly influences consumer choices and satisfaction when selecting shopping malls, impacting in-store spending. Furthermore, facility managers consistently identify restrooms as challenging to maintain. In Malaysia, public toilet cleanliness has long been a concern, with 20% receiving low ratings due to inadequate maintenance. Unfortunately, limited attention and resources are allocated to address these ongoing issues, as many mall restrooms still rely on inflexible paper-based management methods. Despite some technological solutions being introduced for public toilet management, they remain relatively novel and expensive in Malaysia, posing budgetary constraints for mall operators. Therefore, cost-effective solutions take precedence when implementing a new toilet management system. This research introduces an innovative, budget-friendly mobile-based system featuring an interactive panel with Raspberry Pi technology to revolutionize shopping mall toilet management. This mobile application allows supervisors to efficiently schedule cleanings, monitor progress, and assess cleanliness based on user feedback. Cleaning staff can promptly respond to user requests via the app, and users can request services and rate conditions. Usability tests reveal that 81% of users are satisfied with the system, meeting their expectations and enhancing operational efficiency. This comprehensive system facilitates effective communication among cleaning supervisors, cleaners, and users, ensuring consistently satisfactory restroom conditions. It promotes hygiene standards in shopping malls, which positively impacts both consumer perceptions and business outcomes for the malls.

Keywords:
Public toilet management; toilet hygiene; smart toilet; raspberry pi

1. Introduction

Public toilets play a fundamental role in meeting our basic physiological needs for urination and defecation, which can arise unexpectedly and at any place or time. These facilities are readily available in public areas, including shopping malls, but their utility is often compromised by improper maintenance and poor hygiene conditions. Several studies have shed light on the

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widespread issue of subpar toilet conditions resulting from inadequate maintenance practices. This problem is exacerbated by the communal nature of public restrooms, where numerous users share the same facilities, increases the risk of contamination by various pathogens, including E. coli, hepatitis A, and viruses like SARS-CoV-2 as highlighted in studies [1–6]

Piha & Räikkönen [7] and Yusuf *et al.*, [8] emphasize the significant impact of restroom hygiene on consumers' choices and satisfaction in choosing a shopping mall. The use of restrooms is linked to extended in-store time, resulting in increased spending. Surveys during and post-COVID-19 pandemic, such as the one by Big Red Rooster and ENGINE Insights, found that 98% of American consumers prioritize restroom cleanliness. In fact, 36% have changed their shopping habits to avoid public restrooms [9]. The Bradley Corporation's Healthy Handwashing Survey revealed that 51% of Americans believe poorly maintained restrooms harm businesses, while 60% are willing to spend more at establishments with clean restrooms. These findings highlight how restroom cleanliness significantly impacts consumer perceptions and business outcomes [10].

The 2021 CMM In-House/Facility Management Benchmarking Survey Report provides insights into how the global pandemic has affected facility managers and in-house service providers, including their adaptations, and anticipated future trends [11] . Facility managers consistently identify restrooms as a particularly challenging area to maintain. This challenge persists, as a 2023 survey found that 40% of respondents shared the same sentiments [12].

This heightened awareness has prompted a shift in priorities, with more resources and attention being devoted to maintaining impeccable toilet hygiene standards. This includes the establishing standard guidelines [13–15] for better restrooms maintenance and allocation of funds toward innovative toilet monitoring and management tools, such as smart technologies and IoT solutions, aimed at enhancing and managing the restroom experience for shoppers. Additionally, a computerized maintenance management system streamlines maintenance tasks, including complaint handling, record-keeping, scheduling, and finances [16].

In Malaysia, public toilets issues been a concern among citizens and visitors for years. News Straits Times reported that out of 26,081 public toilets under local authority control, 20% or 5,241 received ratings of two stars or less due to cleanliness issues [17]. Regrettably, less attention and limited resources are allocated to addressing these ongoing cleanliness concerns. Many public restrooms in shopping malls still rely on paper-based schedules and checklists for toilet management, with cleaning supervisors conducting manual inspections. This fixed cleaning routine schedule is unable to ensure toilet cleanliness at all times and respond promptly to user needs. The facilities themselves continue to suffer from issues such as unpleasant odors and clogged toilets. These persistent challenges significantly tarnish the image and reputation of shopping malls, emphasizing the ongoing need for effective toilet management solutions.

Despite some technological solutions being introduced for public toilet management, they remain relatively novel and expensive. For instance, Sunway Pyramid shopping invested nearly RM500,000 in Malaysia's inaugural Internet of Toilet (IoT) in 2021 [18] , while automated toilets established in Kuala Lumpur city cost approximately RM400,000 each, as highlighted by Khairiah Talha [19] . Research conducted by Norazman *et al.*, reveals that cost is a significant barrier to adopting Building Maintenance Management Systems (BMMS) in Malaysia, emphasizing concerns about implementing new technology for maintenance management due to expenses [20].

Given that most mall operators in Malaysia operate within constrained budgets for toilet management, cost-effective solutions take precedence when implementing a new toilet management system. This project introduces an innovative mobile-based system equipped with an interactive panel embedded with Raspberry pi designed to transform mall toilet management. The solution offers an innovative, budget-friendly and scalable option for mall operators, serving as an

initial step towards a fully integrated smart toilet management system. Through the mobile application, supervisors can efficiently schedule cleanings, track progress, and assess cleanliness based on user feedback. Simultaneously, cleaning staff can report their work and promptly respond to user requests via the app. In addition, the interactive panel allows users to request cleaning services and rate toilet conditions. This comprehensive system improves communication and adopts a user-centric approach to enhancing shopping mall toilet cleanliness, promising a more sanitized and hygienic public restroom experience.

2. Related Works

Toilet management systems have evolved significantly in response to heightened customer concerns about toilet hygiene, directly impacting shopping values. Innovations such as smart technologies, IoT-based monitoring, and sustainable solutions, along with attentive responses to customer feedback, strive to improve restroom experiences, aligning with evolving shopper expectations and significantly boosting satisfaction.

Chai *et al.*, implemented an IoT button system at Brigham and Women's Hospital for a pilot study, assessing restroom usage and cleaning staff feedback [21] . The system has limitations, including unclear user intent and staff errors, causing a rise in requests and hampering task completion [22].

Numerous facilities management solutions companies, including Bunzl, Advantech, and UnaBiz, have embraced the integration of smart technology into toilet management systems. These innovations encompass interactive panels, mobile phones, and IoT monitoring tools, revolutionizing the way public restrooms are maintained and enhancing the overall user experience.

Bunzl Canada, for instance, unveiled WandaNEXTTM, a cutting-edge digital cleaning management system [23]. Equipped with a web-based tablet, it streamlines resource requests and facilitates real-time data collection. While it promptly notifies facility managers, one limitation is its inability to establish direct communication with cleaning staff or assign tasks to specific individuals, primarily due to the absence of unique identifiers. In contrast, Advantech's restroom management system [24] offers a robust solution for monitoring restroom cleanliness and enhancing service quality. Its interactive feedback terminal empowers patrons to request services conveniently while enabling cleaning staff to document completed tasks, thereby fostering efficient and responsive restroom management. UnaBiz's Smart Toilet Management takes a different approach by deploying interactive devices and straightforward IoT solutions, such as sensors [25] . These innovations empower facility managers to optimize operational processes and elevate the restroom experience for tenants, showcasing the potential of technology to drive improvements in public restroom management.

As With the raise of concerns on toilet hygiene and risk of diseases transmissions as reported in the studies [2-6, 26]. Vast of innovative in smart toilets to avoid transmission of diseases. Kumar *et al.,* [1] introduced an IoT based smart testing toolkits that can be installed in public toilets so that people can safely use them without any fear. Keerthana and Lohalavanya [27] made use of the proximity sensor, biometric system, gas sensor and a dashboard to monitor and store the data of the cleaners to maintain public toilets effectively. Mishra *et al*., [28] have developed Smart Toilet system using Bluetooth low energy (BLE) beacons and readers technology to provide an effective system for indoor public toilets management. Lokman *et al.*, [29] IoT-based smart toilet management system, incorporating privacy-compliant Infrared, temperature, and humidity sensors. It deploys auto-Regressive Integrated Moving Average (ARIMA) and Long Short-Term Memory

(LSTM) to enhance prediction accuracy while optimizing resource-efficient scheduling via an evolutionary algorithm and constraints.

In line with these innovations, the Raspberry Pi is an affordable and expandable single-board computer widely applied in various fields. For example, Pu'ad *et al.*, created a portable synthesis gas analyzer with an IoT monitoring system, using Raspberry Pi and sensors for a cost-effective solution in Malaysia's biomass industry [30]. Qasim *et al.*, designed an IoT real-time monitoring system that integrates with Short Message Service (SMS) for monitoring home hazards and initiating subsequent actions [31]. Gollapalli *et al.*, utilized a Raspberry Pi to create a smart mirror for real-time monitoring and interaction with various data and apps such as time, date, weather, calendar, reminders, and news updates [32]. On the other hand, Pradeepkumar *et al.*, employed Raspberry Pi-powered IoT technology to monitor client feedback on their surroundings related to a specific activity [33]. In a study by Nguyen *et al.*, they designed an affordable monitoring system using Raspberry Pi for real-time motion detection in live streaming cameras. This system efficiently reduces storage requirements and cuts down on investment expenses. The live feed is accessible via web browsers, including mobile [34]. IoT Blood Pressure Monitoring System (IBPMS), developed by Hashim *et al.,* [35] utilizes a Raspberry Pi as an online blood pressure monitoring gateway, enabling users to consistently access their blood pressure readings through the Telegram application and email service.

3. Proposed Solution

3.1 Mobile App and Interactive App Modules Breakdown

This project proposes an affordable and efficient Toilet Management System that integrates a mobile application with an embedded interactive panel utilizing Raspberry Pi technology. This versatile system is tailored to serve three primary user groups: cleaning supervisors, cleaners, and toilet users.

The mobile application boasts features specifically designed to simplify the daily tasks of cleaning supervisors and cleaners, making it easier than ever to plan, assign, and execute cleaning tasks efficiently. They can interact with the system effortlessly through the mobile-based toilet management application, accessible on their mobile devices.

Meanwhile, the interactive panels strategically placed in the restroom are tailored to enhance the experience for toilet users. These panels empower users to provide real-time feedback on the overall cleanliness of the facility and request cleaning services whenever necessary. For a detailed breakdown of the features, please refer to Figure 1. With this comprehensive Toilet Management System, we aim to elevate restroom hygiene and convenience for everyone involved.

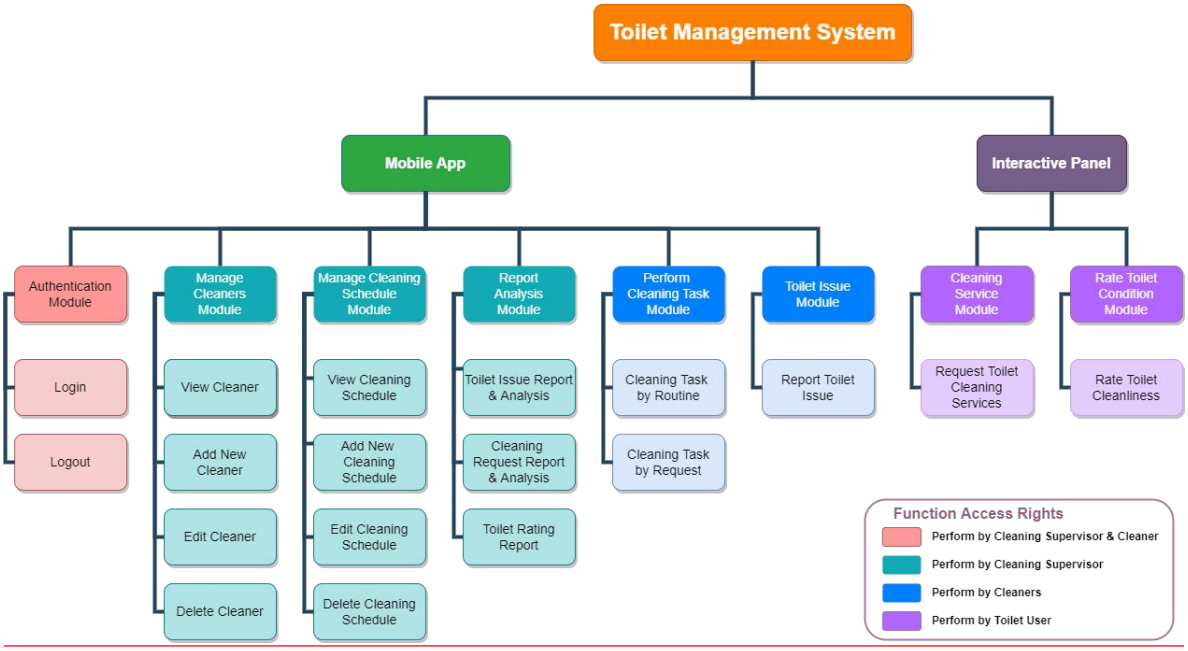


Fig. 1. The module breakdown of the proposed toilet management system

3.2 System Architecture Design

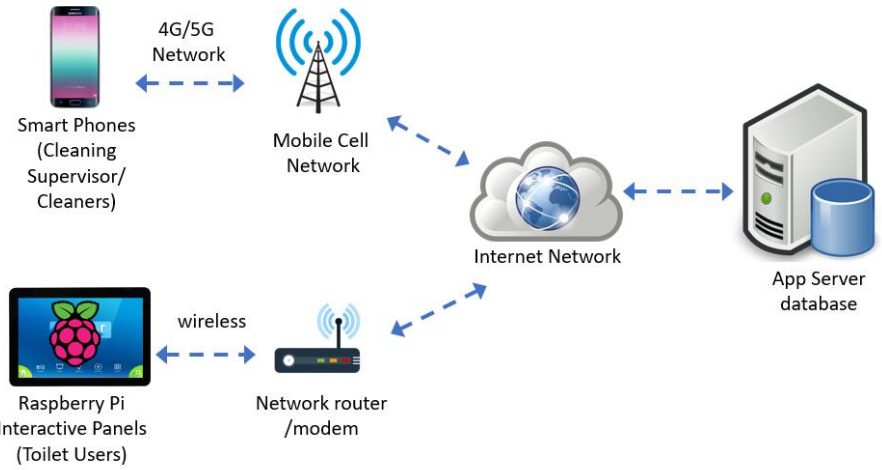


Fig. 2. System architecture design of the proposed toilet management system

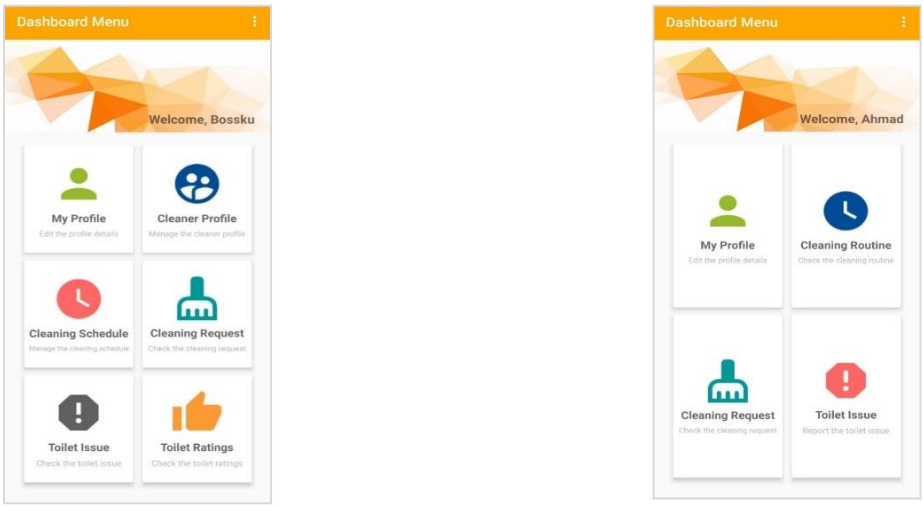
The system architecture design of the toilet management system is presented in Figure 2. Both cleaning supervisors and cleaners interact with the system through a mobile-based toilet management application installed on their mobile devices. The data is initially transmitted via mobile cell networks, then routed through the internet network before reaching the cloud server. This cloud server serves as a real-time database, responsible for storing and managing various functions, including the dispatch of push notifications to multiple devices. This connection to the cloud server enables real-time communication between the cleaning supervisors and the cleaners.

On the other hand, interactive panels, integrated with Raspberry Pi devices, will be mounted on the toilet walls. These panels provide interfaces for toilet users to request cleaning services and rate the cleanliness of the facility. The Raspberry Pi devices are connected to a network router, and cleaning service requests are transmitted as push notifications to the designated cleaner and supervisor through the cloud server, ensuring prompt action is taken.

4. Results

4.1 Mobile Application Dashboard Menu

In the mobile-based Toilet Management System application, the cleaning supervisor and the cleaner have different dashboard menu interfaces to allow them to perform specific tasks as illustrated in Figure 3(a) and (b). Via the function buttons, the cleaning supervisor can manage the cleaner and own profiles, manage cleaning schedules and view the toilet conditions according to the statistical data analysis of cleaning requests, toilet cleanliness ratings and reported toilet issues. On the other hand, there are fewer functions provided for cleaners which only allow cleaners to manage their profile, record their cleaning time routine, report toilet issues and complete the cleaning request sent from toilet users.

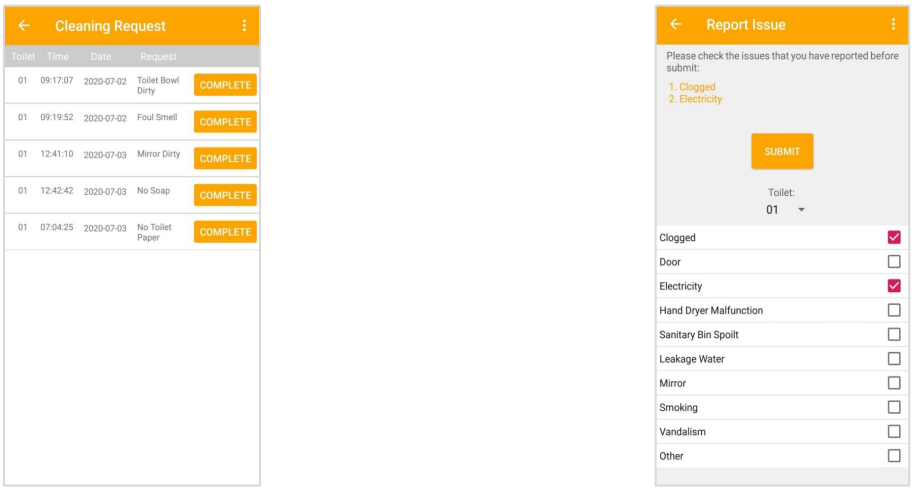


(a) (b)

Fig. 3. User Interfaces for (a) cleaning supervisor dashboard and (b) cleaner dashboard

4.2 Cleaning Task Module

Cleaning requests are sent to designated cleaners and supervisors as shown in Figure 4(a). Cleaners handle tasks, and supervisors monitor request status for mall restroom upkeep. Cleaners can report issues as in Figure 4(b), cross-check them, and confirm before submitting.

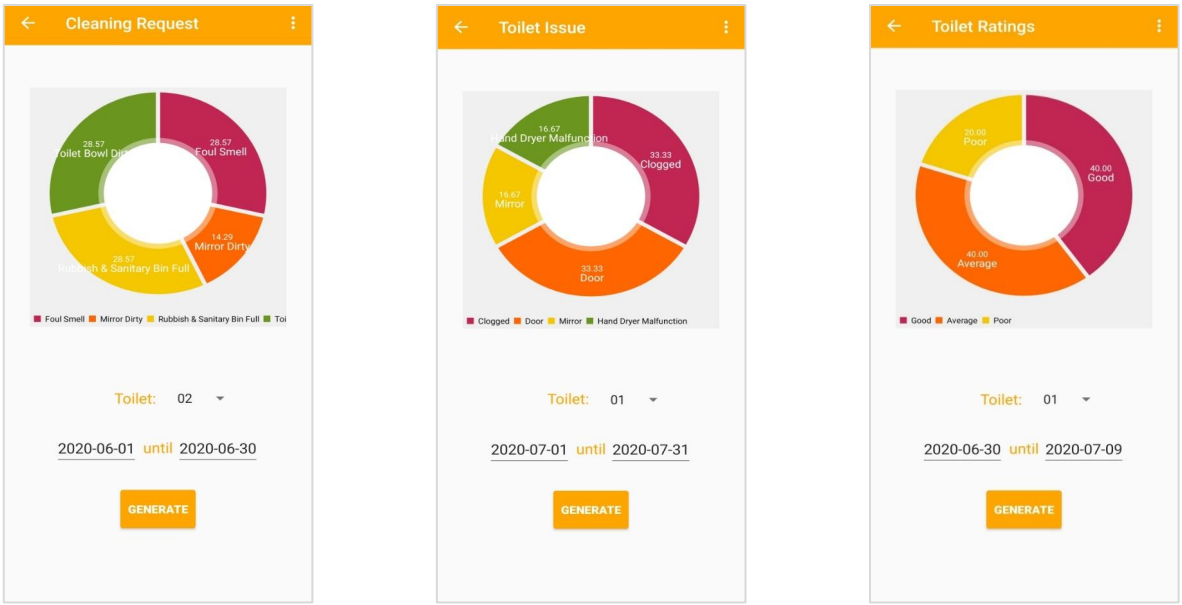


(a) (b)

Fig. 4. User Interfaces for (a) cleaning requests sent by toile users and (b) report issues

4.3 Report Analysis Module

Besides, the supervisor is also able to assess the performance of the cleaners by viewing the statistical data on the occurrence frequencies and type of cleaning requests issued by toilet users shown in Figure 5(b) and the toilet condition rating in Figure 5(c) for the toilets in charged by the cleaner under reviewed.

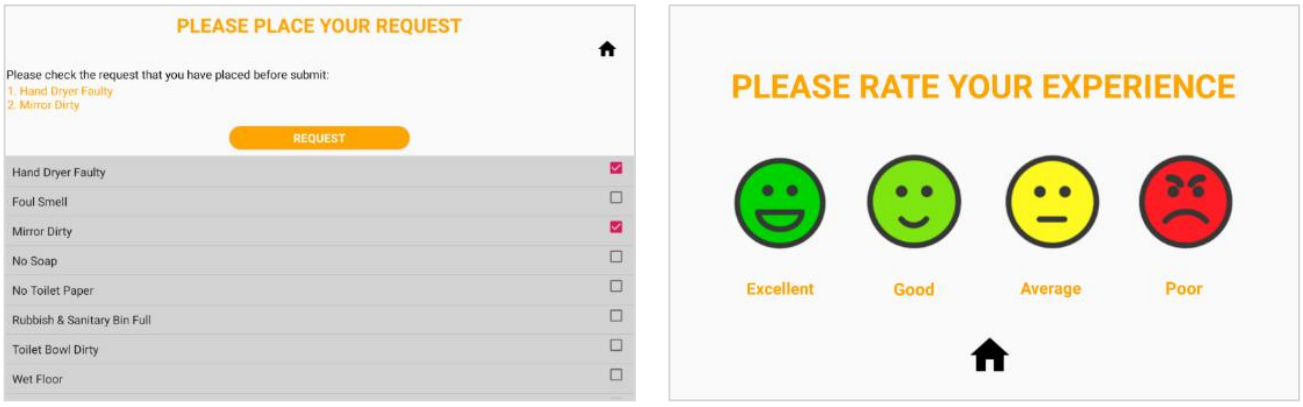


(a) (b) (c)

Fig. 5. User interfaces of statistical data (a) cleaning request (b) toilet issues reported and (c) toilet ratings

4.4 Cleaning Service Request and Toilet Rating Modules

Figure 6 shows the user interfaces of the interactive panel-based toilet management system application. Figure 6(a) shows the interface for toilet users to request cleaning services and Figure 6(b) shows the rating interface for toilet users to rate the cleanliness of the toilet.



(a) (b)

Fig. 6. User interfaces of Request cleaning service (a) and Rate toilet conditions (b) on the interactive panel

5. Testing and Results

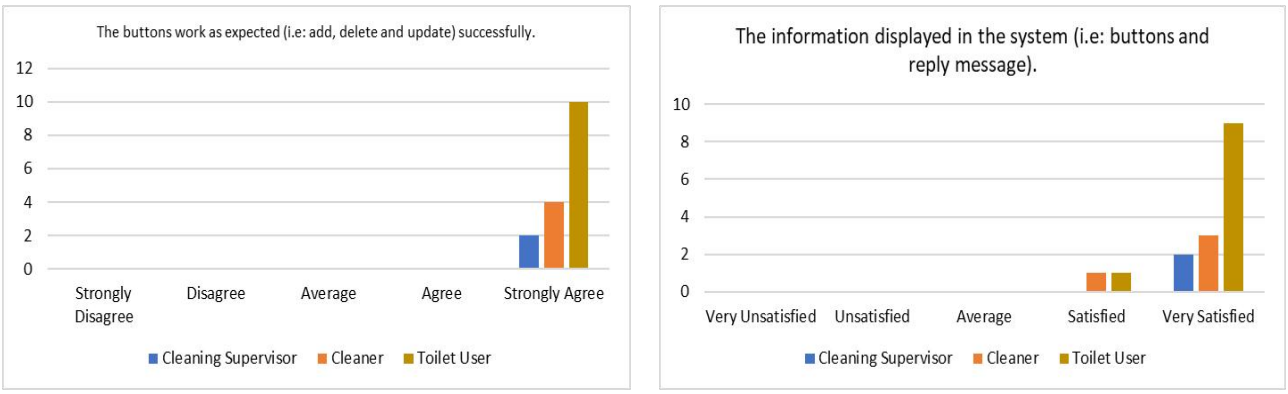
The toilet management system undergoes functionality testing and usability testing to ensure that the desired system is working and has fulfilled all the requirements stated in Figure 1 above.

5.1 Functionality Testing

Functionality testing is performed to ensure the developed toilet management system has fulfilled all the user requirements based on the use cases of the system. 13 test cases have been designed to test each use case and all functions have successfully passed the tests.

5.2 Usability Testing

Usability testing is carried out for 3 groups of users of the system namely the cleaning supervisor, cleaners and toilet users to get feedback on how usable the system is, which includes the functionalities and user interface design of the system. Overall, all the users strongly agreed that the functions provided in the system worked as they expected and most of the users (87%) were satisfied with the interface design of the system. Figure 7(a) shows the user feedback after exploring the features provided in the toilet management system and Figure 7(b) depicts the user feedback on the user interface (UI) design and usability of the system.



(a) (b)

Fig. 7. User feedback on toilet management system usability test

Overall, the system is operating effectively and fulfilling the majority of user expectations. As illustrated in Figure 8, 81% of users express satisfaction with the system, finding it aligned with their expectations. However, some users have higher expectations, desiring features like the ability for toilet users to provide comments or suggestions instead of being limited to predefined options and the inclusion of functions for monitoring cleaner performance.

Fig. 8. Test results for the expectation of the different types of users

5. Limitation and Future Works

The system has certain limitations, such as the inability of cleaning supervisors to identify specific issues within the toilet because cleaners can only report problems without detailing the specific area or problem. Consequently, supervisors must inspect the site in person to address the issue. Additionally, users are restricted to predefined cleaning service requests on the interactive panel, limiting their ability to provide feedback.

For future enhancements, consider the addition of a chatroom to facilitate seamless communication between supervisors and cleaners. This could also involve allowing text descriptions and image uploads for more detailed issue reporting. The incorporation of a mapping feature for each toilet unit would allow users to specify the location of their reports more precisely. Furthermore, consider integrating IoT technology, such as air quality sensors, touchless toilet paper dispensers, and sanitizer dispensers, which could alert cleaning services when poor air quality is detected. These enhancements have the potential to significantly improve the overall effectiveness and usability of the system.

6. Conclusion

In conclusion, the project successfully achieved its objectives, introducing a toilet management system that replaces paper-based task recording, enhancing the management and maintenance processes in shopping mall restrooms. Identified limitations provide directions for future improvements. Overall, the system facilitates effective communication among cleaning supervisors, cleaners, and users, ensuring consistently satisfactory restroom conditions in shopping malls.

Acknowledgement

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