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Case Report

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A proposed Smart School Facility Management System (SSFMS)

By

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ABSTRACT

Purpose

The objectives of the study are to identify the complications arising from existing maintenance practices in Kuwait's governmental schools and to propose a centralized digital maintenance management application that enhances efficiency, safety, and responsiveness in Kuwait's public education system.

Design/methodology/approach

To accomplish the first objective, a questionnaire was designed to collect data on the maintenance level from stakeholders in governmental schools, followed by a site visit to identify the most critical issues.

A proposed system uses the newest digital technology, including mobile apps and cloud platforms, to create a user-friendly and efficient solution. It applies key principles such as user interface, fast data retrieval, ongoing management follow-up, and comprehensive reporting. The system leverages ArcGIS, Workforce, and Survey123 software to improve visualization and connect with existing governmental geographic systems. It was validated through a practical prototype in one school.

Findings

The survey showed that 76.32% of the school stakeholders are not satisfied with the maintenance practice. They pointed out that most schools lack a clear and proper maintenance system. The proposed prototype system showed remarkable success in achieving the proposed system objectives.

Research limitations/implications

This research focused on defining the problems faced by school stakeholders in Kuwaiti governmental schools and did not include the non-governmental schools. The other limitation is that the proposed system was applied only in one school as a trial.

Practical implications

The present study highlights the most critical points to be solved in the school maintenance system in Kuwait and proposes a developed system to overcome these problems.

Social implications

The public education sector in Kuwait contains 983 government schools. The research provides many recommendations to enhance the practice of the governmental schools. This study could significantly improve safety, functionality, and the overall educational environment.

Originality/value

This might be the first trial to identify maintenance problems faced by governmental schools in Kuwait. This research uses modern technology and a user interface to enhance the level of governmental school maintenance performance.

Keywords:
Education facilities, Facility management, smart application, system validation

INTRODUCTION

Any building facility has to be maintained on a regular, timely basis. The maintenance function is better perceived and valued in any organization. It is considered that maintenance management is viewed as an underdog function; now it is considered as an internal or external partner for success (Pintelon and Parodi-Herz, 2008).

Maintenance of the school is a critical part of an efficient educational environment. It includes a range of activities aiming to keep the school's infrastructure in optimal condition, thereby ensuring a safe and conducive learning atmosphere for students and staff. The effects of school maintenance stretch beyond the visible upkeep of buildings and facilities.

One of the primary concerns in any educational institution is the health and safety of its inhabitants. Regular maintenance ensures that potential hazards, such as faulty wiring, deteriorating structures, or malfunctioning equipment, are promptly identified and rectified. According to the National Center for Education Statistics (NCES), well-maintained facilities reduce the risk of accidents andhealth issues, providing a secure environment for students to learn and staff to work (U.S. Department of Education, 2019).

The physical condition of a school directly impacts the learning environment. Studies have shownthat students in well-maintained schools tend to have higher academic achievement and better attendance rates (Earthman, 2004). Adequate lighting, comfortable classroom temperatures,and well-ventilated spaces all contribute to an environment where students can focus and thrive (Filardo, M. 2008).

While school maintenance requires investment, it leads to long-term economic savings. Regular upkeep can prevent costly major repairs or replacements in the future. A report by the National Forum on Education Statistics emphasized that preventive maintenance is more cost-effective than reactive maintenance, as it prolongs the lifespan of school facilities and equipment (National Forum on Education Statistics, 2019).

In Kuwait, education is a priority and is seen as a key factor in the country's growth and development. The government has comprehensively invested in education, which is reflected in the large number of government schools - 983 in total - spread across the nation. The distribution of schools in Kuwait is shown in the pie chart in Figure 1. Government schools make up 76% of all schools in Kuwait.

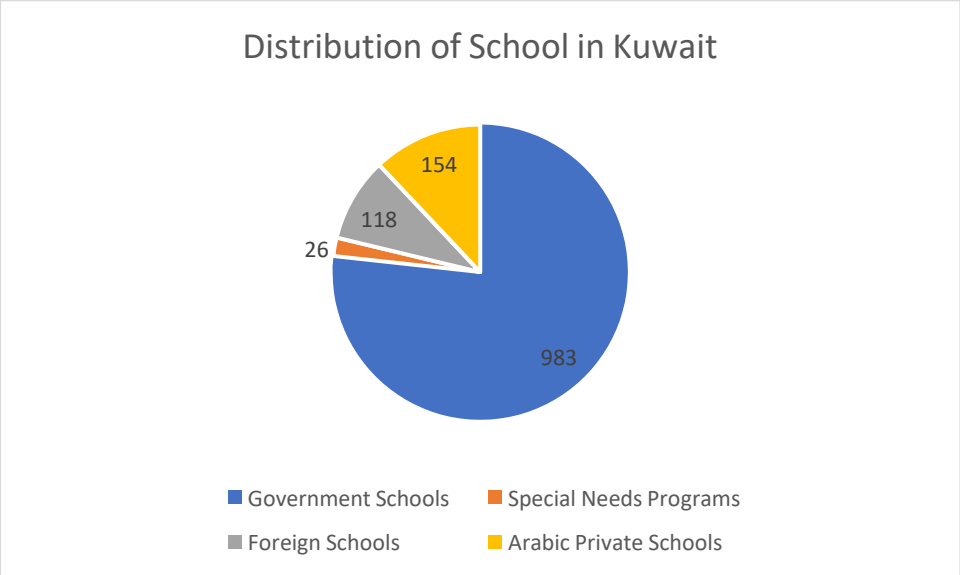


Fig. 1. Distribution of Schools

Despite these efforts, the schools in Kuwait face a significant challenge: maintaining their buildings and facilities. This issue is critical because it affects the safety, health, and overall learning environment for students and staff. Problems such as damaged infrastructure, malfunctioning air conditioning, and unsafe electrical installations are common in many schools. The current process for reporting and addressing these issues is outdated and inefficient, often leading to delays and unresolved problems. This not only negatively affects the learning environment but also causes risks to the safety and well-being of students and staff.

The Smart School Facility Management System (SSFMS) was considered a solution for most of these challenges. It is a digital, centralized system designed to modernize the process of maintaining school facilities management.

This studyaims to replace the traditional, manual methods of dealing with maintenance issues that are used in the Ministry of Education in Kuwait (MOE) with a more efficient, quick, technology-driven approach to maintenance. This system is expected to deal with maintenance problems reported on time and resolved quickly, minimizing disruptions to the educational process, and ensuring a safer environment for students and staff.

Study Objective

The study aims to propose a complete process to improve maintenance efficiency used in MOE. This objective will be provided by developing a digital platform for reporting maintenance issues, workflow automation, promoting inclusive stakeholder engagement, optimizing resource allocation, and reducing wasteful expenditure. It also emphasizes the importance of ensuring compliance with safety regulations and standards, promoting cost-effective resource management, and contributing to a sustainable and progressive educational system.

Background

Improving the quality of school facilities is an expensive undertaking. However, when the positive impacts of facility improvement on teachers and students are translated into dollar figures, the rewards of such investments far outstrip the cost of the investments (Chan 2016). In recent years, the integration of smart technologies in maintenance and facility management hasbeen transformative. The change from conventional methods to advanced technological solutions marks a significant improvement in operational efficiency. Central to this revolution is the Internetof Things (IoT), which has enabled real-time monitoring, predictive maintenance, and automation (Atzori, et al. 2010). These innovations have led to enhanced service delivery, resource optimization, and significant cost reductions. These technologies have been adopted in various sectors, including education, healthcare, and corporate facilities, displaying their various benefits. Because

of the efficiency of using smart technology in maintenance works, a huge number of applications were introduced, and the sector of educational facilities was not exceptional. For example, the Massachusetts Institute of Technology (MIT)represents a landmark in IoT implementation within an educational framework. Their campus system, enriched with smart sensors, manages energy usage, conducts predictive maintenance, and heightens security measures. This approach ensures operational reliability and efficiency, setting a benchmark for IoT applications in educational institutions. An innovative project to create one of the world's smartest university campuses has been started by the University of Birmingham. This system demonstrates how campus facility management can be improved using Internet of Things (IoT) technology. The smart campus makes use of real-time space monitoring to maximize facility utilization and enhance the university experience. Facility management has advanced significantly with this move to a proactive, data-driven approach. by integrating IoT sensor data with IT systems, the project improves decision-making. Staff members can better understand the massive amounts of data generated by using an analytical platform, which helps to promote efficient campus operations. This technology guarantees that a varietyof campus systems are managed effectively and easily (Siemens, 2021).

In the American University of Sharjah (AUS), the implementation of a multi-attribute utility decision support tool represents an innovative step in campus management. This tool is part of AUS's transition to a 'Smart Campus', which combines advanced technology to improve operations. One important part of this project is getting feedback from individuals on campus, likestudents, faculty, and staff, to make sure the technology meets their needs and expectations.

The development of this tool involved a thorough process, starting with identifying key criteria fora Smart Campus, followed by surveys and analysis to understand the needs of different campus groups. The focus was on areas like smart security, easy navigation, and maintenance.

The decision-making process uses the Multi-Attribute Utility Theory (MAUT), a decision-making technique. MAUT helps in objectively evaluating different attributes and choosing the most beneficial solutions for the campus. This approach makes the decision-making process at AUS more structured and ensures optimal outcomes for their smart campus transformation (Ahmed, et al. 2022). The University of Houston has integrated the Modo Campus App, which encompasses the UH Go mobile app, as a content management system. This versatile app offers various functionalities, including lodging maintenance requests. Additionally, users can suggest new features for the app through a form on the university's marketing webpage. The app undergoes regular maintenance updates, ensuring continuous service improvement. Augustana University employs the Asset Essentials App by Brightly Software for handling maintenance requests. Users can download this app, create an account, andsubmit maintenance requests, with the option to add specific details and photos. This approach simplifies and streamlines the maintenance management process at the university. Brightly Software is an asset management system that enhances maintenance management and operational efficiency. It allows users to handle a wide range of tasks, from managing assets to planning preventive maintenance, leading to reductions in maintenance spendand work order hours. The application also offers a centralized platform for asset tracking and decision-making. Regarding district schools, the Los Angeles Unified School District uses maintenance issues through a mobile app developed by CitySourced, which is integrated with IBM Maximo software for managing physical assets and work orders. The app allows students, teachers, and parents to reportmaintenance concerns like water leaks or broken windows by uploading a photo. Beyond school maintenance, it also addresses broader community issues such as potholes and public safety.

Types of Maintenance Required in Schools

Schools require various types of maintenance to maintain their infrastructure and overall functionality. Corrective maintenance, or reactive maintenance, which addresses unforeseen issues promptly, sudden, or quick maintenance issues action ensuring minimal disruption to school activities. Preventive maintenance involves routine inspections and repairs to prevent potential problems before they occur. Cosmetic maintenance focuses on the appearance and aesthetics of school facilities, boosting morale and motivation among students and staff. Safety maintenance

ensures all facilities meet safety standards and regulations, prioritizing the well-being of students, staff, and visitors. Examples of safety maintenance include checking fire extinguishers, ensuring playground equipment is secure, and addressing potential trip hazards.

Facility management principles

Maintenance management services and approaches depend on the level of requirements and primary maintenance objectives. This approach has been changed for many years between organizations. Several trials were conducted in the literature to identify the various divisions that make up maintenance management services. One of the most important approaches that has been introduced to manage services in buildings and services is the facility management approach. This approach aims to improve productivity, safety, and requirements interchange within or between public and private organizations. It aims to improve efficiency, effectiveness, and service consistency, which would result in cost benefits for an organization. (Rajini & Kaluarachchi, 2019).

To enhance the application of FM in buildings, many techniques are integrated with the FM approach. BIM and block chain are examples of these integrations. Moradabadi et al (2024) investigated the effect of using BIM integrated with the FM principles to reduce the total life cycle costing (LCC). They found that BIM-based optimization can lead to substantial cost reductions. They provide a framework that helps designers create more effective BIM models, enhancing facilities management (FM) and reducing LCC. Kern et al 2024 proposed to integrate BIM with the FM process in educational buildings to enhance the information flow. The visual appeal of the facility management and BIM integration facilitates information flow and access. It optimizes the use of the digital model through the most prolonged phase of the life cycle of a building (post-occupation phase). Patacas et al (2020) identified several gaps in the BIM for the Facility Management (FM) area. These include the lack of a framework to cover the entire BIM-FM workflow, the limited use of open standards for data sources for the operational phase, and the lack of a common data environment to validate and integrate the data (both graphical and non-graphical) required for the maintenance and operations of the BIM-FM. Peng et al. 2024 carried out a comprehensive bibliometric analysis of 291 BIM-FM documents from the WOS database covering the 2003-2023 period. The findings demonstrate the body of knowledge of BIM-FM: technological integration and innovation, strategies for implementation and take-up, energy sustainability and efficiency, training and professional development, and data management and analysis. They contribute significantly to the growing dynamic discipline and present the research pathway to its development. Singh and Kumar (2024) identified the barriers to adopting Blockchain-Enabled Building Information Modelling in Facility Management. The most critical barriers are “limited collaboration” and “communication among stakeholders,” “legal constraints in certain jurisdictions,” and “challenges in establishing trust and governance models.

There are very limited trials to apply the principles of FM in the construction industry in gulf region. Jafer and Mohammed (2026) aimed to identify the priority factors influencing bridge maintenance in Iraq. They mentioned that the top five significant factors influencing bridge maintenance prioritization in Iraq were bridge condition, traffic volume, human-related risk, bridge location, and maintenance cost. Mawed (2024) proposed a specific performance measurement tool for the UAE facility management industry to assess performance and establish strategic enhancements accurately. He introduced more than 50 measures to evaluate the efficiency of applying the FM approach in the UAE industry. These measures covered the safety, contractual, health, and customer satisfaction. In KSA, it is noticeable that there is an increase in FM in Saudi buildings. Akbar et al. (2025) explored the factors influencing the growth of the facilities management (FM) industry in Saudi Arabia. The study identified that leadership, technical knowledge, and problem-solving skills are the most required skills. While technology integration and climate-related maintenance are the most challenging. The study also assessed that the economic growth and government infrastructure investments were the strongest drivers of FM expansion.

In Kuwait, AlSabah and Al-Tabtabai 2024 discussed the application of the principles of FM in one of the major public entities in Kuwait. They compare the efficiency of costing of traditional and FM principal applications. They conclude that applying FM in such types of entities has many advantages. AlRasheed et al. 2024 proposed an outsourcing FM approach to manage the non-core services in MOE in Kuwait. Because of the limited research work and limited application of FM in public facilities in Kuwait, there is a gap in research and industry to evaluate the importance of applying technologies in usual maintenance duties in public entities in Kuwait.

Methodology

The methodology for designing the Smart School Facility Management System in Kuwait was comprehensive and involved several key steps. First, to evaluate the efficiency of the current maintenance system that is currently used in MOE, two surveys were conducted. The first survey applies a questionnaire asking a sample of all stakeholders who deal with MOE about their perspective on the maintenance approach used, and the other survey is a site visit for one of the schools in the state of Kuwait. The questionnaire was designed and distributed to a random sample of MOE clientele. The questionnaire aims to gather input from a diverse group of stakeholders, including teachers, staff, and students, to understand the specific maintenanceneeds and challenges of each school. Analyzing the collected data to identify the key requirements for the proposed Smart School Facility Management System (SSFMS)

The questionnaire is divided into two parts. The first part is the general information part, and the second part includes the participants' perception regarding the level of efficiency of the status of the maintenance system in MOE. The questions are driven by previous research work and from brainstorming discussions of this study's authors. The questionnaire was web-distributed to more than 300 participants. A total of 181 diverse participants—comprising teachers, staff, engineers, students, principals, and others. The other application to evaluate the efficiency of the current management system is to conduct a school site visit and evaluate the status of school facilities. This visit was conducted after contacting school principals and being approved to visit. The site visit was conducted to Al Firdous Intermediate School for Girls to observe the current state of infrastructure and maintenance procedures. This included taking photographs and conducting interviews with staff. An evaluation of the current maintenance system is done to determine its advantages and disadvantages. Based on this analysis, designing a digital,centralized system to modernize the maintenance process. This proposed system will utilize the latest digital technology, including mobile applications and cloud-based platforms, to create a user-friendly and efficient system. The proposed system is introduced to overcome current system deficiencies. The proposed system deploys the principles of user interface, quick data retrieval, maintaining management follow-up, and generating sufficient reporting. This proposed system will utilize ArcGIS for geospatial data analysis and mapping, aiding ineffective planning and resource allocation. The proposed system utilizes ArcGIS, Workforce, and Survey123 software to enhance the system interface visualization and to link with the currently used governmental geographical systems.

The proposed system was validated in a practical prototype application in one school. The system shows valuable enhancement in maintenance work efficiency.

RESULTS AND DISCUSSION

Data Analysis

Current Maintenance Strategies and Challenges in Kuwait's Education Sector

The Ministry of Education has been trying to provide alternatives to the maintenance procedure and the reporting of issues in schools since the beginning of the 2022/2023 academic year. The ministry currently employs an online communication strategy, allowing school administrators to report maintenance issues through various platforms, including WhatsApp and email. This approach involves assigning engineers to different educational zones who act as the primary contacts for maintenance concerns.

However, this system faces several challenges such as: depending on manual reporting, lack of automation, and reactive, not proactive approach to maintenance in addition, due to the large number of schools of maintenance requests can be too many, so managing this huge number of

maintenance work order needs a new approach to maintenance management. Figure 2 shows the cause-and-effect figures showing the reasons for the current system deficiency.

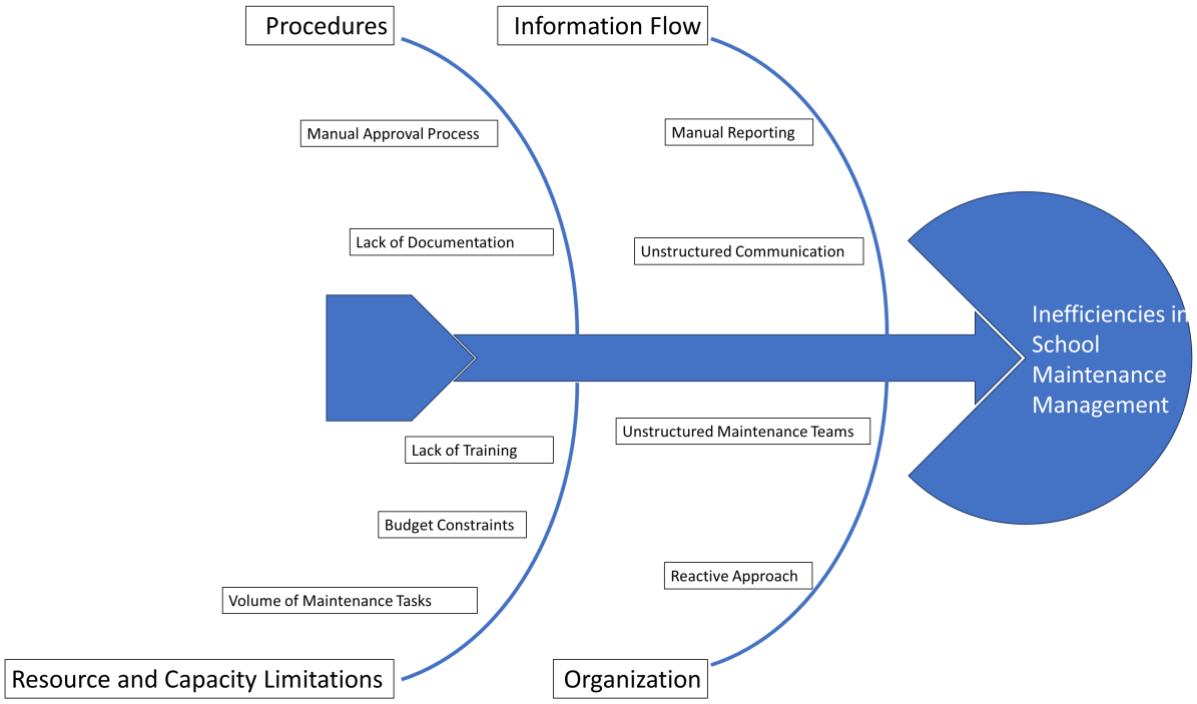


Fig.2. Cause-and-effect of current system deficiency

As seen in Figure 2, the data and information flow through manual platforms and unstructured communication. Information is distributed through informal channels, which can lead to miscommunications and inefficient handling of maintenance requests.

The approach used of maintenance is the reactive approach. The reactive approach is performed in reaction to reported issues ratherthan proactively identifying and preventing potential problems. The maintenance tasks are performed by unstructured maintenance teams. Maintenance personnel are assigned to schoolsbut without a structured system to prioritize and manage tasks.

Regarding the current procedures used. The procedures are conducted manually. Requests and approvals are handled manually, which can be time-consuming and inefficient. The procedures used lack professional documentation of maintenance tasks,approvals, and completions.

Due to the large number of schools and the high number of requests, maintenance tasks cannot be efficiently completed. leading to inefficient maintenance task completion. Other problems include a lack of training in facility management and budget constraints.

Questionnaire analysis

The principal goals of the survey were to assess the existing state of school facility services, evaluate the efficiency of current maintenance strategies, and identify areas for the integration of smart technologies from the stakeholders' perspective.

Demographic Analysis

Table 1 shows the designation of respondents and their years of experience for the questionnaire' respondents.

Table 1: questionnaire' respondents' demographic analysis

Designation	%	Years of	%
Teacher	75	Less than 1	9
Staff	14	1-5 years	29

Engineer	6	5-10 years	20
Student	2	10-15 years	14
Principle	2	More than	28
Other	1		

As shown in Table 1, major responses were from teachers (75%) of respondents and from all ranges of years of experience.

The questionnaire consists of 16 questions asking to evaluate certain elements of maintenance tasks and approaches in MOE. Table 2 shows a summary of the questionnaire participants' answers regarding the efficiency of maintenance services provided by MOE. The participants were asked to evaluate the level of efficiency of the current used hard and soft services. Participant evaluation will be on a 5 Likert scale (very bad, bad natural, accepted, and very good) status. To show the dissatisfaction level, the value of dissatisfaction combines the bad and very bad evaluation status, while the accepted level adds the accepted and very good level of service status. As seen from Table 2, The feedback indicated a spectrum of dissatisfaction with the current maintenance system either in hard facilities or soft facilities.

Urgent Improvement and Maintenance Frequency:

The participants were asked to identify areas requiring immediate improvement and determining the frequency of maintenanceneeds was another focus of the survey. The washroom facilities are positioned out as the most critical areaneeding immediate improvement, as shown in Figure 3.

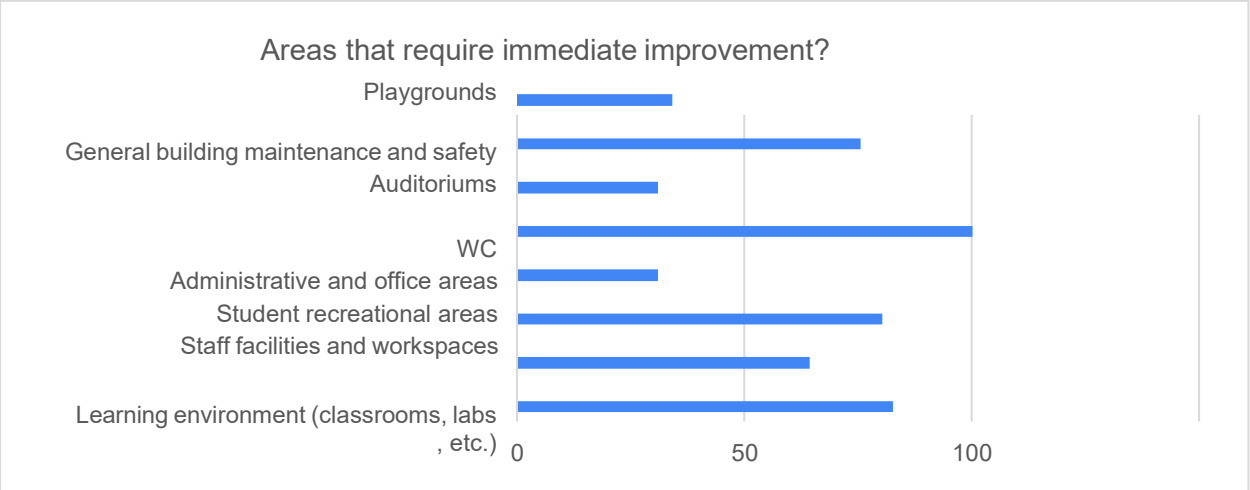


Fig. 3. Immediate Improvement Needs

Facility Satisfaction and Challenges:

The participants were asked to identify the most significant challenge. The lack of proper maintenance and repair, and insufficient resources, are the most significant challenges, as shown in Figure 4.

Table 2: Current evaluation of current service facilities

Evaluation of the existing hard and soft services	sub.	Number of Respondents								
		V. Bad	Bad	Not satisfied	% of Dissatisfaction	Natural	Accepted	Very Good	satisfied	% of satisfaction
Please identify the level of existing hard services facility status.	building inspection	27	24	51	75.00%	32	7	10	17	25.00%
	mechanical and electrical maintenance	35	17	52	82.54%	37	3	8	11	17.46%
	networking	34	15	49	81.67%	40	5	6	11	18.33%
	heating and cooling	32	20	52	81.25%	36	5	7	12	18.75%
	fire system safety	22	24	46	73.02%	37	7	10	17	26.98%
	Garbage Collection and Disposal Services	23	20	43	68.25%	37	9	11	20	31.75%
	Management of Computer Systems	29	22	51	78.46%	35	5	9	14	21.54%
	Staff Transportation Services	29	26	55	77.46%	29	8	8	16	22.54%
Please identify the level of existing soft services facility status.	Gardening and Flooring	29	22	51	75.00%	32	6	11	17	25.00%
	Cleaning and Disinfection Services	28	26	54	75.00%	28	9	9	18	25.00%
	Furniture and Curtain Maintenance	39	20	59	77.63%	24	9	8	17	22.37%
	General Safety in Buildings (Cameras):	21	26	47	71.21%	34	7	12	19	28.79%
In general, are you satisfied with school facilities?		28	30	58	76.32%	24	12	6	18	23.68%

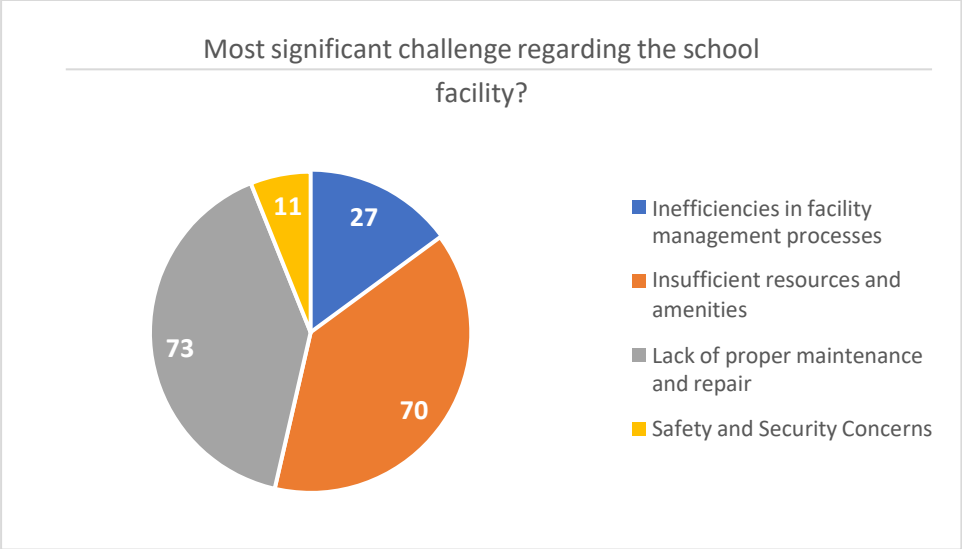


Fig. 4. Significant Challenges

Time elapsed to maintain maintenance

Additionally, the period of resolving reported issues varied greatly, with about 30% of problems remaining unsolved, as shown in Figure 5. These results emphasize the necessity for a more efficient and resourceful maintenance system.

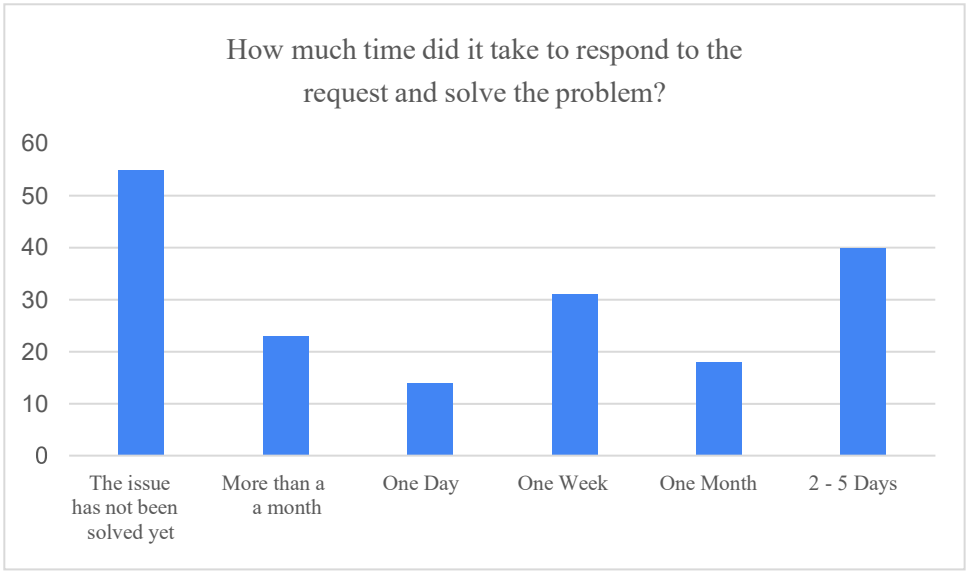


Fig. 5. Response Time to Reports

Staff efficiency

The respondents were asked to evaluate the efficiency of the current staff in maintenance tasks. Table 3 shows their responses. As seen from Table 3, the respondents encourage the idea of assigning technical departments responsible for maintenance either in school or in the educational region.

Table 3: Staff Efficiency

	yes	no	not sure
Staff Trained	48	51	82

Staff comply with contracts	31	50	100
There is a need for a technical department in schools or an educational region	127	11	43

Maintenance budget

The respondents asked to judge the sufficient maintenance budget, 42 % said that they suffer from the insufficient budget, while only 10 % of respondents were comfortable with the allocated budget.

The questionnaire results highlighted a critical need for enhancement in Kuwait's school facility services. Widespread dissatisfaction is evident, particularly in areas like building inspection, maintenance,and cleanliness. The frequent need for improvements in essential services like washrooms and HVAC systems underscores their impact on health and learning. Moreover, the mixed responses on administrative capabilities, contract efficiency, staff training, and budget issues suggest systemic inefficiencies. The strong support for technological solutions, such as a smart maintenance system, indicates a readiness for digital transformation to address these challenges effectively.

Site Survey

An observational site visit was made to Al Firdous Intermediate School for Girls to check out the current state of the school's infrastructure and maintenance procedures. During the visit, photographs were taken and interviews with staff were conducted to learn more about their experiences and problems with school maintenance. The school staff suffered from the very long process of maintenance orders and the rareness of response. Because of that, the staff found themselves responsible for maintenance costs from their equity. The site visit showed many deteriorations and bad or malfunctions for many educational facilities. Figure 6 shows samples of the taken photos during the site visit.







Fig. 6. School Site Visit Photos

The observed conditions at Al Firdous Intermediate School proved an urgent need for a systematic, responsive maintenance management system. The various issues, ranging from basic infrastructural decay to critical safety concerns, underscore the urgency of this need. The lack of adigital reporting and communication system, combined with the absence of timely responses and support from the ministry, demands the introduction of a streamlined, transparent, and accountablemaintenance management application.

The Proposed System (SSFMS)

The Smart School Facility Management System)SSFMS) aims to introduce a more structured and efficient approach to maintenance management. By moving away from the current manual and reactive system. The SSFMS also aims to enhance the overall maintenance process, ensuringthat Kuwait's educational facilities are well-maintained and conducive to a productive learning environment. This application would facilitate not only the prompt reporting of issues but also ensure that they are addressed in a timely and efficient manner, enhancing the safety, functionality, and overall quality of the educational environment. The proposed digital maintenance management application aims to transform the unstructured, reactive, and manual processes of the existing system into a structured, proactive, and digitalized maintenance management procedure. Features of the proposed system include:

- Digital Reporting: Users can report maintenance issues through a dedicatedapplication, resulting in immediate and structured reporting.
- Centralized Database: All maintenance requests and communications are stored in a centralized database, enabling better tracking and management.
- Real-time notifications: The system provides real-time notifications to relevantpersonnel, enhancing responsiveness.
- Proactive Maintenance: The application can be programmed to send reminders for the scheduled preventive maintenance tasks.
- Structured Maintenance Teams: Tasks are assigned to maintenance personnel basedon the specific school or zone, organizing the maintenance process.
- Digital Approval Process: Maintenance requests go through a digital approval process, ensuring a structured and efficient handling of tasks.
- Comprehensive Documentation: The system documents all steps of the maintenance process, from reporting to resolution, enabling better accountability and compliance.

Figure 7 shows the SSFMS input, process, and anticipated outputs.

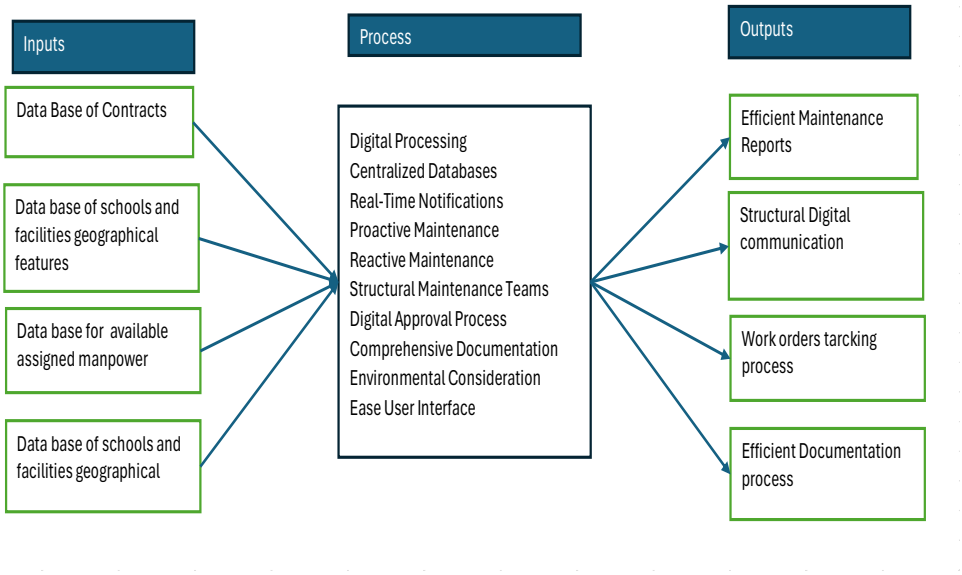


Fig. 7. SSFMS input, process, and anticipated outputs

To maintain the application of the proposed SSFMS, several steps are suggested for application by the MOE in Kuwait. These steps can be summarized as: before design stage, design stage, test and validation stage, and application stage

The before-design stage contains a survey for all required maintenance tasks in general, as it will be applied in the school. To understand the specific maintenance needs of each school. The current and best organizational structure that can deal with the proposed system. This stage involves teachers, administrators, and maintenance staff to ensure the system meets their needs. The design stage utilizes the latest digital technology to create a user-friendlysystem. This step includes the required software and hardware associated with the application system. The second stage is system design, followed by the training and testing step. The suggested training, testing, and validation step important to ensure the efficiency and capability of the proposed system before the application step. Based on the analysis of system test and validation, a complete system can be introduced to MOE to apply.

SSFMS Design

In this system, a dedicated application for the Ministry of Education has been developed. In addition, the existing services provided by ArcGIS are utilized to show how

the system would workin real life. The SSFMS is conceptualized as a mobile platform, designed to modernize and enhance the maintenance process in schools. This application, through its user-friendly interface and comprehensive features, significantly aids in the efficient management of school maintenance tasks.

The proposed system integrates the most recent software to enhance system application. SSFMS integrates ArcGIS, Workforce, and Survey123 software on mobile platforms empowering each Kuwaiti school with the tools to manage maintenance tasks more effectively. The mobility aspectensures that maintenance staff can respond swiftly and accurately, fostering a well-maintained educational environment.
ArcGIS is a leading geographic information system, that helps manage school maintenance in Kuwait. Each school, equipped with ArcGIS on their smartphones and other devices, can visualize and analyze maintenance needs. This accessibilityenhances the ability to identify and address issues swiftly. The Workforce from ArcGIS is adeptly used to create and manage work orders. Each school, as a unique user, utilizes the app on their mobile devices to generate and assign maintenance tasks. Thismobile accessibility ensures that work orders are handled promptly and efficiently, promoting better task management. Survey123 complements this system by offering robust on-site data collection and job completion reporting capabilities. Maintenance staff, using Survey123 on their mobile devices, record detailedinformation about the maintenance work, including observations and photos. Immediate data capture and reporting streamline the maintenance process, allowing for real-time updates and enhanced communication.

The primary concept of the application involves allowing users (Dispatchers)— from different schools—to create a maintenance request. The user submits the issue and any necessary photos, which are then transmitted to a database. Subsequently, a designated individual assesses the validity of the request. Upon approval, it is forwarded to the maintenance personnel (technician) associated with the specific school or zone. After completing the job, the maintenance personnel provide a work completion report, which is validated by specific staff members. If it is not approved, the maintenance personnel may be asked to redo or revise the work. The request is onceagain forwarded to the staff, and upon approval, it is logged into the database. Furthermore, the user who generated the request is notified. Users can also peruse any requests they have made andview their status. Each school will have one designated username. Figure 8 shows the data flow for the proposed system.

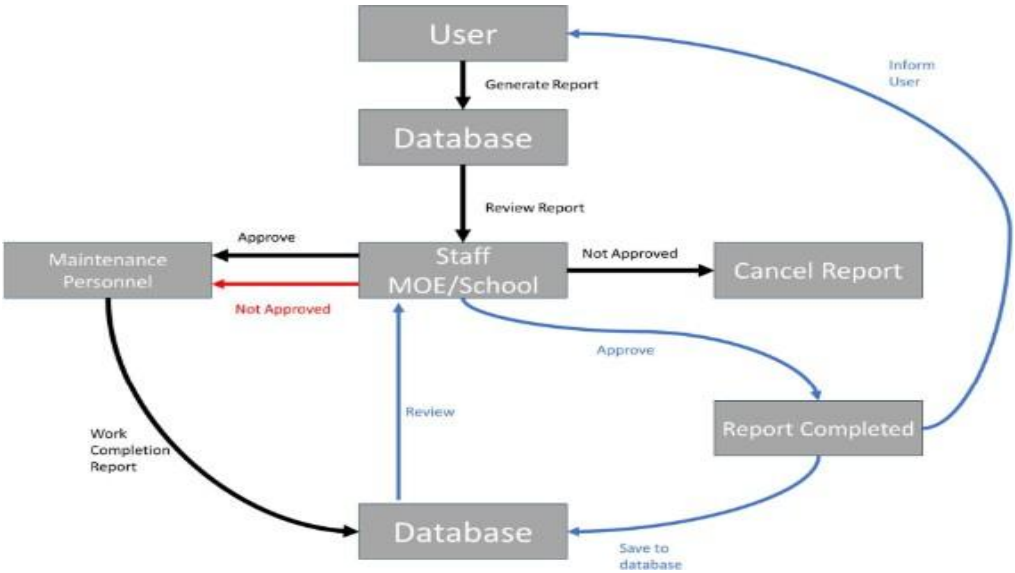


Fig. 8. System Data Flow

The application consists of several steps to manage maintenance issues. It involves issue reporting,

database transmission, issue validation, task assignment, maintenance work, work completion report, validation, database logging, user notification, and request status tracking. Schools and dispatchers are involved in identifying and documenting maintenance issues. A centralized database is used to store and organize maintenance requests. Designated approval personnel assess the validity of reported issues, assign tasks to the right personnel, and ensure the quality and completeness of the work. The application also logs the validated work completion report into the database, ensuring transparency and communication. Users can check their requests and view their status, fostering a transparent and accountable maintenance management process.

Model Validation- Application Functionality and Workflow

The proposed system will be verified by application through many succeeding mobile application screens. The welcoming page (Figure 9) guides users on services and how to use them. Figure 10 shows the school inventory services, which provide a comprehensive view of all items onschool grounds. It includes crucial details like the date of installation, serial numbers, nextscheduled maintenance, and precise locations of each item. Figure 11 shows the work order generation window. While creating a work order, the dispatcher specifies essential details like the problem type, urgency, area, and a description of the issue, accompanied by a relevantphoto for clarity. Figure 12 shows the tracking work order screen. Schools can monitor the status of all issued work orders, with updates on whether they are pending, canceled, or completed. This feature ensures transparency and allows schools to stay informedabout the progress of their maintenance requests. Once maintenance work is completed, the worker updates the work order,converting it into a comprehensive job completion report. The report includes before-and-after photos, completion date, costs incurred, andany remarks from the worker, offering a complete overview of the job (Figure 13).



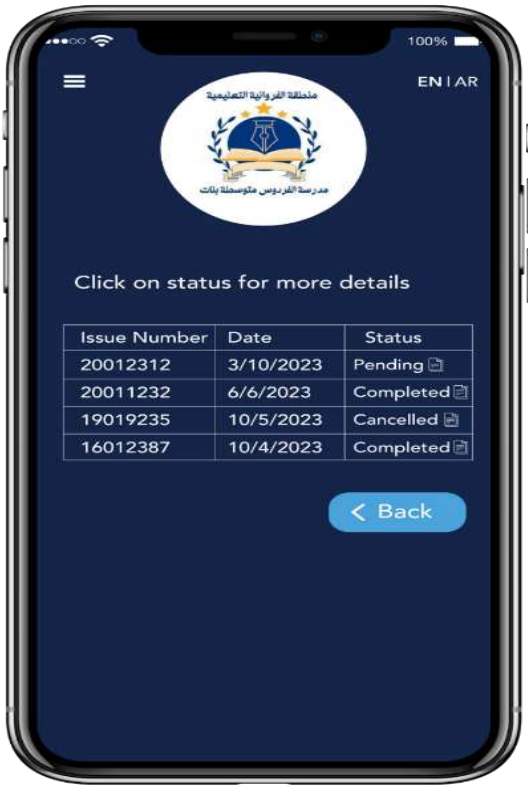
Fig. 9. Welcome page and school page



Fig. 10. Inventory



Fig. 11. Work orders generation



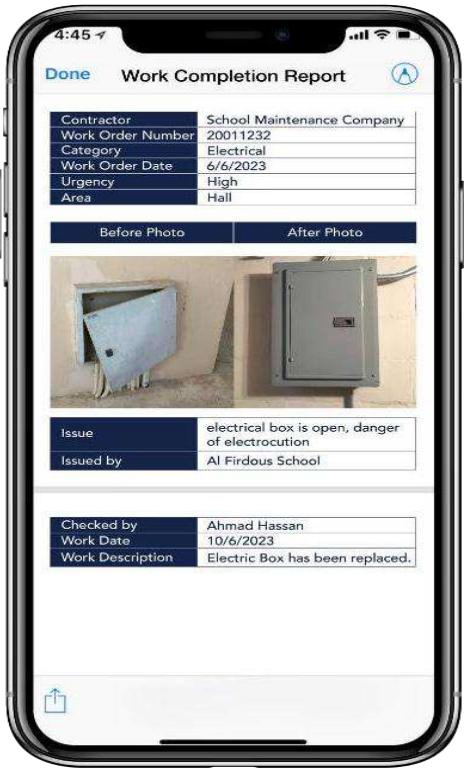


Fig. 12. Work order tracking status

Fig. 13. Job Completion Report

A prototype of the proposed system was tested in one school in Kuwait and its efficiency in quick and structural maintenance work tasks.

CONCLUSION

The implementation of the Smart School Facility Management System in Kuwait represents a step in addressing the persistent challenges of school maintenance. This comprehensive study, integrating cutting-edge digital solutions and strategic planning, aims to overhaul the existing, inefficient maintenance management practices. Its significance lies not only in enhancing the operational efficiency of school maintenance but also in fostering safer, healthier, and more conducive learning environments.

Kuwait's educational sector, despite its emphasis on quality education, has been grappling with inefficient maintenance management, leading to deteriorated school facilities and potential safety hazards. The reliance on outdated, manual reporting methods has resulted in delayed responses and unresolved maintenance issues, adversely affecting the learning and teaching conditions.

The existing system's shortcomings, such as a lack of structured communication, reactive maintenance approaches, and resource limitations, have been significant contributors to the inefficiency of school maintenance in Kuwait. The proposed system addresses these imperfectionsby introducing digital reporting, structured maintenance teams, and a comprehensive documentation process.

The study's importance extends beyond mere infrastructural upkeep. It plays a pivotal role in ensuring health and safety standards, fostering an enhanced learning environment, and achieving economic efficiency through preventive maintenance strategies. Additionally, the system aligns with Kuwait's broader educational and national developmental goals.

Surveys conducted among a diverse group of stakeholders and site visits, for a school, have been instrumental in understanding the ground realities and specific needs. These insights have been critical in shaping the system's design and ensuring its relevance and effectiveness.

The Smart School Facility Management System, by digitizing the maintenance process, promises a swift and systematicapproach to reporting and resolving maintenance issues. Through the integration

of a user-friendlyapplication and the utilization of ArcGIS technology, the system aims to ensure timely action, effective resource allocation, and enhanced communication among stakeholders.

The incorporation of ArcGIS technology is a game-changer, providing geospatial data analysis and aiding in effective planning and resource allocation. The use of ArcGIS tools like Workforce and Survey123 on mobile platforms enhances the system's functionality, allowing for efficient work order management and comprehensive on-site reporting. A practical application of the proposed system was done in a school as a prototype; it showed remarkable success in achieving system objectives.

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Conflict of Interest

The authors agree that this research was conducted in the absence of any self-benefits, commercial, or financial conflicts.

Data Availability

All data used are available upon request from the corresponding author.

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Declarations

Ethics declarations

Ethics approval

All methods were carried out in accordance with the relevant guidelines and regulations issued by Kuwait University, Kuwait.

Ethical Statement

The questionnaire was designed and revised by the authors, and all participants involved in this study provided informed consent before their inclusion in the study.

Consent to participate

Informed consent to participate in this study was obtained from all individual participants included in the research.

Competing interests

The authors declare no competing interests.

Clinical trial number:

Not Applicable

Consent for publications

Not Applicable

Authors contribution

Hashem Al-Tabtabai carried out most of the work, Ehab Soliman made the statistical analysis, and wrote the first paper draft. The final version of the study was reviewed by Al-Tabtabai

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