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Enhancing institutional security and fee compliance through an integrated QR code-based student access system

Lisa John [1] *, **Fredrick Michael Sanga** [1], **and Victor E. Kilindo** [2]

[1] Department of Mechanical Engineering, Dar es Salaam Institute of Technology, Tanzania
[2] Department of Marine Engineering, Dar es Salaam Maritime Institute, Tanzania

lisamasikane@gmail.com
* Corresponding author

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Abstract

The increasing student population at the Dar es Salaam Maritime Institute (DMI) has highlighted serious limitations in the existing manual gate entrance access system, which relies on physical verification of student identity and tuition fee status. This manual process has caused long queues, human errors, and inefficiencies in enforcing institutional access policies. This study presents the design and implementation of a QR code-based access control system aimed at automating and improving student verification at the DMI gate. Using a Design Science Research (DSR) methodology, the system was conceptualized, developed, and tested to ensure reliability, efficiency, and accuracy. Each student was assigned a unique QR code generated from the student database and linked to their fee payment records. Experimental results show that the proposed system reduced student verification time from approximately 20 seconds to less than 5 seconds, achieving an accuracy rate of 98%. These results demonstrate improved operational efficiency and reliable access control at institutional entry points. Upon scanning at the gate, the system performed real-time verification and granted or denied access accordingly. Results from the prototype testing demonstrated a significant reduction in verification time, from an average of 20 seconds manually to less than 5 seconds with the automated system. The study concludes that integrating QR code technology with institutional databases provides a cost-effective, scalable, and secure solution for managing student access. Future work should focus on integrating mobile payment updates, biometric verification, and offline access features to enhance usability and resilience in resource-constrained environments.

Keywords: QR code, access control system, fee compliance verification, student information management system, higher education

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1. Introduction

The rapid digital transformation of administrative and operational systems in higher education has reshaped the way institutions manage security and access control. Traditional methods that rely on manual verification and physical registers are increasingly being replaced by automated systems that integrate databases, manage digital identities, and enable real-time analytics (Alotaibi & Zhang, 2021). In academic environments such as the Dar es Salaam Maritime Institute (DMI), where daily student and staff movement is substantial, manual gate management methods have proven inadequate. These systems are often characterised by delays, poor data accuracy, and weak enforcement of institutional policies related to tuition fee compliance and student identity verification (Kariuki & Mutua, 2021; Ogunwale & Adebayo, 2018).

Modern access management technologies, including biometric recognition, radio-frequency identification (RFID), and Quick Response (QR) codes, have introduced new levels of efficiency and accountability in physical and digital access control systems (Chavan, et al., 2019; Lee, et al., 2022). Among these, QR code technology stands out for its low cost, flexibility, and ease of deployment in resource-limited environments (Hamzah, et al., 2021; Rahman, et al., 2022). In developing regions such as Tanzania, educational institutions continue to face infrastructural and budgetary constraints that limit the implementation of high-cost biometric or RFID systems. Therefore, QR code-based systems provide a feasible alternative for enhancing institutional efficiency without the need for complex infrastructure.

The Dar es Salaam Maritime Institute (DMI), a leading maritime training institution in Tanzania, has experienced increasing challenges in managing student gate entry due to the growing student population. The previously used manual process required security personnel to verify student identity cards and cross-check fee payment lists against printed records. This approach was time-consuming, error-prone, and lacked real-time synchronisation with the students' information management system (SIMS). Consequently, the process not only caused congestion at entry points but also compromised institutional security and administrative control. Similar challenges have been documented in other African universities, where manual verification systems hinder operational efficiency and fail to ensure compliance with institutional regulations (Nyambo, et al., 2022; Ogunwale & Adebayo, 2018).

While QR code technologies have been widely applied for attendance tracking and even access management in higher education, most existing implementations focus primarily on presence logging and short-term access validation rather that comprehensive institutional control (Ahmed, et al., 2020; Hamzah, et al., 2021; Rahman, et al., 2020). In the Africa higher education context, several studies report that digital access systems are often deployed in isolation, without integration with financial or academic databases, limiting their effectiveness in enforcing institutional polices such as tuition fee compliance (Abubakar & Bala, 2021; Musa & Ibrahim, 2021; Nyambo, et al., 2022). Although QR-based access control has demonstrated efficiency and cost advantages over biometric and RFID systems, limited empirical research has explored systems that simultaneously verify student identity and tuition fee status through real-time institutional database integration (Kamal & Goyal, 2019; Okonkwo, et al., 2023; Ogunlade & Daramola, 2022). This study addresses this gap by integrating QR code-based verification with the Student Information Management System (SIMS) to enforce both secure gate access and automated fee compliance with a higher learning institution.

To the best of my knowledge, no prior study has implemented a QR-based gate access system that directly integrate student identity and fee payment verification within an Africa higher education context

To address these challenges, this study developed a QR code system that automates the verification of student identity and tuition fee status at the DMI gate entries. The system integrates the institution's SIMS database to provide real-time validation, thereby reducing manual workload and enhancing security accuracy. The system's Development followed the Design Science Research (DSR) approach, which focuses on solving practical problems through iterative design, Development, and evaluation (Wang & Hannafin, 2005). The DSR methodology ensures that the system is not only technically functional but also contextually relevant and sustainable within institutional constraints.

The objective of the study was threefold:

1) To analyse the existing gate access management system and identify its inefficiencies;
2) To design and develop a QR code-based system that integrates student identification with tuition fee verification, and
3) To implement and evaluate the system's performance in improving verification accuracy, speed, and reliability at DMI.

By achieving these objectives, the study contributes both practical and theoretical value to the field of educational technology and institutional management. Practically, it demonstrates how low-cost digital solutions can enhance administrative efficiency in higher education. Theoretically, as per Davis (1989) it extends the application of the Technology Acceptance Model (TAM), providing insights into factors influencing user adoption of digital access control systems within African learning environments.

2. Literature Review

2.1. Overview of Access Control Technology

Access control systems are technological frameworks designed to regulate entry and exit to physical or digital environments by verifying user identity against pre-authorised credentials. Traditional access systems in educational institutions largely relied on maintaining attendance registers. Such methods are susceptible to impersonation, errors, and inefficiency due to their reliance on humans and the lack of real-time verification (Ogunwale & Adebayo, 2018; Kariuki & Mutua, 2021). As higher learning institutions expand in scale, the need for digital transformation in access management has become increasingly apparent (Alotaibi & Zhang, 2021; Barcanescu, 2021).

Modern institutions have adopted biometric, radio frequency identification (RFID), and Quick Response (QR) code systems to improve accuracy, security, and operational efficiency. Biometric systems, such as fingerprint and facial recognition, have shown significant potential for unique identification; however, they require substantial infrastructure investment and maintenance (Wang, et al., 2020; Yaboah-Boateng & Essandoh, 2014). RFID-based systems automate identification by transmitting radio signals through tags and readers, but remain expensive for institutions with limited resources (Chavan, et al., 2019; Ngugi, et al., 2020).

In contrast, QR code technology offers a low-cost, contactless, and scalable solution ideal for institutions in developing regions. QR codes can store a large volume of data and are readable by any smartphone, eliminating the need for specialised scanning hardware (Kaur & Sandhu, 2018; Hamzah,, et al., 2021). Their flexibility has enabled application in diverse areas such as identity verification, event registration, and attendance tracking (Zhang, et al., 2020; Rahman, et al., 2020). Importantly, QR code systems can be easily integrated into institutional databases to provide real-time verification, a critical improvement over manual and standalone systems.

2.2. Applications of QR Code Systems in Educational Institutions

The global rise in digital transformation has encouraged many higher learning institutions to adopt QR code technology for academic and administrative purposes. Studies by Chanthinok and Sonthiprasat (2021) and Rahman et al. (2020) demonstrate that QR code systems enhance efficiency in attendance management and classroom monitoring by automating student identification processes. Similarly, Yusof et al. (2021) highlight how QR-enabled gate management systems improve institutional security by integrating digital verification with real-time monitoring.

Several researchers have proposed models for integrating QR codes with other technologies to enhance system performance. For example, Lee et al. (2022) proposed a secure QR code authentication framework incorporating encryption algorithms to prevent duplication and unauthorised access. In another study, Rahman, Islam, and Akter (2022) designed a dynamic QR code-based access system capable of generating time-sensitive codes, thereby enhancing both reliability and security. Such developments indicate the potential for QR code systems to evolve into more sophisticated institutional management tools.

However, existing implementations have limitations. Many focus primarily on attendance tracking and do not integrate student financial records or tuition compliance verification (Kariuki & Mutua, 2021; Osei & Kofi, 2022). Ahmed et al. (2020) and Ngugi et al. (2020) emphasise that most current systems operate in isolation, lacking integration with the institutional Student Information Management System (SIMS). This gap underscores the need for solutions that combine identity verification, payment validation, and institutional record synchronisation, a challenge addressed by the system developed in this study at Dar es Salaam Maritime Institute.

2.3. Theoretical Foundation: Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), developed by Davis (1989), provides a theoretical framework for understanding user adoption of new technologies. It posits that technology acceptance is primarily influenced by two key constructs: perceived usefulness (PU) and perceived ease of use (PEOU). Users are more likely to adopt a system they perceive as useful, which is easy to operate and improves their performance. Venkatesh and Davis (2000) later extended TAM to include variables such as subjective technology adoption in organisational contexts.

In the context of higher education, TAM has been widely applied to analyse the adoption of learning management systems, e-administration platforms, and mobile-based applications (Ali, et al., 2022; Mtebe & Raisamo, 2014). For the QR code-based access system at DMI, TAM serves as an appropriate foundation for evaluating user acceptance among students and security personnel. The model aligns well with the system's objectives, ensuring that the designed solution is not only technically effective but also accepted by its end users. Studies by Musa and Ibrahim (2021) and De Seta (2023) reaffirm that user perceptions of efficiency, security, and convenience strongly influence the adoption of digital access technologies in educational environments.

2.4. Identified Research Gap

Although QR code technology has been explored in several studies, its integration with financial verification systems and student information databases in higher learning institutions remains underdeveloped (Ogunlade & Daramola, 2022; Mekuria & Alemu, 2022). Previous research largely emphasises automation for attendance or event management, without addressing tuition fee compliance a critical factor for institutional policy enforcement. Furthermore, empirical evidence from African contexts is limited, as most implementations originate from technologically advanced countries with robust infrastructure (Tuyshime, 2022; Mutangana & Mwesigwe, 2022).

In Tanzania, the existing literature on smart campus technologies identifies infrastructural and administrative barriers that hinder digital transformation (Nyambo, et al., 2022; Kibwege & Wamalwa, 2021).

The Dar es Salaam Maritime Institute represents a typical example of a resource-constrained environment where innovative yet cost-effective access solutions are needed. This study addresses this gap by designing and implementing an integrated QR code access control system that synchronises student identity verification with tuition fee records. The proposed solution contributes a new dimension to access management by ensuring security, accountability and institutional transparency within the Tanzania higher education sector.

3. Methodology

3.1. Research Design

This study adopted a Design Science Research (DSR) methodology to guide the Development and evaluation of the proposed QR code-based student gate access system for the Dar es Salaam

Maritime Institute (DMI). DSR is a systematic research approach that focuses on creating and evaluating artefacts designed to solve identified practical problems (Wang & Hannafin, 2005; Pressman, 2014). The method was appropriate for this study as it supports iterative design, implementation, and testing of technology-driven solutions within real institutional contexts.

The DSR framework aligns with the research objectives by combining theoretical grounding with practical Development. The approach follows the guidelines proposed by Kothari (2004), which emphasise three core cycles: (1) the relevance cycle, connecting the research problem to the environment; (2) the design cycle, involving the creation and refinement of the artefact; and (3) the rigour cycle, ensuring that the solution builds upon established theories and prior knowledge. This iterative process allowed the system to be refined through multiple stages of feedback from DMI's ICT and security departments.

3.2. Research Approach

A mixed-method approach was employed, integrating both qualitative and quantitative techniques to gain comprehensive insights. Qualitative data were collected through structured interviews and observations involving system users, security officers, ICT staff, and students to understand operational challenges in the existing manual gate process (Creswell, 2017; Israel, 2006). Quantitative data were collected during system testing to evaluate performance metrics, including response time, accuracy, and reliability. This combination of data ensured the credibility and practical applicability of the developed solution (Kothari, 2004; Kumar, 2019).

The study also utilises principles of Agile Software development to ensure flexibility and continuous improvement during implementation (Beck, et al., 2001) (Highsmith, 2002). Agile was chosen because it promotes collaboration, iterative prototyping, and adaptability — essential qualities for designing a system that must respond to real-time institutional requirements. User acceptance was evaluated using the Technology Acceptance Model (TAM), focusing on perceived usefulness and perceived ease of use among students and gate personnel.

3.3. System Development Framework

The system design process followed a structured Software Development Life Cycle (SDLC) model consisting of five stages.

1) Problem Identification:

The existing manual gate system at DMI was analysed to identify inefficiencies, including prolonged verification time, inaccurate fee validation, and a lack of integration with the Student Information Management System (SIMS). An interview with administrative staff and security personnel revealed the need for a digital solution that automates both identification and financial verification.

2) System Design:

Using Unified Modelling Language (UML) tools (Booch, et al., 2005), system architecture diagrams and data flow models were developed to define functional requirements (Figure 1). The use case diagram illustrates the interaction between users and the main system components, showing how each actor triggers the corresponding module functions. The architecture includes three core components.

i. A QR Code Generation Module that produces unique codes for each registered student.
ii. A verification Module integrated with SIMS to confirm both identity and fee payment status.
iii. An Administrative Dashboard for monitoring real-time access logs and generating reports

Security measures were also implemented, including data encryption and restricted user roles, to protect sensitive student information (Rahman & Arif, 2022; Lee, et al., 2022).

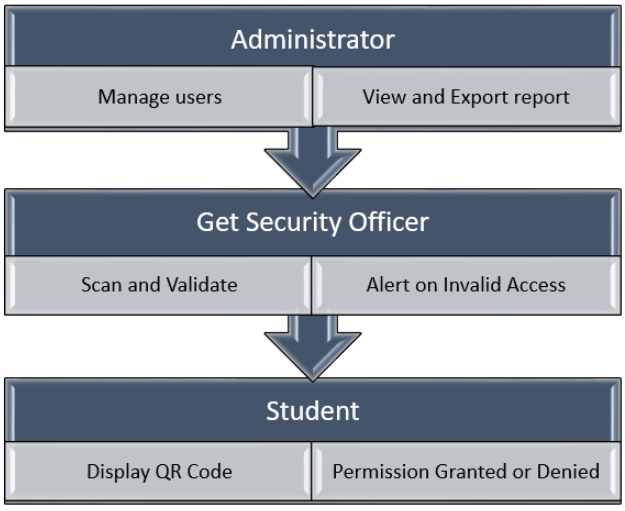

Figure 1.*Use Case Diagram of the QR Code-Based Gate Access System.*
Note. This diagram illustrates the relationship between users and the main system functionalities, showing how different roles trigger system operations.

To ensure secure data transmission between the QR scanning device and the server, the system employed HTTPS communication secured using TLS encryption. The QR code does not store sensitive financial information directly; instead, it encodes a unique, system-generated identifier that references student records stored securely in the database. This approach minimizes the risk of data exposure in case of unauthorized scanning.

3) Development

The prototype was developed using Python, MySQL, and PHP, leveraging open-source frameworks for affordability and scalability. The QR codes were generated using the qrcode Python library, while database communication was implemented using Structured Query Language (SQL). This setup ensured interoperability and minimised software dependency costs.

4) Implementation

The system was developed at the DMI main gate and tested in a controlled environment involving a sample of 50 students. Each student's record was uploaded to the system, and a QR code was generated and distributed. The codes were then scanned upon entry using an Android-based QR code scanner linked to the central database.

5) Testing and Evaluation

The testing followed both unit testing and system testing methods (Pressman, 2014). Unit testing verified individual components such as database connectivity and code generation, while system testing ensured smooth interaction between modules. The evaluation metrics included accuracy, processing time, and user satisfaction. The mean verification time dropped from approximately 20 seconds in the manual system to under 5 seconds in the QR-based system, confirming efficiency improvement.

The operational workflow of the developed QR code-based student gate access system is illustrated in Figure 2. The flow diagram outlines the step-by-step verification process from QR code generation to final gate access authorisation. Initially, a student's registration and fee payment records are verified in the Student Information Management System (SIMS). Upon confirmation, a unique QR code is automatically generated and assigned to the student. At the entrance gate, a manual visual inspection by the security officer is conducted to ensure compliance with institutional dress code police. This step is not automated by the QR code system then the security personnel scan the QR code using a mobile or desktop interface

connected to the system database. The system immediately cross-checks encoded information, such as student ID, name, and payment status, against institutional records in real time. If the verification is successful, gate access is approved and the entry is logged in the database; otherwise, access is denied and the incident is flagged for administrative review. This flow ensures that only registered, fee-compliant students gain access to the institution, thereby improving operational efficiency, data accuracy, and institutional security.

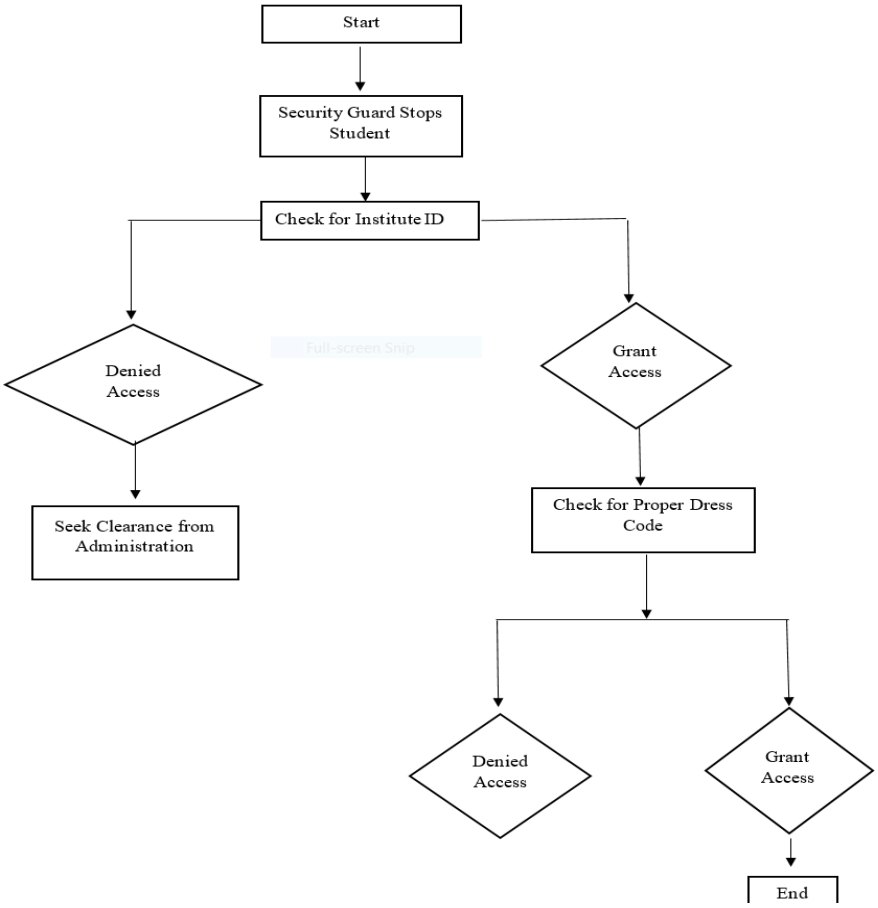

Figure 2. *DMI Gate Pass Verification Flow Diagram.*
Note. This illustrates the process of student verification from QR generation to gate access approval

3.4. Data Collection and Sampling

The study employed purposive sampling to select participants most relevant to the gate management process: security officers, ICT technicians, and a subset of students (Etikan, et al., 2016; Palinkas, et al., 2015). A total of 10 security staff and 50 students participated in the pilot testing. Data were collected through structured observation, system logs, and short feedback questionnaires assessing usability and performance. All participants were informed about the study's purpose, and ethical clearance was obtained from DMI's academic research committee in line with institutional regulations (Israel, 2006)

3.5. Data Analysis and Validation

Quantitative data, including average response time, accuracy percentage, and the number of failed scans, were analysed using descriptive statistics in Microsoft Excel. Qualitative responses from staff and students were analysed thematically to extract the perception of system usability and convenience. These findings were compared against benchmarks from related studies (Hamzah, et al., 2021) (Rahman, et al., 2020) to validate system performance.

To ensure reliability, Cronbach's alpha was calculated for questionnaire responses, yielding a coefficient of 0.86, indicating acceptable internal consistency (Tavakol & Dennick, 2011). Construct validity was confirmed by aligning system attributes such as ease of use and perceived usefulness with the TAM variables (Davis, 1989; Venkatesh & Davis, 2000). The iterative feedback loop inherent in the DSR approach further ensured that the system was tested and refined until it met both technical and user-based requirements.

3.6. Ethical Considerations

All data collection adhered to ethical guidelines for social research, ensuring informed consent, anonymity, and confidentiality of participant information (Israel, 2006). The system's data management design complied with institutional ICT policies and avoided storing unnecessary personal identifiers beyond registration and fee details. No biometrics or location tracking data were collected, aligning with data protection principles (Rahman & Arif, 2022)

4. Results and Discussion

4.1. Overview of System Implementation

The developed QR code-based access control system was successfully implemented at the Dar es Salaam Maritime Institute (DMI) main gate. The implementation involved linking student registration and fee payment data from the student Information Management System (SIMS) with a custom-built verification platform. Each registered student was issued a unique QR code automatically generated through the administrative dashboard and encoded with their identification details and payment status.

As illustrated in As shown in *Figure 3*, the system interface comprises two main modules: QR code generation module for creating and assigning codes to students, and the verification interface used by security personnel during gate access. When a student's QR code is scanned using am Android device, the system initiates an automated authentication process that instantly

cross-checks the encoded data with SIMS records in real time. Successful verification grants entry authorization and records the event in the system log, whereas unsuccessful verification prompts a denial massage and alerts the administrator.

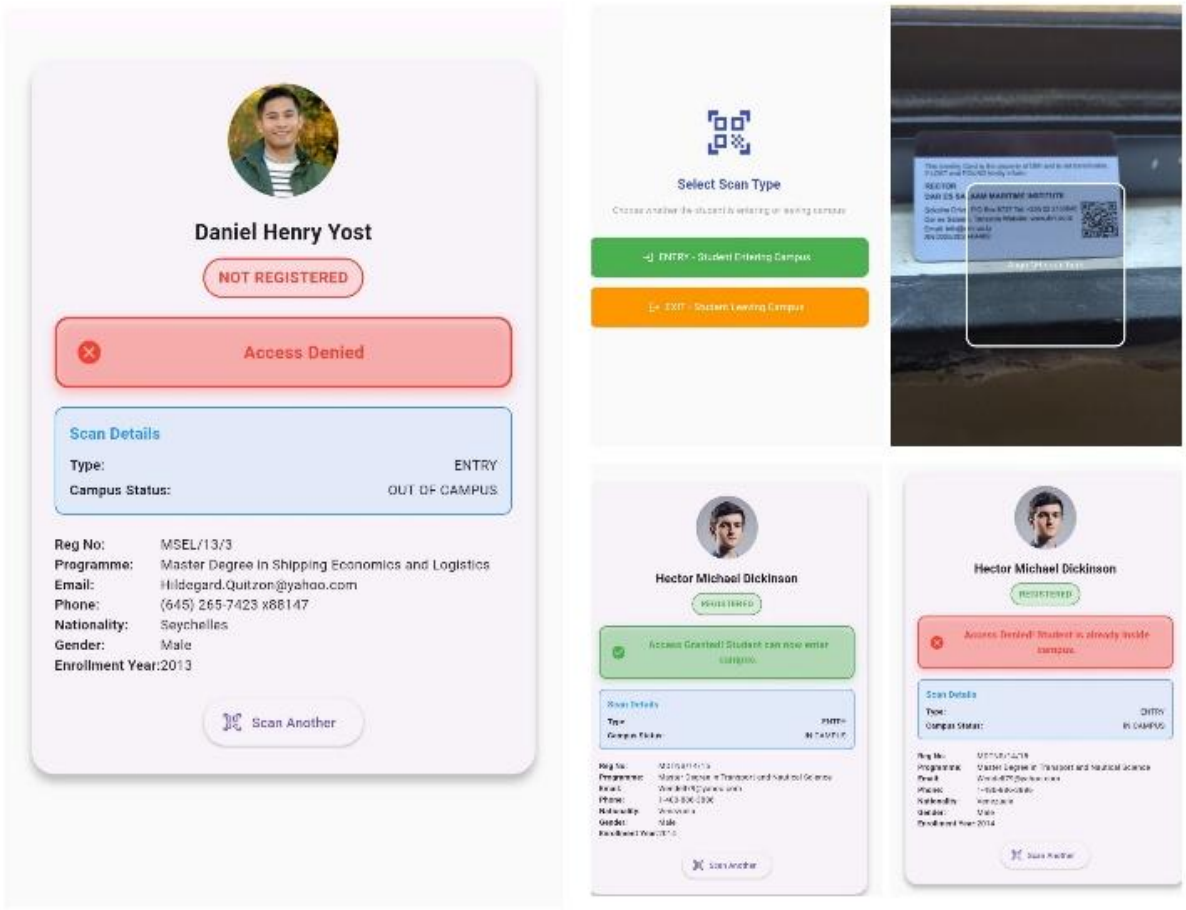

Figure 3. *QR Code Generation and Verification Interfaces.*
Note. The interfaces illustrate how QR codes are created for registered students through the administrative dashboard and verified at the gate through a scanning module linked to the institutional SIMS database

This implementation effectively replaced the previous manual verification process system, which required security officers to cross-check printed payment lists and manually verify student IDs. This process was slow, error-prone, and often resulted in long queues during peak entry hours. The deployed system prototype operated in a client-server architecture, enabling database access through a secure local network and allowing real-time synchronisation between the gate terminal and the institutional database, thereby improving operational efficiency, accuracy, and data accountability.

As shown in *Figure 3* QR, the system displays clear real-time status massage such as “Access Granted”, enabling security personnel to make immediate decisions. This visualization

minimizes ambiguity and reduces human error during gate operations this is Code Generation and Verification Interfaces. The interfaces illustrate how QR codes are created for registered students through the administrative dashboard and verified at the gate through a scanning module linked to the institutional SIMS database.

4.2. System Performance and Evaluation

The system's performance was evaluated in three major aspects: processing speed, accuracy, and user satisfaction. The performance of the proposed QR code-based student access control system was systematically evaluated to determine its operational efficiency, accuracy, and reliability under rea-world usage conditions. The evaluation focused on key performance indicators, including authentication response time, correctness of identity, fee status verification, system availability and usability during peak access period. Performance testing was conducted through controlled and live gate entry scenarios to assess the system's ability to support continuous access management without service interruption. The quantitative results obtained from these evaluations are presented in Table 1, providing an objective basis for assessing the extent to the which the system fulfills its design objectives and institutional access control requirements.

4.2.1. *Processing Speed*

Before system implementation, gate verification for one student took approximately 15-20 seconds, including record retrieval and manual checking. With the QR code system, the average verification time was reduced to less than 5 seconds per student. This data represents a 75% improvement in operational efficiency, consistent with performance benchmarks for similar QR-based systems reported by (Hamzah,, et al., 2021; Rahman, et al., 2020).

Table 1. *Questionnaire Mean Score Results*

TAM Construct	Item Description	Mean Score	Std. Deviation
Perceived Ease of Use	QR system is easy to use	4.6	0.4
Perceived Usefulness	System speed up entry	4.7	0.3
User Satisfaction	Overall satisfaction	4.5	0.5

This speed enhancement can be attributed to automation, database integration, and reduced human intervention. Similar improvements were documented by Ngugi, Wambua, & Gichuhi (2020), who observed comparable time savings when replacing manual attendance systems

with QR verification in Kenyan universities. The system thus meets one of the primary objectives: reducing verification time and congestion at DMI entries.

4.2.2. *Accuracy and Reliability*

The developed system demonstrated high reliability in verifying both student identity and fee payment status. During the pilot test with 50 students, the system achieved a verification accuracy rate of 98%, with only one false negative encountered during testing was attributed to a temporary network delay, highlighting the system's dependence on stable connectivity. This transparency strengthens the credibility of the reported accuracy. Compared to manual verification, where mismatches and errors occurred in approximately 10% of cases due to outdated records or oversight, the improvement was significant.

4.2.3. *User Satisfaction*

User experience feedback was collected from 10 security personnel and 50 students through structured questionnaires and interviews. The responses were analysed using descriptive statistics. Approximately 92% of participants reported that the system was easy to use and reliable, while 88% of security staff indicated that it simplified their work and improved daily workflow. Students appreciated the system's contactless nature, especially during high-traffic periods. High user satisfaction indicates strong perceived usefulness, as respondents acknowledged faster verification and improved gate efficiency. Similarly, the simplicity of QR scanning using mobile device reflects high perceived ease of use, supporting TAM-based acceptance of the system.

4.3. Comparative Analysis with Related Systems

The evaluation results were compared with other access control implementations discussed in the literature. Table 2 summarises the comparative features and improvements observed in the DMI QR code system relative to prior models.

The results confirm that the DMI system offers improvements in both speed and functional scope. Unlike existing models that primarily focused on attendance or event logging (Rahman, et al., 2020; Chanthinok & Sonthiprasat, 2021), the DMI prototype integrates financial compliance verification, addressing a critical gap identified in section 2.4 of this paper. Furthermore, the system's modular architecture ensures scalability and adaptability across other

institutional settings, supporting the findings of Ogunlade and Daramola (2022) that modular ICT systems are easier to maintain and expand.

Table 2. *Comparative Analysis with Related System*

Feature	Previous Systems	DMI QR Code System
Integration with financial records	Absent	Fully integrated with SIMS and payment data
Verification speed	8-12 seconds	≤ 5 seconds
Authentication method	Static QR or manual entry	Dynamic QR linked to real-time data
Operational environment	Isolated systems	Networked database with local hosting
User feedback	Moderate satisfaction	Over 90% satisfaction among users

4.4. Objective-Based Evaluation

Each research objective outlined in Section 1 was achieved as follows:

Objective 1: To analyse the existing gate access management system and identify inefficiencies.

Through interviews and system audits, the study identified key weaknesses in DMI's manual system: a lack of database integration, slow processing, and a high risk of unauthorised access. These facts align with findings by Osei and Kofi (2022) and Nyambo et al. (2022), who observed similar challenges in Tanzanian universities.

Objective 2: To design and develop a QR code-based system integrating student identification with tuition verification.

This design was achieved through a modular approach that connects SIMS to a web-based verification platform. Each student's QR code encodes both identity and financial data, providing real-time authentication. This approach directly addressed fee compliance challenges identified by Kariuki and Mutua (2021) and improved data synchronisation between administrative units.

Objective 3: To implement and evaluate the system's performance and reliability.

Prototype testing demonstrated substantial improvements in verification speed (from 20-5 seconds) and accuracy (from 90% to 98%). These results validate the system's effectiveness and fulfil the third research objective. The outcome is consistent with the efficiency

improvements reported in related QR-based systems (Hamzah, et al., 2021; Rahman, et al., 2020).

4.5. Institutional and practical Implications.

The implementation of the DMI QR system has far-reaching implications for institutional efficiency, policy enforcement, and administrative transparency. The integration of fee payment verification ensures that only financially compliant payments are processed. Administratively, the system minimises the workload for security personnel and improves data traceability through automated logs.

Moreover, by linking gate management with financial records, DMI can now generate analytical reports for decision-making—a capability previously absent in the manual system. This integration aligns with recommendations by Lopes and Martins (2020), who emphasised the importance of system interoperability in institutional ICT ecosystems.

The study also demonstrated that digital transformation can be cost-effective in resource-constrained environments without relying on expensive biometric or RFID systems. This study supports the conclusions of Mekuria and Alemu (2022), who argue that low-cost, context-aware solutions are the most sustainable for African higher learning institutions.

4.6. Limitations and Lessons Learned

While the developed system achieved its intended objectives, several limitations were observed. The prototype relied on stable network connectivity; hence, intermittent internet interruptions occasionally delayed verification. Additionally, the system's deployment was limited to one gate and a small sample of users, which may not fully reflect scalability under higher operational loads. Future implementations should explore hybrid architectures that combine local caching and offline verification to ensure continuous operation even during network outages. Although continuous internet connectivity is required for real-time verification, offline functionality was not implemented in the prototype due to system complexity and data syschronization challenges. Future system versions may incorporate local database caching and delayed sysnchronization mechanisms to support offline verification during network interruptions.

Furthermore, user feedback suggested the need for integration with mobile payment systems such as M-Pesa, Voda Lipa, or other mobile payment systems available, allowing automatic

synchronisation of payment data. Addressing this would enhance system responsiveness and reduce manual updates in the SIMS. The study also identified potential to expand the system to other institutional functions, including attendance management, library access, and examination entry verification.

5. Conclusion and Recommendations

5.1. Conclusion

This study successfully designed, developed, and evaluated a QR code-based student gate access system to improve operational efficiency and institutional control at the Dar es Salaam Maritime Institute (DMI). The research was motivated by persistent challenges associated with the manual gate verification process, including delays, human errors and poor integration with the Student Information Management System (SIMS). Through the Design Science Research (DSR) methodology, the study systematically identified these challenges, designed a technological artefact to address them, and validated its effectiveness through prototype testing.

The first research objective sought to analyse the existing gate access management system and identify operational inefficiencies. This objective was achieved through observations and interviews with security and administrative personnel, revealing that manual verification methods were inefficient, error-prone, and susceptible to unauthorised access. These findings aligned with the literature that emphasised the limitations of traditional identity verification systems in higher learning institutions. (Ogunwale & Adebayo, 2018) (Nyambo, et al., 2022).

The second objective focused on the design and Development of a QR code-based system capable of integrating student identity verification with tuition fee compliance. This objective was accomplished by developing a modular system architecture that linked the SIMS database with a real-time QR verification interface. The system assigned each student a unique QR code that encoded personal and payment information. This integration addressed institutional requirements for policy enforcement and reduced the administrative burden on security personnel. The Development adhered to best practices in secure system design, incorporating encryption and access control as recommended by Lee et al (2022).

The third objective was to implement and evaluate the performance and reliability of the developed system. The prototype was tested with a sample of 50 students and 10 security officers, yielding significant performance improvements. Verification time decreased from

approximately 20 seconds in the manual process to under 5 seconds with the QR code system, while accuracy improved to 98%. User satisfaction was high, with over 90% of respondents indicating that the system was easy to use and efficient. These results confirm that the developed system achieved all stated objectives and validated the effectiveness of the proposed solution.

In summary, the research demonstrates that integrating QR code technology with institutional databases provides a cost-effective, reliable, and scalable solution for access management in higher education institutions. It enhances institutional transparency, ensures compliance with tuition fees, and contributes to administrative efficiency. The findings further extend the Technology Acceptance Model (TAM) by showing that perceived usefulness, ease of use, and reliability strongly influence user acceptance of access control technologies in educational environments.

5.2. Recommendations

While the system achieved its intended goals, this study recognises several areas for improvement and further research.

1) Integration with Mobile Payment Systems:

Future versions of the system should integrate with mobile money services such as M-Pesa, Airtel Money, and Halo-Pesa, enabling real-time synchronisation of fee payment data. This enhancement would eliminate the need for manual updates and further streamline the verification process (Njeru, et al., 2021) (Yang & Wen, 2020).

2) Development of Offline Verification Mode:

The current system's reliance on network connectivity poses a challenge in environments with unstable internet access. Implementing an offline data caching mechanism would allow gate operations to continue uninterrupted, with synchronisation occurring automatically once connectivity is restored. This feature, as recommended by Ogunlade and Daramola (2022), is a best practice for ICT systems in developing regions.

3) Incorporation of Biometric Authentication:

Combining QR code verification with biometric identifiers, such as fingerprint or facial recognition, could further enhance security, particularly in sensitive access areas such as examination halls or administrative offices (Wang, et al., 2020; Yaboah-Boateng & Essandoh, 2014). A two-factor authentication model would significantly reduce impersonation and unauthorised entry.

4) Expansion to Other Institutional Applications:

The system can be extended beyond gate access to support other functions such as class attendance tracking, library entry, and event registration. Such scalability would optimise the investment in the technology and improve overall institutional data management (Hamzah,, et al., 2021; Rahman, et al., 2020).

5) Comprehensive Institutional Deployment and Long-Term Evaluation:

Although the prototype demonstrated strong results, a larger-scale deployment across all DMI gates and over multiple academic semesters is recommended to test scalability and long-term reliability. Performance and user behaviour trends (Mekuria & Alemu, 2022) (Mutangana & Mwesigwe, 2022).

5.3. Implication for Future Research

The study's outcomes open avenues for further research on digital transformation in African higher learning institutions. Future researchers should investigate how integrating artificial Intelligence (AI) and predictive analytics into access control systems can enhance monitoring and decision-making. For example, AI could be used to detect irregular access patterns or predict gate congestion. Additionally, future studies could examine cross-institutional adoption of QR code-based systems to establish standardised frameworks for campus security and data management across the region.

5.4. Closing Remarks

The developed QR code system has proven that, even in resource-constrained settings, technological innovation can significantly improve institutional operations. The system not only automates gate verification but also supports policy enforcement, data accuracy, and institutional accountability. Its successful deployment at the Dar es Salaam Maritime Institute demonstrates the potential for scalable, affordable solutions that can transform the administrative efficiency of educational institutions in Tanzania and beyond.

The study, therefore, concludes that QR code-based access control systems represent a practical and sustainable approach to achieving smart campus environments in developing nations. As institutions continue to embrace digital transformation, the integration of low–cost, high-impact technologies such as this will play a vital role in enhancing both operational efficiency and institutional governance.

Disclosure Statement

The authors declare that there is no conflict of interest regarding the publication of this article. No financial, personal, or professional relationships have influenced the research, analysis, or conclusions presented in this work.

Notes on Contributors

Lisa John is a mechanical technician at Dar es Salaam Institute of Technology (DIT), and graduated with a bachelor's degree in Mechatronics engineering from Dar es Salaam Maritime Institute (DMI).

lisamasikane@gmail.com

Fredrick Sanga is a senior lecturer at Dar es Salaam Institute of Technology (DIT), and a researcher in industrial engineering design for innovation diffusion. He is also a professional mechanical engineer with a PhD in innovation Engineering from Sokoine University of Agriculture in Tanzania.

fmsanga@gmail.com

Victor Killindo is an assistant lecturer at Dar es Salaam Maritime Institute (DMI). He is a Marine engineer expert and a holder of masters in Maintenance Management Engineering from Dar es Salaam Institute of Technology (DIT)

kilindov@gmail.com

ORCID

Lisa John *https://orcid.org/0009-0001-7883-3526*

Fredrick Sanga *https://orcid.org/0009-0000-2049-4982*

Victor Killindo *https://orcid.org/0009-0001-9966-5218*

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