https://doi.org/10.3126/juem.v3i1.84863

SMART CANTEEN SYSTEM FOR NEPALESE INSTITUTIONS USING ESP32 AND NFC: A LOW-COST IOT APPROACH

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Submission Date: 21 July 2025 Accepted Date: 1 August 2025
Revised Date: 29 July 2025 Published Date: 30 Sept. 2025

Cite this: Adhikari, P. and Thapaliya, S. (2025)., Smart Canteen System for Nepalese Institutions Using ESP32 and NFC: A Low-Cost IoT Approach, JUEM 3(1), 146 – 154, https://doi.org/10.3126/juem.v3i1.84863

ABSTRACT

The institutional canteens that operate in the traditional way often have a lot of operational inefficiency such as long queues, human errors during the Billing and the manual nature of the transaction process. The present paper explains the designing process and prototyping of a Smart Canteen Payment System, answering the questions regarding the use of low-cost IoT solutions, including the ESP32 microcontroller and PN532 NFC module. The system integrates hardware with a locally running web-based application for the purpose of easy identification of users, payment processing, and the real-time sales monitoring. The prototype cuts out the manual interaction, enhances accuracy of the transactions and provides dynamic menu and user management due to overcoming the limitations of the current systems: semi-automated systems. Controlled tests performed in the form of functional tests proved its ability to reduce errors and stimulate quicker service. Large-scale deployment and longitudinal testing have yet to be carried out, but there is a clear potential demonstrated by the system in being deployed on a larger-scale in resource-limited institutional environments such as Nepal. Thus, the present paper provides an effective prototype of redesigning the campus canteen service with smart, contactless alternatives.

Keywords: *NFC, canteens, microcontrollers, IoT technology*

1. Introduction

1.1 Background

Canteens are a crucial part of institutions and workplaces yet there are still many that are using manual contexts of cash dealing as well as records that are handwritten in Nepal and this leads to delays in communication and slows down the financial management due to complications in the calculations made (Faruki et al., 2023). Surely customers and staff perish in long queues especially during peak hours (Drummond & Sheppard, 2011).

The world is going digital through technology by providing automated billing and receipt of payment through alternatives to cash through such services in automation (Pangasa & Aggarwal, 2022). The advantage of NFC + Cheap IoT microcontroller such as ESP32 is that it allows a cost-effective implementation on smaller institutions.

Although many studies have been conducted on RFID and QR-code payment system in cafeterias (Hidayat et al., 2024), not much has been done on NFC-IoT in Nepal institutional canteens (Havaš et al., 2024). Traditional canteen operating under manual operations face several challenges: slow and tedious ordering and payment process, no easy way to view historical sales and stock data, and accounting for transactions becomes difficult due to a lack of structured follow-up mechanisms. To address the existing challenges the web-based application with the feature of placing and managing order and capable of supporting NFC-based payment using student ID cards has been developed. Additionally, the system will include a dashboard for sales visualization and automated email notifications to keep stakeholders informed. The purpose of the research is to design and prototype a smart canteen payment system in Bharatpur institutions to better control the efficiency and accuracy of transactions and make them monitored in real-time (Chand, 2025), which will pave the way to adopting it in the rest of the institutions.

2. Literature Review

The canteen process has been enhanced in the recent past due to advancement of digital payment and automated ordering system used in canteens across different parts of the world. Thakare created a Canteen Management System that works based on web-based ordering and secure databases but has limitations regarding scalability and high levels of security (Thakare et al., 2025). Tejaswini suggested a cashless system based on QR codes that allows receiving contactless payments, however, it is sensitive to QR codes damage and has a heavy usage load (Sharma et al., 2021).

Ambika presented the similar system, based on RFID, that provides the real-time order reporting, however, it is at-risk of losing the cards and does not imply the advanced reporting (Ambika et al., 2020). Pandey built a full-fledged web-based system that had a real-time inventory and dashboards, but its infrastructure requirements restrict it to large canteens (Pandey et al., 2024). Wong, L., and others optimized QR ordering by introducing demand forecasting and auto-billing yet necessitates always available internet along with high costs of setting it up (Wong et al., 2023).

Most current solutions are based on the RFID or QR technology and huge infrastructure (Chehri et al., 2021). The provision of low cost IoT-based NFC solutions coupled with web platforms that are locally deployed (and thus provide visualization of real-time sales along with their accountability) remains lacking in resource-deprived environment, such as in Nepal.

3. Methodology

3.1 Requirement Gathering:

Surveys and interviews with the canteen personal and students defined the main needs: quick and correct transactions and quick and easy reporting; local data storage and reporting; and ease of use. Among the chosen hardware, there were ESP32 Devkit v1, PN532 NFC reader (ISO14443A compliant), local PC server, and thermal printer. Back-end technology was Python (Flask), MySQL, PHP, and Web.

3.2 System Design:

A modular architecture has been presented where each of the modules is a component of order management (NFC reading), payment validation (UID check and transaction logging), and visualization of the Ultra-wideband (dashboard). Figma was used to prototype interfaces to make them simple. The overall architecture of developed system is shown in figure 1.

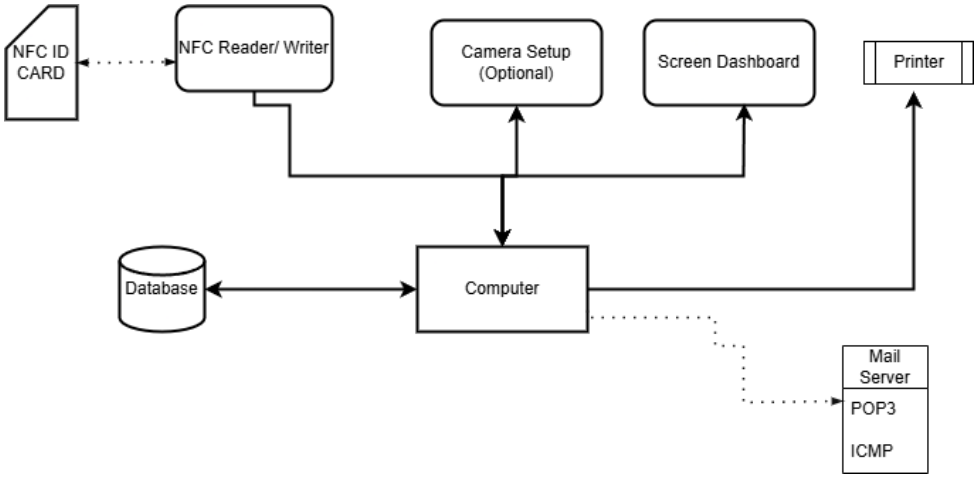

Figure 1 System Architecture

3.3 Technology Stack:

Backend was written in Python and PHP; frontend was written in HTML, JavaScript and Tailwind CSS. A Mysql was where the user, item and transaction data were stored. Printed circuit board designs developed by Draw.io, EasyEDA and Fritzing.

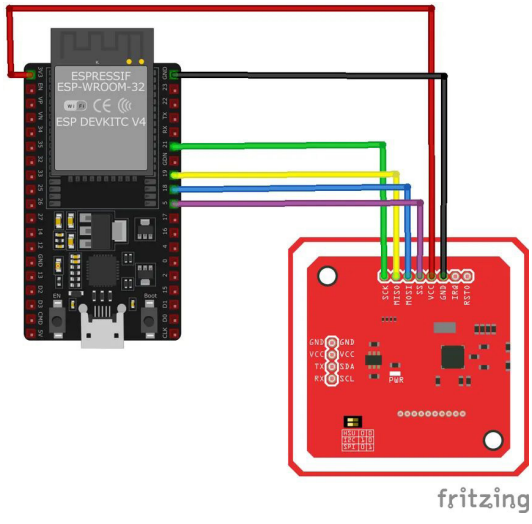

Figure 2 Esp32 to PN532 SPI Connection

3. 4 Hardware Integration:

PN532 NFC module as connected through the SPI interface to provide proper communication based on ISO14443A standards. The UID information is serially sent towards PC server. Diagram of ESP32 to PN532 SPI Connection is shown in Figure 2.

3.5 Software Workflow:

Flask application continuously kept a watch on NFC reads, verified the cards against MySQL, saved transactions and updated the dashboard asynchronously to display in real-time. Offline data anchorage files.

3. 6 Development Process:

The use of an integrating on Git and agile iterative development allowed satisfactory stability when integrating the hardware and software elements.

3. 7 Validation:

Multiple NFC-taps simulations demonstrated a transaction responsiveness in less than 5 seconds. System was graceful with unregistered cards where it prompted the user. Functional testing was done by 5 users, they gave feedback to improve automation in loading balance on card and printing.

3.8 Replication:

Design results in easy replication in other institutions with limited configuration change and equipment set up.

4. Discussions and Results

4.1 System Results

A Smart Canteen Payment System was very well progressed and tested, with major goals, which have been met:

Web Application: Remote access and authentication, dynamic menu, transaction history, and administration with scalable backend/frontend are supported by separate user interfaces of students and staff.

Time-Based Menu Scheduler: The menu items of each meal, such as breakfast, lunch, and dinner are displayed automatically and require little changes from admin side.

NFC Integration: Solid SPI-based interface between PN532 and ESP32 allowed secure reading of the UIDs and has been tested using dummy data.

Prepaid Balance Management: Each NFC card is associated with a specific student record and has automatically updated balance visible on the interface in real-time.

Reporting and Tracking of Sales: Tracking of sales quantities and monthly sales reports is done on

the admin dashboard and transaction histories are downloadable to enhance control on finances.

Email Notification System: Transactional emails to students and optionally parents will be automated which increases transparency.

Billing System: Thermal printing (semi-automated), which occurs on a successful transaction as a trigger of backend records.

4.2 Results Appraisal

Operational Efficiency: Automation eliminated errors of the manual billing and ease the pressure on the staff during peak hours.

Automation and transparency: Email icons increased the confidence as it gave specific purchase records to students and parents.

Safe NFC Detection: SPI reliable communication and debounce logic eliminated misreads, and the transactions were valid.

Budget Control: Budget control becomes easy through the real time sales reports that enable the budgeting process, maintain inventory planning and identification of sales trends or anomalies.

Difficulties: Driver dependency has been evidenced with semi-automated printing due to unique driver of each connected printing device, and fully un-attended printing is an area that can be enhanced in the future.

Local Suitability: The local servers used by the system and availability of low-cost IoT devices makes the system suitable to Nepali institutions with little to no connectivity to the internet.

4.3 System outputs

Web application interface with the dynamic menu, tracking of transaction, automated notification, printed bill is shown in Fig 3, 4, 5 and 6 respectively.

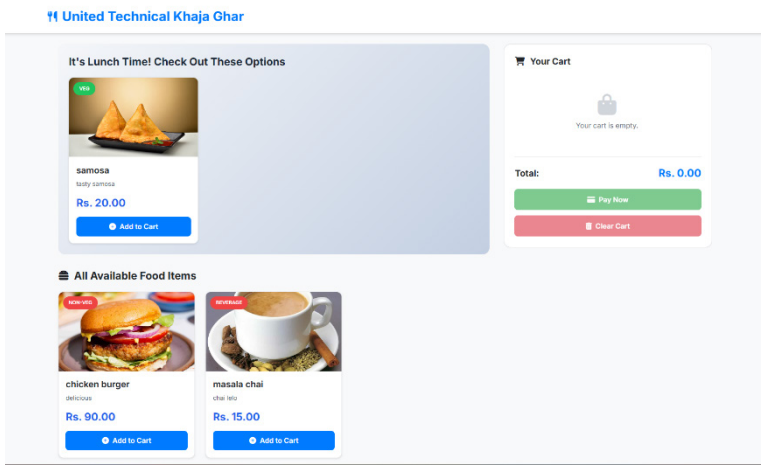

Figure 3 Time based Dynamic Menu

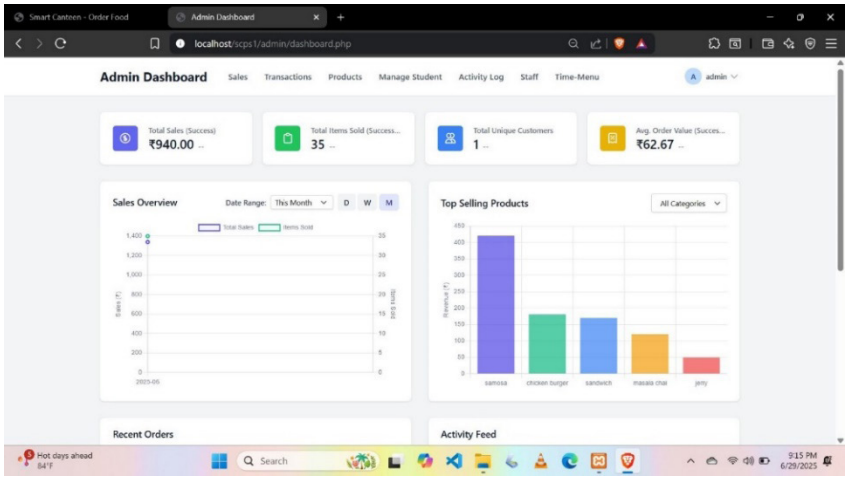

Figure 4 Tracking of Transaction

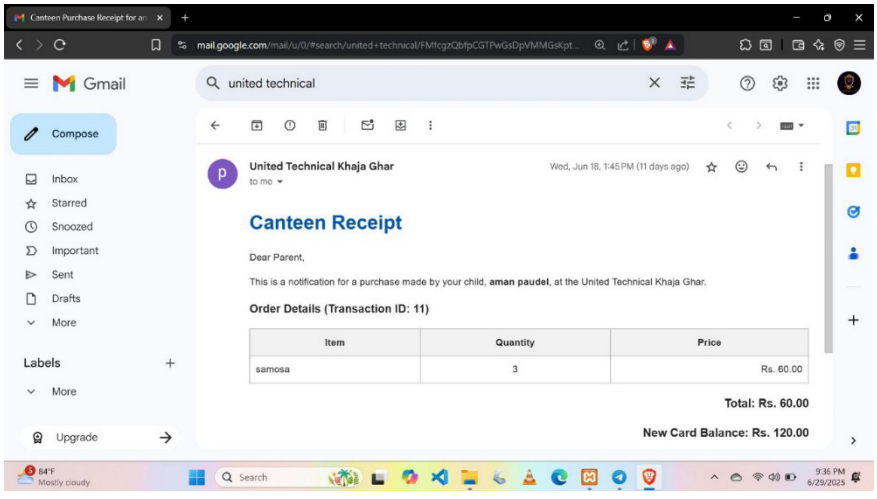

Figure 5: Automated Notification

Figure 6 Printed Bill

5. Suggested Improvements and Advancement of Room

Smart Canteen Payment System creates a good base on-top of which the automation can be done and on which the functionality must be enhanced and diversified.

Cloud Migration: Rehosting of backend services into cloud will enable central location management of data across campuses, high scalability, and flexibility to build reliable back up system and real time analytics that can be remotely available (Alam, 2021).

Greater NFC Uses: NFC cards can also include the greater uses of transport paying by a campus transport card, in library applications, retail purchases and attendance monitoring items, which are many individual applications integrated into a single processed and secure system (Kulkarni, 2021).

Biometric Security: It will be introduced i.e.; a fingerprint or facial recognition incorporated to improve validation and eliminate invalidation along with making authentication more comfortable than other authentication systems based on PIN (Patra et al., 2022).

AI and ML integration: The predictive analytics can assist in menu planning, reduce waste and individualizing nutrition, dynamic pricing, and promotion can be used to facilitate the desired levels of load in kitchens and generating more revenue (Mishra et al., 2025).

Altogether in a nutshell, cloud infrastructure deployment, expanded application of the NFC, biometrics and utilization of AI will help the system become more scalable, safer, and smarter approach to smart campuses.

6. Conclusion

The above exploration sought to design, install and validate a Smart Canteen Payment System which is a higher order of traditional canteen operations to use Internet of Things (IoT) and web infrastructure. The main aim was to tackle widespread challenges--that is, human fallibility in billing, deficient payment performance, lack of real time monitoring, and inadequate visibility of canteen operations using the traditional methods.

Pairing the inexpensive PN532 NFC chip with an ESP32 microcontroller, the study succeeded in proving that user authentication and payment actions are possible to achieve at scale and without much expense. The dynamic management of the menu, sale and schedule synchronization across servers enabled the functionality of the web-based interface and the server-side database to increase the functional reliability and user experience of the operations.

A number of technical issues, which were not to be dealt with by design improvements, that is, unreliable communication, occasional power outages, and variable data synchronization, were addressed by design. The following design improvements were performed: UART-based communication to SPI-based communication, inclusion of debounce logic and retry, and atomic transaction processing.

Even though the other functionalities, such as a complete NFC-based backend program and an automated receipt printing feature are currently in development, the modules and extendable system design allow the system to be easily adapted to the context of different institutions. The expansion of the related services is also based on the design, specifically campus transportation, library systems and attendance tracking.

Moving forward, the addition of cloud computing, ability to automate user authentication via biometrics, and machine-learning could transform this solution into an entire ecosystem related to a smart campus, where not only efficiency of operations will be increased, but also data-related decision-making, safety, and end-user satisfaction.

The work now has a closing statement that supplies a practical and versatile model in the way of institutions that aim at intelligent infrastructure and therefore lays a precedent to the larger use of intelligent and connected campus services.

7. Conflict of Interest

There is no conflict of interest by the authors. This study was carried out without biasness and any commercial or money factor that could have influenced the findings or joined conclusions that are proposed.

8. Acknowledgements

The authors are extremely grateful to the members of faculty and technical staff of Department of Computer Engineering, United Technical College, whose guidance and support were very valuable in the development of this project. A particular appreciation is expressed to the involved students and canteen staff who donated their time and comments when the testing was taking place. We also recognize all the open-source groups and resources which allowed the implementation of the software and hardware parts. The author did not have any external funding.

References

Alam, T. (2021). Cloud-Based IoT Applications and Their Roles in Smart Cities. Smart Cities, 4, 1196–1219. https://doi.org/10.3390/smartcities4030064

Ambika, Kumar R, S., & S Nair, S. (2020). Cashless Canteen Management System. International Journal of Innovative Technology and Exploring Engineering, 9, 579–582. https://doi.org/10.35940/ijitee.g5095.059720

Chand, D. (2025). Canteen Service Quality and Student Satisfaction: A Case Study of a Private College in Kathmandu. Nepalese Journal of Hospitality and Tourism Management, 6, 129–143. https://doi.org/10.3126/njhtm.v6i1.76497

Chehri, A., Zimmermann, A., Schmidt, R., & Masuda, Y. (2021). Theory and Practice of Implementing a Successful Enterprise IoT Strategy in the Industry 4.0 Era. Procedia Computer Science, 192, 4609–4618. https://doi.org/10.1016/j.procs.2021.09.239

Drummond, C., & Sheppard, L. (2011). Examining primary and secondary school canteens and their place within the school system: a South Australian study. Health Education Research, 26, 739–749. https://doi.org/10.1093/her/cyr036

Faruki, T., Tasnim, R., Mabud, M. B., Tuhin, R. A., Reza, A. W., & Arefin, M. S. (2023). A Comparative Analysis of the Impacts of Traditional and Digital Billing Methods. Lecture

Notes in Networks and Systems, 113–126. https://doi.org/10.1007/978-3-031-36246-0_12

Havaš, L., Kraš, M., Srpak, J., & Tomičić, E. (2024). Application of NFC

Technology in Authentication Edulearn Proceedings, 1, 3910–3917. https://doi.org/10.21125/edulearn.2024.0991

Hidayat, F. A., Rubianto, T., Nurkhasanah, Saputro, I. P., Ticoalu, V. E., & Prasandy, T. (2024). Menu Ordering Application using QR Code With User Experience Analysis. 2024 9th International Conference on Business and Industrial Research (ICBIR), 101–105. https://doi.org/10.1109/icbir61386.2024.10875903

Kulkarni, R. D. (2021). Near Field Communication (NFC) Technology and Its Application. Techno-Societal 2020, 745–751. https://doi.org/10.1007/978-3-030-69921-5_74

Mishra, V., Sahu, S., Jyothi, P. C., Gupta, A., Pragati, K., & Krishan, K. (2025). AI enable smart canteen management system. CRC Press EBooks, 495–499. https://doi.org/10.1201/9781003616252-81

Pandey, S., Quraishi, R., Salian, A., & Bhagat, S. (2024). Development and Evaluation of a Comprehensive Web-Based Canteen Food Ordering System.