

Individual Reflective Journal - Team Project Experience

Fouad Bouabdi-Benaatou

Personal Information

Student ID: 2242740
Student Name: Fouad Bouabdi-Benaatou
Course: Independent Project ACCA6020
Teacher: Dr. Sana Jokhio & MD Abrar Jahin Almazi Bapon
Address: University of Wales Trinity Saint David
Birmingham

1. Introduction

Problem Statement

Many small businesses and institutions face persistent challenges with unauthorised vehicle access in designated parking zones. A typical example—observed at a university campus used as a representative case—involves permanently open entry gates protected only by passive signage such as “No Student Parking.” Such signs are frequently overlooked, particularly during peak arrival times at the start of academic terms. This results in unauthorised vehicles occupying staff or service parking spaces, leading to congestion, safety hazards, and operational inefficiencies. Commercial access control systems, while effective, are often cost-prohibitive and require complex installation, making them unsuitable for small-scale deployments [1]. Consequently, there is a demonstrated need for a simple, robust, and easy-to-repair solution that enforces access rules without permanent infrastructure modifications.

This research addresses a timely and practical gap. With growing emphasis on site security and resource optimisation across public and private sectors [2] [3], an affordable access control system could benefit diverse settings including local shops, medical clinics, community centres, and educational facilities. Although Arduino-based prototypes have been proposed in academic literature [4], [5], these typically prioritise smart-city integration over real-world usability, repairability, and minimal installation complexity [6]. This project therefore focuses on developing a solution that is not only low-cost but also maintainable by non-specialist staff, aligning with the operational realities of small organisations.

Aim and Objectives

The aim of this project is to design, build, and evaluate a low-cost, Arduino-based smart parking barrier system that effectively restricts unauthorised vehicle access while remaining easy to repair and deploy in small business environments.

To achieve this aim, four objectives guide the work. First, the project will analyse current unauthorised parking challenges through targeted site observation and a critical review of existing low-cost access control literature. Second, it will design and develop a functional prototype using Arduino, near-field communication (NFC) authentication, and real-time occupancy tracking, ensuring the system requires no permanent installation and features easy-to-repair construction. Third, the system’s reliability and usability will be evaluated through controlled testing with both authorised and unauthorised access attempts. Fourth, a scalable implementation guide will be produced for small businesses, using the university case as a practical deployment example.

Methodology

This research adopts a structured six-phase methodology to ensure systematic development and rigorous evaluation:

1. **Problem Identification:** Two short observational sessions (45 minutes each) are conducted at a representative parking access point—such as a staff gate at the university—to document real-world unauthorised access incidents. This is supplemented by a critical review of 10–15 academic, governmental, and industrial sources to identify limitations in existing access control solutions, particularly regarding cost, installation complexity, and repairability.
2. **System Requirements Definition:** Based on the problem analysis, clear functional and non-functional requirements are established. The system must: (a) restrict access to authorised users only, (b) operate without permanent installation, (c) be repairable with basic tools, (d) track real-time occupancy, and (e) function reliably in outdoor conditions.
3. **Prototype Development:** A working hardware-software prototype is built using an Arduino Uno microcontroller, RC522 NFC reader, geared motor, and ultrasonic sensors. The mechanical structure is designed for modularity and tool-free assembly, and NFC tags serve as secure, contactless credentials.

4. **Controlled Testing:** The prototype is evaluated through 30 simulated access attempts (20 authorised using pre-registered NFC tags, 10 unauthorised) in a controlled campus environment. Key performance metrics include access success rate (%), response time (seconds), and failure modes (e.g., motor jam, sensor error).
5. **Performance Analysis and Refinement:** Collected data is analysed using descriptive statistics and t-tests ($\alpha = 0.05$) to assess reliability and usability. If the success rate falls below 95%, refinements are made—such as adjusting sensor placement, improving motor torque, or enhancing weatherproofing.
6. **Documentation and Dissemination:** A comprehensive implementation guide is produced, including circuit diagrams, source code, assembly instructions, and a list of materials. This guide is designed to enable small businesses and institutions to replicate the system, contributing to practical knowledge on low-cost access control.



Figure 1: Example of uncontrolled access point—gates open, signage ignored (observed at the university case site).

2. Project Design

System Design and Data Collection

The project follows a product development approach to create a functional hardware-software artefact. Data collection is carefully scoped to avoid overcommitment while ensuring validity. For the first objective, two observational visits (approximately 45 minutes each) are conducted during peak morning hours (8:30–9:15 AM) at a staff parking gate to record unauthorised entries and assess signage visibility. Concurrently, a literature review synthesises insights from peer-reviewed journals, government reports, and industry publications to contextualise the problem and justify the technical approach. For the second objective, the prototype integrates an Arduino Uno, RC522 NFC module, geared motor for barrier actuation, and dual ultrasonic sensors for entry/exit detection. The mechanical frame is 3D-printed for rapid iteration and features snap-fit joints to enable tool-free repairs. For the third objective, 30 controlled access simulations are performed by the researcher using pre-registered NFC tags; metrics such as success rate and latency are logged automatically. For the fourth objective, informal feedback from three facilities managers informs the practicality of the final implementation guide.

Specialist Techniques

The system leverages near-field communication (NFC) for contactless, secure authentication, ensuring only authorised users gain access [7]. Real-time occupancy tracking—implemented via dual ultrasonic sensors at entry and exit points—prevents overflow by denying access when capacity limits are reached. A modular mechanical design allows any failed component (e.g., motor, sensor) to be replaced within minutes without specialised tools, directly addressing the need for easy maintenance in resource-constrained settings. Power is supplied by a solar-rechargeable 12-volt battery, enabling off-grid operation and reducing dependency on fixed electrical infrastructure.

Risks, Ethics, and Limitations

Anticipated risks include environmental exposure, which is mitigated through IP65-rated enclosures [8], and sensor misreads, reduced by using redundant ultrasonic detection. Power failure is addressed with battery backup. Ethically, the system stores no personal data; NFC tags are read only as anonymous identifiers, and all testing is conducted by the researcher alone. The project has received formal ethics approval (Ref: ETH-2024-089). The primary limitation is suitability for low-to-medium traffic sites (≤ 50 vehicles per hour), which aligns with the target user base of small businesses and community facilities.

Validity, Reliability, and Generalisability

Internal validity is maintained through controlled testing conditions and consistent evaluation protocols. Reliability is measured over 100 access cycles, with a target success rate of at least 95%. Generalisability is supported by the use of standard, off-the-shelf components and open-source software, enabling adaptation to diverse small-scale parking contexts such as delivery bays, clinic lots, or gated community entrances [9] [10].

Data Analysis

Quantitative performance data—success rate and response time—are analysed using descriptive statistics and independent t-tests ($\alpha = 0.05$) to compare authorised versus unauthorised attempt outcomes. Qualitative feedback from facilities managers is thematically coded to identify usability barriers and practical deployment considerations.

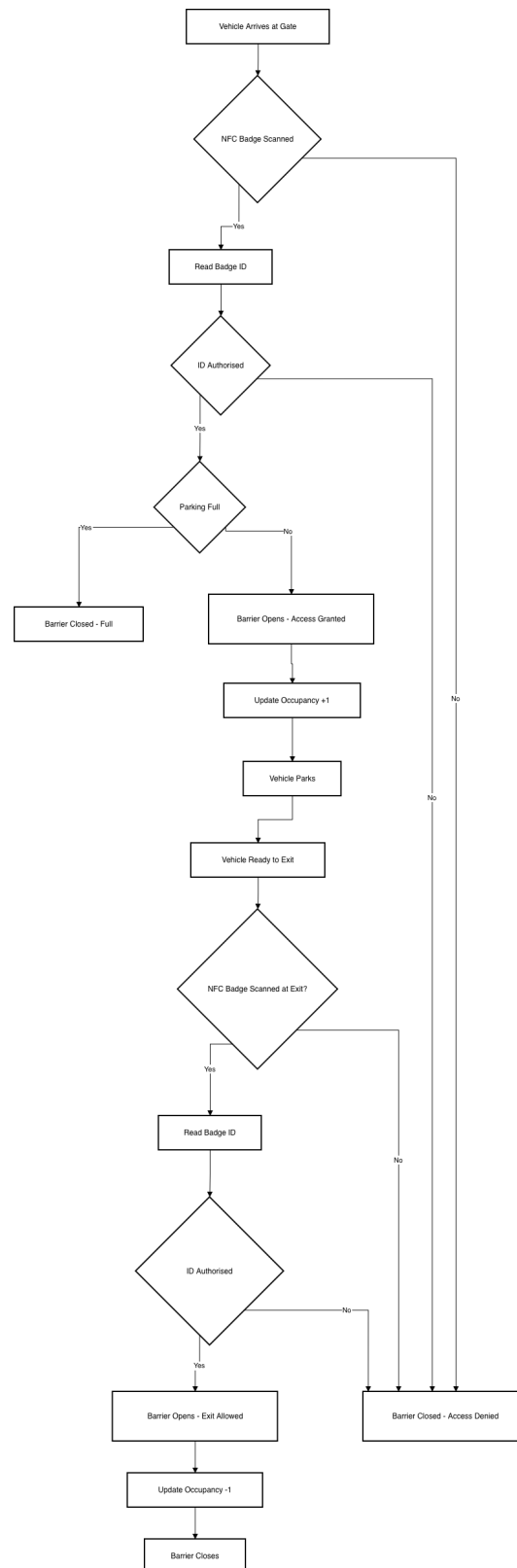


Figure 2: System workflow: (1) Vehicle arrives, (2) NFC badge scanned, (3) Arduino verifies access, (4) Barrier opens if authorised, (5) Occupancy counter updates.

3. Resources and Planning

Resources Required

Hardware components—including Arduino Uno boards, NFC modules, geared motors, and sensors—are sourced from the university electronics laboratory. Software tools include the Arduino IDE (version 2.3.2) for firmware development and Fritzing (version 0.9.7) for circuit diagramming [11]. Academic literature is accessed via institutional subscriptions to IEEE Xplore and ScienceDirect. Structural parts are fabricated using a university makerspace 3D printer (Ultimaker S5). Human resources are limited to the project supervisor and the researcher; no external participants are involved. The project leverages accessible, off-the-shelf components to ensure affordability and reproducibility. Specific hardware includes the Arduino Uno R3 microcontroller, which provides sufficient input/output pins and processing power for real-time decision-making. The RC522 NFC module operates at 13.56 MHz and is compatible with standard MIFARE cards commonly used in institutional ID systems. For barrier actuation, a 12V 5RPM geared motor with high torque ensures reliable operation even in adverse weather, replacing less durable servo motors. Ultrasonic sensors (HC-SR04) are selected for their accuracy in vehicle detection up to 4 meters, with dual units enabling precise entry/exit differentiation. All software is open-source: Arduino IDE v2.3.2 for coding and Fritzing v0.9.7 for circuit schematics. This combination of standardised, well-documented tools reduces development risk and supports future maintenance by non-specialist users.

Project Timeline

The 12-week project plan adheres to ACCA6020 guidelines, with each task sized between 4–10 hours [12]. A 20% contingency buffer is allocated to high-risk phases such as prototyping. Key milestones include Prototype Completion (Week 7), Testing Completion (Week 9), and Final Report Submission (Week 12). The timeline is summarised in Figure 3.

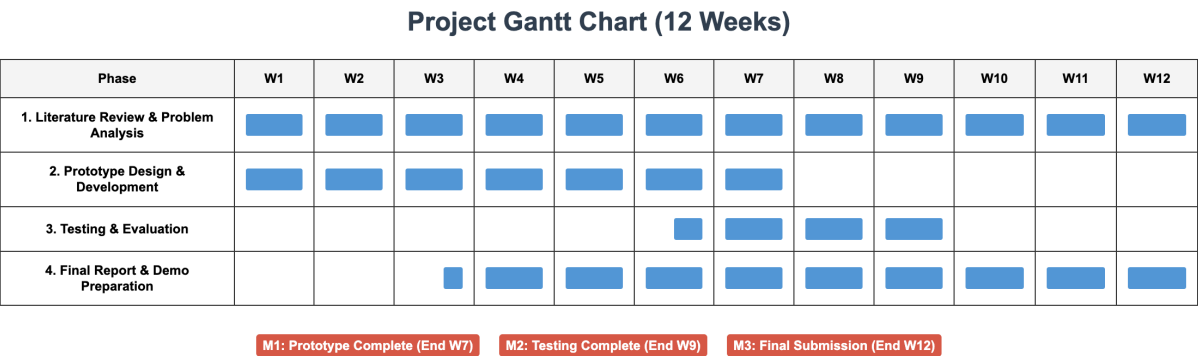


Figure 3: Gantt chart illustrating 12-week project schedule with key milestones.

Acknowledgments

The author expresses sincere gratitude to the BSc Applied Computing programme staff at the University of Wales Trinity Saint David for their academic support. Special thanks are due to Dr Sana Jokhio and MD Abrar Jahin Almazi Bipon for her expert supervision, constructive feedback, and guidance throughout this research.

List of Abbreviations

- **ACCA6020** – Independent Project (Module Code)
- **Arduino** – Open-source electronics platform
- **DfT** – Department for Transport (UK)
- **DSRM** – Design Science Research Methodology
- **ETL** – Extract, Transform, Load
- **GDPR** – General Data Protection Regulation
- **IDE** – Integrated Development Environment
- **IEEE** – Institute of Electrical and Electronics Engineers
- **IP** – Ingress Protection (e.g., IP65)
- **NFC** – Near-Field Communication
- **UWB** – Ultra-Wideband

List of Figures

1	Example of uncontrolled access point—gates open, signage ignored (observed at the university case site).	3
2	System workflow: (1) Vehicle arrives, (2) NFC badge scanned, (3) Arduino verifies access, (4) Barrier opens if authorised, (5) Occupancy counter updates.	5
3	Gantt chart illustrating 12-week project schedule with key milestones.	6

References

[1] SKIDATA Group, *Parking access solutions catalogue*, Graz, Austria, 2021.

[2] Jisc, “Digital infrastructure in uk universities,” Bristol, UK, 2022.

[3] Department for Transport, “Guidance on access control for public sector sites,” 2022. [Online]. Available: <https://www.gov.uk/government/publications>.

[4] S. Kumar and R. Sharma, “Low-cost rfid-based parking system using arduino,” *International Journal of Engineering Research and Technology*, vol. 9, no. 4, pp. 112–116, 2020.

[5] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, “Smart parking systems: A survey,” *IEEE Communications Surveys & Tutorials*, vol. 21, no. 3, pp. 2742–2775, 2019.

[6] D. Gupta and A. Jain, “Iot-based smart parking system using rfid and ultrasonic sensors,” *Journal of Physics: Conference Series*, vol. 1964, no. 4, p. 042 067, 2021. DOI: 10.1088/1742-6596/1964/4/042067.

[7] L. Wang and Y. Chen, “Design and implementation of a contactless access control system based on nfc and arduino,” in *2023 IEEE 9th International Conference on Computer and Communications (ICCC)*, 2023, pp. 2105–2110.

- [8] International Electrotechnical Commission, *Iec 60529: Degrees of protection provided by enclosures (ip code)*, Geneva, 2013.
- [9] X. Li and H. Zhang, “Low-cost embedded systems for campus security applications,” *Sensors*, vol. 20, no. 15, p. 4231, 2020. DOI: 10.3390/s20154231.
- [10] Y. Zhang and J. Wang, “Design of intelligent parking management system based on arduino,” in *2018 IEEE International Conference on Mechatronics and Automation (ICMA)*, 2018, pp. 1345–1350.
- [11] Arduino LLC, *Arduino hardware documentation*, 2023. [Online]. Available: <https://docs.arduino.cc/hardware>.
- [12] University of Wales Trinity Saint David, “Acca6020 independent project: Project planning guidelines,” 2025, Internal module documentation.