MILESTONE 1 REPORT

IADE – MSC IN CREATIVE COMPUTING AND ARTIFICIAL INTELLIGENCE (M-CCIA) IN COLLABORATION WITH CICLA

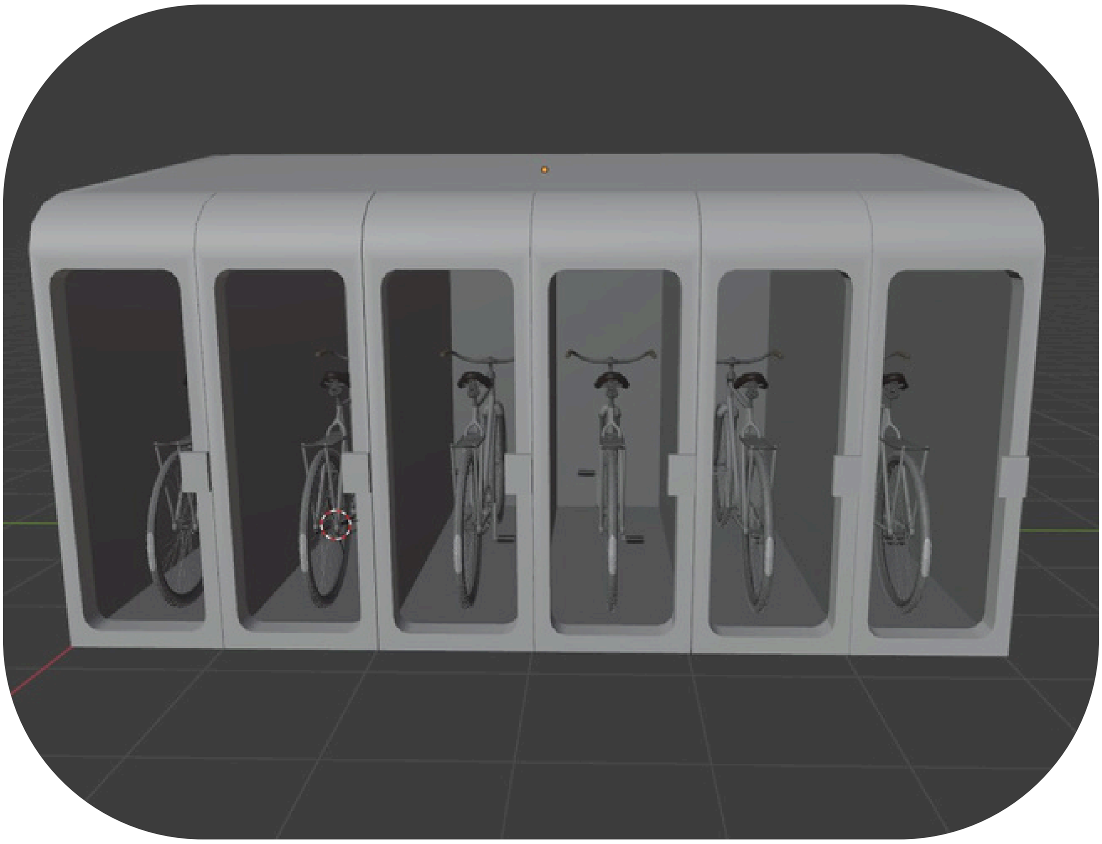

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Table of Contents

1. Introduction

Urban mobility is rapidly evolving, with cities worldwide embracing cycling as a sustainable mode of transportation. However, safety, convenience, and energy efficiency remain major barriers to widespread adoption.

This report presents the development of **Energize**, an **AI-powered, solar-driven smart bicycle parking system**. The system merges **Artificial Intelligence (AI)**, **Internet of Things (IoT)**, and **renewable energy technologies** to deliver a solution that is **secure**, **sustainable**, and **intelligent**.

Developed under IADE's **Project-Based Learning (PBL)** methodology, the project is a collaborative effort with **Cicla**, a company specializing in urban bicycle parking solutions. The collaboration allows students to apply academic knowledge to real-world challenges, blending creativity, technology, and practical engineering.

Energize proposes an innovative approach to bike storage — transforming passive parking areas into **interactive, data-driven systems** that empower users and city planners alike.

2. Problem Statement

Context

Urban populations are increasingly adopting bicycles as a primary means of transportation due to their affordability, flexibility, and low carbon footprint. Yet, despite the growth in cycling culture, infrastructure development has lagged behind. The **lack of smart, secure parking systems** has created significant obstacles for users and city administrations.

Current Issues

1. **Theft and Vandalism:** Traditional racks offer minimal protection, and public areas lack surveillance or alert systems.
2. **Energy Dependence:** Existing electronic parking solutions depend on external power grids, limiting deployment in remote areas.
3. **No Data Feedback:** Cities lack analytics on parking usage, peak hours, or occupancy, making infrastructure management inefficient.
4. **Poor User Experience:** Most parking systems lack integration with digital services or real-time feedback.

The Need

A new generation of **intelligent, autonomous bicycle parking** is required — one that integrates **smart sensors**, **machine learning**, and **sustainable energy** to ensure both safety and scalability.

3. Project Goal

The main goal of the **Energize** project is to design and prototype a **connected, modular bicycle parking system** that is both secure and environmentally sustainable. The system aims to demonstrate how **AI and IoT technologies** can redefine the relationship between users, public infrastructure, and the environment.

Specific Objectives

- Implement an **RFID access system** for secure entry and user tracking.
- Deploy **IoT sensors** to monitor parking bays and detect anomalies.
- Integrate **machine learning models** for real-time anomaly detection and predictive analytics.
- Power the system entirely through **solar panels** with local energy storage.
- Develop **user-facing and admin-facing interfaces** for data visualization and control.
- Foster collaboration between design, technology, and sustainability fields through interdisciplinary teamwork.

4. Concept Description

Energize is conceived as a **smart urban node** — a physical and digital infrastructure element that interacts with users, collects data, and functions autonomously.

Main Features

- **RFID Access System:** Users identify themselves via RFID cards or digital credentials, ensuring secure entry and tracking usage data.
- **Sensor-Based Detection:** Motion, vibration, and proximity sensors monitor each parking unit, detecting unusual activity such as forced removal or movement.
- **Solar Energy Integration:** The entire system is powered by photovoltaic panels, enabling deployment even in areas without electrical grids.
- **Cloud Connectivity:** All data collected by sensors is transmitted to a cloud platform for analysis and visualization.
- **Interactive Dashboards:** Data is visualized in real time for both users and administrators, displaying occupancy, energy production, and system health.

Design Philosophy

Energize emphasizes **modularity, scalability, and autonomy**. The system's structure is designed to be adaptable, with potential for integration into **smart city networks**, **university campuses**, and **corporate mobility programs**.

5. Technical Overview

5.1 IoT Architecture

The IoT architecture connects physical sensors with cloud-based systems through microcontrollers. This forms the foundation for **data acquisition**, **processing**, and **interaction**.

Data Flow:

Sensors → ESP32 Microcontroller → Wi-Fi → Cloud Database → Visualization Interface

Components:

- **Sensors:** Motion, vibration, proximity, and solar energy sensors for activity and environmental monitoring.
- **Microcontroller (ESP32):** Manages data acquisition, wireless communication, and low-power operation.
- **Power Source:** Solar panels connected to battery storage and a charge controller for energy regulation.
- **Database:** Cloud platforms like Firebase or ThingSpeak host real-time sensor data.
- **Visualization Tools:** Front-end visualization in **P5.js** (user-facing) and **Unity** (admin-facing).

Advantages:

- Low-cost, scalable hardware.
- Real-time remote monitoring.
- Integration capability with other smart systems (e.g., weather APIs or city data).

This setup creates a **closed feedback loop** between hardware and software, enabling adaptive system behavior.

5.2 AI and Machine Learning

The AI module introduces **autonomy and predictive intelligence** to the system.

Core Applications:

1. **Anomaly Detection:** Machine learning models analyze motion and vibration data to detect suspicious activities, such as potential theft.
2. **Usage Forecasting:** Predictive models anticipate peak usage times, allowing better resource planning.
3. **Energy Optimization:** AI algorithms analyze solar output and system load to balance energy consumption efficiently.

Methodology:

- **Data Preprocessing:** Raw sensor data is filtered to remove noise and standardize units.
- **Feature Extraction:** Relevant variables like vibration frequency, access timestamps, and solar output are identified.
- **Modeling:** Basic classification models (e.g., Decision Trees, k-Nearest Neighbors) are tested for prototype feasibility.
- **Evaluation:** Model performance is validated using simulation datasets.

Benefits:

- Enhances safety through proactive alerts.
- Supports data-driven urban planning.
- Demonstrates applied AI principles in a real-world system.

5.3 Interface Design

The **user and administrator interfaces** are essential for engagement and transparency.

User Interface (P5.js)

- Displays live data on parking slot availability.
- Provides energy usage information and system health indicators.
- Enables RFID or app-based unlock features.
- Built for responsiveness and simplicity on web browsers or mobile devices.

Admin Dashboard (Unity)

- Visualizes IoT data in a 3D environment for situational awareness.
- Displays system alerts, energy trends, and predictive analytics.
- Offers maintenance tools and access logs for diagnostics.

Together, the interfaces bridge the physical and digital layers, allowing real-time system interaction.

6. Team Roles and Collaboration

Name / No.	Role	Responsibilities
Angela Xavier (20251484)	AI & Visualization	Researches and implements ML models, processes data, and designs dashboards.
Muhammad Zidane (20200057)	IoT & Hardware	Configures ESP32 microcontrollers, connects sensors, and manages system integration.
Caleb Okeke (20231697)	Interface & UX	Develops UI/UX layouts, mockups, and interactive prototypes using P5.js and Unity.

Collaboration tools include:

- **GitHub** – version control and code management.
- **Notion/Trello** – project planning and task tracking.
- **Google Drive** – shared documentation and media storage.

Regular cross-functional meetings ensure consistent progress and alignment between design, hardware, and AI development.

7. Timeline

Phase	Focus	Weeks	Deliverable
1	Research & Concept Development	1–3	Concept proposal, partner analysis, design brief
2	Prototyping & Technical Integration	4–8	IoT and AI prototype with working communication layer
3	Refinement & User Experience	9	Enhanced UI and finalized data interaction
4	Presentation & Exhibition	10	Final prototype demonstration and report submission

Each phase includes **testing, documentation, and review checkpoints** with faculty and industry partners.

8. Next Steps

1. Assemble and test the IoT hardware system with full sensor integration.
2. Collect and label datasets for AI model training.
3. Develop both P5.js and Unity dashboards.
4. Test usability and refine system interactions.
5. Prepare media, technical documentation, and final presentation for Milestone

9. Conclusion

The **Energize** project illustrates how **AI, IoT, and renewable energy** can work together to shape the future of urban infrastructure. The project's modular, autonomous design supports environmental sustainability, security, and intelligent user experiences.

By integrating computation and creativity, Energize positions itself as a **scalable solution** for the growing needs of **smart, sustainable cities**.

10. References

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