LETSCYCLETORECYCLE

QR-code based
E-Waste Tracking Prototype

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MCIS – Data Engineering
Capstone Project
Youngstown State University

INTRODUCTION

Electronic Waste — What We Know ?

- E-waste (discarded electronics like phones, laptops, TVs) is one of the fastest-growing and most hazardous waste streams globally.
- South Asia is heavily affected due to rapid growth in technology use and weak recycling systems, with India seeing a 43% rise in e-waste.
- Informal recycling (burning, dismantling, acid baths) exposes workers, women, and children to toxins such as lead, cadmium, and mercury.
- These exposures cause long-term, irreversible health effects, especially in vulnerable populations.
- Yet there is no unified system showing a device's path from drop-off → processing → final outcome.

(This gap motivated the development of the tracking prototype.)

BACKGROUND

- Research shows e-waste is increasing rapidly, and most devices are handled informally without proper tracking (Forti et al., 2023; Heacock et al., 2016)
- South Asia faces serious risks due to weak recycling infrastructure and hazardous practices like open burning (Vishwakarma et al., 2022)
- Existing ICT systems rely on paper logs, spreadsheets, or fragmented tools with no unified device history
- This project addresses that gap by creating a database-driven tracking prototype connecting device intake → processing → final outcome

Technical Stack Used

- VS Code
- Python Application
- Oracle Database
- QR Code PNGs
- Flask
- Customer Portal
- Employee Portal
- NGROK

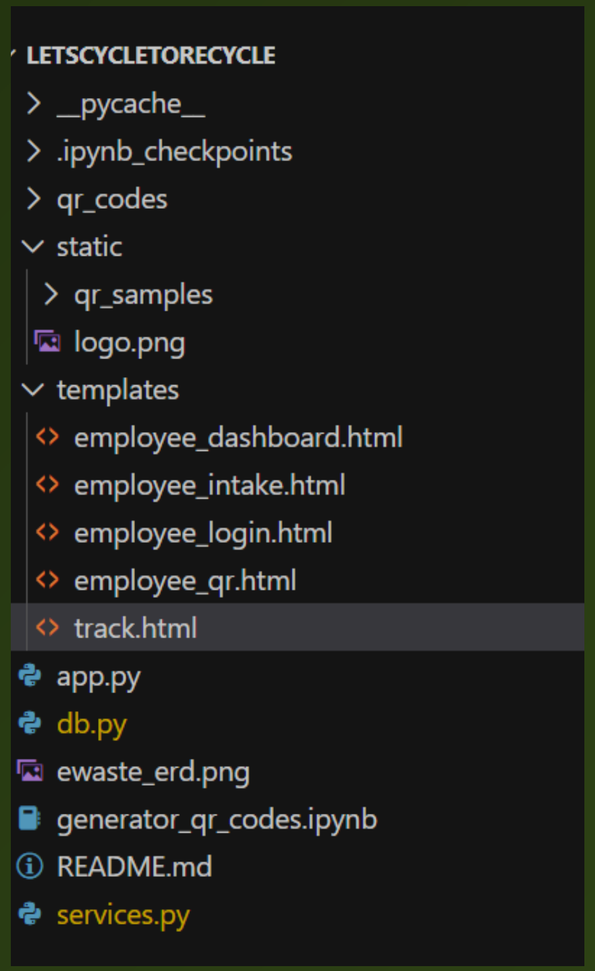
PROBLEM STATEMENT

We Throw It Away, But It Never Goes Away

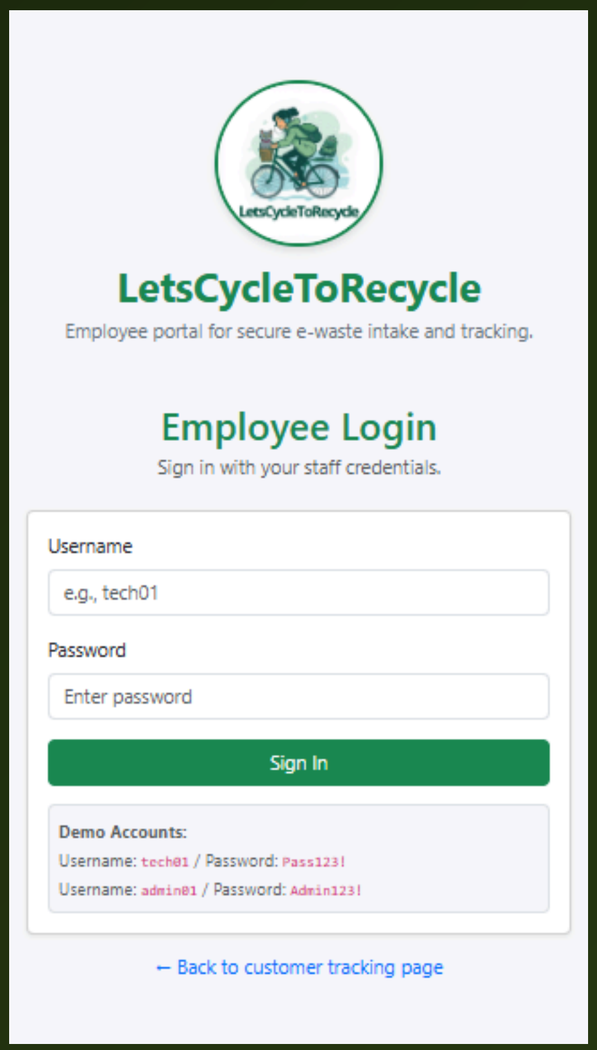
- E-waste is growing at an unprecedented rate, driven by rapid device replacement and short product lifecycles — yet most of it is not biodegradable, adding long-term environmental and public health burdens.(Forti et al., 2023)
- Informal and unsafe recycling practices (burning, acid leaching, open dismantling) release toxic substances into soil, water, and air, exposing communities, especially women and children, to irreversible health harm. (Heacock et al., 2016; Vishwakarma et al., 2022)
- Despite the scale of the crisis, there is no unified system to track an e-waste device from drop-off to its final outcome, leaving customers, recyclers, and regulators with no transparency or accountability in the disposal process.

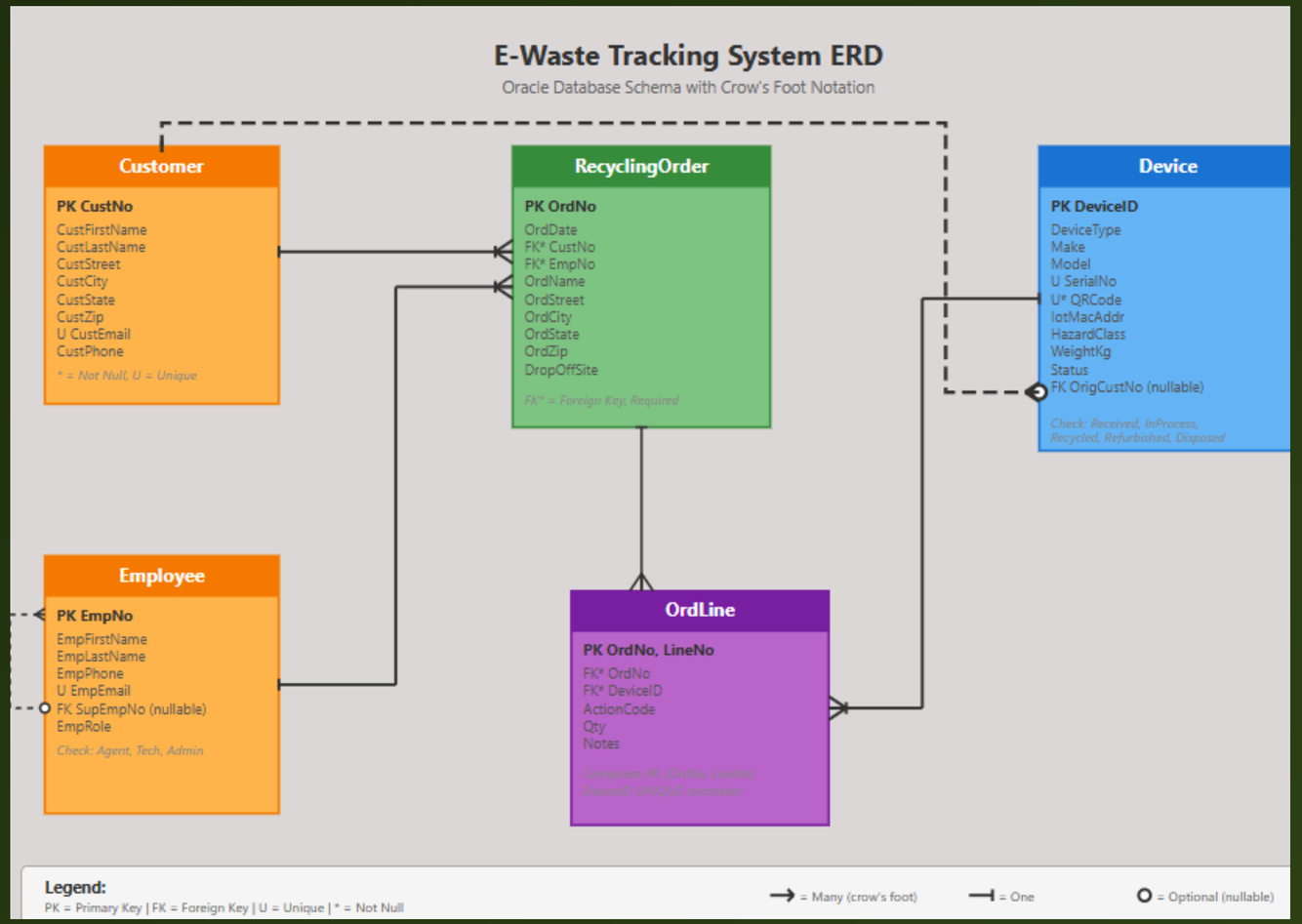
METHODOLOGY

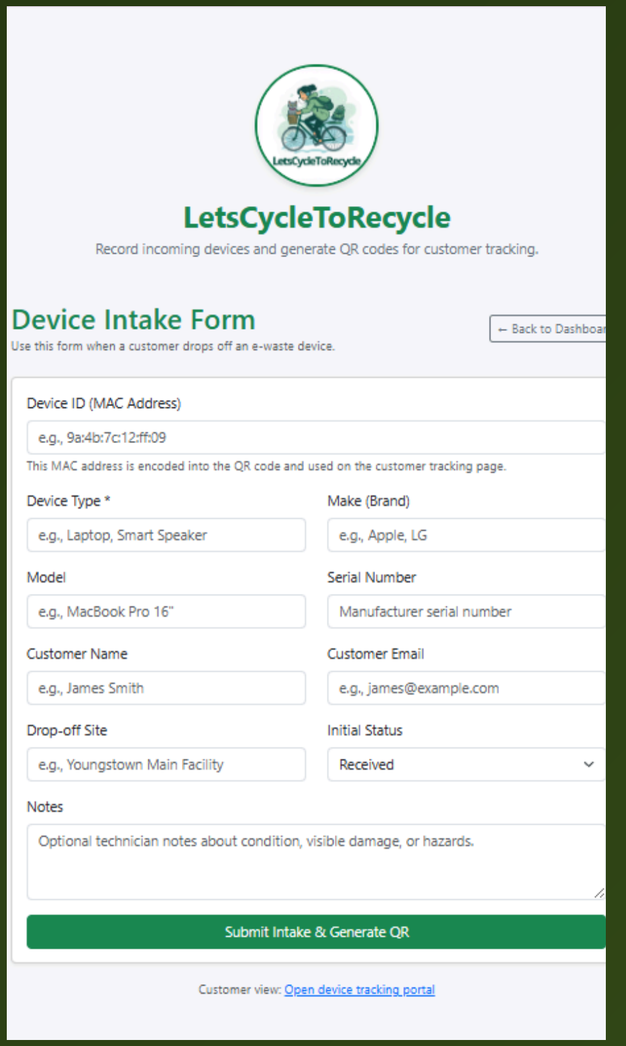
- Designed the **LetsCycleToRecycle** system using a normalized Oracle database with five core tables to model the full e-waste intake → processing → outcome workflow.
- Developed a modular Python–Flask application for device intake, customer registration, and real-time tracking.
- Implemented automated QR code generation, linking each device to a public tracking page via ngrok.
- Structured the backend using:
  app.py (routing & pages)
  services.py (Oracle logic & QR generation)
  db.py (database connectivity)
- Built a Customer Tracking Portal and a prototype Employee Intake Portal fully integrated with Oracle through the modern oracledb driver.



Methodology - System Components (Visual Overview)

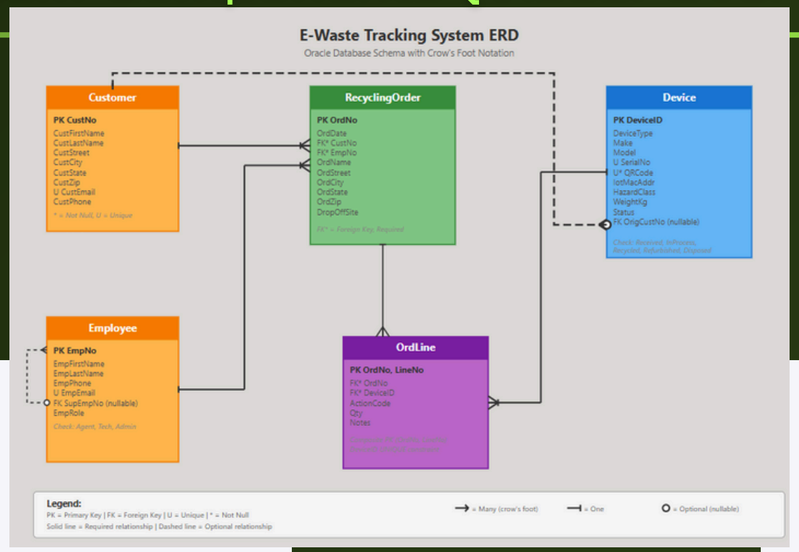






Employee Login → Device Intake Form → Oracle Database (ERD) → Customer QR Tracking Page

Methodology - System Components (Visual Overview)



LetsCycleToRecycle

Track the recycling progress of your electronic device using your QR-code.

Track Your Device

Enter the Device ID (MAC address) printed next to your QR code.

aa:bb:cc:11:22:33 | Track Device

Device: aa:bb:cc:11:22:33

Type: Ipad
Make: APPLE
Model: Ipad 10"
Serial No: SN-I12222-111
Hazard Class: Medium
Weight: 1.0 kg
Drop-off Site: Youngstown Main Facility
Received Date: 2025-11-28
Registered Customer: John Merit

Current Status: Received

Recycling Status Timeline

Received	Device received at LetsCycleToRecycle center
Under Recycle Check	Technician inspecting components
In Laboratory	Hazardous materials being processed
Recycled	Metals recovered and logged

Employee portal → Login or Device Intake

Device Intake

↓

QR Generated

↓

Customer Scan

↓

Live Tracking

LetsCycleToRecycle

Track the recycling progress of your electronic device using your QR-code.

Device **24** has been registered.

Device MAC Address
aa:bb:cc:11:22:33

Public Tracking URL
https://unproductive-nonmutually-catharine.ngrok-free.dev/track/aa:bb:cc:11:22:33

QR Code

This QR code can be scanned by anyone on any WiFi. Perfect for presentation demo.

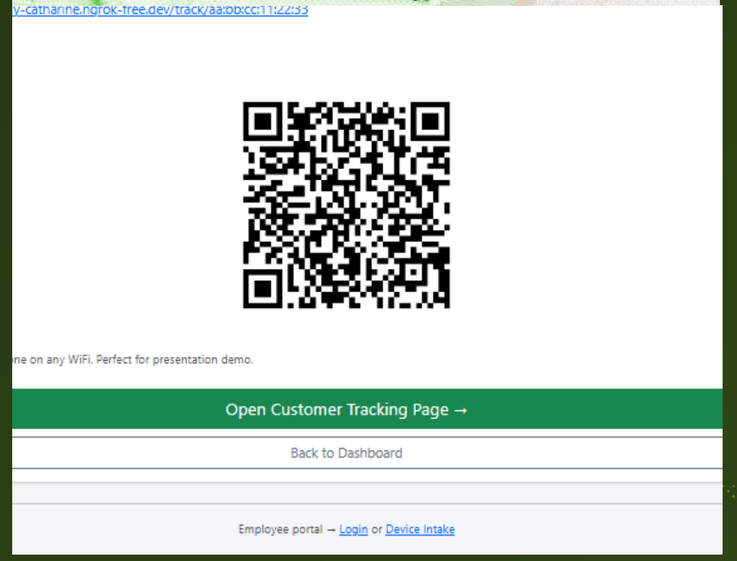
Open Customer Tracking Page →

Back to Dashboard

Employee portal → Login or Device Intake

EXPERIMENTS

- Tested device intake workflow by inserting multiple sample devices and customers into Oracle using the Flask form.
- Validated QR code generation by scanning codes from different devices (Android, iPhone, laptop) and confirming correct routing to the tracking page.
- Verified live tracking functionality by updating statuses in Oracle and observing real-time changes on the customer portal.
- Tested ngrok tunneling to ensure QR codes worked externally on mobile data outside the local network.
- Confirmed referential integrity across all five Oracle tables (Customer, Device, RecyclingOrder, OrdLine, Employee).



Discussion

- This prototype demonstrates that e-waste devices can be tracked end-to-end using QR codes, Oracle integration, and a lightweight Flask application.
- With cloud deployment (e.g., Render, AWS, or Oracle Cloud), the system can operate as a public platform, eliminating the need for ngrok and enabling 24/7 scanning and updates.
- Recycling facilities could adopt this system to register every incoming device, providing customers with transparent, real-time tracking and improving trust in the recycling process.
- Centralized tracking across facilities would help reduce loss, mishandling, and unsafe informal recycling, especially in regions with weak accountability.
- Scaling the platform could support analytics dashboards for material recovery, device volumes, hazard classification, and compliance reporting.

Conclusion

- LetsCycleToRecycle successfully demonstrates that e-waste devices can be uniquely identified, tracked, and transparently monitored using QR codes, Flask services, and an Oracle-based data model.
- As e-waste continues to grow globally and remains largely untracked, this prototype shows how digital systems can bring much-needed visibility and accountability into the recycling process.
- The prototype proves the feasibility of building a full digital chain, from device intake → QR assignment → real-time customer tracking, aligned with real recycling workflows
- The next phase is to deploy the system on a cloud platform like Render, enabling a stable public URL for 24/7 QR scanning without ngrok.
- After cloud deployment, the project will expand into a fully hosted website and eventually a mobile app, improving accessibility for customers, employees, and recycling partners.
- With continued development, LetsCycleToRecycle can scale into a practical tool for recycling centers, supporting accountability, reducing unsafe disposal, and helping communities make more responsible tech decisions.

Contribution

- This project was completed as an individual capstone, including system design, Oracle schema implementation, Flask application development, QR integration, UI design, and testing.
- Faculty Coach: Professor Todd Jones provided weekly guidance through meetings, offering direction on database normalization, ERD relationship structure, and the use of MAC/unique identifiers for device traceability.
- Additional insight from Advanced Database (CSCI 6950) supported improvements in schema design, referential integrity, and SQL query development.
- All coding, QR pipeline setup, ngrok testing, UI templates, and final system integration were completed independently.

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Thank you

Professor Todd Jones

For continuous guidance, weekly meetings, and mentoring throughout the development of this capstone project.

Dr. Yu

For academic support and instruction that strengthened my foundation in database systems and data engineering.

Youngstown State University – MCIS Program

For providing the opportunity and resources to complete this project.

Thank you for your time and attention.