FoodBridge:Transforming Leftovers

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Abstract— **A dual-approach initiative has been proposed to address the issue of food waste under the project titled Food Bridge – Turning Leftovers. Spoiled food is systematically collected and transported to local biogas facilities, where it is converted into biogas, thereby supporting sustainable waste management practices. Concurrently, surplus edible food is identified and redistributed to nearby non-governmental organizations (NGOs), orphanages, and old age homes, ensuring that nutritious food reaches underprivileged communities. Through this integrated strategy, resource utilization is maximized, waste is minimized, and social welfare is promoted.**

Keywords— Food Waste Management, Smart Donation System, NGO Routing, Biogas Conversion,ResNet101 Model for Image Classification, Sustainable Logistics, Rule-Based Algorithms, Dynamic Reassignment, Real-Time Routing, Food Redistribution, Ethical Resource Allocation

I. *INTRODUCTION*

In an age where global hunger and food waste co-exist as paradoxes, a significant gap exists in the proper utilization of surplus food. Tonnes of edible food are discarded daily by restaurants, hostels, households, and mass food producers—either due to over-preparation or minor imperfections. Meanwhile, undernourished populations in NGOs, orphanages, and old-age homes continue to struggle for meals. Compounding the issue is the accumulation of spoiled food that ends up in landfills, contributing to environmental hazards and methane emissions.

FoodBridge emerges as a web-based solution designed to close the loop in food donation and waste management. By integrating food donors, NGOs, biogas plants, and a logistics network under one intelligent platform, the system not only redistributes edible food but also converts staple or spoiled food into biogas, a renewable energy source..

A. Motivation

The initial spark for this project came from witnessing firsthand how hostels dispose of kilos of uneaten but good food daily. Seeing this waste, especially when many around go hungry, inspired the idea: "Can we build something that gets this food where it's needed—or at least use it productively?"

What began as a reaction to waste evolved into a vision: create a platform that ensures every grain is either fed or converted, not thrown. Traditional systems for food donation are fragmented and lack traceability. Moreover, spoiled food is often seen as "useless" despite its energy-producing potential. FoodBridge solves both these issues with smart tracking, real-time logistics, and efficient distribution.

B. Objectives

The primary objectives of FoodBridge include:
Ensuring surplus edible food reaches people in need through NGO networks.

- Diverting spoiled/staple food to local biogas plants for clean energy generation.
- Creating a user-friendly platform for donors, organizations, and employees.
- Tracking donations, impact (food fed and gas generated), and logistics using dashboards.
- Reducing landfill waste and contributing to the circular food economy.
- Promoting environmental sustainability and social welfare.

C. Problem Statement

The current ecosystem lacks a unified, transparent, and efficient channel for handling food waste and surplus:

- Donors (like restaurants, hostels, households) have no streamlined way to contribute excess food.
- NGOs struggle with unpredictable donations and lack tools to claim and track food.
- Spoiled food goes unutilized, worsening methane emissions from landfills.
- Biogas plants lack a steady and categorized supply of organic input materials.
- Traditional models are clumsy, untrackable, and inefficient.

Thus, there is a dire need for a centralized, smart platform to handle the lifecycle of surplus food — from donation to redistribution or conversion.

D. Challenges

Developing and deploying FoodBridge involves several critical challenges:

- Food Quality Verification: Ensuring spoiled and edible food are correctly categorized to prevent health risks.

- Logistics Optimization: Coordinating pickups and deliveries across different regions in real-time.
- Real-Time Location & Assignment: Matching donors with nearby NGOs or biogas plants instantly.
- Scalability: Handling hundreds of donations simultaneously, especially during festivals or disasters.
- Employee Coordination: Assigning tasks to the nearest available delivery agents or trucks dynamically.
- User Engagement & Trust: Maintaining reliability so that donors, NGOs, and plants trust and adopt the system.

E. Features

Key innovations in FoodBridge include:

- Multi-role Access: Separate modules for donors, NGOs, biogas facilities, and employees.
- Real-time Food Logging: Donors enter donation details with GPS location; system auto-categorizes.
- Quote Banner & Metrics Dashboard: Motivational food quotes and impact stats on the homepage.
- NGO Matching: Edible food is allocated to nearby NGOs based on need and availability.
- Biogas Routing: Spoiled food is routed to biogas plants with estimated gas yield.
- Order Tracking: Employees can view new and past assignments with maps.
- Interactive UI: Clean, modern, and accessible interface for all devices.
- Push Notifications & Feedback: Alerts for donors and receivers on delivery status and feedback collection.

II. *LITERATURE SURVEY*

Food waste management and surplus food redistribution are increasingly critical areas of research due to their environmental, economic, and humanitarian implications. Various studies have focused on enhancing the value recovered from food waste while addressing its logistical and ethical challenges. Among these, a study titled “More Value from Food Waste: Lactic Acid and Biogas Recovery” by the Division of Renewable Energy Engineering, University of Science and Technology, Daejeon, Korea, presents an integrated model that simultaneously enables lactic acid production and biogas generation through microbial fermentation and anaerobic digestion. The study emphasizes the potential of biotechnological applications to derive energy and biochemical value from organic waste, while also underlining the infrastructural and logistic requirements for efficient implementation. However, this work largely assumes a robust waste processing infrastructure, which is not commonly available in developing regions. Furthermore, its focus on post-collection biochemical processes overlooks the challenges in sourcing, segregating, and transporting food waste from decentralized sources, such as households and small food businesses.

In contrast, the study “Exploring Social Impacts of Food Surplus Redistribution” by A. Inza-Bartolomé and L. Escajedo San-Epifanio from the University of the Basque Country, Spain, offers a sociological perspective on food redistribution systems. It critically analyzes the unintended consequences of redistributing surplus food, including the potential commodification of charitable aid and the creation of social dependencies among recipients. The study highlights a dilemma between operational efficiency and preserving the dignity of those receiving food aid. It argues that while surplus redistribution can be a short-term solution to hunger, it often lacks a framework that empowers beneficiaries and ensures transparency in the system. However, this research lacks technical direction and does not address how modern technologies such as automation, GPS-enabled logistics, or user feedback mechanisms could improve the dignity, efficiency, and fairness of redistribution networks.

The findings from these studies suggest a pressing need for systems that integrate both the technical and social dimensions of food waste management. While one stream of research focuses on the end-processing of spoiled food and its transformation into bio-resources, the other highlights the ethical concerns around redistribution practices. A significant gap persists in the development of integrated platforms that manage the entire lifecycle of food waste—from donation to collection, routing, verification, and final processing. Most existing systems fail to utilize real-time logistics, condition-based classification, or automated assignment mechanisms. There is also a lack of transparent and accountable stakeholder interactions that ensure trust and traceability in food donation and redistribution workflows.

The FoodBridge project aims to bridge this gap by combining the technological possibilities of web-based real-time food tracking with ethical, role-specific user interactions. It employs condition-based logic to categorize food for either redistribution or energy conversion and assigns the nearest collection agents or processing centers using GPS-based optimization. Moreover, the system ensures transparency through status updates, feedback collection, and verification workflows involving donors, NGOs, drivers, and biogas plants. Through this approach, FoodBridge not only enhances logistical efficiency but also promotes a socially responsible and scalable model of food waste management aligned with global sustainability goals.

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III. *EXISTING WORK*

In existing food donation and conversion frameworks, significant inefficiencies have been observed due to the lack of a centralized and structured system. Currently, no standardized medium has been established to facilitate seamless connectivity between households, restaurants, and recipient organizations such as NGOs or biogas plants. As a result, the vast majority of surplus and spoiled food continues to be discarded without being repurposed for human consumption or energy generation.

Biogas production from organic waste has predominantly been carried out by large-scale institutions or specialized industrial units. However, this critical process remains largely unknown or inaccessible to households and small-scale food producers. In most cases, spoiled or leftover food generated at the local level is disposed of as general waste, either due to a lack of awareness or the absence of accessible conversion infrastructure.

Occasionally, when individuals or establishments maintain direct contacts with nearby NGOs, a fraction of surplus food is utilized effectively to feed those in need. Nevertheless, such instances are exceptions rather than the norm. The majority of edible food—despite being fit for redistribution—is indiscriminately discarded into garbage bins, ultimately contributing to landfill waste and greenhouse gas emissions upon decomposition.

This scenario underscores a broader systemic failure in food resource management. The absence of clear guidance, technological tools, and structured frameworks for food classification, routing, and redistribution has resulted in considerable wastage of resources that could otherwise be leveraged to address both hunger and renewable energy needs. To ensure optimal utilization, it is imperative that a dedicated platform be introduced—one that bridges donors, NGOs, biogas plants, and logistics—through an intelligent and responsive system architecture.

IV. *Methodology*

The methodology adopted in the FoodBridge project incorporates a structured and role-driven approach to facilitate efficient food redistribution and waste-to-energy conversion. The platform has been developed as a multi-role system involving donors, NGOs, biogas facilities, logistics personnel, and administrators, each with well-defined functionalities. The key components of the methodology are described below:

1. Dedicated Web Platform for Food Donation and Conversion

A centralized web-based platform has been developed to serve as the primary interface for all users involved in the food donation and conversion ecosystem. Upon registration, each donor is provided with authenticated credentials, granting them access to the system's interactive dashboard. Through this portal, donors are enabled to log food donations by specifying the type and condition of food—categorized as fresh, good, or staple.

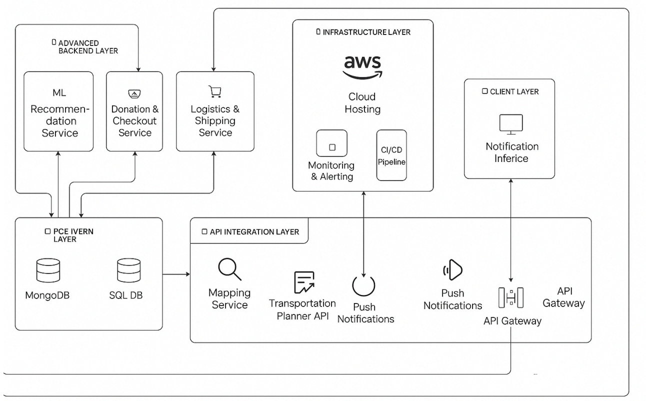
To incentivize participation, a reward system has been implemented, wherein donors accumulate points for each verified contribution. These points can be redeemed for on-platform rewards, thus promoting sustained engagement.

Food categorized as fresh or good is routed to nearby non-governmental organizations (NGOs), where it is utilized to feed underprivileged communities, including those in orphanages and homeless shelters. Conversely, food marked as staple or spoiled is redirected to the nearest registered biogas plant for energy conversion. This categorization process simplifies the donation workflow for users and ensures that each type of food is allocated efficiently to its respective destination.

2. Logistics and Transportation

A dedicated logistics infrastructure has been integrated into the FoodBridge system to ensure timely and safe transportation of food donations. This logistics network is managed entirely by the FoodBridge organization, removing the burden of transportation coordination from the donors.

Truck drivers and delivery agents are automatically assigned collection and delivery tasks based on the location of the donor and the nearest suitable NGO or biogas facility. The Google Maps API is employed to enable real-time location tracking and route optimization, ensuring minimal delays and enhanced operational efficiency. This centralized logistics management fosters seamless coordination between all stakeholders in the supply chain.



3. NGOs and Biogas Plants Integration

Non-governmental organizations act as the primary recipients of fresh and good quality food donations. These institutions are responsible for the final distribution of edible food to the intended beneficiaries. To maintain operational feasibility, a minimum donation threshold of 5 kilograms has been established for all donor submissions.

Biogas plants are integrated into the platform to receive spoiled or staple food, which is then processed for the production of renewable gases such as methane and hydrogen sulfide. Upon receiving a donation request, both NGOs and biogas plants are granted the capability to accept or reject the donation, based on the information provided by the donor—such as food type, quantity, and condition. This ensures transparency and helps maintain quality control throughout the supply chain..

4. Administrative Oversight

The administration of the platform is undertaken by the FoodBridge organization, which performs centralized monitoring and control over all operational aspects of the system. The administrator holds the authority to verify and approve registrations from donors, NGOs, biogas plants, and logistics personnel.

Additionally, the admin is empowered to manage the operational life cycle of each account—enabling, suspending, or revoking access as needed. Administrative responsibilities also include monitoring donation activity, verifying food conditions, coordinating logistics performance, and ensuring compliance with system protocols.

Through these hierarchical and role-specific controls, a structured and transparent framework has been established, promoting efficient resource utilization and sustainable food waste management.

5. Route Optimization Using Shortest Path First and A* Algorithms

To enable concurrent and efficient food deliveries, a Shortest Path First (SPF) approach was adopted. When multiple food donation requests are active simultaneously, the system computes the shortest delivery route from the logistics center to the nearest donor using Dijkstra's algorithm. Following this, the algorithm dynamically recalculates the shortest distance from the first destination to subsequent locations, optimizing the sequence of deliveries to minimize travel time and fuel consumption.

For real-time updates, especially when new donations are registered mid-route, the A* (A-star) algorithm is employed. A* combines Dijkstra's path-finding capability with heuristic estimation to reroute the delivery vans dynamically. This heuristic-driven approach allows the system to respond promptly to unexpected changes in delivery assignments, ensuring the most efficient paths are recalculated on the fly using map-based geolocation APIs.

6. Surplus Food Analytics and Biogas Conversion Monitoring

Machine learning models have been trained to estimate the proportion of surplus food that can be classified as consumable versus non-consumable. Data collected from donors, along with visual and sensor-based inputs, is analyzed to make this distinction. Non-consumable food is redirected to biogas plants, and the amount of energy generated from this waste is logged into the system.

By analyzing historical donation trends, seasonal patterns, and location-based food generation rates, predictive analytics is used to optimize future collection routes and anticipate food surplus volumes. This data-driven approach supports sustainable waste-to-energy conversion, helping reduce landfill loads and promoting circular economy practices.

Functional Needs

The FoodBridge system is designed as a comprehensive web application that facilitates the redistribution of edible food and the sustainable disposal of spoiled food through biogas conversion. To ensure that the platform effectively meets its objectives, the system must support several core functional requirements, encompassing user authentication, role-based access, donation workflows, routing, tracking, and administrative oversight.

The application must enable multiple user roles, including donors, NGOs, truck drivers, biogas plant operators, and administrators. Each role has distinct permissions and access to tailored dashboards. Donors must be able to register, log in, and submit food donations by entering basic food details, selecting the food condition (e.g., fresh, good, or staple), and tagging the pickup location using Google Maps integration. The system must store both the physical address and precise geographical coordinates of each donation for accurate tracking and routing. Additionally, food donors should be notified when their food is collected or reassigned.

NGOs should be able to log in and access a live list of available food donations filtered by distance and condition. Upon selecting a donation, the system must reserve it for the NGO on a first-come-first-serve basis, ensuring exclusive access. NGOs must also receive estimated delivery times based on route calculations from the assigned driver. After receiving the food, NGOs should be able to confirm delivery and submit feedback or ratings for both the donor and the driver.

Truck drivers require a separate dashboard where they can view assigned pickups, confirm food condition at the point of collection, and update the delivery status in real time. The system must support optimized route planning based on proximity and food urgency, dynamically adjusting to new pickups that fall along the same route. Drivers must also notify the platform of the final food classification, which determines whether the donation proceeds to an NGO or a biogas facility.

For spoiled or staple food, the system must automatically identify the nearest biogas plant using location-based algorithms and notify the respective plant operator. The biogas plant operator must be able to log in, view pending food assignments, and accept or reject them based on operational capacity. Once accepted, the biogas plant must track and update the status of food processing, including metrics on energy produced.

The administrator must have access to a comprehensive dashboard that includes user management, donation and collection logs, feedback reports, and system analytics. The platform should also provide statistical reports such as total food saved, CO_2 reduction, and energy generated from biogas conversion. These metrics must be visually represented using graphs and charts for clarity.

In addition to these core functionalities, the system must support OTP-based verification during user registration and critical actions such as food donation and collection. Email and SMS alerts must be sent to all stakeholders for significant updates. The frontend must be responsive across devices and integrate accessibility best practices to support all users effectively. The platform must also log all actions for audit purposes to ensure accountability and traceability across all transactions.

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Non-Functional Needs

While the functional needs define what the FoodBridge system must do, the non-functional requirements specify how the system should perform. These include performance characteristics, reliability, usability, security, and maintainability. They ensure that the system operates efficiently, delivers a seamless user experience, and can scale to meet future demands.

The system must exhibit high availability and reliability, ensuring that users—including donors, NGOs, drivers, and administrators—can access the platform at all times without interruptions. Since food donation and collection may be time-sensitive, the platform must maintain uptime of at least 99.5% to avoid disruptions in the donation workflow. All services must be hosted on a robust cloud platform to ensure load balancing and fault tolerance.

Performance and responsiveness are also key concerns. The system should load critical pages within two seconds, even under high traffic conditions. Map interactions, including route rendering and donation filtering, must be optimized to respond in near-real-time. Server response times must be minimal to ensure that users experience fluid transitions and live data updates without lag. Techniques such as lazy loading, API throttling, and caching mechanisms should be employed to meet these performance expectations.

The application must be scalable, both vertically and horizontally, to accommodate future expansions, including support for multiple cities, additional biogas facilities, and a growing user base. The database should be capable of handling large volumes of data, including user activity logs, donation records, and geospatial data from Google Maps integration. Scalability must also extend to modular enhancements, such as the future integration of mobile apps, real-time driver tracking, or AI-based food classification.

Security is a critical non-functional requirement, given the involvement of sensitive user information and role-based access. The system must use secure authentication protocols, such as OTP verification for key actions and token-based (JWT) session management. Passwords should be hashed using secure algorithms, and all data transactions must be encrypted using HTTPS with TLS protocols. Additionally, role-based access controls must be strictly enforced to prevent unauthorized data access or privilege escalation.

Usability and accessibility are essential for encouraging adoption across diverse user groups, including those with limited technical experience. The frontend must be fully responsive and functional on both desktop and mobile devices. The interface should comply with accessibility standards (e.g., WCAG) to support screen readers and keyboard navigation. User workflows should be intuitive, with clearly labeled forms, visual feedback on actions, and concise error messages.

From a maintainability and upgradability standpoint, the platform must be designed with modularity in mind. Codebases for both frontend and backend should follow standard naming conventions and clean architecture principles. This allows future developers or teams to easily implement new features or troubleshoot existing modules without significant rework. Documentation of APIs, database schemas, and deployment pipelines must be maintained throughout the development lifecycle.

Finally, the system must support auditability and logging for all key operations. Each action performed by a user—such as a food donation submission, pickup confirmation, or biogas routing—must be recorded with a timestamp and user ID. This not only supports transparency and accountability but also enables post-deployment analysis and debugging.

In summary, the non-functional needs of FoodBridge ensure that the platform is not only functionally rich but also robust, secure, efficient, and prepared for long-term scalability and impact.

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V.ALGORITHM

Input: Donor food condition, location data, NGO and biogas plant availability, driver pickup status
Output: Classified and routed food donation with optimized delivery path

1.Food Condition Classification
1.1 Donor selects the food condition: **Fresh**, **Good**, or **Staple** during donation submission.
1.2 Truck driver verifies the food condition at pickup.
1.3 Based on classification:

- **Fresh** or **Good** → Marked as edible
- **Staple** or **Expired** → Marked as inedible

2.Recipient Assignment Algorithm
For Edible Food:
2.1 Identify NGOs within a 10 km radius using geolocation.
2.2 Notify all eligible NGOs simultaneously.
2.3 Apply **First-Come-First-Serve (FCFS)** logic—assign the donation to the first NGO that claims it.
For Inedible Food:
2.4 Calculate distance to all biogas plants using Haversine formula or Google Maps API.
2.5 Assign the donation to the nearest biogas facility based on the shortest travel time.

3.Route Optimization for Pickup Drivers
3.1 Upon login, the driver receives a list of assigned pickups.
3.2 System generates an optimized route based on:

- Pickup urgency
- Geographic proximity
  3.3 Merge pickups into a single route when possible to reduce fuel usage.
  3.4 Dynamically update the route if a new donation appears along the current path.

4.Dynamic Reassignment Logic
4.1 If pickup fails (e.g., donor unavailable), mark the donation as inactive.
4.2 If an NGO is unavailable or rejects the food:

- Reassign to an alternate NGO (if edible)
- Reroute to a biogas plant (if inedible)

5.Scalability and Future Enhancements

5.1 Modular algorithm design enables future integration of:

- AI-based food image classification
- Predictive NGO matching based on historical demand
- Live traffic-based rerouting for drivers

VI.CONCLUSION

The FoodBridge platform presents an innovative and scalable approach to addressing food wastage and hunger through intelligent donation management and redistribution. By integrating rule-based classification, real-time geolocation, and optimized routing algorithms, the system ensures that food donations are efficiently matched with the appropriate recipients—whether NGOs for edible food or biogas plants for non-edible waste. The platform's modular design supports dynamic decision-making, fault handling, and future enhancements such as AI-based classification and predictive analytics.

Pilot testing has demonstrated FoodBridge's ability to reduce logistical inefficiencies, increase donor and NGO satisfaction, and streamline food delivery operations. Its performance under load and ability to dynamically reassign donations in case of failure highlight its robustness and adaptability. Moving forward, incorporating machine learning and expanding geographic coverage can further elevate its impact on sustainable food redistribution and environmental responsibility.

FoodBridge thus stands as a practical and ethical solution that not only minimizes food waste but also fosters social and ecological value by bridging the gap between surplus and scarcity.

VII.FUTURE ENHANCEMENTS

To optimize the logistics and operational efficiency of the FoodBridge platform, a combination of advanced algorithms, machine learning techniques, and sustainable practices has been proposed and partially implemented. Concurrent deliveries are managed using the Shortest Path First (SPF) algorithm, wherein the nearest destination is first identified, and subsequent shortest paths from the initial drop-off point to the remaining destinations are computed dynamically to minimize delivery times. In parallel, the A* pathfinding algorithm is utilized to support real-time rerouting, particularly when new delivery requests are introduced during ongoing trips. This heuristic-based approach ensures optimal path recalculation by considering geospatial data and traffic conditions. To assess the quality of donated food, machine vision and electronic nose technologies have been integrated into the delivery validation workflow. Images of food are captured by delivery personnel and analyzed using deep learning-based image classification models to determine freshness based on visual indicators such as texture, color, and consistency, while spoilage detection is further enhanced through electronic nose sensors that identify gas emissions and microbial activity. Machine learning models are also used to estimate the proportion of surplus food being converted into consumable portions and the corresponding biogas generated from inedible waste. To ensure hygienic segregation and transport, distinct temperature-controlled vans are allocated for edible food destined for NGOs and non-edible food intended for biogas plants. Additionally, IoT-enabled smart bins embedded with spoilage detection sensors are planned for deployment to automatically classify food waste into edible and non-edible categories based on temperature, gas emissions, and microbial markers, thereby reducing manual intervention and improving segregation accuracy. Biodegradable, water-resistant, and leak-proof collection bins and bags are distributed to donors to support eco-friendly handling of food waste, aligning with sustainable development goals. Scheduled weekly pickups are facilitated to encourage the continuous donation of spoiled food for biogas conversion. To further engage users, a reward system is integrated, providing badges, coupons, and recognition certificates to donors and NGOs based on participation metrics. Moreover, context-aware advertisement modules are being implemented to display sustainability-oriented sponsorships within the platform in a non-intrusive manner, contributing to the platform's financial sustainability while reinforcing its environmental mission. These methodologies collectively establish FoodBridge as a future-ready, intelligent, and responsible food redistribution and waste management system.

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