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Innovative Domestic Waste and Food Management: A Consumer-Producer Approach

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ABSTRACT

Food waste management has become an urgent global issue requiring innovative approaches in reducing waste and alleviating hunger. This survey paper systematically reviews the current methodologies for food waste management, which focus on mobile and web-based technologies, supply chain optimization, and community-driven applications. It compares major approaches such as Android- based platforms, web-mobile integrated systems, and intelligent algorithms for efficient redistribution focusing on implementation, key features, and impact on food recovery. Geolocation services, real-time tracking, and volunteer coordination are among the most employed techniques that have been cataloged; scalability, usability, and NGO and social organization integrations are also appraised. Significant challenges such as logistical inefficiencies, lack of data, and very low user adoption rates emerged through this analysis. Emergent trends such as machine learning, IoT integration, and advanced hunger search tech- nique capabilities are also analyzed as opportunities for changing the status quo in food redistribution practices. It summarizes the findings of studies such as ”Food Waste Management Using Android,” ”A Web and Mobile-Based Approach to Redistribute Consumable Food Waste,” among others, which are of utmost importance for critical benchmarks and identification of gaps in current solu- tions, providing a roadmap for future advancement in sustainable food waste management.

Keywords: Food waste management, food redistribution, mobile applications, Android-based platforms, web-mobile systems, geolocation services, real-time tracking, sustainable development

1. Introduction

Food waste management has become one of the most pressing challenges globally, especially considering its environmental, economic, and social implications. Approxi- mately one-third of all food produced is wasted, contributing to significant resource inefficiency and environmental degradation, including increased greenhouse gas emis- sions and depletion of natural resources like water and land. Tackling food waste is crucial to achieving several of the United Nations Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production) [1]. As part of the solution, food waste management systems utiliz- ing innovative technologies such as mobile applications, the Internet of Things (IoT), and machine learning (ML) have gained traction in recent years. These systems enable efficient food redistribution, minimize waste, and foster community engagement.

Recent developments in food waste management technologies, particularly those that employ Android-based mobile applications, have revolutionized the way food waste is handled and redistributed. For instance, Android-based applications designed to facilitate food donations and streamline logistics between donors and charities have shown promising results in reducing food waste while addressing hunger [3]. In addi- tion to these mobile solutions, IoT technologies have been integrated into food waste management systems, enabling real-time monitoring of food conditions and waste gen- eration. This combination of IoT and Android interfaces has been proven effective in managing food surplus in restaurants and households [8].

Moreover, the application of machine learning in food waste prediction and opti- mization further enhances the efficiency of these systems. Machine learning algorithms are being used to predict food wastage patterns, optimize food collection routes, and automate the matching of food supplies with needy recipients [12]. A notable example is the ”Development of Leftover Food Management System Using Efficient Hunger Search Techniques,” which employs intelligent algorithms to match surplus food with hunger-stricken populations, optimizing both the food recovery process and its distribution [6].

The integration of these technologies presents a promising future for food waste management systems, offering a more sustainable and scalable approach to address- ing the food waste crisis. However, challenges remain in the areas of data scarcity, system integration, and user adoption [5]. This paper reviews the current state of food waste management systems, comparing their methodologies, performances, and impact on food redistribution. By analyzing various studies and systems, such as

Fig. 1: Several food labels advertise their production to be sustainable.

”Food Waste Management Using Android” and ”A Web and Mobile-Based Approach to Redistribute Consumable Food Waste” [9, 11], we aim to identify gaps in the exist- ing systems and suggest pathways for future advancements in this critical field. Fig. 1 displays several examples of food labels that market the production of their products as being environmentally friendly [2].

1.1 Problem Statement

Food waste is a significant global issue, contributing to environmental degradation, economic loss, and hunger. Despite the availability of surplus food in various sectors, such as households, restaurants, and food supply chains, much of it is discarded instead of being redistributed to those in need. Traditional food waste management systems lack the efficiency, scalability, and real-time coordination necessary to address these issues effectively. With the rise of mobile technologies, IoT, and machine learning, there is an opportunity to develop innovative systems that streamline food redistribution and minimize waste, making the process more efficient, transparent, and accessible. This research aims to explore and evaluate the potential of such technologies to improve food waste management systems and optimize food redistribution.

1.2 Motivation

The motivation behind this research stems from the urgent need to tackle the dual challenges of food waste and hunger. Approximately one-third of all food produced globally is wasted, which not only strains environmental resources but also exacerbates food insecurity in underserved communities [1]. By leveraging advanced technolo- gies such as mobile applications, IoT, and machine learning, this research seeks to develop systems that can facilitate real-time food donations and optimize the logis- tics of food redistribution. Additionally, aligning with the United Nations Sustainable Development Goals (SDGs), especially SDG 2 (Zero Hunger) and SDG 12 (Responsi- ble Consumption and Production), provides a strong foundation for addressing these critical issues.

Table 1: List of Abbrevations and their full forms

Abbreviation	**Full Form**
SDG	Sustainable Development Goal
IoT	Internet of Things
ML	Machine Learning
NGO	Non-Government Organization
GPS	Global Positioning System
API	Application Programming Interface
JIT	Just in Time (Delivery)

B2B	Business to Business
UI	User Interface
UX	User Experience
FCS	Food Supply Chain

1.3 Critical Challenges in Food Management Systems

Food management systems face numerous critical challenges that limit their effective- ness, scalability, and overall impact. These challenges are primarily associated with data limitations, technological integration, stakeholder engagement, operational efficiency, and regulatory frameworks. The following analysis includes references from both the previously provided and the newly added studies.

- **Data Scarcity and Inconsistencies:** A major challenge in food management systems is the scarcity and inconsistency of data on food waste generation, distri- bution, and consumption. In many regions, particularly in developing countries, a lack of structured and reliable data hinders the development of accurate predictive models and decision-making tools [6, 17]. Without sufficient data, it becomes dif- ficult to monitor trends in food surplus or identify areas with urgent food needs. For instance, digital tools that rely on IoT sensors often face challenges in real-time data collection due to infrastructural gaps or resource limitations [8, 18].
- **Integration of Multi-Modal Data:** Integrating data from diverse sources, such as IoT devices, mobile applications, cloud databases, and blockchain systems, poses another critical challenge. Many systems struggle with ensuring interoperability among these components due to differences in data formats, communication pro- tocols, and system architectures [8, 19]. For example, blockchain-based platforms for supply chain transparency often require standardized data inputs, which are not always feasible in diverse environments [22]. This lack of seamless data integra- tion reduces the system's ability to make timely, informed decisions, affecting food redistribution efficiency [13].
- **Scalability and Efficiency:** While many food management systems perform well on a small scale, they often struggle to maintain efficiency when expanded to larger operations. Coordinating donations from multiple sources, such as house- holds, restaurants, and large-scale producers, introduces logistical complexities that existing systems are not always equipped to handle [5, 20]. For instance, AI-enabled supply chain systems can optimize routes and match donations effectively, but their implementation at a regional or global level remains a challenge due to resource constraints and technical limitations [27].
- **Food Safety and Quality Assurance:** Ensuring the safety and quality of donated food is another critical challenge, especially for perishable items. IoT sensors have been used to monitor food conditions such as temperature and humidity, but their adoption is not uniform across all food management systems due to cost and accessi- bility issues [8, 13]. Food safety regulations also vary widely by region, complicating the creation of a unified framework for quality assurance [17, 24]. These limitations can lead to the distribution of unsafe food, which poses health risks to recipients and undermines trust in the system.
- **Cost and Resource Constraints:** Implementing advanced food management sys- tems with IoT, AI, and blockchain technologies requires significant investment in infrastructure, devices, and skilled personnel [9, 25]. These costs are often prohibitive for small-scale organizations and NGOs, which limits the adoption of such systems in low-income regions [12, 18]. The operational costs associated with maintaining IoT devices, cloud storage, and data processing systems further add to the financial burden [19, 23].
- **Lack of Standardization in Technologies:** The absence of standardization in technologies used across food management systems leads to inefficiencies and dupli- cation of efforts. For example, blockchain systems require uniform data formats and integration protocols, which are not always compatible with existing IoT or cloud platforms [22]. Similarly, AI-based models often depend on high-quality, annotated datasets that are not readily available across all regions [19, 26].
- **Regulatory and Policy Challenges:** Regulatory frameworks and policies around food donation and waste management often act as barriers to effective system imple- mentation. In some regions, stringent food safety regulations discourage businesses from donating surplus food due to liability concerns [5, 22]. Additionally, inconsis- tent policies across different regions create challenges for multinational organizations looking to implement standardized food management systems [15, 22].
- **Stakeholder Engagement and User Adoption:** For food management sys- tems to succeed, they require active participation from donors, recipients, logistics providers, and other stakeholders. However, engaging all stakeholders consistently remains a challenge. Many potential users are hesitant to adopt these systems due to privacy concerns, lack of awareness, or perceived inefficiencies [7, 22]. Moreover, platforms with complex user interfaces or limited language options struggle to gain widespread acceptance, especially in diverse regions [10, 25].
- **Environmental and Sustainability Constraints:** While food management sys- tems aim to reduce waste, their operational processes, such as transportation and energy usage, can contribute to environmental challenges. Inefficient routing and resource-intensive

technologies, such as energy-demanding IoT sensors, may offset the sustainability goals of these systems [23, 27]. Addressing these concerns requires a balance between technological advancement and environmental impact.

1.4 Objective

Such is the disease Alzheimer's, which presents a huge public health challenge because it is irreversible and has very few therapeutic interventions. Early detection would be crucial to better outcomes. Current prediction methods suffer from accuracy, accessibility, and scalabil- ity problems. Machine learning advances, biomarkers, and imaging techniques have opened avenues of research; however, the consolidated insights regarding their individual and com- bined effectiveness in AD prediction are missing. This survey paper aims to fill this gap by systematically reviewing and analyzing recent innovations and limitations in key predictive methodologies, ranging from epigenetic biomarkers to artificial intelligence over imaging data and data science techniques. Through this review, we aim to achieve a comprehensive under- standing of current trends, challenges, and opportunities for advancement in early Alzheimer's disease prediction [14].

1.5 Scope of the research

The scope of this research focuses on the development and evaluation of advanced food waste management systems that integrate mobile applications, Internet of Things (IoT) technolo- gies, and machine learning to optimize the redistribution of surplus food. The research aims to explore how these technologies can be employed to improve the efficiency of food waste management by enhancing food donation coordination, monitoring food quality in real-time, and predicting food waste patterns. The use of mobile applications as a tool to facilitate donations and track real-time data is an essential part of this research, as these platforms enable seamless interactions between food donors, recipients, and logistics providers [3]. Fur- thermore, the integration of IoT technologies is explored to provide real-time monitoring and traceability of food, ensuring that donated food meets safety and quality standards while reducing food waste throughout the supply chain [8].

The research also delves into the application of machine learning to predict food waste trends and optimize donation logistics, with the goal of improving system scalability and efficiency. The inclusion of predictive models can help minimize food waste by optimizing

collection routes, matching food donations with recipients, and forecasting future waste gen- eration [6]. In this context, the research addresses critical issues such as scalability of the systems, ensuring they can handle large volumes of food donations across multiple regions. Additionally, the research explores the challenges of integrating multi-modal data, such as sensor data, user input from mobile applications, and backend databases, which is necessary for real-time decision-making and seamless coordination between stakeholders [5].

Another key aspect of the research is evaluating user adoption, exploring how mobile apps and IoT platforms can engage food donors, recipients, and volunteers. The research seeks to identify the barriers to widespread participation in food donation networks and proposes strategies to overcome these challenges, such as improving app usability, increasing awareness, and providing incentives for users to engage in food donation activities [8]. Ultimately, the scope of this research includes a detailed analysis of current food waste management practices, identifying gaps in existing methodologies, and proposing new approaches that integrate emerging technologies to create more efficient, scalable, and user-friendly systems for food waste reduction.

2. Literature Survey

Table 2: Literature Survey

S.no	Title	Author(s)	Journal & Year	Methodologies	Key Findings	Gaps
1.	Food Waste Man- agement Using Android [1]	Aashish Khandkar, Palomi Gawali, Ajay Aswar, Yashaswi, Yash Satpute	*Journal of Modern- ization, 2022*	Android-based app for food donation	Simplifies food donation and connects donors with recipients.	Lacks Scal- ability and features like ML
2.	Sustainable develop- ment goals through reducing food loss	Sobiya Man- zoor Iqra Bashir, Ufaq Fayaz,	*Journal of Future Foods, 2024*	Sustainability framework for reducing food waste	Links food waste reduc- tion to achieving SDGs like Zero Hunger	Provides conceptual insights but lacks practical implementa- tion.

	and food waste [2]	Aamir Hussain Dar			(SDG 2) and Responsible Consumption (SDG 12).	

S.no	Title	Author(s)	Journal & Year	Methodologies	Key Findings	Gaps
3.	Developing Food Charity Oper- ations Man- agement System [3]	Alblihed, Almutairi, Almah- moud, Aladhadh, et al.	*2022 ICCIT, IEEE*	Cloud-based operations management	Automated matching between donors and charities; real- time tracking and logistics.	Limited focus on multi- modal data inte- gration and real- world scalability.
4.	Food Wastage Man- agement Applica- tion Using Android Studio [4]	Sudheepa, Rashmitha, and Maran	*2023 ICAAIC, IEEE*	Android appli- cation for real- time food dona- tion tracking	User-friendly app enabling real-time donations and notifications.	Doesn't have proper match- ing algorithm
5.	A Web and Mobile-Based Approach to Redis- tribute Consum- able Food Waste [5]	Prova, Rayhan, Shilon, and Khan	*2021 ICC- CNT, IEEE*	Web and mobile plat- forms for food redistribution	Combines web and mobile features; geolocation for efficient logistics.	Limited use of predictive models for optimizing food waste management.
6.	Developmen of Left- over Food Man- agement System Using Efficient Hunger Search Tech- niques [6]	t GN, Jee- vith, Nukala, Kumar, Shankar, Kandarp	*2021 Mysu- ruCon, IEEE*	Hunger search algorithm for efficient food matching	Intelligent algorithms improve food redistribution efficiency.	Lacks large-scale deployment and advanced analytics.
7.	Optimizing Surplus Food Manage- ment: A User-Centric Appli- cation Approach [7]	Bharani, Mohanraj, Sujith, and Vinothku- mar	*2024 ICETITE, IEEE*	User-centric mobile application	Focus on usability and user engagement to enhance participation.	Limited inte- gration of IoT or ML for optimization.
8.	Food Waste Man- agement Using IoT and Android Interface [8]	Usharani, Puneeth, Suga- vanan, and Depuru	*2022 ICCIT, IEEE*	IoT-enabled system inte- grated with Android app	Real-time monitoring of food con- ditions; IoT sensors for food safety.	Limited scalability and lacks AI- driven decision- making.

9.	Developing Food Charity Oper- ations Man- agement System [9]	Alblihed, Almutairi, Almah- moud, et al.	*2022* *ICCIT, IEEE*	Operations management with cloud computing	Focus on logistics and automation to stream- line food donations.	Lacks predic- tive analytics and cross- platform integration.
10.	Smart Food Moni- toring System Based on IoT and Machine Learning [10]	Tutul, Alam, and Wadud	*2023* *NCIM, IEEE*	IoT for monitor- ing and ML for waste prediction	Combines IoT and ML to ensure food quality and predict waste patterns.	Implementation challenges in diverse environments.

3. Technologies Used

The papers analyzed explore various technologies employed to address food waste manage- ment, with a focus on leveraging mobile applications, Internet of Things (IoT), machine learning (ML), and cloud computing to optimize food redistribution and minimize waste.

3.1 Mobile Applications

Mobile applications serve as the cornerstone of modern food management systems, offering a digital interface for donors, recipients, and logistics providers to interact seamlessly. These applications simplify the process of donating food by allowing users to input details such as type, quantity, and location of surplus food. For instance, Android-based mobile applications are widely adopted due to their flexibility, affordability, and user-friendly design. Features like geolocation services help identify nearby food banks or recipients, reducing the time and cost involved in food redistribution [4]. Notifications and alerts keep users informed about food availability and redistribution statuses, ensuring timely action. Additionally, mobile apps often integrate with backend databases, which store donation histories, user profiles, and real-time inventory data, enabling efficient tracking and management of food resources [10]. The ease of use and accessibility of these applications significantly increase user engagement, particularly in urban areas where digital literacy is high. However, in regions with limited internet connectivity or low smartphone penetration, the adoption of mobile applications remains a challenge, necessitating complementary offline solutions or hybrid systems [7].

```
# User inputs their food surplus into the mobile app
food_surplus = input_user("Enter type and quantity of food")

# App matches the food surplus with nearby food banks or
    recipients
nearby_food_banks = find_nearby_food_banks(user_location)

# Send donation request to matched food banks
send_donation_request(nearby_food_banks, food_surplus)
```

The pseudo-code begins by collecting information about the food surplus, which includes details like the type of food and quantity. The application then uses geolocation services to determine the donor's location and identify the nearest food bank or recipient in need. Once a match is found, the application sends a donation request to the identified food banks or recipients, allowing them to accept or arrange for the pickup. This process ensures that food donations are made in a timely manner, reducing food waste. The use of mobile applications in food waste management simplifies the donation process, making it accessible to a wider range of people and increasing participation in food redistribution efforts.

3.2 Internet of Things

IoT technology is integral to maintaining the safety and quality of food during storage and transportation. IoT-enabled sensors monitor critical parameters such as temperature, humid- ity, and freshness, providing real-time data to ensure that food remains consumable. For example, temperature sensors are particularly useful for perishable items like fruits, vegeta- bles, dairy products, and meat, where small deviations from optimal conditions can lead to spoilage. The collected data is transmitted to cloud platforms for storage and analysis, enabling stakeholders to act promptly when anomalies are detected [8]. IoT devices also enable predictive maintenance of storage facilities by identifying potential equipment failures before they occur, ensuring uninterrupted cold chain operations [[13]. Furthermore, IoT tech- nologies play a pivotal role in automating inventory management, reducing manual errors, and increasing operational efficiency. Despite these advantages, the implementation of IoT systems often encounters barriers such as high initial costs, the need for technical expertise, and the lack of standardized communication protocols, which can complicate data integration with other systems [19].

```
Start
Initialize IoT sensor for temperature monitoring
While food is in storage do
    Read sensor data
    If temperature exceeds threshold then
        Trigger alert
        Log data to cloud
    End
End
```

IoT devices, such as temperature sensors, continuously monitor the condition of stored food to ensure its quality. If the sensor detects that the temperature exceeds a predefined safe threshold, an alert is triggered, and the data is logged into a cloud database. This helps prevent spoilage by enabling timely corrective actions, such as adjusting storage conditions or prioritizing redistribution of the affected food.

3.3 Machine Learning

Machine learning has emerged as a powerful tool in food management systems, enabling predictive analytics and intelligent decision-making. ML algorithms are trained on historical data to identify patterns in food waste generation, optimize collection routes, and improve donor-recipient matching. For example, ML models can predict the likelihood of food surplus in specific locations, allowing logistics teams to plan redistribution efforts more effectively [6]. These algorithms also prioritize donations based on factors such as urgency, proximity, and the type of food, ensuring that perishable items are distributed first. In addition to logistics optimization, ML is used to analyze consumer behavior and forecast food demand, helping food banks and retailers minimize waste by adjusting their inventories accordingly [13]. The integration of ML in food management systems significantly reduces operational costs and enhances resource utilization. However, the accuracy of ML models heavily depends on the availability and quality of data, which can be a limitation in regions where data collection is inconsistent or incomplete [22].

```
Start
Load historical food waste data
Preprocess data (clean, normalize)
Split data into training and testing sets
Train model using ML algorithm
Evaluate model with testing set
If model accuracy > threshold then
    Deploy model for waste prediction
End
```

Machine learning models are used to analyze historical food waste data and predict future patterns, enabling proactive redistribution strategies. The data undergoes preprocessing to ensure it is clean and standardized before being split into training and testing datasets. The model is trained on the training data and evaluated using the testing data. If the model's performance meets the required accuracy threshold, it is deployed to predict waste patterns or optimize donation logistics in real-time scenarios.

3.4 Geolocation and Mapping Services

Geolocation services are essential for optimizing the logistics of food redistribution. These services use GPS technology to identify the shortest and most efficient routes between donors, food banks, and recipients, minimizing transportation time and costs. Geolocation-enabled platforms can dynamically adjust routes based on real-time traffic conditions, ensuring timely delivery of perishable items [5]. In addition to route optimization, geolocation services help identify potential recipients within a specified radius of a donor, facilitating local redistribu- tion efforts. This capability is particularly useful in urban areas with high population density, where food demand and supply can vary significantly across neighborhoods. While geoloca- tion services improve operational efficiency, they rely heavily on accurate mapping data and stable internet connectivity, which may not always be available in remote or underdeveloped regions [19].

```
Start
Capture donor's location
Search for recipients within a specific radius
If recipient found then
    Calculate shortest route
    Send location details to logistics
End
```

Geolocation services are used to locate food recipients near a donor's location within a specific radius. Once recipients are identified, the system calculates the shortest route between the donor and the recipient. This optimized route information is then shared with the logistics team, ensuring efficient and timely transportation of food items while minimizing delays and costs.

3.5 Artificial Intelligence (AI)

Artificial Intelligence enhances the decision-making capabilities of food management systems by processing large datasets and generating actionable insights. AI-driven systems are used to optimize food redistribution by analyzing factors such as donor and recipient locations, food types, and urgency levels. For example, AI algorithms can recommend the best match for a surplus food item, considering parameters like proximity, nutritional needs, and stor- age requirements [13]. In addition to logistics, AI is employed to analyze historical data on food waste and consumption patterns, enabling systems to predict future needs and adjust resource allocation dynamically. AI-powered chatbots and virtual assistants further improve user engagement by providing instant responses to queries and facilitating smoother interac- tions with the system. Despite its potential, AI implementation is often constrained by the high computational costs and the need for large, high-quality datasets, which may not be readily available in all regions [23].

```
Start
Collect data from IoT sensors, mobile apps, and user interactions
Feed data into AI model
Generate insights (e.g., food matching, optimized routes)
If new food item added then
    Recommend best match (recipient/location)
End
```

Artificial Intelligence integrates data from IoT sensors, mobile apps, and user interactions to generate actionable insights. These insights may include matching surplus food to the most suitable recipients or identifying the optimal delivery route. When a new food donation is added, the AI model evaluates available recipients and logistics options to recommend the best match based on parameters such as urgency, location, and food type, ensuring efficient redistribution.

4. Benchmarks

The reviewed literature highlights several benchmarks that are pivotal in developing efficient food waste management systems. These benchmarks span across technologies, methodologies, and applications, offering valuable insights into best practices and areas for improvement.

One benchmark is the effective use of mobile applications for food donation coordination. Studies have shown that Android-based platforms provide a user-friendly interface for donors and recipients, enabling real-time tracking and seamless communication [4]. The use of noti- fications to alert recipients about available food ensures timely redistribution and minimizes wastage, setting a standard for usability and responsiveness in mobile applications [10]. How- ever, these systems are primarily focused on small-scale operations, highlighting a need for scalability in future implementations [5].

Another critical benchmark is the integration of IoT technologies to monitor food quality. IoT-enabled sensors for temperature and humidity tracking have proven effective in main- taining the safety and quality of perishable food during storage and transportation [8]. These sensors provide real-time data, which can trigger alerts if food conditions deviate from safety thresholds, reducing spoilage [13]. The deployment of IoT devices in food management sys- tems establishes a benchmark for real-time monitoring and automation, crucial for handling large-scale operations [12].

Machine learning (ML) presents another important benchmark by enabling predictive analytics for food waste management. ML models trained on historical data have been used to forecast food waste patterns, optimize collection routes, and improve donor-recipient matching [6]. These predictive capabilities enhance the efficiency of food redistribution by minimizing delays and prioritizing donations based on urgency and proximity [13]. The incor- poration of ML algorithms into food management systems sets a standard for data-driven decision-making, which significantly improves logistical planning [9].

Cloud computing serves as a benchmark for managing data at scale. By providing scalable storage and processing capabilities, cloud platforms enable real-time synchronization of data among multiple stakeholders, including donors, food banks, and logistics teams [9]. This inte- gration ensures that all parties have access to updated information, improving transparency and coordination [15]. The use of cloud-based systems establishes a benchmark for reliability and scalability in food management networks, especially in handling large datasets from IoT devices and mobile apps [12].

The implementation of geolocation services is another notable benchmark. These services allow food waste management systems to calculate the shortest routes for food transporta- tion, reducing delivery times and costs [15]. Geolocation-enabled platforms help identify the nearest recipients, ensuring that surplus food is distributed efficiently and minimizing the environmental impact of redistribution [8]. This sets a benchmark for optimizing logistics in food management systems, particularly in urban areas where transportation is a major constraint [11].

Finally, stakeholder integration is highlighted as a benchmark in several studies. Sys- tems that involve multiple stakeholders, including donors, recipients, NGOs, and logistics providers, demonstrate higher efficiency and broader reach [15]. Web-based platforms that facilitate collaboration and communication among stakeholders have been successful in streamlining food donation processes, ensuring equitable distribution and reduced waste [9]. This sets a standard for designing inclusive systems that cater to the needs of diverse participants in the food redistribution chain [7].

5. Results and Discussions

The survey of existing food management systems revealed significant findings in terms of their evaluation metrics, performance, and overall impact on addressing food waste and redistribution.

5.1 Evaluation Metrics

The effectiveness of food management systems is often measured using several evaluation metrics. These metrics focus on usability, scalability, efficiency, and technological integration, as observed in the reviewed studies.

- **Usability:** Usability is a critical metric to evaluate the adoption and user- friendliness of mobile applications in food management systems. Studies highlighted that Android-based applications with intuitive interfaces are preferred for food dona- tion and recipient coordination [4, 10]. User engagement rates and the simplicity of the interfaces directly influence the success of these systems[7].
- **Efficiency of Food Redistribution:** Efficiency is typically assessed based on the time taken to match donors with recipients and deliver surplus food. Systems that integrate geolocation and IoT technologies demonstrate significantly faster redis- tribution times by optimizing routes and automating food condition monitoring [5, 8].
- **Food Safety:** The reliability of IoT sensors for real-time monitoring of food con- ditions (e.g., temperature, humidity) is a vital metric to ensure that only safe food is distributed. Benchmarks for food safety are often set based on compliance with regional and international standards [13, 17].
- **Scalability:** Scalability metrics evaluate how well the system can handle an increas- ing number of users, donations, and data. Cloud-based systems and AI models are particularly effective in ensuring scalability without performance degradation [9, 19].
- **Environmental Impact:** Environmental metrics, such as carbon footprint reduc- tion and energy efficiency, assess how systems contribute to sustainability goals. Efficient route planning using geolocation and the use of low-energy IoT devices are key factors in minimizing environmental impact [22, 27].

5.2 Performance Analysis

Performance analysis of food management systems highlights key factors such as efficiency, scalability, food safety, user engagement, and environmental impact. Efficiency is a critical parameter, as it determines how quickly surplus food can be redistributed from donors torecipients. Systems that integrate geolocation services and IoT technologies perform excep- tionally well in optimizing logistics and reducing delays. For example, geolocation-enabled platforms use real-time mapping to calculate the shortest routes, ensuring timely delivery of food while minimizing transportation costs and carbon emissions [5]. IoT devices, on the other hand, monitor food conditions such as temperature and humidity during storage and tran- sit, enabling proactive interventions to prevent spoilage and reduce waste [8]. These features collectively enhance the overall operational efficiency of food management systems.

Scalability is another essential aspect of performance, as food management systems must accommodate increasing volumes of food donations and user participation over time. Cloud- based systems provide a high degree of scalability by enabling seamless data storage and processing across multiple stakeholders, including donors, recipients, and logistics teams [9]. These systems can handle large datasets generated by IoT devices and mobile applications without compromising performance, making them ideal for large-scale food redistribution net- works. Similarly, AI-powered systems exhibit strong scalability through predictive analytics, which optimizes food collection routes and matches donations to recipients based on urgency and proximity [6]. However, achieving scalability often requires substantial infrastructural and computational resources, which may be a barrier in low-resource settings [19].

Food safety is a critical benchmark for performance, particularly when dealing with per- ishable items. IoT-enabled systems that incorporate sensors for real-time monitoring of food conditions have set a high standard in ensuring that only safe food is distributed [13]. These systems help identify and address risks such as spoilage or contamination, which are common challenges in food redistribution. Blockchain-based systems further enhance food safety by creating a transparent and traceable record of food supply chains, ensuring compliance with safety standards and building trust among stakeholders [22]. Despite these advancements, the cost of implementing and maintaining these technologies can limit their adoption in smaller organizations or regions with constrained resources [27].

User engagement plays a significant role in the success of food management systems, as active participation from donors, recipients, and logistics providers is essential for efficient operations. Mobile applications with intuitive interfaces and real-time notification systems demonstrate high levels of user engagement, making them effective tools for coordinating food donations and requests [7]. However, user adoption is often hindered by factors such as lack of awareness, limited language support, and privacy concerns [10]. Addressing these challenges requires systems to focus on user-centric design and provide incentives for participation, which can significantly enhance their effectiveness [19].

Environmental impact is increasingly being recognized as a key performance indicator for food management systems. Efficient routing and energy-saving IoT devices contribute to reducing the carbon footprint associated with food redistribution [23]. Systems that pri- oritize sustainability in their operations align with global goals to mitigate climate change while addressing food waste [27]. However, balancing technological advancements with envi- ronmental considerations remains a challenge, particularly for energy-intensive solutions like blockchain and AI [22].

Table 3: Performance of various food management systems

S.no	System	Key Tech- nologies	Efficiency	Scalability	Food Safety	User Man- agement
1.	Android- Based Food Donation Apps	Android, Notifica- tions	High [4, 10]	Moderate [9]	Moderate [13]	High [7, 10]
2.	IoT- Enabled Food Safety Systems	IoT Sen- sors, Cloud	High [8, 13]	Low to Moder- ate [8]	High [13]	Moderate [19]
3.	Blockchain for Sup- ply Chain Trans- parency	Blockchain, Geoloca- tion	Moderate [22]	High [22]	High [22]	Moderate [22]
4.	Cloud- Based Oper- ations Manage- ment	Cloud, Multi- modal Integra- tion	High [9, 19]	High [9, 20]	Moderate [19]	High [7]

6. Challenges and Limitations

The reviewed survey papers identify various challenges and limitations in food management systems that hinder their efficiency, scalability, and widespread adoption. One significant challenge is the lack of reliable and consistent data on food waste generation, distribu- tion, and consumption. Inadequate data limits the development of predictive models, affects decision-making processes, and hinders optimization of logistics for redistribution. This issue is particularly acute in developing regions where food waste records are often incomplete or unavailable, making it difficult to implement data-driven solutions effectively [6, 9]. The absence of real-time tracking and analytics further exacerbates inefficiencies, resulting in missed opportunities for timely food redistribution [13, 19].

Another limitation lies in the integration of multi-modal data from diverse sources such as IoT devices, mobile applications, and cloud databases. Ensuring interoperability among these technologies remains a significant challenge due to inconsistencies in data formats, commu- nication protocols, and system architectures. For instance, IoT sensors generate substantial amounts of real-time data, but integrating this with mobile applications and cloud platforms often requires advanced infrastructure and technical expertise [8, 22]. Such challenges lead to inefficiencies in data processing and delayed decision-making, reducing the effectiveness of food management systems.

Scalability issues are also prevalent, as many food management systems are designed for small-scale operations and struggle when scaled to larger networks. Coordinating food donations and distributions across multiple regions introduces logistical complexities that existing systems are often ill-equipped to handle [5, 20]. For example, while cloud-based systems and AI models provide strong scalability, they require significant computational and financial resources, making them inaccessible for smaller organizations and low-resource settings [9, 27].

Food safety remains a critical limitation, especially when dealing with perishable items. IoT-enabled systems have shown promise in monitoring food conditions, but their adoption is constrained by high costs and limited availability in certain regions. Without adequate monitoring tools, the risk of distributing spoiled or unsafe food increases, undermining trust in the system [8, 13]. Additionally, blockchain-based systems that enhance transparency and traceability face barriers to implementation due to their high computational requirements and the need for standardization across stakeholders [22].

User adoption and engagement are also recurring challenges. Many users, including donors and recipients, are hesitant to adopt food management platforms due to usability concerns, privacy issues, and lack of awareness. Systems with complex interfaces or limited language support struggle to engage a diverse user base, particularly in regions with varying levels of digital literacy [7, 10]. Furthermore, the absence of incentives for user participation often leads to reduced engagement, limiting the impact of these systems [15, 25].

Regulatory and policy challenges further complicate the implementation of food manage- ment systems. In some regions, stringent food safety regulations discourage businesses from donating surplus food due to liability concerns. Additionally, inconsistent legal frameworks across regions create barriers for organizations operating at a global scale, making it difficult to establish standardized processes for food redistribution [5, 24].

Environmental sustainability is another critical area where food management systems face limitations. Although these systems aim to reduce food waste, their operations, such as transportation and energy-intensive technologies like blockchain and IoT sensors, can contribute to environmental challenges. Balancing the need for advanced technologies with sustainability goals remains a key challenge for future systems [23, 27].

7. Conclusion and Future Scope

In conclusion, food management systems are a crucial tool in combating food waste and ensuring the equitable distribution of surplus food. The integration of technologies such as mobile applications, IoT, AI, cloud computing, and blockchain has shown significant promise in improving the efficiency, scalability, and safety of these systems. However, despite these advancements, challenges such as data scarcity, system integration, scalability, food safety, and user engagement continue to limit the widespread effectiveness of these systems. The success of food management systems heavily depends on overcoming these barriers through innovation, collaboration, and the development of robust infrastructure.

Looking ahead, there is a strong need for enhanced integration of emerging technologies like machine learning and blockchain to predict food waste patterns and ensure transparent food distribution networks. The scalability of systems needs to be improved to handle large- scale operations across different regions and stakeholders. Furthermore, addressing the cost barriers and regulatory hurdles will be essential to increasing the adoption of these systems, especially in low-resource settings. Future advancements could focus on refining AI-driven predictive models, improving food safety measures through more affordable IoT solutions, and creating more user-centric interfaces to engage a broader population. Additionally, integrat- ing sustainability goals into food management systems, such as reducing the environmental impact of logistics and operations, will be critical to achieving long-term effectiveness. As the technology landscape evolves, food management systems are expected to play a vital role in achieving global sustainability targets while tackling the pressing issues of food waste and hunger.

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