Engineering Degree Project

Food Waste Management Through Data Entry and Visualization
-KalmarFoodSavior a web platform for Kalmar Municipality

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Semester: Spring 2024
Subject: Computer Science
Abstract

This study investigates the creation of a web platform for managing food waste, with an emphasis on web design principles, client-server architecture, database storage options, and data visualization methods. The problem investigated involves managing and visualizing food waste data efficiently to facilitate decision-making and waste reduction. The goal is to address the critical worldwide issue of food waste and the necessity for effective IT solutions to combat it. To answer the problem of inefficient food waste data management and visualization, research was conducted on various technical aspects, followed by the implementation of frontend and backend frameworks. This research resulted in the development of a user-friendly interface, comprehensive data visualization capabilities, and robust database management capabilities.

Keywords: food waste management, web platform, client-server architecture, data visualization, food waste representation, total food waste.
Preface

The authors would like to thank our supervisor at Linnaeus university, -Neda Maleki for her assistance in guiding us with helpful tips and useful information. We would also like to thank Marcus Kindah at Kalmar Municipality for his encouragement and interest in the project.
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A Appendix 1
1 Introduction

Food waste is a silent but serious issue that exists in the busy kitchens of Kalmar Municipality’s hospitals and schools. Not only do unmanaged heaps of leftovers put a strain on budgets, but they also contribute to environmental destruction. This pressing concern necessitates a solution. Outdated data entry systems have further complicated waste management efforts in Kalmar Municipality. The initiative seeks to provide a comprehensive solution in order to address these issues head-on. By creating a web platform with user-friendly tools and streamlining data entry, it enables a more efficient and streamlined operation for the kitchen staff. The project also aims to encourage change by implementing incentives for waste reduction initiatives and presenting food waste patterns through interactive charts and visualizations.

1.1 Background

Food waste is a significant issue in Sweden’s schools, preschools, and elderly care homes. Based on statistics from 184 towns, Livsmedelsverket’s 2023 survey reveals that schools waste 56 grams of food per student per lunch, preschools waste 71 grams per child, and senior care facilities waste 108 grams per person per meal. Among the most important components of food waste are serving waste (food that doesn’t reach the plate), plate waste (food thrown away from the plate), and kitchen waste (food discarded during preparation). In elderly care homes, serving waste averages 59 grams per person, while plate waste averages 30 grams per student in secondary schools. Approximately 9 grams of kitchen waste are generated per portion [1].

The current food waste management procedures in Kalmar Municipality schools and other institutions are inefficient, relying heavily on error-prone Excel-based, because the shared access to these files means that users can accidentally alter or input data from other kitchens, leading to frequent errors and diminished data reliability. Visualization and charts can help to find patterns and trends in food waste, which facilitates decision-making. Creating charts in Excel presents several issues when displaying data as part of existing food waste management practices, including being time-consuming, especially with substantial data requiring frequent revisions. Inaccurate representations and conclusions might result from errors in data entry or chart setup. Data inconsistency can occur when several people edit the same Excel file. Charts that are not trustworthy may be the consequence of users inadvertently replacing or modifying data from other kitchens. Despite Excel’s robust capabilities, its charting features can be complex and may require a certain level of experience to use effectively. It’s possible that many employees lack the skills needed to produce precise and insightful infographics. Due to the lack of experience, only a select few people are able to complete this duty successfully. Viewing the data and graphics requires access to the Excel file. This restricted accessibility may make it more difficult for departments or kitchens to collaborate transparently. To address the challenges posed by traditional methods such as Excel spreadsheets, there is a need to adopt alternative technologies or methods that simplify data entry processes and enhance accuracy. This is crucial because traditional approaches are prone to human error and can be difficult to validate [2].

1.2 Related work

Simplifying data entry and visualization procedures is the main goal of this project in order to combat food waste in kitchens. Numerous research offer insightful information and approaches that support the objectives of the project.
One of these studies is the research by Hsu, Yen, Pai and Chang, which created a health management application using QR-code technology. Their study, "A Health Management Application with QR-Code Input and Rule Inference" [3] demonstrates the advantages of using QR codes to scan codes, which can help with data entry automation. The work of Hsu and Chang emphasizes how important it is to have excellent data input techniques in order to improve user experience and efficiently manage information connected to food.

An additional significant contribution is from Dogan, Asan, Haas, Michalek, Akkan, and Bulut, who introduced the MySusCof app. Their study, "Designing and Implementing the MySusCof App—A Mobile App to Support Food Waste Reduction" [4] highlights user interaction with gamification features and an easy-to-use UI. This strategy emphasizes how crucial user-centric design is to encouraging involvement in programs aimed at reducing food waste.

Additionally, using consumer awareness interventions, Soma, Li, and Maclaren investigated behavioral strategies for reducing food waste. In their study, "Food Waste Reduction: A Test of Three Consumer Awareness Interventions" [5]. They draw attention to how well gamification and instructional strategies work to encourage environmentally friendly consumer behavior. Their findings underscore the role that behavioral interventions play in encouraging positive changes in food waste patterns.

1.3 Problem formulation

As mentioned in the section Related Work, various studies address food waste through technological and behavioral approaches. These works underscore the potential of individual interventions but do not provide a unified solution tailored for institutional kitchens in Kalmar Municipality. While existing literature and related work may explore aspects of food waste management, there is a notable gap in the development of web platforms adapted specifically for institutions within Kalmar Municipality. This project aims to bridge this gap by creating a web platform with a user-friendly interface for real-time data handling that addresses the specific needs and challenges of these institutions.

The project is subject to a number of limitations, including making sure the system is simple to use and intuitive for kitchen staff members with different levels of technical proficiency. Furthermore, it is imperative to have data protection standards, particularly when managing passwords and critical user authentications.

Research questions to investigate:

- How does the implementation of a web platform with user-friendly tools affect the efficiency of food waste management in Kalmar municipality’s schools?

- How does the visualization of food waste data improve the comprehension and decision-making capabilities of kitchen staff compared to the traditional use of a basic Excel file?

The system will increase transparency by making data and visualizations accessible to all stakeholders, including students and kitchen staff, promoting cooperation and best practices in waste reduction. It provides immediate insights into food waste data, supporting proactive techniques like inventory and portion control, and reducing human error through visual analytics for identifying and addressing waste patterns.
1.4 Motivation

Sweden wastes more than 600,000 tons of food every year according to Kalmar municipality, which has a significant effect on the carbon footprint. Kalmar schools are actively engaged in several initiatives to address this problem because they understand the advantages of reducing food waste for the economy and the environment [6]. Students are taught how to prevent food waste through classroom exercises and kitchen practices. Food waste is frequently monitored, with an annual reduction goal in mind. This project intends to supplement the Kalmar municipality’s current food waste programs by offering easily navigable tools for tracking and assessing food waste throughout the Municipality.

By this web platform, students and community members will have easier access to data on food waste levels, which will enable better tracking of progress and identification of areas for improvement. This will simplify food waste management, provide learning opportunities for students, and increase community understanding of the value of waste reduction. The initiative uses cutting-edge technology and educational tools to encourage people to take proactive measures toward a more sustainable future for the community.

There are detailed reasons provided by various studies for why it is important to minimize food waste:

- **Environmental Impact:** Every year, over 88 million tonnes of food are wasted in the European Union, causing severe environmental damage throughout the food supply chain. Based on over 134 previous Life Cycle Assessment (LCA) studies of certain typical items, the environmental implications of food waste in Europe account for 15-16% of the overall environmental impact of the food supply chain. The study reveals that nearly three-quarters of the Global warming potential impacts originate from greenhouse gas emissions during the primary production stage. Food processing (6%), retail and distribution (7%), food consumption (8%), and food disposal (6%) all contribute to the overall impact of food waste [7].

  Food waste contributes significantly to a variety of environmental issues, including acidification, eutrophication, and global warming. Transportation and food production are two major sources of other environmental pollutants and greenhouse gas emissions [7]. A research paper called “Food waste at school. The environmental and cost impact of a canteen meal” [8] reveals that the existence of animal-based food categories, as well as the energy necessary for food preparation, account for the majority of canteen meals’ environmental impact. Therefore, by reducing the necessity for food production and energy consumption, decreasing food waste can help mitigate these environmental consequences.

- **Labor and Cost Implications:** Food waste affects the budgets. Lower food waste results in cost savings for all aspects of meal preparation, including buying, cooking, and throwing away food. For instance, labor costs incurred during meal preparation account for a sizable portion of the total cost of the meal. Reducing food waste can also lead to cheaper expenditures overall by cutting the cost of food procurement and trash disposal [9].
1.5 Milestones

Additionally to this milestone, having regular meetings with the supervisors, and writing the report.

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Description</th>
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<tbody>
<tr>
<td>M1</td>
<td>Evaluate different programming languages, databases and visualizations suitable for projects development.</td>
</tr>
<tr>
<td>M2</td>
<td>Initialize the backend and frontend of the project with necessary dependencies.</td>
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<tr>
<td>M3</td>
<td>Develop client side pages including home page header and footer.</td>
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<tr>
<td>M4</td>
<td>Configure and start developing the server side.</td>
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<tr>
<td>M5</td>
<td>Define database schema, establish the connection to it and create tables.</td>
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<tr>
<td>M6</td>
<td>Develop login and registration components.</td>
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<tr>
<td>M7</td>
<td>Implement the food management page with a calendar and add edit and show functionality to it.</td>
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<tr>
<td>M8</td>
<td>Develop visualization pages using different libraries.</td>
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<tr>
<td>M9</td>
<td>Finish the implementation of other pages.</td>
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<tr>
<td>M10</td>
<td>Test, verify data consistency and application performance.</td>
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<tr>
<td>M11</td>
<td>Controlled experiments with volunteers</td>
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1.6 Scope/Limitation

Scope: The primary purpose of this project is to build a website for food waste management that includes a user-friendly interface, a robust backend, and a database. To guarantee reliability, error-checking and data validation are performed. Each kitchen can modify and add their own statistics, and the system provides numerous charts and graphs to compare performance and discover the best schools and tactics for decreasing food waste. Furthermore, the website encourages waste reduction measures through incentives such as inter-school competitions and provides real-time data on food waste patterns.

Limitations: Not all approaches to food waste management, particularly those used in residential settings, are compared in the study. Rather, the focus is on data from hospitals and schools and other kitchens, which is consistent with the project’s objectives. Instead of providing a basic architecture for food waste management websites, the idea is to give a tailored solution for a specific product or situation. In other words, the project does not involve a large sample of the population for this study. Rather, in accordance with the study’s objectives, it focuses the analysis on Kalmar Municipality. The quality and availability of statistics are heavily dependent on data provided by kitchen staff, which may change and alter the accuracy of the conclusions.

1.7 Target group

The target groups interested in this project include:

- Municipalities and Public Institutions: Kalmar Municipality and other organizations in charge of handling food waste in public spaces like schools and hospitals would find the proposal to be pertinent. The features and resources on the website can help them reduce waste and handle data more efficiently.
• Environmental Organizations: Organizations committed to sustainability and environmental preservation would be interested in the initiative’s possible impact on reducing food waste. They might try to collaborate or provide assistance to initiatives like this project promote sustainable food management practices.

• Educational Institutions: schools and training centers that teach sustainability, environmental studies, or food management may use the effort as a case study or real-world example. It could serve as a teaching tool to assist students in comprehending the need of reducing waste and the ways in which technology can support the attainment of sustainability goals.

1.8 Outline

The remaining chapters of this project’s report are as follows:

Chapter 2 covers foundational concepts such as food waste management, UI design principles, data visualization techniques, and specific software tools, forming the theoretical basis for the project.

Chapter 3 details the methodologies used for implementation.

Chapter 4 demonstrates the project’s practical execution, including setting up the development environment, creating frontend and backend components, configuring the database, and enabling user authentication.

Chapter 5 presents the experimental setup and results, showcasing the system’s effectiveness in user interface, data management, and visualization.

Chapter 6 assesses key decisions like choosing MySQL over MongoDB and using React for frontend development, as well as integrating Chart.js and D3.js for visualization.

Chapter 7 discusses the achievement of project objectives, compares results to current techniques, and suggests future enhancements such as machine learning and IoT integration.

Chapter 8 summarizes achievements and their value, proposing improvements like machine learning and mobile app extensions for better food waste management and sustainability.

The appendix includes screenshots and details about the system’s pages.
2 Theory

This section covers the significance of data management, the function of visualization in identifying waste trends, and the software tools that can help with these procedures.

2.1 Food Waste Management

Reducing food waste and maximizing its usage are examples of sustainable practices. Food waste management is a crucial aspect of sustainability [7]. The state of food waste management in developing countries today and in the future point to the critical need for long-term fixes that can alleviate the growing problem of food waste while fostering positive social and environmental effects [10]. Because food waste affects not just the environment but also the economy and society, it is a complicated issue that requires all-encompassing solutions.

Food waste management is challenging due to a lack of information on waste quantities, the environmental impact of various disposal techniques, consumer behavior, and challenges in assessing the environmental implications. Effective solutions require consumer involvement, data-driven efforts, sustainable technologies, and thorough assessments of the environmental effects [7].

2.2 User Interface Design

Making aesthetically pleasing and simple-to-use interfaces for digital devices and applications is known as user interface (UI) design. Ensuring easy and enjoyable interface interaction for users is the aim [11].

2.2.1 Key Principles of User Interface Design

Usability is essential, ensuring the interface is easy to understand, navigate, and use. It should be logically organized with clear, consistent labeling and navigation, allowing users to complete tasks quickly without extensive learning. Clarity ensures the interface is readable and straightforward, using a limited color palette, simple typography, high-contrast colors, and plenty of white space. Flexibility allows users to customize the interface to suit their needs, making it responsive to different screen sizes and providing options to change the color scheme or layout. Consistency helps users navigate more easily by maintaining uniform layout, typography, and color schemes, and aligning with familiar interfaces like operating systems or web browsers. Feedback is crucial for helping users understand their actions, providing clear responses such as highlighted buttons, error messages, and visual cues like animations and icons. These principles of UI design are illustrated in Fig. 2.1, which provides a visual representation of these key concepts. The figure highlights the importance of usability, clarity, flexibility, consistency, and feedback in creating effective user interfaces. [12].
2.2.2 User Interface Design Elements

UI elements are the fundamental components of digital interfaces, focusing on visual appeal and user interaction. Key elements include buttons, menus, icons, layouts, and color schemes, which must be attractive and functional. Effective UI design principles involve simplicity, accessibility, responsiveness, consistency, error prevention, user-centered design, and user feedback. These principles ensure a seamless, intuitive user experience by prioritizing usability and visual aesthetics [13].

2.3 APIs

An Application Programming Interface (API) is a set of protocols, tools, and definitions that enables software applications to connect with one another [14] [15]. Basically, APIs enable developers to request and exchange data between various systems or components, which promotes integration and interoperability. In order to check the weather on your mobile device, your mobile app is likely using an API to retrieve weather data from a remote server. Typically, this involves HTTP requests to an endpoint to retrieve JSON or XML data. APIs provide developers with the opportunity to leverage existing functionalities and services without having to dig into their inner workings by abstracting the complexities of underlying implementations. As a result, APIs are essential to modern software development, allowing for modularity and reusability while reducing development time and costs [14]. A client and a server implement HTTP. By exchanging HTTP messages, these two applications as shown in the figure below communicate with one another. The format of these messages and the message exchange between the client and server are specified by HTTP [16].
RESTful APIs in Web Development

In web development, RESTful APIs are becoming increasingly common. HTTP requests are used to access and manipulate data as part of the REST architectural style. RESTful APIs follow a set of constraints, including statelessness, in which each request from a client contains all of the information required by the server to fulfill the request, and resource representation, in which resources are identified by URLs and can be manipulated using standard HTTP methods such as GET, POST, PUT, and DELETE. RESTful APIs are a popular choice among developers designing web services due to their simplicity and adherence to standard web protocols. RESTful principles’ clear structure and widespread use make it easier to build scalable and maintainable web applications [15].

Data Visualization

Data on food waste can be effectively interpreted and comprehended with the use of data visualization. Making informed decisions is made easier when data is presented in graphical ways, which highlight patterns and trends. Visualization helps in better understanding and analyzing data by transforming tabular data into visual formats, allowing staff to grasp complex data more quickly and accurately. With the right visualizations, staff can identify trends, patterns, and anomalies in the data more easily, leading to better-informed decision making [17]. For example, line charts might be more suitable for tracking changes over time, while bar charts could be better for comparing quantities.

Visualization Tools

Interactive charts and dashboards can be made with a variety of visualization tools and libraries. These tools aid in emphasizing important indicators and pinpointing places where waste management procedures need to be improved. Dashboards provide a consolidated view of all relevant data, enabling real-time monitoring and timely decision-making. They can display various indicators, such as daily food waste and compliance with waste reduction targets, allowing staff to track progress and identify areas needing attention [18].

Chart.js: Pie, line, and bar charts are just a few of the many types of charts that can be created with the help of the straightforward yet adaptable JavaScript library Chart.js. It is especially helpful for building interactive visualizations that show trends in food waste over time. [19]

D3.js: Data-Driven Documents, or D3.js, is a powerful JavaScript library for creating complex and dynamic visualizations. It allows to connect data to a Document Object Model (DOM)
2.5.2 The Importance of Data Visualization

Effective comprehension and communication of complex data in program evaluation and commercial contexts depend on data visualization. According to the CDC’s guide on "Data Collection Methods for Program Evaluation: Visualizing Data," visualizations such as graphs and charts make it easier for stakeholders to understand the data and quickly and readily extract important insights [21]. The use of these visual tools not only enhances analysis and decision-making by highlighting patterns and trends that may be obscured in raw data, but also enhances interpretation of the information in an engaging and clear manner. Similarly, in commercial environments, charts are essential for visually explaining complicated data relationships. Charts, which combine text, symbols, and pictures, make it easier to compare numerous datasets, enhancing audience comprehension and retention when compared to text-heavy presentations [22]. They are essential for strategy creation and informed decision-making, and they add clarity and credibility to presentations for executives and managers alike. The automation of chart production increases their utility by allowing firms to assess performance data more efficiently and generate meaningful insights.

2.6 Software Tools for Food Waste Management

A number of software tools and technologies is used to support the data entering and visualization operations. The creation of an extensive and well-rounded IT system for handling food waste is made easier by these tools.

2.6.1 MySQL as a Relational Database Management System

The open-source relational database management system MySQL is widely used. It has strong data storage, retrieval, and manipulation capabilities and is used for managing massive datasets [23]. MySQL makes sure that all information on food waste and inventory is easily accessible and safely preserved. It supports SQL (Structured Query Language) for data management and manipulation and is made to handle structured data using a set schema. Applications requiring a reasonable volume of data and a small number of users can benefit from relational databases like MySQL. Because MySQL uses established schemas to organize data into tables, any data must have its structure (tables, columns, and data types) determined before any data can be inserted [24].

2.6.2 MongoDB

A fully managed cloud database solution, MongoDB Atlas supports many clouds, including AWS, Azure, and Google Cloud. It has attributes like high availability, integrated security, and automated scaling. With integrated analytics, performance optimization, and automated backup, Atlas streamlines database administration. It is appropriate for contemporary applications that need dependable, scalable, and flexible data storage since it supports a wide range of data formats and workloads [25].
2.6.3 React.js

A JavaScript package called React.js is used to create user interfaces, especially for single-page applications. It enables developers to design flexible and dynamic interfaces, manage state effectively, and produce reusable user interface components. With its user-friendly platform for data entry and visualization, React improves user experience. Developers can gradually implement it for certain application sections or the full user interface (UI) due to its adaptability [26].

The useState hook, which controls state in functional components, is a fundamental component of React. Changeable data that impacts rendering is represented by state. In addition to initializing state, the useState hook offers a way to update it. UseState, for instance, keeps track of the count and changes it in a basic counter component, which causes re-renders to maintain the UI’s alignment with the data. Managing interactive interfaces and dynamic changes is made easier by this reactive design. For large-scale applications, React’s reusable components and one-way data flow guarantee a tidy, manageable codebase [27].

2.6.4 Node.js

Programs written in JavaScript can run server-side thanks to the Node.js runtime environment. Because of its V8 engine-based event-driven, non-blocking I/O model, Node.js is an excellent choice for developing fast and scalable network applications. Using asynchronous I/O, it is a single process that manages multiple requests concurrently without interfering with the main thread. With Node.js, JavaScript may be utilized on front-end as well as back-end projects, giving developers a standardized workspace and npm access to a vast library ecosystem [28].

Routing, serving static files, managing various HTTP verbs, and utilizing templates are not supported by Node.js by itself. Implementing these fundamental web development tasks from start might be laborious. These chores are made easier for developers by Express.js, a web framework for Node.js that makes it simple to create reliable online apps.

2.6.5 Express.js

Express enables the definition of routes for different URL paths and HTTP methods (GET, POST, PUT, DELETE, etc.). This facilitates the effective organization of the routing logic and the handling of various request types [29]. It can dynamically generate HTML replies by integrating with different view engines like as EJS, Pug, and Handlebars for example. By incorporating data into templates, this facilitates the creation of dynamic web sites. It makes settings for many situations possible. This covers establishing middleware, ports, and further application settings. Express has middleware routes that can be used to handle requests and then send responses. This covers managing sessions, cookies, logging, authentication, and other things. With middleware packages, Express’s simple core can be greatly expanded. These packages offer extra functionality including handling cross-origin requests (CORS) and implementing security features like setting HTTP headers.

2.6.6 Cross-Origin Resource Sharing

Web browsers have added CORS, a security feature, to prevent sites from sending requests to a domain different than the one that provided them. This is a crucial part of online security to protect users from malicious websites attempting to obtain sensitive information from another
website. However, there are legitimate scenarios (such as when a web application needs to consume resources from a different domain) when cross-origin requests are necessary. The CORS npm package is middleware for the popular Node.js web application framework Express.js. This middleware allows developers to control and monitor how their web applications handle cross-origin requests by turning on the server-side CORS option. The CORS package offers a number of configuration options that make it easier to enable CORS. It sets the required headers by default to approve all cross-origin requests. It does, however, offer options to define which headers, methods, and origins are allowed [30].
3 Method

This section provides an overview of the methodology used in the project, highlighting the adoption of both the Design Science Method and controlled experiments.

3.1 Research Project

In this project, the methods that are adopted are both the Design Science Method and controlled experiments. The Design Science Method serves as a compass, meticulously charting out the requirements and expectations from Kalmar Municipality institution kitchens for the project. Every research question is tested through controlled experiments. These experiments involve comparing the new results of the web platform with Excel data and the predetermined requirements. This process guarantees that this project meets expectations precisely, and makes sure the enhancements are facilitated by the system. Subsequently, the systems are presented to the Kalmar Municipality supervisor for validation.

3.2 Method

The methodology involves comprehensive research and analysis to gather essential information on various aspects of the IT system:

3.2.1 Design Science

Central to the design science method is the creation of a purposeful IT artifact designed to address a organizational problem [31]. The design science method operates on the principle that knowledge and understanding of a design problem and defining its requirements and its solution are acquired through the creation and application of an artifact [32]. This artifact, described effectively, enables its implementation and application within the appropriate domain [31].

In alignment with the design science method, the project involved creating an web platform system tailored to add, edit, and visualize data effectively. The artifact involves the creation of a web platform for food waste management with client-server architecture, database storage solutions, data visualization techniques, and web design principles. Through the creation of this system, valuable insights into the intricacies of the problem domain and potential solutions are gained. This artifact will not only provide a solution to the organizational challenge but also serve as a means to acquire knowledge and understanding of the problem and its resolution through practical application.

In adherence to the design science method, regular convening of meetings with the supervisor at Kalmar Municipality entails. These meetings serve as platforms for discussing the requisite requirements and identifying areas for improvement within the system. Furthermore, a discussion on the specific datasets needed for visualization using charts, ensuring alignment with organizational objectives. A dataset, sourced from our supervisor at Kalmar Kommun, consists of real data encompassing information from 20 schools in Kalmar over a week. This qualitative data forms the backbone of the analysis, providing valuable insights into the educational landscape and facilitating informed decision-making.

This process requires generating new knowledge, as the design and development of such a system are not routine but innovative. This involves exploring new ideas, methods, or approaches
not widely adopted before, thereby breaking away from routine practices and introducing new solutions and technologies. So a comprehensive literature review has been conducted to gather essential information and resources from the library. This review aids in informing the understanding of best practices, relevant methodologies, and emerging trends in data management and visualization both in general and for food waste management. To gather essential information and knowledge on the creation of web platform, research is conducted focusing on several key areas: client-server architecture, database storage solutions, data visualization techniques, web design principles, and the UI design process. The UI design process that is followed consists of seven steps: user research, defining objectives, wireframing, visual design, prototyping, testing and iteration, and development handoff. The process begins with understanding user needs through research, followed by setting clear design goals. Wireframes are created to outline the structure, then refined into visual designs. Prototypes are developed for testing with real users to identify and fix issues. Finally, detailed design specifications are prepared for developers to ensure the final product aligns with the design vision [33]. The goal is to compile various perspectives and insights on these topics to form a robust foundation for informed decision-making. In addition to exploring these technical aspects, the research includes research of different programming languages and databases. The aim is to identify the most suitable solutions for this project that ensure optimal performance and results. This involves evaluating the strengths and weaknesses of each solution in the context of the specific project requirements.

3.2.2 Controlled Experiments

A controlled experiment involves manipulating independent variables while keeping all other variables constant to isolate their effects on dependent variables [34] [35]. This method is crucial for establishing cause-and-effect relationships and minimizing biases in research. It typically entails controlling variables by maintaining them at constant levels, measuring and statistically controlling for them, and balancing variables through randomization [35]. The project’s controlled experiments are conducted by three volunteers to systematically test and compare both systems, web platform and Excel, providing valuable insights into their relative effectiveness or efficiency. The three volunteers, simulating the roles of kitchen staff responsible for data entry and food waste management, who participated in the experiment are briefed on the experiment’s objectives and procedures before commencement. The experiment manipulates the independent variables which are the web platform and Excel while maintaining constant control over other variables such as the kitchen data to enter, tasks performed, calculated task durations, and the same provided information and structures to volunteers. This control ensures that any differences observed in performance metrics (speed, accuracy, efficiency) and user feedback (ease of use, satisfaction, preference) are attributed to the system used rather than external factors.

3.3 Reliability and Validity

Two essential components of the collaboration with Kalmar Municipality are validity and reliability. Consistent software implementation and data gathering techniques are essential for reliability. Inappropriate approaches or uneven implementation might lead to potential problems. Validity is contingent upon the congruence of study objectives, technique, and data collection. All things considered, methodological rigor and careful assessment of possible biases are necessary to ensure both validity and reliability.
Validity: In order to guarantee that kitchen staff enter data accurately, validity is essential to the initiative. Real-time feedback and cross-verification techniques support data accuracy validation and enable error rectification prior to final submission. Controlling for external factors, such as differences in menu types, kitchen sizes, or staff practices, which could affect the data. Collecting metadata about these variables and incorporating them into the analysis to control for confounding factors. For example, calculating total measured food waste per eater in grams by dividing the total measured food waste (kg) by the number of eaters, and accounting for the type of food served.

Reliability: Since kitchen staff will be entering data into the system, their skill level, consistency, and attention to detail may vary, reliability is an important component of this project. It is essential that different users enter data into the system in an identical manner. Variations in data entry procedures may have an impact on how reliable the information gathered and entered is.

Ensuring that the system is user-friendly for kitchen staff with varying technical expertise to maintain consistent data entry and usage. Developing an intuitive interface, providing clear instructions, and conducting training sessions for kitchen staff to ensure consistent usage and data entry across different users. Adding clear instructions, tooltips, and error messages will be provided to guide users through the data entry process, reducing the likelihood of errors. Providing a support page that gives them information about how the application works.

3.4 Ethical considerations

Ethical concerns are essential to guaranteeing the privacy and rights of persons, especially when it comes to data gathering and utilization. Even though the main goal of the project is to provide a user interface for entering and visualizing food waste data, there are still moral issues that must be resolved:

Informed Consent: Every participant needs to be properly informed about the purpose(s) of the data collection, how the data will be used, and any risks involved. A page was added in the website called “privacy policy” contains necessary information and how the data would be used. To see the privacy policy page, please refer to the Appendix section titled "Privacy Policy Page view."

Information security: putting strong data security procedures in place against abuse, disclosure, and illegal access to data. Encryption methods, access restrictions, and secure storage techniques—such as hashing passwords—which is used to ensure data integrity and secrecy.

Ethical considerations are taken into account throughout the experiment to ensure the well-being and rights of the participants. Participants are provided with informed consent forms outlining the purpose and procedures of the experiment, and their confidentiality is maintained throughout the study. Additionally, participants are free to withdraw from the experiment at any time without consequences.

3.5 Team Work

We worked mostly together on all parts but here are details on what sections each student is responsible for:
Marah is responsible for: 1.3, 1.4, 1.5, 1.6, 1.7, 2.3.1, 2.4.1, 2.4.4, 2.4.6, 3.3, 3.4, 4.2.2, 4.2.3, 4.4, 4.5.3, 4.5.4, 4.5.7

Shaimaa is responsible for: 1.1, 1.2, 1.8, 2.1, 2.2, 2.3.2, 2.4.2, 2.4.3, 2.4.5, 3.1, 3.2, 4.1, 4.2.1, 4.3, 4.5.1, 4.5.2, 4.5.5
4 Implementation

This chapter describes the development of the food waste management web platform called KalmarFoodSavior. The website architecture includes several key components in the header section: Home, Food Management, Kitchen Visualization, Ranking, and Authentication (Login/Register), and also in the Footer section: about us, contact us and privacy and policy. Each of these components is intricately integrated into the server-side structure to ensure a cohesive and efficient user experience in managing food waste data.

4.1 Software Architecture Overview

The architecture is divided into three main layers: the frontend, backend, and database. Each layer interacts with the others to provide a seamless user experience and efficient data management. This study uses React.js and CSS for the frontend, JavaScript (Node.js, Express.js) for the backend, and MySQL for the database. The development environment utilized is Visual Studio Code. See Fig. 4.3 for an overview of the software architecture.

![Software Architecture Overview for Food Waste Management System](image)

Figure 4.3: Software Architecture Overview for Food Waste Management System

4.2 Setting Up the Development Environment

The project began by setting up the development environment, which included installing Visual Studio Code (VS Code), Node.js, and creating the necessary project structure.
4.2.1 Project Structure

The project is structured by creating two main folders: one for the frontend (client) and one for the backend (server).

Client Folder: Contains all frontend-related files and the React application. Inside the src directory of the client folder, the files and folders organized as follows:

- Components: This folder includes reusable UI components:
  1. Footer.js: Defines the footer component of the website.
  2. Header.js: Defines the header component of the website.

The KalmarFoodSavior web platform includes several key components to ensure a robust, user-friendly experience. Utilizing React.js, a dynamic and responsive user interface was built for efficient updates and smooth interactions. Custom CSS maintains a consistent and appealing design across various components and pages. Middleware functions handle frontend authentication, managing user sessions and validating tokens to ensure secure access. The application’s structure includes a pages directory with React components for each page (e.g., Home.js, Register.js, Ranking.js), providing a modular codebase. A config.js file manages environment variables like the PORT number, simplifying configuration. React Router in App.js enables seamless navigation between pages. Interactive data visualizations using Chart.js and D3.js display food waste data clearly, helping users analyze trends and make informed decisions. The application is fully responsive, ensuring an optimal viewing experience on all devices.

Server Folder: Contains all backend-related files, including routes, middleware, and database interactions. The server-side structure includes the following files:

- calcFunctions.js: Contains utility functions for various calculations related to food waste data.
- config.js: Holds PORT number.
- insertDB.js: Manages the insertion of data into the database, including functions to add new records and establish connection.
- PathHandler.js: Handles various paths and routes for API requests, directing them to the appropriate controllers.
- server.js: The main entry point for the backend server, which sets up the Express.js server, connects to the database, and initializes the application.

This structure ensures a clear separation of concerns, making the codebase more manageable and scalable.

4.3 Database Implementation

To ensure seamless operation of the web platform, the necessary database setup and initialization procedures have been implemented, after creating a MySQL connection following the steps of the MySQL [36]. Database implementations include creating the required database and tables, inserting initial data, and establishing a connection to the MySQL database server.
4.3.1 Database Configuration in the system

The mysql2 package library is utilized in a Node.js environment to interact with the MySQL database server. The database configuration parameters such as host, username, password, and database name are specified within the code.

The ‘establishConnection’ function is responsible for establishing a connection to the MySQL database server.

After establishing database connection two tables are created "users" and "kitchens". The Users Table (Table 4.1) stores user data such as email, hashed password, institution type, and institution name. The Kitchens Table (Table 4.2) holds information about food waste generated by kitchens on different days, including fields such as date, amount served food, and total food waste.

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Id</td>
<td>INT, AUTO_INCREMENT, PRIMARY KEY</td>
</tr>
<tr>
<td>email</td>
<td>VARCHAR(255), UNIQUE, NOT NULL</td>
</tr>
<tr>
<td>password</td>
<td>VARCHAR(255), NOT NULL</td>
</tr>
<tr>
<td>type</td>
<td>VARCHAR(255)</td>
</tr>
<tr>
<td>kitchen</td>
<td>VARCHAR(255), UNIQUE</td>
</tr>
</tbody>
</table>

Table 4.1: Users Table
<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>id</td>
<td>INT, AUTO_INCREMENT, PRIMARY KEY</td>
</tr>
<tr>
<td>year</td>
<td>INT, NOT NULL</td>
</tr>
<tr>
<td>week</td>
<td>INT, NOT NULL</td>
</tr>
<tr>
<td>day</td>
<td>VARCHAR(50), NOT NULL</td>
</tr>
<tr>
<td>amountServFood</td>
<td>FLOAT</td>
</tr>
<tr>
<td>minusMat</td>
<td>FLOAT</td>
</tr>
<tr>
<td>storageWaste</td>
<td>FLOAT</td>
</tr>
<tr>
<td>preparationWaste</td>
<td>FLOAT</td>
</tr>
<tr>
<td>cookingWaste</td>
<td>FLOAT</td>
</tr>
<tr>
<td>kitchenWaste</td>
<td>FLOAT</td>
</tr>
<tr>
<td>servingWaste</td>
<td>FLOAT</td>
</tr>
<tr>
<td>plateWaste</td>
<td>FLOAT</td>
</tr>
<tr>
<td>totalFoodWaste</td>
<td>FLOAT</td>
</tr>
<tr>
<td>eaters</td>
<td>INT</td>
</tr>
<tr>
<td>totper</td>
<td>FLOAT</td>
</tr>
<tr>
<td>procent</td>
<td>FLOAT</td>
</tr>
<tr>
<td>Eatenfood</td>
<td>FLOAT</td>
</tr>
<tr>
<td>dish</td>
<td>VARCHAR(255)</td>
</tr>
<tr>
<td>unavoidableFoodWaste</td>
<td>FLOAT</td>
</tr>
<tr>
<td>savedFood</td>
<td>FLOAT</td>
</tr>
<tr>
<td>email</td>
<td>VARCHAR(255), NOT NULL</td>
</tr>
<tr>
<td>kitchen</td>
<td>VARCHAR(255), NOT NULL</td>
</tr>
</tbody>
</table>

Table 4.2: Kitchens Table

These tables are connected through the "email" and "kitchen" columns. The "users" table stores user data including their institution type, and institution name. The "kitchens" table references these attributes to associate each food waste entry with a specific user and kitchen. Thus, the "email" and "kitchen" columns serve as foreign keys referencing the "users" table, and some values such as data can not be NULL.

4.4 Backend Implementation

The backend system is built using Node.js and Express.js. The Node.js is a JavaScript runtime built on Chrome’s V8 JavaScript engine. It allows developers to use JavaScript for server-side scripting. The version that is used is v16.9.1 [37].

Express.js is a minimal and flexible Node.js web application framework that provides a robust set of features for web and mobile applications. The version that is used is v4.17.1 [38].

-Server-Side Implementation: The server is responsible for handling requests from clients, processing data, and interacting with the database.

This architecture includes middleware components such as CORS, which enables cross-origin resource sharing, and bodyParser, used here to parse incoming JSON requests. These middlewares enhance the API’s ability to interact with clients and process data seamlessly. The server interacts with a database through a custom module named ‘insertDB.js’. This module likely encapsulates functions for establishing a connection to the database and executing SQL
queries to retrieve and manipulate data. By leveraging this custom module, the API can efficiently manage data persistence and retrieval operations. Express.js defines multiple routes that correspond to specific functionalities within the system, which handle various types of HTTP requests.

Example for servers data implementation:

The method in the figure below is designed to retrieve data for a specific kitchen entry based on its ID from the kitchens database table, to display the data in the website. It extracts the id parameter from the request URL (GET) in the client file, and define it in SQL query to select all columns from the kitchens table where the id matches the provided ID. If an error occurs during the query execution, a 500 Internal Server Error response is returned with the error message.

```javascript
handleKitchenByIdRequest(req, res) {
    const id = req.params.id;
    const sql = "SELECT * FROM kitchens WHERE id = ?";
    this.db.query(sql, [id], (err, data) => {
        if (err) return res.status(500).json({ error: err.message });
        if (data.length === 0) return res.status(404).json({ message: 'Kitchen not found!' });
        return res.json(data[0]);
    });
}
```

Figure 4.4: JavaScript code to handle kitchen by ID request.

Other server methods works in similar way, by fetching the URL(POST, PUT, GET, ..) and provide the needed implementation, which could be saving data in the kitchens table using another sql query.

The figure below shows an example of an SQL insert query used to save data into the kitchens table.

```javascript
const sql = "INSERT INTO kitchens (year, week, day, amountServFood, kitchen, email) VALUES (?, ?, ?, ?, ?, ?)";
```

Figure 4.5: JavaScript code to insert data into the kitchens table.

The server-side implementation plays a crucial role in the web platform, facilitating communication between clients and the database. By defining Express routes and utilizing middleware, ensures efficient handling of requests and seamless interaction with the system’s components. The ‘PathHandler’ class encapsulates the server’s logic, providing a structured approach to request handling and data processing. Overall, the server-side implementation contributes to the functionality and reliability of the system.

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4.5 Frontend Implementation

The frontend was developed using React.js. Various pages were created to handle different functionalities of the application. See the figure below for an overview of the web platform structure.

![Web Platform Structure Diagram](image)

Figure 4.6: Web platform Structure Diagram

The implementation employs UI design concepts to provide a straightforward and visually appealing user experience targeted to efficient food waste management. A simplified layout and straightforward navigation are essential for usability, and consistent labeling facilitates engagement. A well-chosen color palette, high contrast elements, and plenty of white space all contribute to clarity and also flexibility is essential, fitting different screen sizes. This platform uses React to reduce the need for page refreshes, delivering a seamless experience and making interactions smoother and more efficient. A unified design approach promotes consistency across layouts, typography, and color palettes. This platform provides a seamless and delightful experience for all parties involved in food waste management by focusing on simplicity, accessibility, reactivity, and a user-centric approach. Notably, images like Kalmar Slott and other relevant pictures on the homepage demonstrate our dedication to emphasizing user interaction and participation with sustainable waste management procedures.

4.5.1 Creating the React App

A new React application was initiated in the client folder using the following command:

```
npx create-react-app client
```

This command generated a basic React project structure, which was customized to fit project needs.

4.5.2 Header and Footer Components

Header Component:
The Header component facilitates navigation within the application, providing links to other pages: Home, Food Management, Data Visualization, and Ranking and a section for authentication (login/logout) that changes based on the user’s authentication status. Here’s a brief overview of the key parts:

State Management: Uses useState to manage the state of the navigation menu with a toggle function to toggle the navigation menu’s active state. Navigation Links from react-router-dom provide navigation to different pages and a conditional button for login/logout based on the isLoggedIn probability that shows either a logout button or a login link.

Code for the Header: Below is the code used to create the dynamic header with Toggleable Menu and Login Icon:

```jsx
import React, { useState } from 'react';
import { Link } from 'react-router-dom';
import logInIcon from '../img/logIn/logInIcon.jpeg';

const Header = ({ isLoggedIn, handleLogout }) => {
  const [menuActive, setMenuActive] = useState(false);

  const toggleMenu = () => {
    setMenuActive(!menuActive);
  }

  return (...
```

Figure 4.7: React code for the Header component.

Footer Component: The Footer component includes links to various informational pages such as Contact Us, About Us and Privacy and Policy. It also features social media icons linking to external social media for Kalmar Kummon. These components ensure that users can navigate the application efficiently while also having access to important information and social media links.

4.5.3 Home Page

The Home component manages the display of a slideshow with informative content and handles user login status. State management and the useEffect hook are used to track and initialize the current slide index and user login status. State Initialization: Tracks the current slide, login status, and user email as shown in the figure below. Effect Hook: Fetches login status and user email from local storage upon component mount. Slide Navigation: Updates the current slide index based on user interaction.
useEffect(() => {
    const isLoggedInStatus = localStorage.getItem('isLoggedIn');
    setIsLoggedIn(loggedInStatus === 'true');
    const storedEmail = localStorage.getItem('email');
    setUserEmail(storedEmail || '');
    // If there’s no email in local storage, set it to an empty string
}, []);

Figure 4.8: React useEffect hook to check login status and email.

useEffect: Initializes isLoggedIn and userEmail from local storage when the component mounts.

handleLogout: Updates the state and local storage to reflect the user’s logout status.

4.5.4 Food management

The application is designed to manage and monitor food waste data for different kitchens. Users must first select a kitchen and then a day to display the kitchen’s data. The data are fetched in the application from the server side (API) or are sent to it to be handled or stored in the database. If data exists for the selected kitchen, it will be displayed in a user-friendly format. Logged-in users who are authorized and with access to specific kitchen they can add, edit, or delete data from it.

- Date Selection: Implemented using a calendar, allowing users to select dates which triggers data fetching and form population. This is achieved using ‘react-big-calendar’ and ‘date-fns’ for date manipulation.

- Form Data Submission: The form captures various food waste metrics and submits them to the backend. State management handles form inputs and submissions.

- Data Fetching and Display: When a date is selected, an API call retrieves the corresponding food waste data, which is then displayed in the form.

4.5.5 Kitchen Visualization

Multiple pages have been developed for visualizing food waste data, each providing unique insights through different types of charts and graphs. Below are the descriptions and important code snippets for each page:

1. ChartByWeek Page

The ChartByWeek page visualizes weekly food waste data for a specific kitchen and year. It displays the data using bar and doughnut charts that are imported from "react-chartjs-2" and configuration defaults from chart.js library. First using asynchronous function the data are fetched from the server for the selected week and filters it based on the year. And while fetching the data a message display ("LOADING"), and if there are no data for the selected week another message is displayed.
After fetching the data, charts are configured with appropriate labels, datasets, and title options. The data prop of the Bar component is configured with labels, which are the days of the week extracted from the data, and datasets, which include descriptions such as "Total matsvinn," data points for the bar chart, bar colors, and border widths. The options prop of the Bar component includes chart options like indexAxis, determining the axis on which the bars are displayed, and plugins.title for configuring the chart title with display, text, and color settings.

Similarly, the Doughnut component from react-chartjs-2 is used to render a doughnut chart. The data prop of the Doughnut component is configured with labels representing the days of the week and datasets that describe the data, provide data points for the doughnut chart, set colors for each segment, and determine the width of the segment borders. The options prop of the Doughnut component includes chart options for configuring the title’s display, text, and color. See the figure below to view both chart and bar visualizations.

![Figure 4.9: Visualization of food waste data by week.](image)

2. ChartByYear Page

The ChartByYear page provides yearly food waste data for a specific kitchen with detailed view of food waste trends over the year. It in similar way as weekly visualization it displays the data using bar, doughnut, and line charts. See Fig. 4.9.
3. CombinedChart Page

The CombinedChart page allows users to select a kitchen, year, and week to view both weekly and yearly data simultaneously. Provides dropdowns for selecting a kitchen, year, and week. Displays both weekly and yearly charts for the selected criteria using ChartByWeek and ChartByYear components, which ensures a cohesive user experience by integrating multiple views on a single page.

4. Comprehensive Page

The Comprehensive page aggregates food waste data across all kitchens and years as shown in the figure below, displaying the information in bar charts. It fetches and displays comprehensive food waste data across all kitchens and years and uses a Bar chart to present the total food waste by the kitchen.
5. Visualization Page

The Visualization page is a crucial part of the project that displays graphical representations of food waste data for different kitchens over selected weeks and years. The page integrates D3.js for data visualization and Axios for data fetching. Axios is an HTTP client that uses promises, suitable for both browser and node.js environments, and emphasizes its user-friendliness and adaptability [39]. React hooks are used also in this page for managing state (useState) and creating references (useRef) for the SVG element where the D3 visualization will be rendered as shown in the Fig. 4.10.

Figure 4.11: Viewing all kitchens for a specific year.

Figure 4.12: Viewing all kitchens for a specific week.
Axios is used to fetch data from the server based on the selected week and year. The data is visualized using D3.js. The visualization includes a stacked bar chart showing different types of waste (preparation, cooking, serving, and plate waste) for each kitchen. When the component is rendered, it first sets up an SVG element for the chart. Once the data is fetched from the server, the data is processed to create a stacked bar chart, with each type of waste represented as a different color. The X-axis represents the kitchens, and the Y-axis represents the amount of waste. The chart includes interactivity features, such as tooltips that display the amount of each type of waste when hovering over the bars.

A legend is also included to indicate the colors corresponding to each type of waste. The visualization is cleared and re-rendered each time the data changes, ensuring that the chart always reflects the most recent data.

4.5.6 Ranking Page

The Ranking page is designed to display the performance of different kitchens based on their total food waste as shown in the figure below. It ranks the kitchens from least to most waste generated, awarding the top three kitchens with gold, silver, and bronze medals. This visualization aims to encourage waste reduction by highlighting the best-performing kitchens.

![Top Kök efter Matsvinn](image)

In a useEffect hook, an asynchronous function is defined to fetch data from the server. The fetched data is aggregated by kitchen to calculate total food waste, and then sorted to determine the rankings. The sorted data is stored in the component’s state. The component renders a table displaying the rankings, the table rows include conditional rendering for displaying the medal images for the top three kitchens. The top three kitchens are awarded medals using conditional rendering. The index of each kitchen in the sorted data array determines whether it receives a gold, silver, or bronze medal, or just a rank number.

4.5.7 Authentication (Login/Register)

The authentication module is a critical component of the system, responsible for handling user login and registration.

1. User Registration:
The user registration functionality handles the creation of new user accounts. When a user submits their registration information, these inputs are controlled components, with their state managed by the useState hook. When the form is submitted, an HTTP POST request is sent to the server with the provided user data. If the registration is successful, the kitchen name is stored in localStorage, and the user is redirected to the Login page. If the registration fails, an error message is logged to the console. When storing passwords in a MySQL database, it’s crucial to hash them using bcrypt to securely protect user data. Hashing is a one-way cryptographic process that converts plaintext passwords into irreversible strings of characters. This ensures that even if the database is compromised, the original passwords cannot be easily obtained. Only the hashed password is stored in the database, not the plaintext password.

2. User Login:

Upon form submission, the extension sends an HTTP POST request to the server with user credentials. The server compares the provided hashed password with the stored hashed password in the database for authentication. If successful, the application updates the isLoggedIn state and stores it in localStorage along with the user’s email. The user is then redirected to the homepage. Login failures prompt error messages, with a logout function available to clear localStorage.
5 Experimental Setup and Results

This section describes the experimental setup and results of three experiments conducted to evaluate the efficiency of the Kalmar Municipality’s web platform for food waste management. The experiments addressed specific research questions related to user interface design, data management, and data visualization. In the experiment, each participant used a personal computer in a home-based setup. Using this setup, it simulates a real-world situation where staff members work independently.

- Participants: Three volunteers participated in the experiment, simulating the roles of kitchen staff responsible for data entry and food waste management.

Setup:

- The primary tool used was the web platform, designed with a user-friendly interface to streamline data entry and management processes.

- A comparison was conducted to evaluate the performance and user experience differences between Microsoft Excel and the web platform.

5.1 Experimental Setup

5.1.1 Experiment 1: Efficiency and Data Management of a web platform

The objective of this experiment is to evaluate how the implementation of a web platform with user-friendly tools affects the efficiency of food waste management in Kalmar municipality’s schools. This involves assessing the system’s performance, user experience, and data integrity compared to Microsoft Excel.

The tasks that are involved in this experiment include familiarization, data entry and management, and access restriction tests. The familiarization process involved participants receiving detailed instructions on how to use both the web platform and Microsoft Excel for data entry and management, and they were given enough time and explanation about both systems to familiarize themselves with both systems.

For data entry and management, participants performed routine data entry and food waste management tasks using an old list of food waste data from various schools over five days. This data included categories such as food waste, cooking waste, and plate waste.

Access restriction tests consisted of two parts: the unauthorized access test and the authorized access test. In the unauthorized access test, participants attempted to access and modify data from other kitchens without proper authorization to evaluate the system’s security measures. They also tried to add and modify data without logging in to test the system’s ability to restrict unauthorized access. In the authorized access test, participants logged in using their assigned credentials and performed data entry and modification tasks to ensure they could only modify their own data, not data from other kitchens.
Scenario execution, as shown in Fig. 5.14, involved participants executing data entry tasks using both the web platform and Microsoft Excel, recording their experiences and the time taken for each task. Participants then provided feedback on the user interface, noting the ease of use and any difficulties encountered.

Performance metrics and user feedback included measuring the time taken to complete data entry and management tasks using both the web platform and Microsoft Excel, collecting feedback on the ease of use and noting any difficulties encountered with both systems, and evaluating the system’s ability to prevent unauthorized access and ensure that each kitchen could only modify its own data.

5.1.2 Experiment 2: Impact of Data Visualization on Decision-Making

To evaluate how the visualization of food waste data enhances the understanding and decision-making capabilities of kitchen staff compared to the traditional use of a basic Excel file, an experiment conducted involving the entry and analysis of food waste data. This data included details such as preparation waste and plate waste. Participants first entered food waste data for various schools using both the web platform and Microsoft Excel. The IT system, equipped with advanced data visualization tools, was then compared to Excel to assess its effectiveness. The experiment aimed to determine how well the IT system’s visualization capabilities help users understand and make decisions based on the food waste data.
Scenario Execution: The figure above shows the scenario execution in this experiment. Participants were asked to find specific data points using both the web platform and Excel. These tasks included identifying the week with the least total food waste for a specific institution, determining the day of the week with the least food waste, finding the institution with the least total food waste during a year, and identifying the kitchen with the least total food waste overall. Participants provided feedback on their experiences with both systems, and the time taken to perform comparisons and identify trends in both systems was recorded.

5.2 Results

This section presents the results of the three experiments conducted to evaluate the effectiveness of the web platform for food waste management in Kalmar municipality’s institutions. Each experiment’s results are detailed below.

5.2.1 Results of Experiment 1

The results of the experiment showed that the web platform significantly improved the user experience and efficiency of data entry compared to Microsoft Excel.
Figure 5.16: The calendar in the web platform.

Figure 5.17: The data entry interface in the web platform.
Participants completed data entry tasks 30% faster in experiment 1 on average using the web platform compared to Excel, primarily due to the intuitive calendar view. This feature allowed users to select specific dates directly without manually converting dates to week numbers, significantly reducing errors and simplifying date selection. The IT system also decreased data entry errors through its intuitive interface and validation checks. User satisfaction was much higher with the IT system, with participants rating their experience compared to Excel.

The figures 5.16, 5.17, and 5.18 shown above illustrate the differences in user interfaces, highlighting how the IT system aims to streamline data entry and improve user experience.

Participants found it challenging to add data to specific days using the Excel file because it only displayed week numbers. When asked to add data for a specific date in the format (day-month-year), users had to manually convert the date to the corresponding week number, which was cumbersome and time-consuming. Conversely, the web platform provided an intuitive calendar view. Users could easily select the desired date from the calendar and directly add information without needing to look up and convert the date, significantly simplifying the process. Moreover, when users needed to go back and recheck their previously added data in Excel, it became increasingly challenging as the dataset grew larger. Finding the desired week became more difficult and time-consuming with a bigger dataset. In contrast, the web platform allowed users to quickly and easily navigate through past entries using the calendar view, making data retrieval much simpler and more efficient.
All unauthorized access attempts were denied, as shown in Fig. 5.20, demonstrating the system’s robust security. Authorized modifications were successfully executed, confirming the system’s ability to enforce data access restrictions. In contrast, the lack of proper access controls in Excel allowed anyone with the link to edit and add data to any kitchen, as illustrated in Fig. 5.19.

These figures highlight the robust access control mechanisms of the web platform compared to the lax controls in Excel.

The web platform’s ability to restrict data access to authorized users stands in contrast to the unrestricted access in Excel. This improvement ensures that only authorized users can modify data, leading to a reduction in potential errors and enhancing data integrity.
5.2.2 Results of Experiment 2

The web platform’s data visualization tools greatly enhanced the understanding and decision-making capabilities of kitchen staff compared to using a basic Excel file.

The table 5.3 below shows the average of time taken for the participation to find specific data:

<table>
<thead>
<tr>
<th>Task</th>
<th>IT system</th>
<th>Excel file</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week with least total food waste for an institution</td>
<td>10 sec</td>
<td>35 sec</td>
</tr>
<tr>
<td>Day with least food waste in a week for a kitchen</td>
<td>9 sec</td>
<td>13 sec</td>
</tr>
<tr>
<td>Institution with least total food waste in a year</td>
<td>6.6 sec</td>
<td>8.5 sec</td>
</tr>
<tr>
<td>Kitchen with least total food waste overall</td>
<td>3 sec</td>
<td>11.11 sec</td>
</tr>
</tbody>
</table>

Table 5.3: Comparison of Task Completion Time between IT System and Excel.

The IT system demonstrated several advantages over Excel in managing and analyzing food waste data. It significantly reduced the time required to perform comparisons and identify trends. Participants rated the IT system’s visualization tools much higher (average 9/10) for ease of use and effectiveness in understanding food waste data, compared to Excel (average 3.5/10). While comparing data across different kitchens and time periods was cumbersome in Excel, the IT system allowed for quick and comprehensive comparisons.

Figures 4.8, 4.9, 4.10, and 4.11 demonstrate how the web platform simplifies data visualization and comparison, making it easier for users to understand and act on the information. Unlike Excel, where data is presented only in numerical form without any visual context, the IT system transforms this data into intuitive and interactive visual formats.

Participants noted a significant advantage of the web platform’s Ranking page (See Fig. 4.12), compared to Excel, ability to effortlessly access a list of kitchens based on their total food waste. Unlike Excel, where manual calculations and sorting were required to generate such a list, the system automatically fetched and sorted data from the backend. This eliminated the need for participants to perform time-consuming calculations or search through whole datasets.

With the web platform, participants could simply navigate to the Ranking page and instantly view kitchens ranked according to their total food waste. The system aggregated data from each kitchen, calculated total food waste, and sorted kitchens in ascending order based on this metric. As a result, participants could access the list of kitchens without any additional effort or time investment, streamlining the process and enhancing efficiency. In contrast, Excel lacked this automated functionality, requiring participants to manually calculate the total food waste for each kitchen and then sort the data accordingly. This process was not only tedious and time-consuming but also prone to errors, particularly as the dataset grew larger.

Participants also highlighted the motivational aspect of the web platform’s Ranking page. One participant expressed that this recognition would likely motivate students to showcase their school’s name at the top of the list, fostering a sense of responsibility.

They also pointed out the integral role of the web platform’s visualization and chart features in demonstrating the potential cost savings associated with effective waste reduction strategies. Participants noted also that the system’s visualization tools facilitated easy comparison of food waste data across various time periods and institutions. By visualizing trends in food
waste generation and pinpointing peak periods of waste production, decision-makers could implement targeted interventions to reduce waste and subsequently lower associated costs. Additionally, participants recognized the utility of these visualization tools in informing inventory management decisions, allowing for more efficient procurement practices and minimizing surplus inventory costs.
6 Analysis

The analysis of the food waste management system implementation reveals several insights and conclusions:

Answer to RQ1:

How does the implementation of a web platform with user-friendly tools affect the efficiency of food waste management in Kalmar municipality’s schools?

The implementation of a web platform with user-friendly tools significantly enhances the efficiency of food waste management in Kalmar municipality’s schools. The results from Experiment 1 reveal several key improvements in user experience, data entry efficiency, and security. Participants completed data entry tasks 30% faster using the web platform compared to Excel. This improvement is largely due to the intuitive calendar view, which allowed direct date selection without manual conversions to week numbers, thus reducing time and errors. The platform’s user-friendly interface and validation checks further minimized data entry errors, leading to higher data integrity. The 30% increase in speed translates into significant time savings for staff. This efficiency allows staff to focus more on other important tasks, such as analyzing data, planning, and improving kitchen processes. Quicker decision-making is made possible by faster data entry, which also results in more timely updates and real-time data availability.

Because of the user-friendly interface, new users can adopt and choose it more quickly to utilize it consistently. Increased motivation and engagement from high user satisfaction can motivate personnel to use the system efficiently and regularly. The necessity to convert dates to week numbers made it difficult for users to add and retrieve data in Excel. The web platform’s calendar view simplified this process, making it easier to add and retrieve data. The intuitive calendar view simplifies the data entry and retrieval process. Without having to go through the laborious process of translating dates into week numbers, users may swiftly choose dates and go over previous entries. Because it retains efficiency even with higher data volumes, this feature is especially helpful as the dataset gets bigger. Users may monitor and evaluate historical data efficiently thanks to simple data retrieval and navigation. This capacity is essential for monitoring development, seeing patterns, and adjusting in order to eventually decrease food waste. Better reporting and accountability are also supported by improved data management.

The platform guarantees greater data integrity by lowering data entry errors. In order to recognize trends and make wise decisions, accurate data is essential for managing food waste. Decreased errors also translate into less time needed for data correction, which increases productivity even further. Strong security measures were displayed by the web platform, which prevented unwanted access and made sure that only authorized changes were permitted. Excel, on the other hand, lacked adequate access safeguards, making it possible for anybody with the link to alter and add data. By limiting access, the platform guards against unauthorized changes and possible manipulation by ensuring that only authorized workers can alter data for their own kitchen. For the data to remain reliable and intact, this security precaution is essential. Every kitchen that has controlled access is responsible for its own data entries. Because employees are aware that their entries are safe and traceable, this accountability lowers the possibility of mistakes. Improved security measures foster stakeholder and user trust while guaranteeing adherence to data protection laws. Secure data management reassures stakeholders that the data is accurate and reliable, supporting also informed decision-making. The web platform’s
implementation in Experiment 1 shows substantial improvements in efficiency, accuracy, user satisfaction, and security compared to Excel.

Answer to RQ2:

How does the visualization of food waste data improve the comprehension and decision-making capabilities of kitchen staff compared to the traditional use of a basic Excel file?

The visualization of food waste data using the web platform significantly enhances the comprehension and decision-making capabilities of kitchen staff compared to traditional Excel files. The results from Experiment 2 reveal several key improvements:

Dynamic and interactive visualizations using libraries like Chart.js and D3.js transform complex data into accessible formats. For instance, while Excel requires manual inspection of rows and columns, visual tools such as bar charts, line graphs, and pie charts enable staff to quickly identify trends, patterns, and anomalies. This simplification is crucial for effective data comprehension. The visualization tools aid in demonstrating potential cost savings associated with effective waste reduction strategies. By providing clear visuals on waste trends, the system helps in making informed inventory management decisions, which can minimize surplus and reduce costs.

The amount of time needed for data-related tasks is significantly decreased by the web platform. Finding the week with the least amount of food waste took only 10 seconds on the web platform compared to 35 seconds using Excel, as Table 5.3 illustrates. Staff members are able to save more of their attention to putting solutions into practice rather than getting data. In addition to offering insights, the system’s real-time data handling capabilities assist proactive waste management strategies including inventory and portion control. Staff members can take prompt corrective action by being alerted to critical problems via real-time visualization.

User feedback further underscores the advantages of the web platform. Participants rated the IT system’s visualization tools significantly higher (average 9/10) for ease of use and effectiveness compared to Excel (average 3.5/10). The web platform’s automated functionalities, such as the Ranking page, streamline processes by automatically fetching and sorting data. This eliminates the need for manual calculations and reduces the risk of human error, enhancing overall data management accuracy. The Ranking page’s motivational component is also very important. Employee accountability and competitiveness are encouraged by the ranking system’s exposure and acknowledgment, which results in more thoughtful waste management practices.

The web platform’s data visualization tools greatly improve the comprehension and decision-making capabilities of kitchen staff compared to an Excel file. This is evidenced by enhanced data clarity, reduced task completion times, real-time insights, higher user satisfaction, automated functionalities, motivational impacts, and better cost management. These factors collectively provide a comprehensive and effective solution for managing food waste in kitchens. The successful implementation of the web platform can serve as a model for other institutions. By demonstrating the practical benefits of such a system, other schools, municipalities, and organizations can adopt similar solutions to improve their food waste management practices. This scalability potential highlights the broader impact of the findings, promoting more efficient and sustainable food waste management practices across different contexts. These improvements have practical implications for day-to-day operations, long-term data management, and broader adoption of efficient food waste management practices. The results underscore the value of in-
vesting in user-friendly, secure, and efficient data management systems to achieve sustainable food waste reduction goals.
7 Discussion

The experiments conducted provide evidence that the web platform offers significant advantages over traditional Excel-based methods in managing food waste data. The primary objectives of the project—improving data entry efficiency, ensuring data integrity, and enhancing decision-making through effective data visualization—were successfully met.

7.1 User Interface Design

The user-friendly interface of the IT system played a crucial role in improving the efficiency of data entry. The calendar view allowed users to select specific dates directly, eliminating the need to manually convert dates to week numbers, which was a cumbersome process in Excel. Validation checks further reduced errors, ensuring that the data entered was accurate and consistent. This feature is particularly beneficial for users with varying levels of technical expertise, making the system accessible and easy to use.

Additionally, the efficiency of the IT system becomes even more apparent when considering the scalability of data management. Currently, the experiments were conducted with data spanning only two weeks. As the volume of data increases over time, the challenges associated with using Excel will become more pronounced. In larger datasets, Excel’s limitations in managing and visualizing data efficiently will result in significantly higher task completion times. The web platform, designed to handle and visualize large datasets effectively, will maintain its efficiency and user-friendliness even as the amount of data grows. Therefore, the IT system not only provides immediate improvements but also ensures long-term scalability and efficiency in food waste management.

The IT system’s access control mechanisms effectively prevented unauthorized data modifications, ensuring that only authorized personnel could access and modify specific datasets. This robust security feature is a significant improvement over Excel, which lacks proper access controls and can lead to data integrity issues. By restricting data access to authorized users, the IT system ensures that data is managed securely and reliably, reducing the risk of errors and enhancing overall data integrity.

7.2 Data Visualization

The data visualization tools provided by the IT system enabled kitchen staff to quickly identify trends and make informed decisions. The ability to visualize data in various formats (weekly, monthly, yearly) and the ease of comparing data across different parameters significantly enhanced the decision-making process. Visualization tools such as bar charts, line graphs, and doughnut charts made it easier for users to understand complex data, identify patterns, and pinpoint areas for improvement. The comprehensive visualization capabilities of the IT system represent a major advancement over Excel, where data visualization is limited and less intuitive.

Even though Excel has the capability to visualize data, it can be challenging, especially for users with limited experience. The IT system’s built-in visualization tools provide a more accessible and efficient way to analyze and interpret food waste data.
7.3 Experiment reflection

It is purposeful to exclude real kitchen staff users from the experiment Kalmar Municipality. The experiment aims to evaluate the systems’ efficiency in managing food waste in a controlled environment. To ensure that volunteers’ performance and input in these assessments accurately represent their true opinions toward the new IT solution, it is best to use volunteers who are not previously familiar with the Excel-based system. This method reduces the possibility of bias resulting from participants’ prior familiarity and potential bias. Therefore, in a setting that closely mimics real-world circumstances, objective insights into the system’s usability, data management capabilities, and overall user experience are gathered.

In the experiments, participants were split into two groups: one person utilized the web platform initially, while the other used Microsoft Excel first. Variability in participants’ first experiences and IT system comparisons are introduced by this hybrid approach to the series. In contrast to the participant who started using the IT system, those who started with Excel might have influenced their impressions of the IT system differently. Because of their previous experience, participants who used Excel first might appraise the IT system more favorably or harshly. On the other hand, the person who was first exposed to the IT system may evaluate it without regard to previous system prejudice.

7.4 Technology Choices

7.4.1 MySQL vs. MongoDB

The decision to use MySQL over other databases such as MongoDB was based on several factors. MySQL’s structured schema is well-suited for applications like food waste management that require fixed-schema data. MySQL efficiently handles complex joins, which are necessary for the relational data used in this project. It also provides strong consistency and supports SQL for data manipulation, making it a reliable choice for managing structured data such as daily food waste records. MySQL’s capability to handle relational data with structured queries ensures data integrity and simplifies the process of data retrieval and manipulation.

7.4.2 React.js for Frontend Development

React.js was chosen for the frontend due to its component-based architecture, which allows for the creation of reusable UI components. This modular approach simplifies the development process and enhances maintainability. React’s state management capabilities, through hooks like useState and useEffect, provide a seamless way to handle dynamic data and user interactions. Its virtual DOM improves performance by minimizing direct DOM manipulations, resulting in a responsive user interface. Additionally, React’s ecosystem, including libraries like React Router for routing and various charting libraries, supports the development of rich, interactive web applications.

7.4.3 Choice for Chart.js and D3:

The combined use of Chart.js and D3.js allows the project to leverage the strengths of each library effectively. Chart.js with react-chartjs-2 is used for straightforward and common visualizations, offering ease of use, quick implementation, and a responsive design. This is particularly beneficial for pages like ChartByWeek, and ChartByYear where standard chart types and
quick updates are required. While more challenging to learn, D3.js is utilized for more complex and highly customized visualizations, such as those on the Visualization page, that show different types of food waste (preparation, cooking, serving, plate) across multiple kitchens for a selected week and year.

7.4.4 Relation to Related Work

This project’s findings align closely with established research in food waste management and sustainable IT platform, drawing parallels with existing solutions such as Hsu et al.’s QR-code health management application [3] emphasizing user-friendly interfaces and data visualization but in different branches. Similarly, Dogan et al.’s MySusCof app [4], which uses gamification to promote sustainability, reflects our project’s strategy to encourage behavior change in reducing food waste. Moreover, Soma et al.’s focus on consumer awareness interventions underscores our use of data visualization and feedback mechanisms to enhance sustainability practices in institutional kitchens [5]. The necessity for a custom solution arose from specific challenges in Kalmar Municipality’s institutional kitchens, where off-the-shelf software often lacks features like real-time data handling and user-friendly interfaces for varying technical proficiency levels. Tailoring the IT system aimed to directly address these challenges, improving food waste management efficiency and supporting sustainable practices effectively within institutional settings. This approach aligns with current research trends while highlighting the importance of bespoke IT solutions in meeting the diverse needs of sustainability initiatives in complex organizational contexts.

7.5 Limitations

While the platform shows promise, there are several limitations to consider which affect the generalizability and scope of the conclusions. The experiments were conducted with a limited number of participants and focused on specific school kitchens within Kalmar Municipality, which may not represent the broader spectrum of kitchens with different practices and challenges. Additionally, the participants in the experiments were not actual kitchen staff from Kalmar, which may affect the relevance and applicability of the findings to real-world scenarios. Furthermore, the controlled environment of the experiments might not fully capture the complexities and unexpected issues that can arise in real-world kitchen settings. The accuracy of the conclusions is heavily dependent on the quality and consistency of the data provided by kitchen staff, with variations in data entry accuracy potentially impacting the reliability of the results. The system’s effectiveness also relies on the willingness of staff to consistently and accurately input data, and resistance to adopting new technologies or inconsistencies in data entry can limit the system’s impact.

The scope of the experiments primarily focused on data management and visualization efficiency, without extensively testing other factors such as long-term user satisfaction, system scalability under high data loads, and integration with existing kitchen workflows. While the experiments focused on immediate improvements in comprehension and efficiency, they did not assess the long-term impact on waste reduction or operational efficiency, nor did they measure sustained behavioral changes among staff. The system’s reliance on internet connectivity and proper functioning of integrated technologies means that any issues with the internet or software could hinder its effectiveness. Unlike Excel, which can function offline, technical difficulties like software flaws or server outages could prevent access to vital data. A web-based system’s construction and upkeep can also be expensive, involving costs for hosting, software
development, and continuing technical support. These expenses may be more than the advantages for some institutions, especially those with tight budgets. Some kitchens or institutions can find it difficult to use the online platform if it calls for extra resources like hardware upgrades or specialized IT support.
8 Conclusion

The web platform for controlling food waste data in several kitchens was successfully deployed in this project. By leveraging technologies such as Node.js, Express.js, React.js, MySQL, D3.js, and Chart.js, several important goals were accomplished:

User Authentication and Authorization: Mechanisms were implemented to ensure secure access, allowing only authorized users to manage and edit their data. The user-friendly design and intuitive interface contribute to a positive user experience, making the system accessible to users with varying levels of technical expertise.

Efficient Data Management: The system facilitates efficient input, editing, and visualization of food waste data, significantly improving data management procedures. Using modern web development frameworks and technologies ensures the program is scalable and maintainable, capable of handling increasing data quantities and user expectations.

Interactive Visualization: The integration of D3.js with Chart.js allows for dynamic and interactive data visualizations, offering users clear and insightful representations of food waste data. Visual tools enable users to easily detect trends, patterns, and anomalies, leading to more informed judgments.

Significance and Impact: The project’s findings are important to a variety of stakeholders, including the food industry, and supporters of sustainability. Kitchens can implement waste reduction strategies, pinpoint areas for development, and promote environmental sustainability by tracking and analyzing food waste data. Enhancements to waste management protocols can be encouraged and decision-making supported by the insights obtained by visualizing food waste indicators.

8.1 Future work

With more time, the platform could integrate advanced features to significantly enhance its capabilities in reducing food waste and optimizing operations. One potential feature is AI-driven waste reduction suggestions, where AI analyzes historical and current data to predict future food needs more accurately, thereby minimizing over-purchasing and excess food preparation. By examining waste data, AI can recommend modifications to recipes, ensuring the quantity of ingredients used aligns more closely with actual consumption patterns. This could include adjusting portion sizes or suggesting alternative ingredients that are less likely to be wasted.

Future enhancements to the IT system could further improve its functionality and impact. One potential area for development is the integration of machine learning algorithms, which could provide predictive insights and optimization recommendations based on historical data, helping to manage food waste proactively.

Additionally, incorporating Internet of Things (IoT) devices for real-time monitoring could enhance data and provide immediate feedback on waste levels. A study by Ahmadzadeh, Ajmal, Ramanathan, and Duan [40] highlights the importance of utilizing emerging technology to expedite data gathering and analysis procedures. Their research on the use of IoT sensors to track food waste and consumption in real time offers valuable insights that could be applied to this system. Implementing such proactive waste management techniques could support more effective and focused food waste reduction activities in institutional kitchens, aligning with
their findings. By leveraging the insights, future work can aim to create a more robust and dynamic food waste management system, incorporating both predictive analytics and real-time data monitoring to optimize waste reduction strategies effectively.

Furthermore, expanding the system to include mobile applications would increase accessibility, allowing users to manage food waste data from anywhere. These advancements could amplify efforts in food waste reduction and sustainability, making the IT system an even more powerful tool for managing food waste in institutional kitchens.
References


A Appendix 1

In this appendix you will see some screenshots of the complete system for managing the food waste with different pages.

Figure 1.21: Home Page

Home Page Overview:

The Home page as shown in the figure above, serves as the main entry point for users, providing a slideshow with informative content. Each slide has a different background image and text. It contains Header and Footer like every other page in the website. The Header displays user login status and includes a logout place. The Footer provides additional navigation or information links at the bottom of the page.
Privacy and Policy page overview: Below is an image of the privacy policy page as it appears on the website:

![Privacy Policy Page](image)

Figure 1.22: Privacy and Policy page

Login Page Overview:

The Login page allows users to log into their accounts by providing their email and password as you can see in Fig. 1.23. Users enter their email and password into text fields. The user login functionality validates user credentials and ensures secure access to the application. When a user attempts to log in, the system checks the provided email and password against the stored hashed password using bcrypt. If the credentials are valid, the user is successfully logged in otherwise, an error message is returned and shown in client side. There is also a link to the registration page for users who don’t have an account.

![Login Page](image)

Figure 1.23: Login page
Register Page Overview:

The Register page allows new users to create an account by providing their information. Users enter their email, password, kitchen name, and select their institution type from a dropdown menu. Business Type Selection: The dropdown menu allows users to select their institution type of business (e.g., preschool, primary school, high school, eldercare, hospital) as shown in Fig. 1.24. Both log in and register pages include user-friendly forms with clear input fields and labels, making it easy for users to log in or register. The Login page focuses on authentication, while the Register page collects more detailed information to create a new account. The flow between these pages ensures a smooth user experience for accessing the system. The system hashes the password before storing the user’s information in the database.
Figure 1.25: View data in details

Food Management Page Overview:

The Food Management page is designed to help users track and manage food waste in various kitchens. Users can select a kitchen from a dropdown menu. The kitchen names are fetched from the backend and displayed in the dropdown. There is also a calendar component that allows users to select dates. Special styling highlights specific dates, and users can click on a date to fetch or input data for that day. Users can input data related to food waste (e.g., amount of food served, storage waste, preparation waste, etc.) into a form. The form data is validated and submitted to the backend.

Fetched data is displayed in a detailed format, showing various metrics related to food waste as shown in the figure above. Users also can edit existing data by changing input values and submitting the updates. The system checks user authorization to ensure that users can only add or edit data for their designated kitchens.
Figure 1.26: Select kitchen, year and week.

For the code source, please visit the following link: GitHub Repository