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Information Management System to boost Companies Sustainability

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Dedicatória

Dedico este trabalho aos meus pais, cujo amor e apoio constante foram fundamentais para alcançar todos os meus objetivos. Aos meus avós, cujo apoio incondicional e sabedoria guiaram as minhas decisões, moldando o caminho que percorri. E não posso esquecer as minhas irmãs, verdadeiras fontes de inspiração e encorajamento, que estiveram ao meu lado em todas as fases do meu percurso académico, tornando-se pilares essenciais do meu percurso.

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Resumo

A precisão, as informações em tempo real e os processos bem organizados são essenciais no domínio da gestão da segurança alimentar. As plataformas digitais que representam sistemas de informação avançados são atualmente essenciais para todas as partes envolvidas no negócio alimentar. Apesar do valor reconhecido das tecnologias digitais, como os dashboards, existe uma falta flagrante no corpo de conhecimento em torno dos dashboards de produtividade concebidos para as partes interessadas na segurança alimentar, particularmente no âmbito do HACCP. Esta tese explora as duas dificuldades: Para uma melhor prestação de serviços, as empresas do sector da segurança alimentar necessitam de informações detalhadas sobre a produção e a produtividade. Estes fluxos de dados são também extremamente úteis para os gestores otimizarem a atribuição de recursos e garantirem os mais elevados níveis de eficiência operacional. A monitorização das nuances da produção e da produtividade pode alterar drasticamente as táticas de utilização de recursos, melhorando a qualidade global da gestão da segurança alimentar.

Esta tese descreve o processo de criação de dashboards únicos para monitorizar estas variáveis cruciais e afirma que estas ferramentas são aliadas cruciais para os decisores. Este estudo combina de forma elegante a criação de um item e a sua avaliação crítica através da lente da Design Science Research (DSR). O objetivo final do projeto é apresentar um dashboard de controlo que se repercuta nos principais intervenientes da indústria de segurança alimentar e que se destaque pela sua proeza tecnológica e capacidade de revolucionar a navegação de gestão na indústria.

Palavras-chave: Gestão da Segurança Alimentar, Plataformas Digitais, HACCP, Dashboards de Produtividade, Afetação de Recursos, Eficiência Operacional

Abstract

Precision, real-time insights, and well-organized processes are essential in the field of managing food safety. Digital platforms that represent advanced information systems are now essential for all parties involved in the food business. Despite the recognized value of digital technologies like dashboards, there is a glaring lack in the body of knowledge surrounding productivity dashboards designed for food safety stakeholders, particularly under the HACCP umbrella. This thesis explores the two difficulties: For better service delivery, companies in the food safety spectrum need detailed information on production and productivity. These data streams are also extremely helpful to managers for optimizing resource allocation and guaranteeing the highest levels of operational efficiency. Monitoring the nuances of production and productivity may drastically alter resource utilization tactics, improving the overall food safety management quality.

The paper describes the process of creating unique dashboards to track these crucial variables and claims that these tools are crucial allies for decision-makers. This study elegantly weaves together the creation of an item and its critical assessment via the lens of Design Science Research (DSR). Initial results highlight the urgent need for a more thorough investigation of production and productivity. Custom dashboards have great promise for supporting monitoring, in-depth analysis, and subsequent decision-making. The project's ultimate goal is to present a dashboard that resonates with key players in the food safety industry and stands out for its technological prowess and ability to revolutionize managerial navigation in the industry.

Keywords: Food Safety Management, Digital Platforms, HACCP, Productivity Dashboards, Resource Allocation, Operational Efficiency

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List of Acronyms

AI	-	Artificial Intelligence
DSR	-	Design Science Research
ETL	-	Extraction Transformation Load
FAO	-	Food and Agriculture Organization
FSMS	-	Food Systems Management Systems
GDP	-	Gross domestic product
GMP	-	Good manufacturing practice
HACCP	-	Hazard Analysis and Critical Control Points
IDAR	-	Iterative Development and Action Research
IoT	-	Internet Of Things
PRP	-	Prerequisite Programs
RFID	-	Radio Frequency Identification

Chapter 1 - Introduction

Since the COVID-19 pandemic broke out, technology has developed rapidly and been adopted by most companies [1].

Changes in technology and the workplace itself are driving this transformation. Every part of your daily work, including the way we communicate, cooperate, learn, and develop, is affected by this transition. Food safety is a growing concern around the world, and the food safety management system has been developed to ensure food quality and safety throughout the supply chain. Information technology and digital information have played an increasingly important role in this system, enabling food traceability, data collection and real-time analysis. In the United States, most of the estimated 75 million cases of foodborne illness are the result of inadequate worker hygiene practices. Surprisingly, documentation shows that between 30% and 50% of people do not wash their hands after using the restroom. The primary means of reducing cross-contamination in a food processing plant is proper employee training [2]. These good hygiene practices are elements of the prerequisite programs of a Food Safety Management System. The World Health Organization describes prerequisite programs (PRP) as "essential food safety practices that need to be implemented before and during HACCP installation" [24].

Food safety is a growing concern worldwide, and the food safety management system has been developed to ensure food quality and safety throughout the supply chain. Information technology and digital information have played an increasingly important role in this system, enabling food traceability, data collection and real-time analysis.

The Hazard Analysis and Critical Control Point (HACCP) system is a widely used methodology for ensuring food safety. It involves identifying the potential hazards at each stage of the food production process and establishing measures to ensure that these hazards are controlled. According to the Food and Agriculture Organization (FAO), "The implementation of food safety standards, such as HACCP, is critical to ensuring food quality and safety throughout the supply chain" [22].

Information technology and digital information have been increasingly used to improve the effectiveness of HACCP. According to World Health Organization (WHO), "Digital technology has the potential to revolutionize the way we manage food safety, enabling food traceability, and increasing responsiveness to food safety threats" [23].

Good manufacturing practices (GMP) are practices used by businesses to ensure that food products are efficiently produced and controlled to quality standards. GMP was developed to reduce the risks of contamination at various stages of the manufacturing process that cannot be eliminated through quality testing of the final product. This principle covers all areas of production, from raw materials, facilities and equipment to staff training and personal cleaning.

This research aims to develop the food safety management system and HACCP and GMP digital standards to optimize the process and reduce "food waste" and more sustainability and efficiency in the process.

After collecting the requirements, this digital platform will be used and tested by food industry establishments to understand how their efficiency and performance has been affected. The research questions we aim to answer are as follows: What is the best way to automate a food safety management system?

Chapter 2 - State of the Art

Given the challenges mentioned above, the purpose of this chapter is to elucidate the ideas addressed and applied in the business, thereby clarifying its theoretical foundation. It also seeks to illustrate the subject's relevance by examining previous work in this field.

2.1. Good Practices in Information Systems Development

Information system development is a multi-step, complicated process that ranges from requirements analysis to system implementation and maintenance. To guarantee that the system is built successfully and efficiently, it is crucial to adhere to sound development methods. The use of a software development methodology, configuration management tools, test automation tools, sound programming habits, the use of error monitoring and tracking tools, adhering to information security standards, and other critical practices are only a few of the crucial ones.

Carefully analyse the system requirements before you start coding: Before you begin developing an information system, it is crucial to understand completely understand the project requirements and the needs of the end users. This includes gathering information about the target audience, the system goals, and the desired functionality. Doing a careful requirements analysis before you start coding can help avoid problems and rework in the future.

An integrated approach to software development combining the Agile Life Cycle and the Waterfall Model was explored. This hybrid methodology aims to capitalize on the strengths of both systems: the flexibility and adaptability of Agile and the structured, phase-based approach of Waterfall. Agile is ideal for projects with evolving requirements, promoting rapid iteration and constant collaboration. On the other hand, the Waterfall methodology suits projects with well-defined and stable requirements, offering clear milestones and comprehensive documentation. Use configuration management tools: Tools such as Git allow you to track code versions and manage contributions from multiple developers. This helps keep the code organized and ensures that all developers are working with the latest version of the code.

Use test automation tools: Test automation tools allow you to automatically test the code and detect errors. This helps ensure that the code is high quality and stable before it is released into production.

Use good programming practices: Good programming practices include object-oriented programming and software design. Following these practices can help ensure that code is readable, reusable, and easy to maintain.

Use error tracking and monitoring tools: Error tracking and monitoring tools allow you to identify and fix problems quickly. This helps ensure that the system is always working correctly and that problems are resolved as quickly as possible.

Following information security standards: It is important to follow information security standards to protect the system data and its users. This includes encrypting sensitive data and using strong authentication.

2.2. Food Sector Industry

The food industry is an economic sector that involves the production, processing, packaging, distribution, and sale of food. It is a global industry with a wide variety of products and processes. The food industry is regulated by various laws and regulations to ensure food safety and protect the health of consumers.

HACCP is a food safety management system that focuses on identifying and controlling hazards that can affect food safety. It is based on seven principles: hazard identification, hazard assessment, hazard control, verification, recording and documentation, training, and updating.

FSMS (Food Safety Management System) is a management system that covers all aspects of food safety, including HACCP, but also includes other areas such as quality, environment, occupational health and safety, and regulatory compliance.

GDP (Good Distribution Practices) is a set of rules and regulations that focus on food distribution, including transportation, storage, and handling. Its purpose is to ensure that food is kept in good condition during distribution to ensure food safety and quality.

GMP (Good Manufacturing Practices) are a set of rules and regulations that focus on food production. Their purpose is to ensure that food is produced under clean and safe conditions, using appropriate equipment and processes, and that it is packaged and labeled appropriately.

These systems and regulations, including HACCP (Hazard Analysis and Critical Control Points) and other international standardization norms, are designed to ensure that the food industry meets strict safety and quality standards in order to protect consumer health and prevent public health problems. Although they can be integrated globally, each country can have its own additional regulations, which allows for local adaptation to international guidelines, thus ensuring a balance between global uniformity and regional specificity. This holistic and flexible approach is key to maintaining the integrity and safety of the food chain in different cultural and regulatory contexts around the world.

2.3. Related Work

To comprehend the study that other researchers completed, a systematic review of the literature (SLR) was carried out. The optimum methodological approach, according to Kitchenham (2009), is to recognize and assess the data from all relevant studies that have been undertaken up to this point about a particular area of interest, then summarize it to identify any gaps that may already exist.

2.3.1. Research Stage

Figure 1 depicts each stage of the research process in accordance with Kitchenham's (2009) proposed stages. The selection of documents in accordance with the inclusion and exclusion criteria and a quality evaluation are two ways that each phase improves the study's quality. In planning this systematic review, we identified the need to evaluate the current use of digital solutions in food safety, with a view to optimizing and standardizing Key Performance Indicators (KPIs) for food safety management systems. Understanding these digital applications is key to adapting emerging technologies to the specific needs of the sector, thus ensuring effective and efficient implementation that can reinforce safety and regulatory compliance.

The aim of this review is to discover the best way to automate food safety management systems, a measure that has the potential to significantly increase operational efficiency and accuracy in monitoring safety standards. To achieve this end, a review protocol will be adopted that includes the selection of strategic keywords, the application of specific filters and the definition of data sets, as well as clear inclusion and exclusion criteria, ensuring a focused and high-quality analysis of the available evidence.

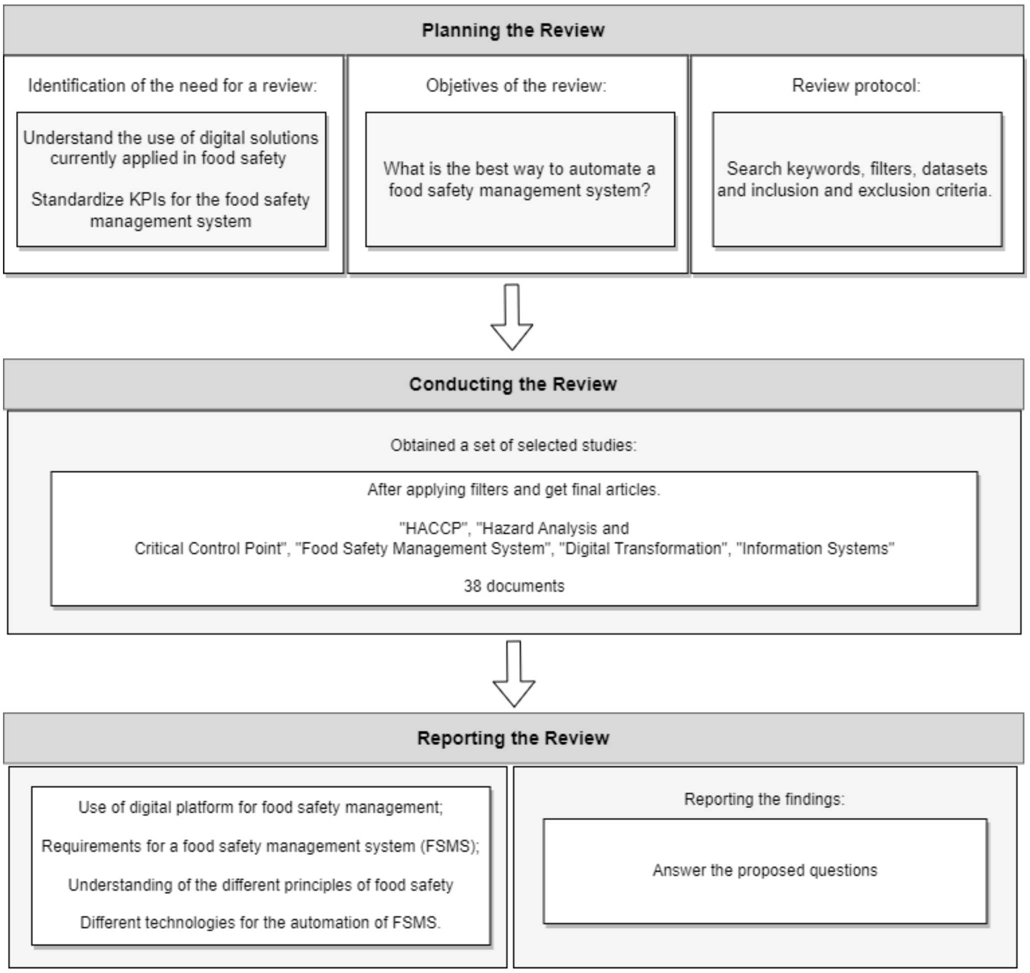


Figure 1 - SLR Stages

2.3.2. Search Process

Throughout the research process, the main databases used for document acquisition were Scopus, Google Scholar, EBSCO, ACM, and Web of Science. To make the whole process systematic, a set of keywords were used in these same databases. The keywords used were: "HACCP", "Hazard Analysis and Critical Control Point", "Food Safety Management System", "Information System", "Digital Transformation". In each category the keywords were also combined using the Boolean "OR" and "AND", e.g. between ("Food Safety Management System") AND ("Information System" OR "Digital Transformation").

In order to discover the best and most relevant articles, 3 filters were performed. Filtering from the quality questions and criteria was not performed, as it would reduce the number of articles, which would not be good for my literature review. From these filtering results, a list of 38 articles was developed for this review. Table 1 shows how each iteration was done.

Table 1 - Filtration process and iterations results

Filtration Interactions	Description	Count
First filtration	Identification of relevant studies from selected databases using the defined keywords.	13575
Second Filtration	Exclude documents based on the past 10 years.	7586
Final Filtration	Exclude documents based on abstracts and English	38

It is important to understand that Google Scholar does not allow to search in abstracts. So, in this database the same keywords were looking in titles. Considering that all the there databases presented a large amount of literature this measure did not make the process unfeasible. This metric did not make the procedure impractical, especially given the fact that all the other databases included a substantial amount of literature.

The results of the filtering procedure for each term are shown in Figure 2. It is evident that most of the searched phrases return few results, and some simply return none.

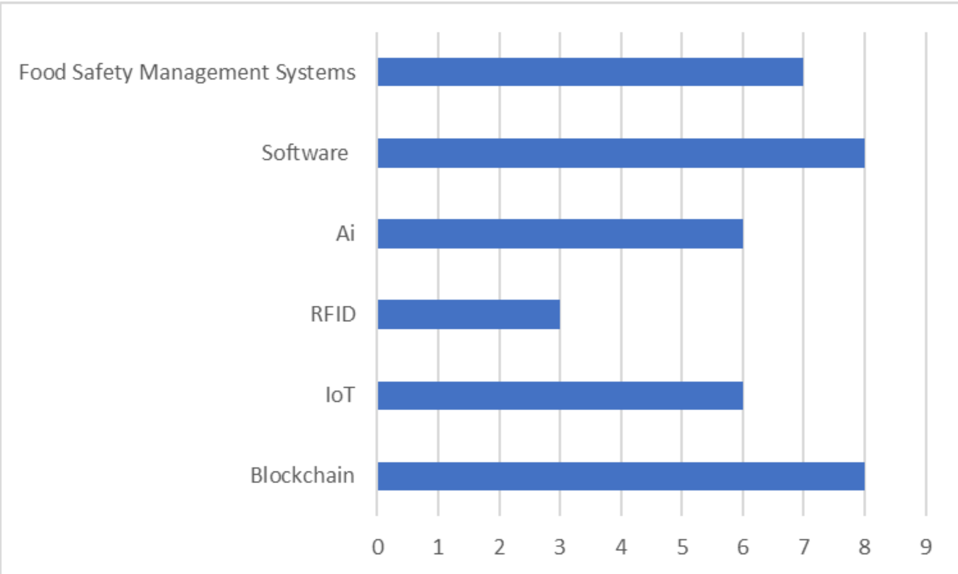


Figure 2 - Number of Papers Collected by keywords.

2.3.3. Inclusion and Exclusion Criteria

The criteria presented in Table 2 were used to synthesize all the material found in international journals and conferences, in order to get better information about which automation is best for the food safety management system. To obtain recent information, all research was based on the last ten years (between 2013 and 2023) and to be able to have written the articles in English.

Table 2- Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Written in English	Not written in English
Scientific papers in conferences or journals and books	Non-free documents nor Master Thesis
Publication date greater than or equal to 2013	Documents with publication date less than 2013
Abstract relevance	No abstract relevance

2.3.4. SLR Result

Only 38 papers were chosen after a thorough study of the literature, all of which addressed food safety, the HACCP concept and the food safety management system, trying to find a relationship between these and digital information.

From the papers offered it is clear that there is sufficient research to justify which automation is best for the food safety management system, particularly when considering its technical development.

It is clear that most of the publications discuss food safety and digital transformation, which is beneficial for the efficiency of companies.

Most of the articles gathered discuss food safety, HACCP, and food safety management system relating to all the technologies useful for there to be a digital transformation in this area.

Blockchain and Internet of Things (IoT) is a great innovation for tracking supply chains "that can provide an information platform for all supply chain members with openness, transparency, neutrality, reliability and security" [35].

Table 3 - Papers distributed by subject

Subject	Papers Related
BlockChain	[27]; [35]
Iot-Internet of Things	[31]; [35]
RFID	[33]
Artificial Intelligence	[25]
Software	[2]; [5]; [11]; [21]; [26]
Food safety Management Systems	[12]; [16]; [17]; [19]

Chapter 3 - Research Methodology

Design science research was the research approach employed in this study. The DSR technique used in this case is centered on the idea of designing, building, and evaluating the mobile application we want to create. It may be described as the deliberate creation of artifacts with the intention of satisfying certain requirements. It seeks to address a particular problem. Three components make up this methodological approach: conceptual concepts that aid in establishing the DSR, applicable rules for putting the methodology into practice, and steps for performing and carrying out the research. The challenges and the reason for the study should be identified first, followed by the definition of the research's goals and the suggested remedy

After that, the implementation phase begins. The construction of customized mobile software is the artefact that has to be produced, so as soon as a version is finished, it should be shown to RE agents (the fourth step) to get their input and conduct an assessment of the final product, which is the fifth stage of the process. The DSR model can be iterated once more to enhance the application if there are advancements in both the system's functional level and needs.

The dissemination of the discoveries and the outcomes obtained with the manufactured artifact is supposed to be the last phase.

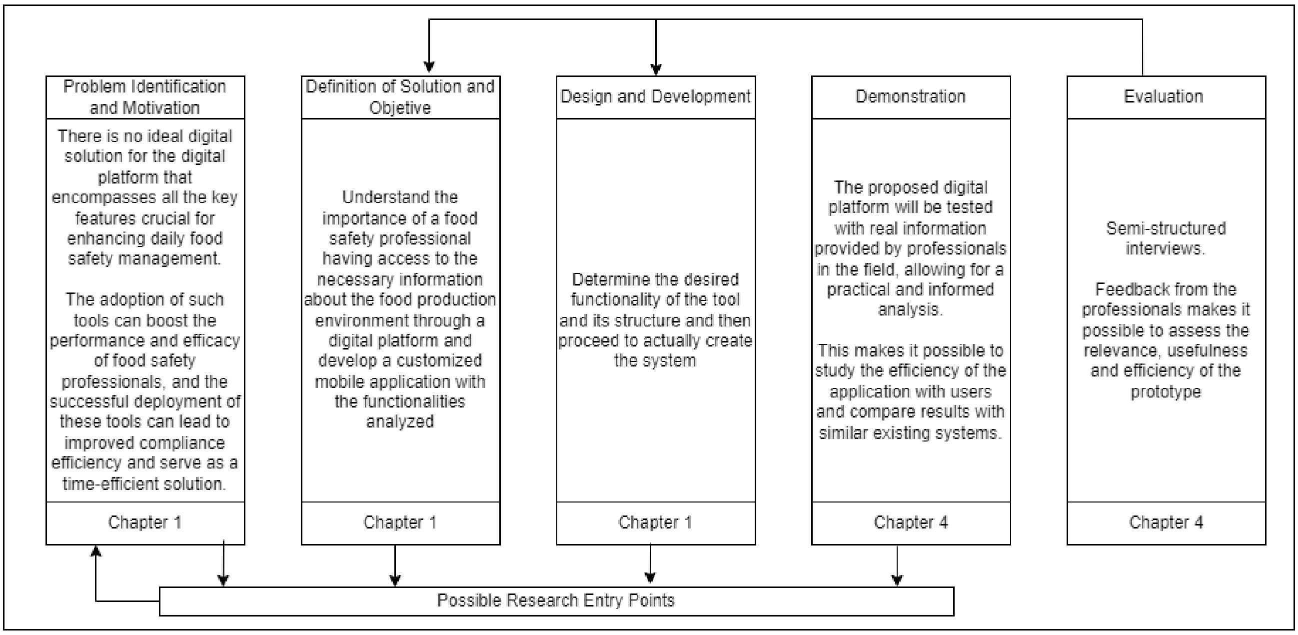


Figure 3 - DSR methodology scheme.

Chapter 4 - Proposal and Evaluation

The project for the Digital Food Security platform was built through a meticulous research process, based on the Iterative Development and Action Research (IDAR) approach. In order to consolidate and optimise the platform proposal, four semi-structured interviews were conducted with renowned food safety experts, all with more than two decades of experience in the field.

These interviews, which lasted an average of one hour and thirty minutes, were organised. The interviewees were introduced to the platform in detail, exploring its functionalities, which included both the section for managers and employees and the mobile application for recording essential data such as temperatures and hygiene protocols. This iterative cycle and the valuable insights gained through the interviews were key to perfecting the platform, ensuring that it fulfils both theoretical foundations and practical real-world requirements. As a result, the platform has been improved in line with best practice and aligned with the expectations of highly qualified food safety professionals.

4.1. First Iteration DSR

Adopting the DSR methodology, I carried out a total of four iterations to perfect the prototype of the proposed Digital Food Safety platform. The information for these iterations was primarily gathered through interviews conducted with experts in the field of food safety. This section details the three key phases of each iteration: the proposal, demonstration and evaluation. Incorporating authentic information from the target organisation provides added familiarity to the interviewees, enabling them to contribute more effectively to building a robust platform for decision support.

4.1.1. Proposal

The platform proposed in the first iteration comprises a website and a mobile application. The website is aimed primarily at managers and employees, allowing them to monitor and manage the various aspects of food safety. In contrast, the mobile application is focused on facilitating real-time data recording, addressing crucial metrics such as temperatures and sanitisation protocols.

Table 4 - Data of the interviewees

DSR Iteration	Gender	Age	Department	Role	Years of Experience
1	Male	54	Consultoria de Segurança Alimentar	Consultor Sénior	25
2	Female	51	Consultoria de Segurança Alimentar	Especialista em Protocolos de Higiene	23
3	Male	48	Restauração	Gestor de Restaurante	20
4	Female	50	Restauração	Chef de Cozinha e Gestora de Segurança	22
Total		203	N/A		90
Avarage		50,75			22,5

4.1.1.1. Research and Analysis

The research and analysis phase proved crucial to the design and refinement of the proposed platform. Within this framework, two main focuses guided the process: the evaluation of the existing market and direct feedback from food safety professionals through semi-structured interviews.

Prior to any significant development, it was imperative to understand the current landscape of the food safety platform market. This assessment provided insights into the common functionalities, existing gaps and emerging needs of the sector. By examining existing solutions, it was possible to determine that many platforms focus predominantly on regulatory aspects, leaving aside more intuitive and interactive functionalities, especially those integrated with mobile applications for real-time data recording.

The wealth of data collected during the interviews offered a deep and practical perspective. Each interviewee, with more than two decades of experience in the field, brought different nuances to the table:

The Senior Consultant emphasised the need for continuous training for users of the platform, given the constant evolution of food safety standards.

The Hygiene Protocols Specialist emphasised the importance of a real-time alert system, particularly for critical situations that could compromise food safety.

The Restaurant Manager focussed on usability, pointing out that many of today's systems are too complex for day-to-day employees, resulting in errors and inefficiencies.

Finally, the Chef and Safety Manager emphasised the need to integrate different types of data (such as temperatures, cooking times, and hygiene protocols) into a single platform.

These interviews not only validated the initial ideas but also introduced new elements to the project, ensuring that the proposed platform was both innovative and deeply anchored in the real needs of the sector.

Public information, especially that made available by regulatory bodies and food safety organisations, was meticulously analysed. As well as identifying standard practices, this analysis helped shape the

KPIs that the platform should monitor. Integrating these KPIs with the insights of the interviews ensured a holistic approach to the platform's development.

4.1.1.2. ETL process

Research and analysis play a key role in the development of successful projects. These processes make it possible to identify specific needs, evaluate existing solutions and extract valuable insights from the data. In this way, we will explore a diagram that represents a comprehensive research and analysis process, with a focus on the restaurant and hotel industry. We will see how this process can lead to significant improvements and innovation in this sector.

The research and analysis process begins with identifying the need that the project intends to address. This involves an in-depth analysis of the problem or challenge that needs to be addressed. By fully understanding the nature of the problem, effective and innovative solutions can be developed. A crucial step is the evaluation of existing solutions. This involves researching and analyzing similar solutions that are already available on the market. The aim is to identify the gaps in these solutions and find areas where the project could bring additional value or innovation. In this process, ETL plays an important role in extracting, transforming and loading the relevant data for analysis. Locating relevant data sources is another important step. This can involve searching databases, websites, APIs or other sources of information. The effective extraction of this data is key to obtaining valuable information for the project. The ETL process is used to extract data from different sources, transform it into a format suitable for analysis and upload it to a secure location for later use. Once the data has been prepared, visualization functionalities and techniques are applied. This involves creating graphs, tables or other visual representations of the data. Data visualization makes it easier to understand the information and identify important patterns or trends. In the context of the restaurant and hospitality industry, this can involve creating dashboards that show key metrics such as occupancy rate, customer satisfaction and revenue per customer. Ongoing monitoring is an essential step in the process. This allows you to track the project's progress over time and identify possible areas for improvement or necessary adjustments. In the restaurant and hospitality sector, monthly monitoring can involve analyzing sales data, customer feedback and operational performance indicators.

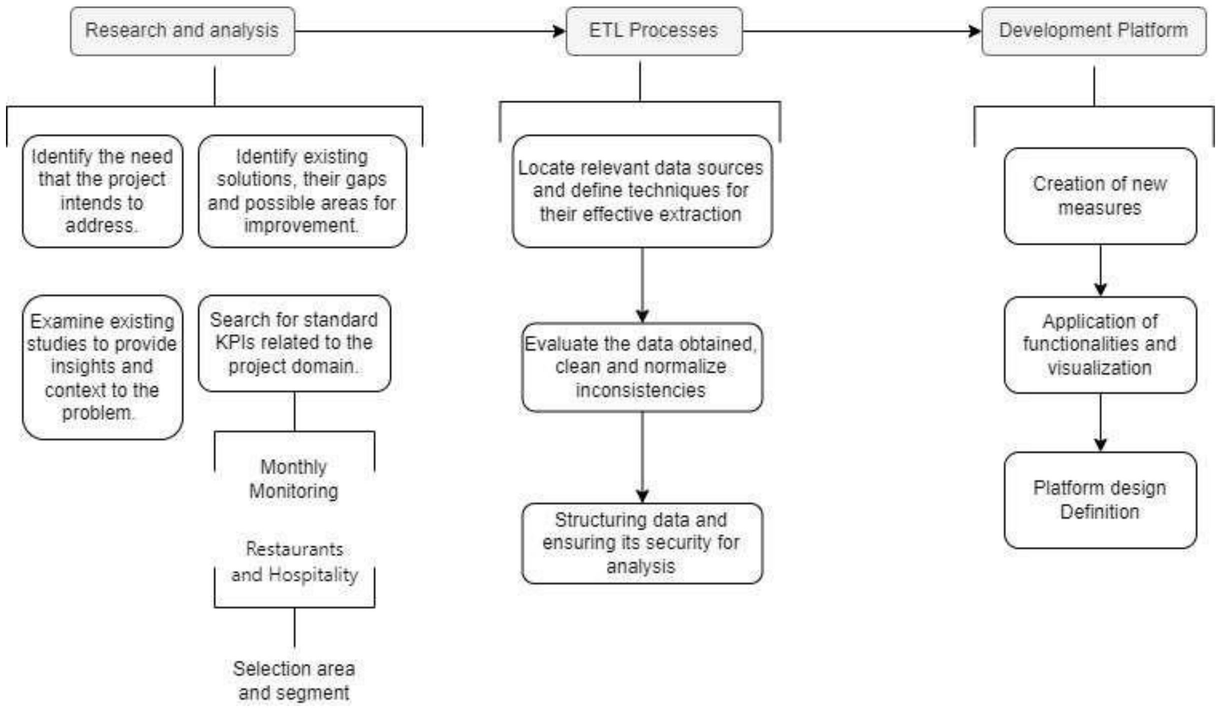


Figure 4 - Proposal Development Workflow

4.1.1.3 Development Platform HACPP Digital

It was crucial to utilize feedback and data acquired during interviews with experts in the industry as the development of the HACCP Digital Platform moved forward. These carefully and thoroughly performed interviews offered insightful information that greatly influenced the project's path. The vital requirement for having an efficient system for tracking temperatures was one of the key issues brought up by the interviewees. Given the significance of temperature in maintaining and assuring food safety, it is obvious that any platform designed to handle food safety must give this capability top priority. An additional component mentioned throughout the interviews was hygiene recording, in addition to temperature recording. At all phases of food manufacturing and delivery, cleaning and sanitizing procedures are essential for preventing cross-contamination and guaranteeing food safety. Based on these invaluable contributions, the HACCP Digital Platform has been designed with a clear focus on the development of two crucial modules: the temperature recorder and the hygiene recorder. The incorporation of these functionalities will ensure that the platform not only meets, but also exceeds the expectations of industry professionals and meets the day-to-day operational needs in food safety management. In addition, it is planned to integrate future functionalities, such as log audits and a greater application of artificial intelligence in the creation of HACCP plans, with a view to continuous optimization and a proactive response to emerging challenges in the sector.

4.1.2 Demonstration

The initial iteration of the evolutionary process used to create the CHEMP Platform was primarily concerned with defining and implementing the essential capabilities required for efficient management of food safety. The major goal of this initial phase was to create a platform that would enable catering and hospitality organizations to consistently and easily track two important parameters: temperature and cleanliness. These two criteria are essential for ensuring consumer protection and food quality. It was discovered via interviews and comments that there was a rising need for a digital solution that could streamline and improve these routine processes.

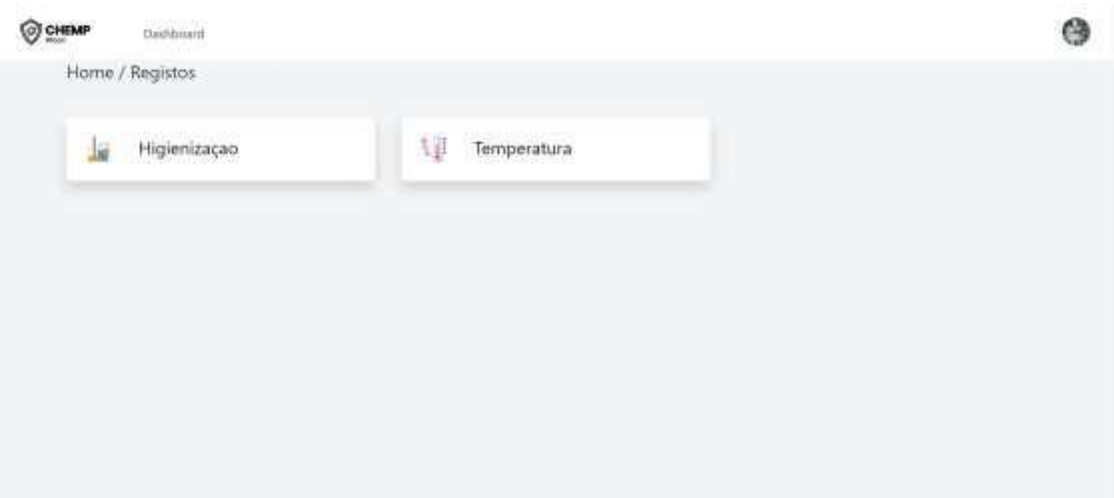


Figure 5- Platform demo (Records)

Figure 6 - Demonstration platform (Sanitization records)

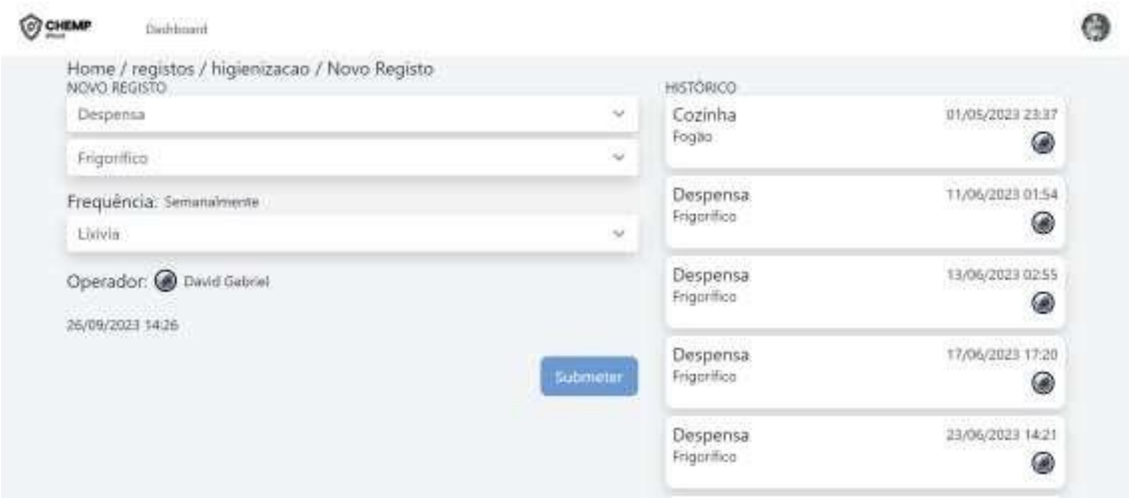


Figure 7 - Demonstration platform (Insert Sanitization records)

Sanitation necessitates thorough and precise recordkeeping as a crucial component of avoiding contamination and guaranteeing food safety. In order to address this, the CHEMP Platform was designed with an interface that enables operators to choose and record certain places and products for sanitization, assign accountability to particular people, and maintain a thorough history of these recordings. This technology not only makes routine sanitization procedure maintenance and verification easier, but it also gives institutions a tool for accountability and transparency.

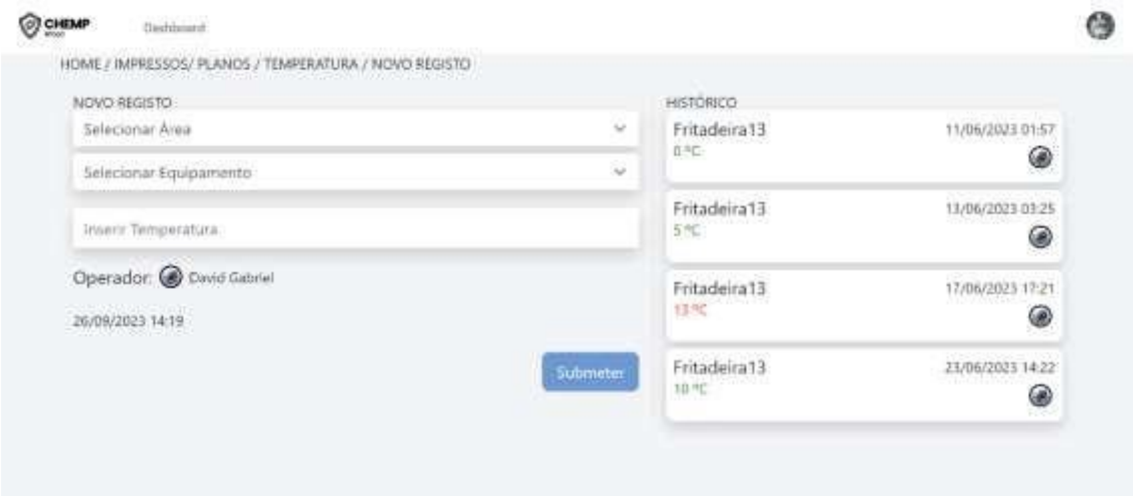


Figure 8 - Demonstration platform (Insert Temperature records)

Figure 9 - Demonstration platform (Temperature records)

In line with the essence of food safety, constant and accurate temperature monitoring is vitally important. Temperature variations, however minimal, can compromise the safety and quality of food, potentially harming consumers. With this in mind, the CHEMP Platform, during its first iteration, integrated a specific module for recording temperatures. The platform's intuitive design allows operators, such as David Gabriel, to easily record the temperatures of different equipment and areas within an establishment. This functionality, visually presented in the "NOVO REGISTO" section, offers a drop-down list for selecting the specific area and equipment, followed by a manual entry of the current temperature. This simplified method ensures that operators can make quick records, minimizing the possibility of errors. In addition, the "HISTÓRICO" section serves as a digital repository of all temperature records made previously, providing a chronological view of temperature variations over time. For example, you can see temperature records for a fryer on various dates, allowing managers and supervisors to track and analyze trends, identify anomalies and take corrective action when necessary. This temperature recording module, backed up by the opinions of the interviewees, makes the CHEMP Platform an indispensable tool for establishments striving to maintain the highest standards of food safety.

4.1.3. Evaluation

Following the initial presentation and interview, we gathered insightful comments from stakeholders. This conversation offered us a thorough picture of the platform's uptake and efficiency thus far. Many praised the way the data was organized and presented, emphasizing how simple it was to reference and analyze. The platform's design prioritized the essential components, creating a less cluttered and more user-friendly layout that makes it simpler to operate. In particular, it was believed that the inclusion of features for temperature monitoring and sanitization was a clear and essential answer to the demands of the industry. Not all of the response, though, was favorable. Some stakeholders had worries, notably with regard to the informational organization. They believed that the data's classification and organization fell short of accepted standards and sector expectations. The absence of certain functions, such as a powerful staff registration system and a document management tool, was also identified as requiring improvement.

Following all of these findings, various suggestions for improvement were offered. The requirement to add a section for document management, enabling users to upload, manage, and consult critical documents, was among the most often highlighted. It was also thought essential to have a tool for staff registration. The installation of a system that would display a whole history of registrations made was another well-liked idea. Users will be able to easily review and analyze earlier entries thanks to this functionality. The second iteration of the project is already being planned and carried out with this input in mind, making sure that comments and proposals are integrated to further strengthen the platform.

4.2. Second DSR Iteration

4.2.1. Proposal

The second iteration of our project served as a crucial turning point for fine-tuning and enhancing the platform's basic functionality based on insightful input from stakeholders. Instead than being only a modification, this phase was a direct reaction to the demands and recommendations mentioned before. The goal was not only to maximize usability but also to increase the tool's relevance and efficiency for its end users by adapting and incorporating these enhancement suggestions. A summary of these adjustments may be seen in Table 5, which identifies the improvement ideas, their types, whether they have been adopted, and the people who made them. The project will stay in line with stakeholder expectations and be prepared for further iterations thanks to this methodical approach.

Table 5 - Implemented Improvements – 2nd Iteration

Second DSR Iteration				
PI	**Proposed improvement**	**Type improvement**	**Implemented?**	**Who suggested?**
PI1.1	Document management tool	Functionality	Yes	Stakeholders
PI1.2	Employee registration system	Functionality	Yes	Stakeholders
PI1.3	Detailed history of records	Functionality	Yes	Stakeholders

4.2.2 Demonstration

Direct input from stakeholders has undoubtedly affected how the platform has developed. The document management portion is highlighted in the photos, and it appears to have been created in direct response to the demands and recommendations made by these stakeholders.

A straightforward and well-organized interface with three separate categories—"Records," "Policy," and "Procedures"—is shown in the figure 10. The user appears to be directed to various facets of document management by these categories. The platform clearly aspires to be more than just a store for documents; it wants to make it simpler to browse and comprehend the business's procedures and regulations.

Delving deeper into the "Policy" category, as shown in the figure 12, the platform introduces an intuitive file management system. This feature allows users to upload, view and organize documents pertinent to the company's policies, something that stakeholders identified as crucial for operational efficiency and compliance.

The figure 11 takes us to a detailed view of a specific document, reinforcing the idea of easy access and management. This level of detail and functionality underlines the platform's commitment to responding directly to the proposals for improvement suggested by stakeholders, guaranteeing a tool that not only stores information, but also makes it accessible and practical for all users.

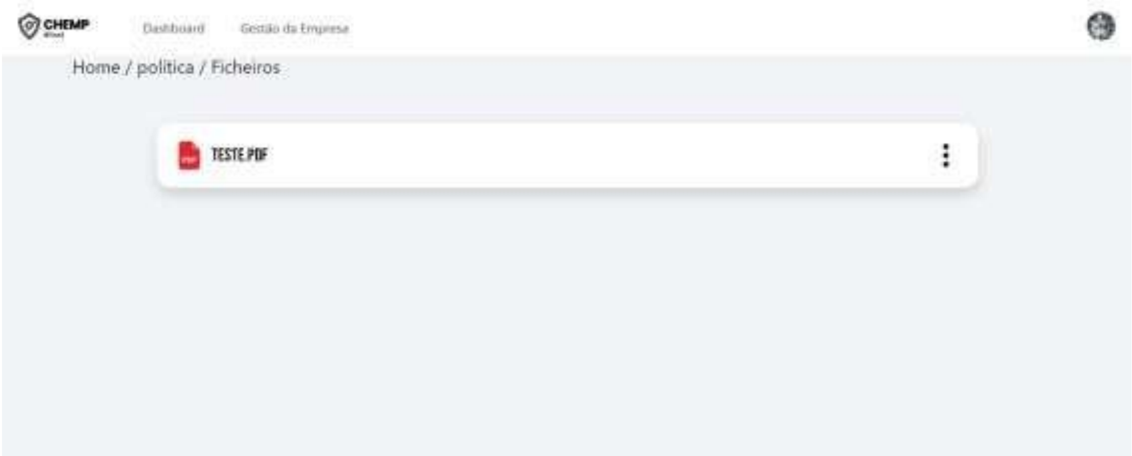


Figure 10 - Platform demonstration

Figure 11 - Platform demonstration (Home Page)

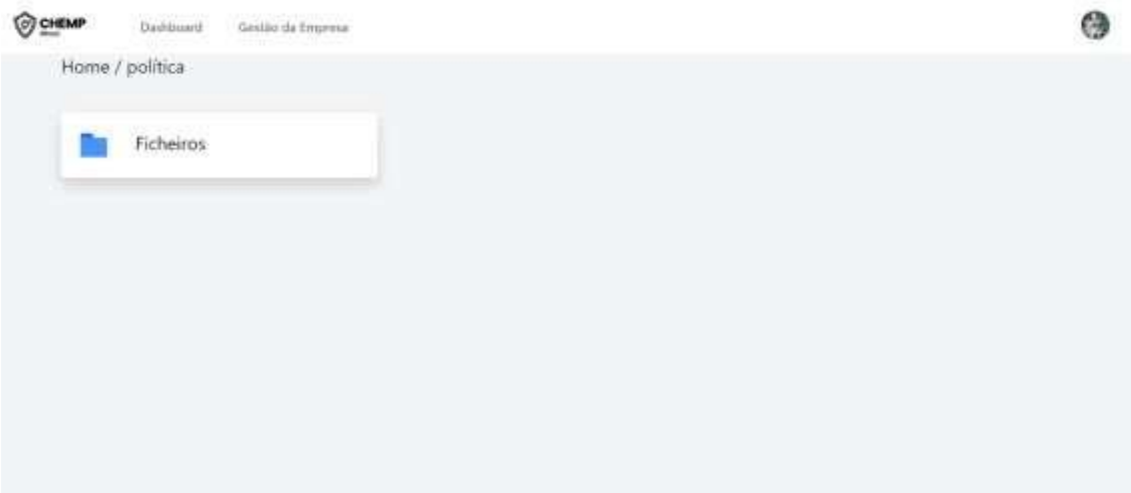


Figure 12 - Platform demonstration (Documents Management)

The Figure 13 focuses on personnel administration. With information like name, email, and the most recent time they were active, this part provides a comprehensive picture of the personnel. The control system that makes sure the maximum number of registered workers is not exceeded is a noteworthy feature. It is simpler to manage human resources and prevent unneeded overloads when the platform warns the user when the limit is reached with a clear message.

The "Logs" are depicted in the figure 14, and they appear to be an in-depth account of all the employee-performed sanitization and temperature monitoring actions. Each line provides a detailed picture of the activities performed, displaying the name of the employee, the particular activity, as well as the date and time the action was recorded. This tool, which enables a fast evaluation and analysis of all the operations carried out, is essential for ensuring compliance with health and safety laws.

The figure 15, which offers a customized "log" for a certain employee, extends this feature even further. Administrators may examine every action taken by a single employee in detail using this pop-up window, which is essential for assessing performance and making sure that all procedures are being followed exactly.

Figure 13 - Employee Management

Figure 14 - Employee logs management

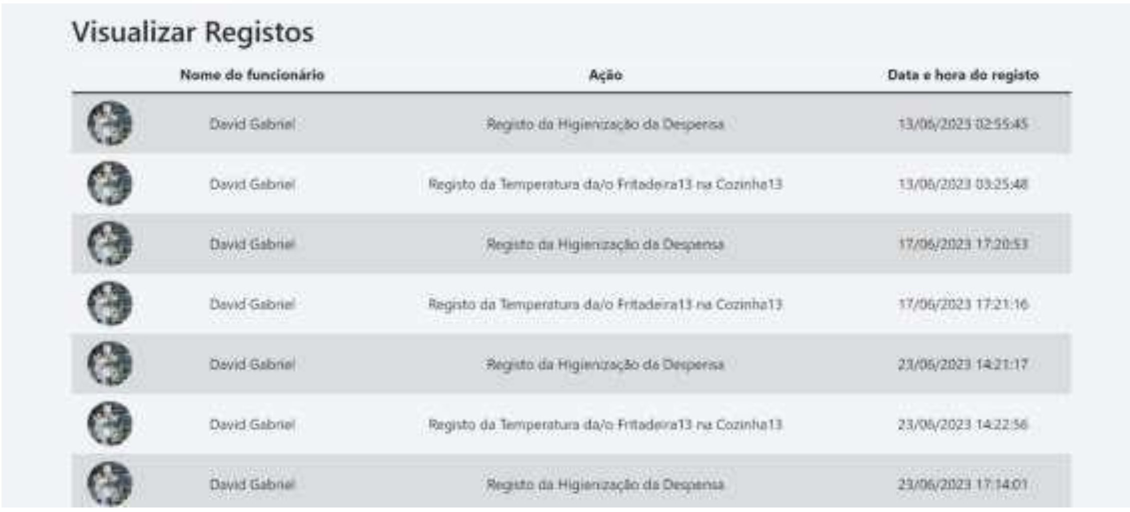


Figure 15 - Total Employee Log

4.2.3. Evaluation

The second interaction revealed significant advancements, particularly in the management of employees and the recording and visualizing of logs. It goes without saying that the ability to track and manage certain operational details while obtaining a detailed view of the logs is a significant step in the right direction. The ability to view specific logs for specific employees makes the platform highly individualized and user-centered, addressing the needs of all parties involved.

However, integrating Generative artificial intelligence to help with the creation of the HACCP plan is an area that may use some more improvements. Working more closely with HACCP experts while the system is being developed may help to improve this function.

Overall, it is clear that the platform has advantages. The user-friendly interface, organized layout, and careful attention to detail stand out. The platform has a tremendous deal of potential to develop into an essential tool in the food safety industry with continuing input and iteration, with a particular focus on expanding Generative artificial intelligence capability for developing the HACCP plan.

4.3. Third DSR Iteration

4.3.1 Proposal

Optimising the identification of Critical Control Points (CCPs) and the definition of corrective actions in the field of food safety while taking into account the needs of stakeholders is the goal of research and development into an integrated approach that combines Artificial Intelligence (AI) with the HACCP (Hazard Analysis and Critical Control Points) methodology. There is a growing need for more effective and automated solutions that can simplify the process while also improving the accuracy and dependability of the plans created, given the complexity and potential errors associated with the traditional methods of creating and maintaining HACCP plans.

4.3.2 Demonstration

Numerous jobs that formerly needed lengthy periods of skilled manual work have been made simpler and automated because to the ongoing development of technology and artificial intelligence. Food safety, notably the development of the HACCP (Hazard Analysis and Critical Control Points) plan, is one of the sectors that has benefitted. In order to do this, a machine learning tool has been created that can generate a HACCP plan in response to a specific prompt, doing away with the requirement for human preparation while preserving the ability to be adjusted by food experts.

The prompt created is:

"Based on the process step *[process step]*, the ingredients as *[foods/ingredients involved]*, and the practices of *[practices]*, generate a HACCP plan in JSON format identifying the Critical Control Points (CCP), the necessary corrective actions and demonstrations to ensure food safety."

Process Step: [Specify the process step (e.g. "Sandwich production", "Bread baking", etc.)] Foods/Ingredients Involved: [List the food or ingredients, e.g. "bread, lettuce, tomato, chicken, mayonnaise"]

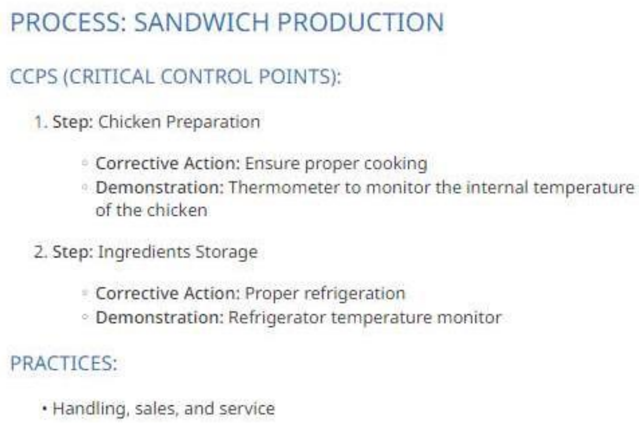
Practices: [Describe relevant handling, sales, and service practices]

The AI tool utilizes the prompt as a specific request to formulate a plan based on the provided data. By employing the Chat GPT API, the application can generate a preliminary plan once users input the stages of the process, the ingredients or dishes, and the related activities. To illustrate this, let's consider an example. When we input the aforementioned details into the system using the Chat GPT API, it can skillfully create a structured recipe.

"Based on the sandwich production process steps, the ingredients such as bread, lettuce, tomato, chicken and mayonnaise, and the handling, sales and service practices, generate a HACCP plan in JSON format identifying the Critical Control Points (CCP), the necessary corrective actions and demonstrations to ensure food safety."

he tool's answer would be:

```
{
   "Process": "Sandwich production",
   "CCPs": [
      {"Step": "Chicken preparation", "Corrective action": "Ensure proper cooking", "Demonstration": "Thermometer to monitor the internal temperature of the chicken"},
      {"Step": "Storing ingredients", "Corrective action": "Proper refrigeration", "Demo": "Refrigerator temperature monitor"}
   ],
   "Practices": "Handling, sales and service"
}
```



PROCESS: SANDWICH PRODUCTION

CCPS (CRITICAL CONTROL POINTS):

1. Step: Chicken Preparation
   - Corrective Action: Ensure proper cooking
   - Demonstration: Thermometer to monitor the internal temperature of the chicken
2. Step: Ingredients Storage
   - Corrective Action: Proper refrigeration
   - Demonstration: Refrigerator temperature monitor

PRACTICES:

- Handling, sales, and service

Figure 16 - PDF Example

In conclusion, the application of AI-based techniques to the field of food safety has the potential to be transformative. Indeed, leveraging AI in this domain can lead to significant advancements in real-time monitoring, predictive analysis, and the overall enhancement of food safety protocols, ultimately benefiting both industry stakeholders and consumers. However, ongoing analysis and subsequent validations are necessary to guarantee that the generated suggestions are precise and suitable for the particular environment. To maximize advantages and reduce potential negatives, automation and human interaction must be balanced.

4.3.3. Evaluation

It has shown to be a promising innovation to use AI into the development of the HACCP plan. AI can effectively identify Critical Control Points (CCPs) based on the process stages, the food produced, served, or sold, as well as other user-defined data, using structured prompts. After the required data is given, AI suggests a plan that includes not only the CCPs but also the corresponding remedial actions and reasons for each point detected.

The evaluation of the stakeholders provided a variety of insightful viewpoints on the use of AI into the HACCP process. The majority of respondents acknowledged AI's potential to streamline and automate the selection of Critical Control Points (CCPs) and the formulation of corrective measures, emphasizing the technology's capacity to change and advance conventional processes. A wholly automated approach, on the other hand, has some stakeholders worried about an over-reliance on technology and the potential for mistakes or omissions. These issues highlight the ongoing requirement for human oversight and verification of the procedure. Many argued that even though AI can be a powerful auxiliary tool, human knowledge and discretion remain indispensable. With the proviso that this technology should be used as a complimentary tool and not a substitute for the expertise and experience of specialists in the industry, the review concludes that there is clear support for the notion of enhancing the HACCP method with artificial intelligence.

4.3. Fourth DSR Iteration

4.3.1. Proposal

The new iteration of the system begins with a careful analysis of the interface presented, which is designed for creating the HACCP Plan. This interface, designed to be intuitive and effective, allows users to enter critical information relating to the food production process, from the process step to the specific ingredients involved. However, as we move into this evaluation phase, it is imperative that we consider the effectiveness of this interface in the light of stakeholder feedback and user experiences.

This iteration will be distinguished by a thorough analysis of the functionalities implemented in the previous phases. We will take a deep dive into each feature, assessing its functionality, effectiveness and relevance. Temperature and sanitization records, which formed the backbone of the first iteration, will be reviewed to ensure that they meet stakeholder expectations and the practical needs of the sector. Likewise, document management and employee and log records, introduced in the second iteration, will undergo a similar evaluation. Issues such as ease of use, data accuracy and security will be addressed, looking for areas of improvement or refinement. The introduction of generative Artificial Intelligence in the third iteration will be the main focus of this evaluation. The aim is to determine whether the AI meets expectations, how it has facilitated the creation of HACCP plans and whether there is room for improvement.

In conclusion, this iteration promises to be a phase of introspection and refinement. With the ongoing collaboration of stakeholders and a focus on continuous improvement, the system is positioning itself as a leading tool in the field of food safety. Effective integration of technology and attention to user needs will ensure that the system remains relevant and valuable well into the future.

4.3.2. Demonstration

In this demonstration, we present the user interface for creating a HACCP Plan in the CHEMP system. The form displayed is designed to be intuitive and simplified, allowing users to define the essential components of the plan with ease. In the "Process Stage" field, users are encouraged to specify the specific stage of production or service. In the example shown, "sandwich production" is referred to, indicating that we are focused on the production of sandwiches. The "Add more stages" feature suggests that the form is dynamic. This means that if the production or service involves several different steps, they can be added sequentially, ensuring a complete and detailed HACCP analysis. In the "Products or Ingredients" field, the ingredients or products used in that step are listed. In our example, we have bread, lettuce, tomatoes, chicken and mayonnaise. This helps to identify specific critical points for each ingredient. Finally, the "Practices" field allows users to detail the specific methods or practices associated with the step, such as handling, sales or service. This is key to identifying areas where there are potential risks or where preventative measures are needed. After filling in all the relevant fields, the user can click on the "Create HACCP Plan" button to generate a structured HACCP plan based on the information provided. This user-centered design ensures that drawing up the plan is both systematic and comprehensive.

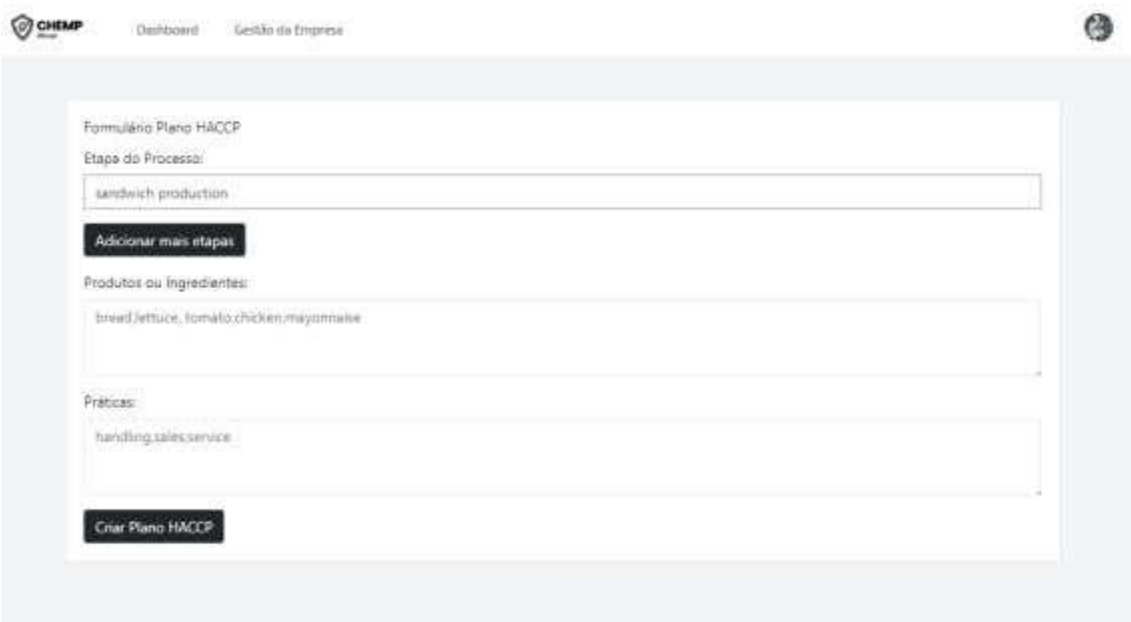


Figure 17 - HACCP Plan Register Form

4.4.2. Evaluation

The process of developing the project to build a digital HACCP platform was meticulously planned out into three key phases. Based on recognized needs and ongoing feedback from stakeholders, each phase was specifically planned with the goal of introducing and upgrading functionality.

The initial phase introduced temperature and sanitization data in order to create the project's sturdy basis. This initial milestone served as both a learning stage when the team discovered the first chances for development and offered critical data monitoring. When stakeholders interacted with the system, they stressed the value of having more understandable and user-friendly user interfaces. This idea became the main focus of the next stages.

The second step then attempted to fill these original requirements. There was a noticeable progression in the project with the addition of functionality including document management, staff registration, and a more sophisticated logging system. The system was elevated to a new level by its capacity to effectively handle, organize, and track information. Stakeholder comments did, however, once more highlight opportunities for development, particularly with regard to the logging system, suggesting that there was space to make it even more reliable and user-friendly.

The project's third and most ground-breaking phase saw the introduction of generative AI, especially with the aid of generative Ai. By leveraging the project, this feature made it possible to create HACCP plans with more automation and ensured that the system could be customized to meet the needs of each user. While this activity was applauded and appreciated for its originality and adaptability by stakeholders, ideas for refining the user interface and laying out more precise standards for productive AI engagement also surfaced. The development and success of the project depended heavily on ongoing communication with stakeholders and the inclusion of input at each level.

Chapter 5 – Conclusion

I am currently working on developing artificial intelligence-based solutions to improve food safety, with a particular focus on automation and predictive analysis. For the future, I plan to expand this research to include emerging technologies, such as the Internet of Things (IoT) and blockchain, to further strengthen traceability and data integrity in the food supply chain. The integration of these technologies aims to offer a more robust and efficient system, capable of predicting and mitigating food safety risks in real time. As far as the roadmap is concerned, the strategy is evolutionary and phased. In the short term, the focus is on implementing and testing AI algorithms for the early detection of anomalies in food production and distribution. In the medium term, I intend to integrate IoT solutions for continuous monitoring of critical parameters such as temperature and humidity. In the long term, the aim is to incorporate blockchain systems to guarantee transparency and total traceability, providing consumers and regulators with a complete and reliable view of the supply chain.A testimony to the potential for innovation when technology is used to solve actual, practical issues is the trajectory of the initiative to develop HACCP plans, which was driven by artificial intelligence. The project showed right away the revolutionary potential of fusing highly specialized technical know-how with cutting-edge technology solutions.

The first phase set the groundwork for what would later emerge as a ground-breaking approach to food safety. We were able to observe that even the simplest operations, when streamlined, may generate tremendous value for stakeholders by introducing temperature and hygienic data. This stage served as the foundation, allowing us to pinpoint problem areas and mold following actions. In the second phase, we included more complicated functionality like document management and staff registration in response to the demands that were expressed. This improvement illustrated the project's adaptability and flexibility, as well as its capacity to meet the sector's ever-changing demands. The project's reliability was increased through the adoption of a better logging system. The third stage saw the emergence of generative AI platforms, which completely changed the game. The ability of generative artificial intelligence to learn and grow has shown it to be more than simply a tool for automation. The adaptability of HACCP plans to each user's unique requirements highlighted this strategy's potential for innovation. Feedback from stakeholders was crucial at each level. Their advice and input helped shape the system's enhancements and modifications, and their active engagement confirmed the system's relevance and practicality. The project ended up serving as an illustration of how interaction between developers and end users may provide original solutions. However, the project also encountered difficulties, much like any new endeavour. The need for user-friendly interfaces, managing expectations, and integrating technology with existing methods were all issues that needed ongoing monitoring and modifications. Looking back, the experiment demonstrated the potential of AI in the field of food safety. However, it also demonstrated that real innovation occurs when technology is developed to meet the needs of people rather than the other way around. We view this endeavour as a milestone rather than a destination for the future. Technology's ongoing development and the industry's rising demand indicate that there will always be potential for innovation. We are hoping that this project can act as a launchpad for more efforts in the future where technology and human expertise will continue to combine for better solutions.

The AI-driven HACCP project is proof of what is possible when cutting edge technology is combined with industry knowledge and ongoing stakeholder feedback. It's a potent mix that we anticipate influencing and enhancing food safety for many years to come.

In the ever-evolving world of food safety, continuous optimization and innovation are essential. The work done so far on the project has laid a solid foundation, but the horizon brings with it new opportunities and challenges that are eager to be explored. One of the most promising avenues for improvement is data visualization. With the growing amount of information that our platform collects and processes, it becomes crucial to turn this data into actionable insights. An intuitive and robust dashboard, which presents real-time information in a clear and concise manner, will allow users to quickly understand the nuances of the HACCP system, identifying trends, anomalies or areas that need attention. In addition, the user experience (UI/UX) has emerged as a vital aspect. Intuitive interaction with the platform not only improves operational efficiency, but also ensures that users can maximize all the functionalities offered. Investing in interactive designs, real-time feedback and a user-friendly interface will make navigation and operation more fluid, encouraging greater user adoption and satisfaction. Last but not least, the advent of the Internet of Things (IoT) presents an invaluable opportunity. The integration of the IoT would allow traceability and registration processes to be automated. Imagine sensors that automatically record temperatures or machines that communicate directly with the platform, updating information in real time. This not only saves time and reduces human error, but also provides a much more accurate and up-to-date view of the procedures in progress. In short, while the project has already reached significant milestones, the road ahead is full of possibilities. With focus and investment in the areas mentioned, the platform has the potential to revolutionize the way food safety is perceived and managed, consolidating itself as an indispensable tool in the sector.

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