

Research Article

Teaching and Learning Innovation in Management of Technology and Innovation: SAS Smart AI Features

Muhammad Azrul Adzahar¹, Nur Syuhada Adilah Mahadi², Putri Sofea Mohamed Yusoff³, Nor Halida Haziaton Mohd Noor⁴, Wan Yusrol Rizal W. Yusof⁵, and Mariam Setapa^{6,*}

¹ Arshad Ayub Graduate Business School; 2024839872@student.uitm.edu.my

² Arshad Ayub Graduate Business School; 2024828662@student.uitm.edu.my

³ Arshad Ayub Graduate Business School; 2024886342@student.uitm.edu.my

⁴ Faculty of Business and Management, UiTM Kelantan Branch; halida552@uitm.edu.my

⁵ Faculty of Business and Management, UiTM Kelantan Branch; wanyusrol@uitm.edu.my

⁶ Faculty of Business and Management, UiTM Kelantan Branch; maria135@uitm.edu.my

* Correspondence: maria135@uitm.edu.my; +60137242641

Keywords:

Smart refrigerator
Artificial intelligence
Food waste reduction
Smart-home technology
Sustainable consumption



Copyright: © 2026 by the authors. Submitted for open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Abstract: The SAS Smart AI-Enhanced Refrigerator System is an innovative smart-home solution developed to reduce household food waste through intelligent food storage management. The system uses AI-based food scanning technology to identify food type, packaging, and freshness before recommending the most suitable refrigerator compartment and temperature zone. Integrated smart compartments and an AI Alert System monitor food placement and provide expiry reminders to minimize spoilage and extend shelf life. In addition to improving food preservation, the system promotes energy efficiency and environmental sustainability. Although currently at the conceptual stage, the innovation demonstrates strong commercialization potential and supports Sustainable Development Goal 12 on responsible consumption.

1. INTRODUCTION

Technological advancement has expanded across all industries in line with global demands. Each technological innovation is developed to simplify human activities and improve quality of life. The home electronic appliance industry, including smart fridge, is not excluded from this rapid development. An intelligent refrigerator is one of the smart systems capable of sensing the refrigerator environment, such as temperature, humidity, and gas levels, to predict the quality of food stored inside based on the collected data (Devarajan, 2022). Manufacturers continuously upgrade their refrigerator products with new technologies to remain competitive and sustainable in the industry. Advances in electronic technology not only make daily life more convenient but also emphasize energy efficiency and reduced electricity consumption. Intelligent fridges enable users to identify food items that are close to spoiling (Dey & Dutta, 2019), prioritize the use of food items approaching their expiration date (Aurel-Dorian Floarea, 2016), and remove spoiled food from the refrigerator (Nasir et al., 2018).

Additional features such as scanning cameras and built-in display screens allow users to record and monitor stored food items. Furthermore, modern fridge can now connect to mobile phones in real time. Collaboration with smartphone technology providers has made fridge smarter and more efficient. Despite these technological advancements, users continue to face food waste issues. Food waste is not a new problem and is becoming increasingly severe, particularly in rapidly developing countries. In 2022, the world wasted an estimated 1.05 billion tonnes of food across the retail, food service, and household sectors, equivalent to 132 kilograms per capita per year, with 79 kilograms per capita wasted at the household level (UNEP Food Waste Index Report, 2024).

Current technological developments alone have not been sufficient to overcome this issue. Each compartment inside a refrigerator has different temperature levels, humidity conditions, and airflow patterns. Incorrect placement of food items such as vegetables, meat, or dairy products can accelerate spoilage. To address this gap, an invention is proposed in the form of a Smart AI-Enhanced Refrigerator System, a technology that not only identifies the type of stored food items but also recommends the most suitable storage zone to maintain freshness and reduce food waste.

2. LITERATURE REVIEW

Global food wastage has been one of the challenges in achieving Sustainable Development Goal 12 (SDG 12), which focuses on sustainable consumption and production by 2030. Based on United Nations Environment Programme (2024), the world generated an estimated 1.05 billion tonnes of food waste in 2022, which represents nearly 19 percent of all food that should be made available to consumers. Households alone contributed 631 million tonnes which was approximately 60 percent of total consumer-level waste equals to an average of 79 kg per person per year. The trends reveal that consumer behaviour and household practices play a large role in global food-waste patterns. Many countries have increased their commitments to SDG 12, yet these efforts are undermined by growing household-level inefficiencies.

Food waste is not only a sustainability issue but it also raises concerns regarding national food security, as the consistent disposal of edible food signifies a direct loss of resources, agricultural effort, and financial investment. Additionally, food waste is responsible for a significant share of global greenhouse gas emissions of about 8% to 10%, which contributes to environmental degradation throughout the food supply chain and during disposal. These combined effects are why it's important for households to reduce food waste in order to support the country's sustainability and food security goals. Despite increased awareness campaigns and policies, many individuals still find it hard to store, manage, and keep track of their food, especially perishable items such as leafy greens, herbs, fruits, and vegetables.

As a result, even countries that strongly support SDG 12 still fail to meet their targets. This ongoing problem calls for practical, user-friendly, and technology supported solutions that can assist households in managing their food better. One of the contributors to household food waste is improper storage of groceries in fridge. Research by Hoffman et al (2023), indicates that a large proportion of discarded food originates from perishables that spoil prematurely due to incorrect temperature zones, poor humidity control, or unsuitable storage locations inside the fridge. Consumers commonly store fruits and vegetables in areas with changing temperatures, place ethylene-sensitive items next to those that release ethylene or forget about items placed deep in the refrigerator compartments. These behavioural and knowledge-based factors suggest that traditional fridge designs and current consumer practices are not enough to address the main causes of food wastage. As digitalisation expands, smart-home technologies such as AI-enabled fridge have gained attention for their ability to track inventory, remind users of expiration dates, suggest recipes, and support meal-planning decisions. Early research

and prototype developments show promising outcomes. For example, studies highlight the potential of image recognition, IoT sensors, and AI-driven models to help consumers monitor food freshness and reduce waste.

However, existing smart-fridge technologies remain underutilised and are limited in their functionality. While current smart fridge features help consumers with tracking and reminders, most systems still don't give clear guidance on how to store food properly to maximise freshness, such as identifying the correct shelf, humidity drawer, or storage container for specific produce items. This gap hinders the full potential of AI-enabled systems from fully supporting the country's efforts to reduce food waste. Therefore, this study aims to address the problem of household food wastage by examining the underutilisation and functional limitations of current AI smart-fridge technologies. The research aims to explore how improved, user-centred AI guidance on proper fridge storage can help households reduce waste, improve food-management habits, and ultimately strengthen progress toward SDG 12.

3. METHODOLOGY

The Smart AI-Enhanced Refrigerator System is an advanced household appliance designed to integrate artificial intelligence and smart sensing technologies to improve food storage efficiency and reduce household food waste. The system is equipped with the following key features:

- i. AI Vision Camera, which identifies food items prior to their placement inside the refrigerator.
- ii. AI-Based Storage Recommendation System, which suggests the most appropriate storage zone for each item based on its characteristics.
- iii. Temperature and Humidity Sensors installed in each compartment to continuously monitor and analyse the internal storage environment.
- iv. Automated Inventory Database, which records and updates item quantities and storage status in real time.
- v. Mobile Application Integration, enabling users to monitor inventory, track stock levels, and receive notifications remotely.
- vi. AI Alert System, which provides timely reminders and warnings related to food freshness, expiry risk, and improper storage.
- vii. Smart Compartment Technology, which supports adaptive storage by aligning food items with optimal temperature and humidity conditions.

Overall, this refrigerator functions not only as a food storage appliance but also as an intelligent kitchen assistant, supporting informed storage decisions, extending food freshness, and enhancing sustainable household food management.

4. FINDINGS

4.1. Functional Specifications of Product Innovation

4.1.1. AI Vision Camera

Based on the current market, the features of Samsung Bespoke AI is AI recognition where it is known as internal camera sensors and algorithms that allow the refrigerator to identify, temperature, and conditions of the food items. This feature works to monitor and classify based on its expiration dates in the refrigerator as it allows it to capture images of the and display it on the SmartThings application or refrigerator's display without opening the door. So, this eliminates the manual way of setting temperatures and modes in the refrigerator. The internal sensor and camera are able to recognise common food items such as fruits, vegetables, packaged food, dairy products, fresh products and so on. According to Samsung Electronics (2025), Samsung Bespoke AI provides AI Vision 2.0 allowing the refrigerator to classify 37 types of fruits and vegetables including lettuce, oranges, carrots, as well as cucumbers. The features also allow the system to identify shapes, colours, conditions and textures of the food items in order to assign a label to the items. It also provides expiration tracking based on the identification, classification of food items and the date detected in the refrigerator. The system allows the users to track expiration date for the packaged food and leftovers products by manually key in the expiration date on the SmartThings app and screen display on the refrigerator. However, there is a limitation for this feature as the internal camera and sensors are unable to identify the food items when the food is stacked closely to one another, when the food items are wrapped inside a packaging or plastic bag. It also failed to differentiate similar food items and recognise various food types such as raw chicken and cooked chicken.

As for the SAS Smart AI features, the new features are different from the existing features in the market as the food scanning devices will be located at the outer part of the fridge near the AI screen display to identify the food item before storing in the refrigerator. This is different from internal cameras as it only allows the scanning process to take place after storage of food. The pre scanning process is important as it provides the users with data inventories. The food items with barcodes or expiration dates can be scanned easily. Where the purpose of the scanner of food items is to collect accurate information on the product name, category, expiration date. However, users can manually input the information of the food items without barcodes or labels. The information such as the product name and the date of storage item in the refrigerator help to estimate the level of freshness based on the standard shelf life of the specific food item to allow the AI to organise the food by its expiration priority. Other than that, the new scanning feature also allows it to identify a wide range of food items and not be restricted to the limit of 37 types of vegetables and fruits. It also can identify a wide category level whether the food items in the packaged, cooked, raw, fresh and frozen state. This is because the scanning process takes places outside of the refrigerator which allow label, barcodes and storage instructions on the packaging to be clearly visible. The benefits of this feature is it consists of saving time for users as instead of manually checking dates users receive display of inventories on the screen display or mobile application and it also prevents overbuying as the system lists out the food items in the fridge as users are less likely to purchase similar food items.

4.1.2. Smart Compartment

In the current market, the availability of Smart AI fridge can be seen from Samsung, LG, Bosch, and Haier. Where it offers various features such as AI food recognition, recipe suggestions, and other features. For instance, Samsung Bespoke AI focuses solely on managing expiry dates and recognizing types of food items in the refrigerator. Samsung Bespoke AI also offers flex Zone feature where it is known as convertible storage where it allows users to store food at different temperature levels such as Freezer mode, Soft-freeze, and Chill mode. This is different from normal fridge that have fixed temperatures for all compartments. Meanwhile, Flex Zone offers users to change modes and temperature of a single compartment to match with the specific types of food. For instance, frozen food products with freezer mode and soft freeze mode are suitable for food items that users plan to cook. There are several benefits that can be highlighted from this feature whereas it increases the storage flexibility as a single compartment can offer multiple modes of storage and purposes to users, it improves the convenience for the user as it allows users to control the functionality of the compartment.

However, there are also limitations from flex Zone as its functionality depends heavily on the user's knowledge of different temperatures suitable for different food products. Meanwhile, users that lack knowledge failed to fully utilize the flex Zone features which contributed to inefficient storage and spoilage. Even though there are several smart AI fridges available in the market. There was no Smart AI fridge that came with smart compartments features that can recommend compartments for specific food items.

As for the SAS Smart AI features, the new feature is known as smart compartment where it combines the functionality of AI sensors, and automation where it suggests to the user the best zone to store the food items inside the refrigerator. This feature guides the user to store food items based on the suitable temperature, humidity, and airflow that are already built into the refrigerator. This feature is linked to the AI food scanning feature as identification, classification of food items and the system will suggest suitable compartments that match the food items that are visible on the screen display or mobile application. For example, raw food items such as meat, lamb, fish, chicken are best to store at low temperature in order to avoid bacteria growth. Meanwhile, milk, beverages are best to store in the middle compartment as the storage at the door of the refrigerator is warmer, which leads to spoilage. Leftover food items usually store in chill mode as the expiry window is roughly about 72 hours.

Hence, the feature benefits the users as it can reduce food wastage as it allows the food items to be stored at suitable temperature and humidity levels. It also lowers the dependency on the user's knowledge as it serves as an educational tool and gives direction to the users through the AI system. Therefore, the smart compartment feature helps in suggesting the correct and accurate compartment for each food item and reduce common mistakes made by the users.

4.1.3. AI Alert System

In the current market, Samsung Bespoke AI refrigerator has integrated Ai Vision Inside features inside its products where it allows AI to track and notify any reminders directly to users on the display screen and mobile application specifically about the food management and inventory updates which connect with the SmartThings app. The use by date alarm is known as one of the notifications that monitor the shelf life of food items in the fridge by utilizing AI Vision Inside as the AI system will send reminders when the expiration date is near. For example, when packaging food or leftover food items are close to expiring and spoilage, the AI system will send notification for users to consume it. These are important features and relevant to the market as it reduces the food from being left and wastage inside the fridge, and encourages better consumptions of food products. In addition, this feature also allows users to monitor and track the food items in the refrigerator where it shows the food list and inventory on the display screen. Whereas, the food recognition system in the existing fridge will recognize the food items and it is recorded in the system. Thus, this feature enables users to track any updates of the inventory lists in their refrigerator without having to open the door and it can eliminate the overbuying of the products that users already have. The Samsung Bespoke Ai refrigerator will display the current inventory, expiry status, and category. For example, the status for meat is expiring soon, and raw chicken is still fresh. However, the limitation of this feature is the blind spot in the refrigerator where the existing AI Vision Inside failed to locate certain food products that are not visible through the internal camera which contribute to the missing food items on inventory list. Other than that, the success of the AI Vision inside is based on user behaviour where if users ignore the notifications from the Smart Thing app, the alert and reminders will be ineffective.

As for the SAS Smart AI features, the new feature is known as AI Alert System where it is created to function beyond the previous feature. It is not restricted solely on inventory reminders or prioritized based on expiration dates. But it is a system that works as a preventive food management AI system. In the existing market, AI Vision inside's alert tracks the presence of food and notify users on its expiration date. However, the new AI Alert System tracks the placement of food items in the

refrigerator and its temperature. It also gives direction and provides correct placement for incorrect food items by sending reminders about spoilage via application as well as display screen on the SAS Smart AI refrigerator. Other than generic reminders, this new feature also updates the user when the frequency of door opening of the refrigerator and other contextual warnings to the users. The AI Alerts also detects movement of food items to reduce spoilage of the food. For example, as for the food items that have low engagement and movement, the AI Alerts will notify users by sending "The leftover noodles have not been reached for 8 days which increased the risks of spoilage. Please discard it". Other than that, the issue pertaining to the blind spot of food items can be prevented as the food scanning camera at the outer part of the refrigerator eliminates any absence or missing of food items on the inventory list. Therefore, the benefits of this feature provide guidance to correct any common mistakes among users in storing the food items and send important notifications and contextual warnings to ensure food safety and maximizing the usage of food items in the SAS Smart AI refrigerator.

4.2. Details of the Product Innovation



Figure 1. The product.

5. DISCUSSION

5.1. Novelty and Uniqueness of Product Innovation

A significant number of households struggle with rapid food spoilage, often due to improper placement of items within fridge compartments. Vegetables placed outside the crisper drawer tend to wilt more rapidly, meat stored on warm shelves may become unsafe for consumption, and dairy left at the door prone to spoils easily. Although modern fridges offer smart features, these features usually focus on inventory tracking rather than proper food placement. Consequently, lead to cost inefficiency caused by frequent grocery replacement due to items spoilage. The core value of this SAS Smart AI Features invention lies in its ability to help users reduce food waste and item spoilage by recommending the best storage location for each grocery item. Every fridge compartment contains multiple temperature sections, yet many users are unaware of which sections are appropriate for storing specific categories of food. By scanning items prior to storage and analysing their optimal conditions, the AI provides accurate guidance that helps preserve freshness for a longer period. This simple yet effective assistance enables users to benefit from better food quality, reduce inefficiency, and overall improved kitchen management. Additionally, the SAS Smart AI feature delivers three key value offerings which are convenience value, financial value, and sustainability value.

5.1.1. Convenience Value

In terms of convenience, the AI feature simplifies the entire food storage process. Users no longer need to guess where to place their groceries or rely on trial and error. With the support of an external scanner and instant on-screen recommendations, the process of storing food becomes quick, accurate, and effortless. The system also includes an AI alert system that notifies users whenever an item is misplaced, sending reminders through the refrigerator's built-in display or the synced mobile application. The system works across all food categories, including meat, vegetables, dairy, drinks, and packed goods, which makes it suitable for any household. By removing uncertainty and providing clear instructions, the SAS Smart AI features save time and reduces confusion. It turns food storage into a smooth, guided experience that fits easily into daily routines and improves overall kitchen convenience.

5.1.2. Financial Value

SAS Smart AI features provide financial value by helping households improve cost inefficiencies lost through food spoilage. When groceries last longer, households are not required to frequently replace items due to premature spoilage. It is beneficial during periods of rising food prices, where wastage can impose a financial burden. By guiding users to store food in the right temperature sections, the AI maximizes freshness and minimizes spoilage. Over time, these incremental savings accumulate into meaningful financial gains. With better storage decisions supported by SAS Smart AI features, households can stretch their grocery budgets more efficiently and maintain better control over their monthly expenses.

5.1.3. Sustainability Value

SAS Smart AI features support sustainability by addressing one of the biggest contributors to household food waste which is incorrect storage. When food spoils prematurely, it increases household waste and contributes to environmental issues such as landfill overflow and greenhouse gas emissions. By helping users to store groceries correctly, the SAS Smart AI features help reduce waste volume and extend the lifespan of food products. This aligns directly with Sustainable Development Goal 12, which emphasizes responsible consumption and production. The SAS Smart AI features promote sustainable habits at home, encourages mindful use of resources, and supports national waste-reduction goals. Through improved storage practices, households can contribute to a more environmentally responsible lifestyle.

5.2. Benefits to Mankind

The SAS Smart AI features include advanced food scanning, smart compartment and AI Alert system. The benefits for mankind is it can reduce the global food wastage issues. The food wastage within the household is caused by improper storage and compartments in the refrigerator. The benefits can be facilitated in reducing the global food wastage as the pre-storage during the food scanning process prevents the forgotten or unused food items in the refrigerator. As the scanning that is located at the outer part of the refrigerator allows the system to get access to the information and inventory list which will be recorded in the system. The food scanning obtains information pertaining to the name of the product, category, packaging type, expiration dates and so on. The food wastages will be prevented completely as all the food items that enter the fridge will avoid any risks of missing items, unscanned and forgotten food items. This is because the pre-storage helps the system to generate accurate inventory lists and its visibility through the mobile application and display screen in front of the refrigerator. Besides, the AI Alert system also will act as a reminder that notify when the food is close to the expiration dates which contribute to the risks of spoilage and food wastage. For instance, it will send a notification when the food is expiring a few days prior. The importance of these features in SAS Smart AI features will generate automatic and live updates which will assist the users on the correct storing and reduce waste at the household level. When the technology is used widely it can contribute to global reductions as it can reduce overbuying, and wastage of food items.

The next benefit is it can reduce workload and save time for users. This is because traditional fridge utilize time to manually check in the inventory lists, expiry dates and create a grocery list of food items which are known as repeated tasks weekly. The tasks can be complicated for busy adults and inexperienced in kitchen management. With the technology of SAS Smart AI features that allow automated scanning, smart compartments and AI Alert system that prevent repetitive tasks within the household. This is because the food scanning will help in identifying the food items before storing it in the refrigerator. After scanning the food items, it will track and record all of the inventory lists automatically which include the freshness estimation and expiration date which eliminates the manual checking process among the users.

Other than that, a traditional refrigerator depends heavily on the user's knowledge but SAS Smart AI refrigerator gives directions and assistance on the proper and correct storage with sustainable temperatures and airflows matches the specific food items. For example, the smart compartments will instruct the user where to store meat, dairy products and other types of food. Therefore, this will facilitate the busy users as well as beginners on proper storage and enhance the food safety in the household.

5.3. Potential of Commercialization

Potential of commercialisation is a vital aspect of innovation analysis, as it evaluates whether an idea can be successfully transformed into a marketable product. Apart from technical development, commercialisation focuses on factors such as market demand, feasibility, and scalability. Assessing these elements helps determine the practical and sustainable use in real-life. In the context of smart appliance technology, understanding potential commercialisation is important due to rapid technological changes and consumer expectations keep evolving. This section discusses the market potential of the proposed SAS Smart AI features, focusing on its readiness for launch and its ability to generate long-term value.

5.3.1. Market Demand

In the context of market demand, it focuses on the extent to which consumers recognise a problem and seek solutions to solve it. Relating to the SAS Smart AI features, food wastage is the major problem faced by the household. A large number of food waste occurs not due to the food being unused

but because it spoils prematurely due to improper storage. According to the Food and Agriculture Organization (FAO), approximately 1.3 billion tonnes of food are wasted globally each year, with household food waste contributing a large share of this figure. This ongoing problem highlights the need for smarter and more user-friendly food management solutions. Although more consumers are adopting smart appliances, current systems mainly focus on inventory tracking rather than providing practical advice to prevent food spoilage. The proposed SAS Smart AI features address this gap by offering precise, real-time storage recommendations tailored to specific food items. In addition, the growing concern on sustainability, and food security further strengthen the importance for these AI driven solutions. This is further supported by a study by Varzakas et. al. (2024), which highlights that global food security is closely linked to sustainability, with sustainable diets and resilient food systems being essential for long-term food and nutrition security. These factors signify that strong and sustained market demand for smart technology solutions that can assist to improve food storage and household food management.

5.3.2. Feasibility

Next, in terms of feasibility, it evaluates whether an invention or innovation can be practically developed and implemented using current existing technologies and resources. The proposed SAS Smart AI features highlight the need for its high technical and operational feasibility. The invention of SAS Smart AI features relies on established technologies such as image recognition for food scanning, machine learning algorithms for smart compartment suggestions, and sensor-based temperature mapping for AI alert systems, all of which have been adopted widely in consumer electronics. Furthermore, the system is made as an add-on module, not a full appliance redesign. According to Lantz et. al. (2022), modular strategies reduce time and cost by reusing components and enabling easy customisation without major redesign. This modular approach appeals to both manufacturers and users, as it reduces development and production costs. The SAS Smart AI features can be integrated with existing smart fridge platforms, like Samsung's AI Bespoke, using software updates and application programming interfaces (APIs). All of the factors stated show that the innovation is technologically viable, cost-effective, and scalable, making its commercial implementation highly feasible.

5.3.3. Scalability

Moreover, in the context of scalability, it assesses the ability of an innovation to grow across markets, user segments, and geographic regions without costs rising at the same rate. According to Moro-Visconti et al (2023), Cloud-based AI systems can easily scale with business needs, allowing rapid growth without major costs or infrastructure changes. Thus, it shows that the SAS Smart AI features are highly scalable due to its software-driven nature. Once the core AI system is developed, it can be used in many fridge models, brands, and markets with little modification. Software updates enable the system to keep improving and adapt to different food cultures and storage habits. The feature is not limited to a specific country or appliance design, making it suitable for global adoption. Furthermore, the use of licensing models will make it easier to scale by allowing the system to integrate with different smart appliance platforms. According to Schilling (2020), licensing is linked to appropriability mechanisms, a strategy that enables firms to capture the rents from its innovation. Schilling discusses how licensing intellectual property (IP) can generate revenue streams and enable wider adoption without heavy investment in production. As adoption grows, data collected from diverse users can enhance the accuracy and effectiveness of the SAS Smart AI features, creating positive network effects. This adaptability can help boost long-term growth potential and market reach. Therefore, the SAS Smart AI features have strong scalability potential, making it ideal for widespread commercial use.

6. CONCLUSION

Existing smart technologies allow users to view the current inventory inside their refrigerators. However, without proper storage recommendations, incorrect placement of food items can lead to spoilage. Monitoring features such as expiry-date tracking are helpful, as they enable users to identify which food items should be consumed first before they go bad. To address this issue, this study proposes the SAS Smart AI Enhanced Refrigerator System, an artificial intelligence-based innovation that integrates AI food scanning, smart compartment recommendations, and a preventive AI Alert System. By analysing food type, packaging, and freshness levels prior to storage, the system provides accurate guidance on suitable storage locations, monitors correct food placement, and issues contextual alerts to prevent food spoilage. This approach supports more systematic and effective food management practices.

Overall, the proposed system demonstrates strong potential in reducing food waste, improving food safety, enhancing user convenience, and supporting sustainable consumption. Although the innovation is currently at the conceptual stage, its modular design and compatibility with existing technologies indicate high feasibility and scalability for future development. Based on the findings of this study, further research and development are recommended. The construction of a functional prototype of the SAS Smart AI-Enhanced Refrigerator System is necessary to evaluate its technical performance and operational effectiveness. User-based testing is expected to generate more accurate results, as real user experiences can be recorded and analysed for future studies.

Secondly, strategic collaboration with refrigerator manufacturers and smart home technology providers is recommended to facilitate system integration, reduce development costs, and accelerate commercialization. Such partnerships can also support continuous system improvement through data learning and user feedback. In addition, support from policymakers and sustainability agencies through awareness programmes or incentive schemes should be considered, as this innovation contributes directly to reducing food waste and protecting the environment.

In conclusion, the SAS Smart AI-Enhanced Refrigerator System represents a forward-looking innovation with the potential to transform household food management practices and contribute significantly to the achievement of Sustainable Development Goal 12.

Acknowledgments: We express our sincere gratitude to everyone who contributed to the successful completion of project innovation especially lecturers, team members, friends, and family for their cooperation, encouragement, prayers, and unwavering support.

References

- Devarajan, R. (2022). Intelligent refrigerator using machine learning and IoT. In *Proceedings of the 2022 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI)*. <https://doi.org/10.1109/ACCAI53970.2022.9752587>
- H. Nasir, W. B. W. Aziz, F. Ali, K. Kadir, and S. Khan (2018). The implementation of IoT Based Smart Refrigerator System. *2nd Int. Conf. Smart Sensors Appl. ICSSA 2018*, pp. 48–52.
- Lantz., M. P. (2022). Effects of customization and product modularization on financial performance. *Journal of Engineering and Technology Management*.
- Lucie K. Ozanne, P. W. (2022). Understanding food waste produced by university students: A social practice approach. *Journal of Sustainability*, Vol.14, (17).
- Moro-Visconti, R. C. (2023). Artificial intelligence-driven scalability and its impact on the sustainability and valuation of traditional firms. *Humanit Soc Sci Commun* 10, 795.
- S. Dey, A. Dutta, M. Mishra, and S. Banerjee (2019). Artificial intelligence based intelligent storage device for commoners. *Proc. 4th Int. Conf. Commun. Electron. Syst. ICCES 2019*, pp.960–965.

- Samsung Electronics. (2025, March 30). Samsung Electronics unveils 'AI Home' vision at Welcome to Bespoke AI event. Samsung Newsroom. Retrieved from https://news.samsung.com/global/samsung-electronics-unveils-ai-homevision-at-welcome-to-bespoke-ai-event?utm_source=chatgpt.com
- Schilling, M. A. (2020). *Appropriability*. In M. A. Schilling, Strategic Management of Technological Innovation (p. 202). New York: McGraw Hill Education.
- Tuany Gabriela Hoffmann, C. M. (2023). Fresh food shelf-life improvement by humidity regulation in domestic refrigeration. *Procedia Computer Science*.
- UN, U. N. (2025). The world wastes 1.05 billion metric tons of food even as hundreds of millions face hunger. Retrieved from SDG Goals: <https://unstats.un.org/sdgs/report/2024/Goal-12/>
- United Nations Environment Programme, U. N. (2024). Global estimates of food waste. Food Waste Index Report 202. Retrieved from <https://www.unep.org/resources/report/food-waste-index-report-2024>
- V. S. Aurel-Dorian Floarea (2016). Smart Refrigerator: A next generation refrigerator connected to the IoT. *Proc. 8th Int. Conf. on Electronics, Computers and Artificial Intelligence (ECAI) 2016*, pp. 4–7.
- Varzakas, T. &. (2024). Global Food Security and Sustainability Issues: The Road to 2030 from Nutrition and Sustainable Healthy Diets to Food Systems Change. *Foods*, 13(2), 306.
- Zohra Dakhia, R. (2025). AI-enabled IoT for food computing: Challenges, opportunities, and future directions. *Journal of Sensors*.