



## A Review on IOT Based Smart Refrigerators

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### ARTICLE DETAILS

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### ABSTRACT

This review paper explores the evolution of home refrigeration technology, highlighting the pivotal role of Smart Refrigerators in reshaping our domestic environments. These cutting-edge devices leverage IoT technology to offer a wide array of innovative features beyond the conventional cooling capabilities. With touchscreens, mobile applications, and voice control interfaces, users can now remotely monitor, adjust temperatures, and efficiently manage their refrigerator's inventory. Moreover, the integration of data analytics and AI algorithms enhances food preservation, minimizes waste, and maximizes energy efficiency, contributing to a sustainable and eco-conscious lifestyle. Smart refrigerators transcend mere functionality, ushering in a new era of personalized convenience, real-time insights, and adaptive capabilities within our kitchens. They seamlessly integrate with other smart devices and applications, creating a harmonious ecosystem that simplifies daily tasks and enhances overall quality of life. In this paper, we delve into the myriad ways in which Smart Refrigerators have revolutionized the way we interact with our kitchens and homes, offering a glimpse into the future of modern living.

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### INTRODUCTION

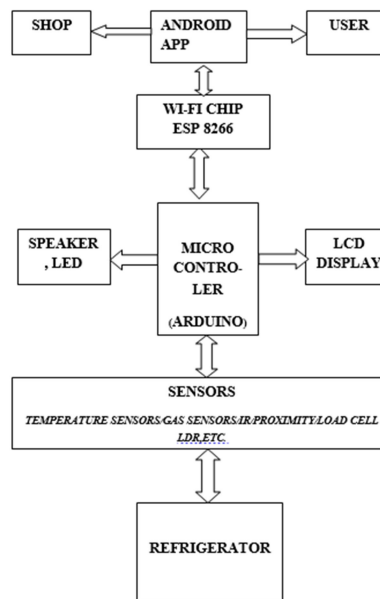
This is an era of technological revolution where the Internet of Things (IoT) is a rising trend and this may change the fabric of our houses. The emergence of intelligent apparatuses has transfigured the way we think about habitation and space in terms of efficiency, convenience and connectivity. Among these unique home inventions Smart Refrigerator, or Smart Fridge, can be firmly regarded as an emblem of technological fusion with people's daily life. There were Sunday afternoon family times in the living room when dad would make us all coke and bier on the icebox or when mom would rush to the icebox for a cool drink during the heat wave. Even though Smart Refrigerators have upgraded these fundamental functionalities, they are phase successfully introduced a new paradigm of smart living, touched screen, mobile applications, voice interfaces, data analytics and AI algorithms. In this review article, we shall try our best to take a deep dive into this extraordinary world of Smart Refrigerators, highlighting the unique characteristics that they come with, their impact and the extent to which they are transforming the kitchens of today and the future. This essay presents an overview of intelligent home appliances through the lens of their features, benefits, and the way they weave themselves into the fabric of our everyday lives. Thus, the main goal of the writing is to gain a better sense of how these smart appliances revolutionize our home experience. What Samsung Smart Home does is they assign you a "Enrich Your Life" slogan in a way of showing you how to have the "total home solution." The purpose of this is to get your life back in order. It provides a means of handling working at home and doing the house duties precisely even while adding an element of fun to the activity. The lesser the branding decision technique, the less consumers have to worry and spend more time with their loved ones. [1]

## 1. Definition and Overview

Intelligent appliances for home are emerging in our daily life. A traditional Refrigerator is used to store food items and to keep them cool for a longer period to prevent them from decaying or bacterial activity, even, a traditional refrigerator is used to freeze items like water, ice cream, etc. Over the period, the computer science era advanced, and there came the emergence of smart appliances for home that can provide us more than the traditional appliances, one of these is a Smart Refrigerator or Smart Fridge.

A smart fridge is a modern home device that incorporates Internet of Things (IoT) technology, providing creative features that go beyond traditional cooling capabilities. It utilises touchscreens, mobile applications, and voice control interfaces to enable monitoring from a distance, adjusting temperatures, and managing inventory. Data analytics and AI algorithms are utilised by these refrigerators to improve

the preservation of food, minimise waste, and maximise energy efficiency. Smart refrigerators revolutionise the way users interact with their kitchens by offering personalised convenience, real-time insights, and adaptive capabilities. They achieve this by smoothly integrating with other smart devices and applications.



**Fig-1. General Flow and Structure of Smart Refrigerator**

## 2. Related Works

Sr. No	System Name	Author	Description
1	IoT based Intelligent home using Smart Devices	Nikhil Kakade, Prof. (Dr.) S. D. Lokhande	Detects the daily requirements of specific items in the fridge and autonomously initiates a purchase request with the grocery store.
2	Smart Refrigerator	Deepti Singh, Preet Jain	Sends a notification to the user's mobile through an application when the food item's weight falls below the threshold value.
3	Smart Refrigerator for Grocery Management	Emily Moin	Analyzes the weight and expiration dates of food items in



			the fridge, then dispatches personalized notifications to the user.
4	Home Automation System using Android and Arduino Board	Poonam B. Patil, Roopali R. Patil, Swati V. Patil	Utilizing a mobile application for remote control of household appliances.
5	Internet Refrigerator-a typical IoT	Folasade Oisanwo, Shade Kuyoro, and Oludele Awodele	The refrigerator is equipped with Wi-Fi capabilities to facilitate the transmission of data.
6	HOME AUTOMATION AND SECURITY SYSTEM	Surinder Kaur, Rashmi Singh, Neha Khairwal and Pratyk Jain	Dedicated to minimizing human effort through the automation of electrical devices.
7	The Design and Implementation of a Wi-Fi Based User Machine - Interacted Refrigerator	Shama Mubeena, N. Swati	Illustrates the monitoring of the refrigerator and alerts the user via email.
8	Raspberry Pi Based Interactive Home Automation System through E-Mail	B. Ramesh, J. Lingaiah	Chooses email instead of Bluetooth for sending notifications to the user, citing its superior efficiency.
9	The exploration of Predictive Analytics: An overview encompassing trends, applications, opportunities, and challenges.	Nishchol Mishra, Dr. Sanjay Silakari	They have identified classification and regression as the primary objectives of predictive analytics.
10	Automated Demand Response Refrigerator Project	Jessica Tran et al	They provided a dashboard for monitoring sensor data and remotely controlling the



			refrigerator.
11	Raspberry Pi Based Interactive Home Automation System through Internet of Things	Soundhar Ganesh S, et al	Employed Raspberry Pi to establish an interface between the internet and embedded systems.
12	A Machine Learning Approach for Stock Price Prediction	Carson Kai-Sang Leung et al	Utilizing a deep learning methodology for Structural Support Vector Machines (SSVMs) to conduct classification on intricate inputs.
13	Home Automation through E-Mail using Raspberry Pi	M.P. Sathish et al	Employed email communication to instruct the Raspberry Pi regarding the operations to be executed.
14	SMART REFRIGERATOR USING INTERNET OF THINGS	Prapulla S B et al	Implemented sensors for the purpose of detecting and monitoring the contents.
15	Product recommendations using linear predictive modeling	Rajendra Banjade, Suraj Maharjan	Implemented linear regression to enhance the performance of the system.
16	Trend Projection using Predictive Analytics	Manjula Ramannavar and Nandini S Sidnal, Seema L Vandure	Employed Linear Regression and Support Vector Machines (SVM) for predicting market sales.

Through their system “IoT based Intelligent house using Smart Devices” Mr. Nikhil Kakade and Prof. (Dr.) S. D. Lokhande [2] have developed and presented a smart system that perceives the daily requirement of specific products in the fridge as cloud platform stores the data and sends automatically the order to the vendor.

The developers Deepthi Singh and Preet Jain [3] have created the system Smart Refrigerator which identify the weight of food items when weighed in the refrigerator. They give notifications on the user mobile applications when they drop below a threshold value which is preset .

For her project,[4] Emily Moin created the product “Smart Refrigerator for grocery Management” which indicates the foodweight and expiry dates within the refrigerator. The app also issues the customized notifications to the user. With this feature, however, you can automatically place your supplies order when your inventory quantity fall to a prespecified threshold.

Poonam B. Patil, Roopali R. Patil and Swati V. Patil presented their idea on Home Automation System Using Android and Arduino Board. The system consists of mobile applications wirelessly managing switches connected to room appliances. [5] communication through GSM based modems and been put in place with the help of wireless communication to mobile devices.

Folasade Osisanwo, Kachi Kuyoro, and Oludele Awodele have done the system innovation "Internet Refrigerator' an instance of IoT." [6]. System bolsters RFID technology. The device operates via Wi-Fi so that data transmits to the system.

Surinder Kaur, Rashmi Singh, Neha Khairwal and Pratyk Jain designed the system “HOME AUTOMATION AND SECURITY SYSTEM”, in this context, the use of automating devices is reduced that decreases human efforts. It is a channel through which it conveys writings and pictures. It is also designed to end up with a saving of electricity.

Shama Mubeena, N. Swathi has come up with the idea, “Data Communication using Wi-Fi Based User Machine-Interacted Refrigerator” [8], that encompasses current trend technology in communication i.e. Wi-Fi, it displays how the refrigerator is monitored, and users are prompted using e-mails.

B. Ramesh and J. Lingaiah have developed a system which they have referred to as "Raspberry Pi-Based Interactive Home automation through E-mail" [9]. In contrast, the direct solution chooses email over BT forever because its efficiency scale is higher than the latter. On the other hand, the use of LEDs to display switching modes is also an alternative.

Nishchol Mishra and Dr. Sanjay Silakari have introduced a model in "Predictive Analytics: Trends, Survey, Applications, Opportunities and Challenges [10]" the authors spot all primary objectives of predictive analytics as they are classification, regression. Categorization of data is conducted by creation of predefined classes and reporting numeric variables used as data attributes; regression is used for analysis of relationships between variables.

The authors of the paper entitled "Automated Demand Response Refrigerator Project" [11] envision a dashboard that the users can view while observing the pressure data and manage the refrigeration device remotely [11].

Soundhar Ganesh S et al., in their paper entitled "Interactive home automation system through the Internet of things (IoT) with the help of raspberry pi" [12], adopted raspberry pi for interface between internet and embedded systems.

Cara Leung et al proposed "Machine learning for stock market prediction" [13] where they used structural support vector machines (SSVMs) including deep learning to perform stock price classification problems in [13].

M.P. Sathish & others in "Home Automation through E-mail using Raspberry Pi" [14] presented the way Raspberry Pi relies on emails to be instructed about the operations to be performed, and the whole communication revolves around the process of writing down the instructions, receiving the instructions, executing the operations and sending acknowledgements.

The work of Prapulla S B et al., titled "SMART REFRIGERATOR USING INTERNET OF THINGS" [15], included temperature checking and stocking sensors for the smart fridge. The advancement refrigerator gives a notification to its customers via SMS or email informing them about appliance status e.g., once the refrigerator is left open for a long time a notification is sent.

Linear predictive modeling technique was introduced by Rajendra Banjade and Suraj Maharjan in "Product recommendations using linear predictive modeling," which made the system dynamic [16].

Seema L Vandure, Manjula Ramannavar And Nandini S Sidnal coming up with "Trend prediction with the help of predictive analytics " in 2021 [17]. In this paper lineal regression and support vector machine techniques were used with the purpose of predicting sales on the market.

### **3. Evolution and Development**

Refrigerators evolved from ice boxes to metal body electrically powered appliances in the last 2 centuries.

#### **(a) Pre-20th Century: Ice Boxes and Natural Refrigeration (1800s):**

- Ice boxes were used to store perishable items with the help of actual ice.
- Natural cooling methods such as placing food in cool, shaded areas or using underground storage were common.

#### **(b) Early 20th Century: Introduction of Mechanical Refrigeration (1900s):**

- The first electric refrigerators were introduced, using a compressor-based system.
- These early refrigerators required manual temperature regulation and defrosting.

#### **(c) Mid-20th Century: Technological Advancements (1950s-1970s):**

- Introduction of automatic defrosting mechanisms.
- Adoption of more advanced insulation materials, improving efficiency.
- Introduction of separate freezer compartments.

#### **(d) Late 20th Century: Energy Efficiency and Design (1980s-1990s):**

- Improvements in compressor technology led to more energy-efficient refrigerators.
- Design focus shifted to aesthetics, integrating refrigerators with kitchen decor.

#### **(e) Early 21st Century: Digital Controls and Energy Standards (2000s):**



- Digital temperature controls and displays became common.
- Energy efficiency standards led to the development of more environmentally friendly refrigerants.

**(f) Mid-2010s: Emergence of Smart Features (2010s):**

- Integration of basic connectivity, such as Wi-Fi, enabling remote monitoring and control.
- Introduction of touchscreens and digital interfaces for easier user interaction.

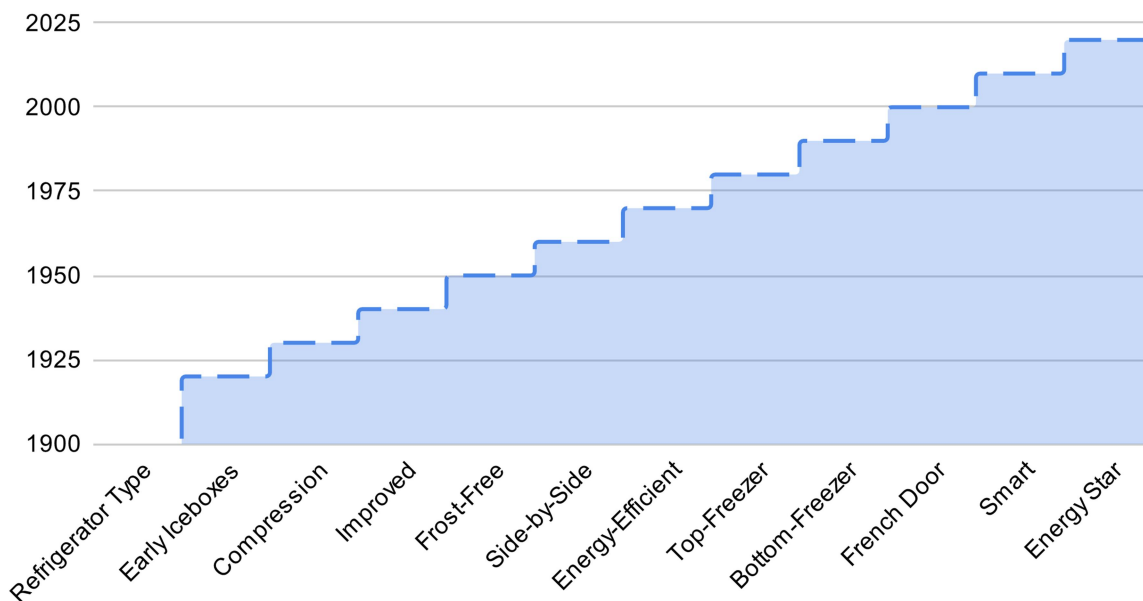
**(g) Late 2010s: IoT Integration and Smart Home Connectivity (2010s):**

- Refrigerators began to be integrated into the broader concept of the smart home.
- IoT sensors allowed for monitoring of inventory, expiration dates, and internal conditions.

**(h) 2020s: Full-Fledged Smart Refrigerators (2020s):**

- Smart refrigerators are equipped with advanced IoT capabilities.
- Voice assistants and mobile apps provide seamless control and interaction.
- AI-driven features predict food spoilage and suggest recipes based on available ingredients.

### Evolution of Refrigerators



## Fig-2. Evolution of Refrigerators over the decades

### 4. Technological Components

#### (a) Internet of Things Integration (IOT):

IOT or Internet of Things refers to the network of actual devices that are embedded with software, sensors, geological receptors, etc. which can exchange data between other devices present in their field of network. The usage of IOT in smart refrigerator allows the users to:

- Remotely Control their Smart Refrigerators
- Check the Inventory remotely and Calculate Low Stocks
- Intelligent Cooling Pattern based of usage.
- Voice Control and AI Integrations

#### (b) Sensors

Sensors are used to detect food items, identify their type, expiration, cooling schedule to prevent them from decaying. Sensors are the most important part of a smart refrigerator. The following are the sensors used in smart refrigerators:

(i) Temperature sensor: To sense the temperature of the main enclosure and the freezer it serves this function. Used to switch to and from, and auto-off the refrigerator by the room's temperature.

(ii) Gas sensor: A gas detector is a device that is used for the purpose of detecting the presence of gases in a given area, which works mostly as a part of safety systems. It is application of this type that is responsible from detection of gases which are made by vegetables. We can detect whether the atmosphere is combustibile, flammable, and toxic by using these devices. [18]

(iii) Proximity sensor: A proximity sensor is a sensor that can be used to detect whether or not there is any object around without having any physical contact at all. The sensors are put into use in a smart refrigerator so as to detect the circumstance where eggs or any common products have not been kept during the past few weeks. [19]

#### (c) Connectivity (WIFI/Bluetooth)

To control the refrigerator remotely or do any such remote tasks, a network is needed between the smart refrigerator and the remote-control device. A connection can be made possible using WIFI or Bluetooth based networks. Using a WIFI network provides much faster speed and allowed distance between the requests and responses, whereas a Bluetooth based connection allows for smaller geographical area coverage and speeds. Using a WIFI connectivity easily allows for having more than one connected monitoring device that can be any phone with the remote-control app installed for that smart refrigerator. Whereas, using Bluetooth Connectivity allows a limited number of monitoring devices.

#### (d) **User Interfaces** (Voice Control, Touchscreen, Mobile App)

The transformative impact of smart refrigerators is exemplified through innovative user interfaces: touchscreens, mobile apps, and voice control. This segment delves into these interfaces within the context of modern refrigeration systems.

##### (i) **Touchscreens:**

Smart fridges integrate touch screens into their exterior, allowing users to adjust settings, access recipes, and monitor inventory seamlessly, sans door opening. This fusion of digital interaction and refrigeration functionality redefines user experience.

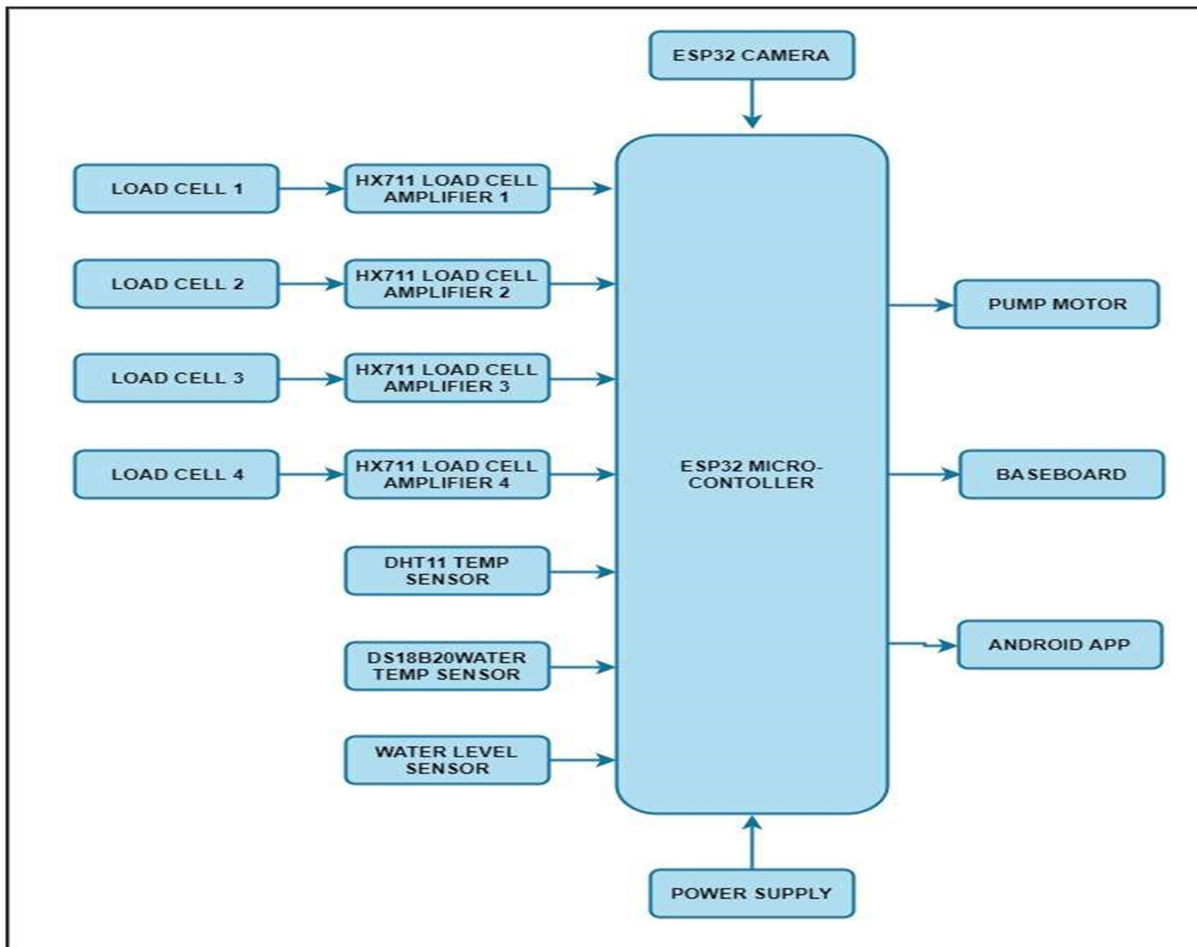
##### (ii) **Mobile Apps:**

The fusion of Wi-Fi connectivity and digital platforms enables remote access to crucial fridge data via mobile apps. Users can anticipate expirations, modify settings, and make informed decisions on-the-go, enhancing operational efficiency.

##### (iii) **Voice Control:**

Voice assistants like Alexa infuse auditory engagement into fridge interaction. From queries about contents to compiling shopping lists through vocal commands, this amalgamation of AI and voice tech underscores seamless human-machine collaboration. Uniting these interfaces accommodates diverse user preferences. Touchscreens offer tactile engagement, mobile apps transcend spatial constraints, and voice control caters to hands-free operation. Foreseeable advancements will deepen interface integration, positioning smart fridges as pivotal in the digitised kitchen landscape.

## 5. System Architecture



**Fig-3. System Architecture of an IOT based Smart Refrigerator [20]**

1. The proposal utilizes ESP32 as the microchip. The project has two modes, they are Automatic Replenish mode and Normal mode.
2. For measuring the quantity of food in the fridge, it uses a digital load cell as well as HX711 load cell amplifiers. This information would, then, be displayed on the app.
3. The algorithm immediately (Order More If Scarce) flicks the switch to order it via the app. With Manual (Normal Mode) and Auto Mode available for food ordering, the user can select the one that fits his/her comfort level. Replenish Mode) mode.

4. It has a DHT11 sensor that reads temperature of the inside chamber of the fridge; water sensor which reports inside water level and water temperature sensor. in our case, to monitor water temperature insides the water container to facilitate molecular interactions.
5. The device also has a water pump for dispensing water when a push button is pressed.
6. The android app will be developed on MIT App Inventor 2.
7. It contains all the sensor values as well as the image of the containers. These images are sent by the ESP32 camera to Android App. It also has settings for providing links for automatic/manual food ordering.

## **6. Major Features of a Modern Refrigerator**

Modern refrigerators come with a variety of unique features that enhance their functionality and convenience.

### **(a) Dual Cooling Systems**

The inclusion of dual cooling systems in modern refrigerators is a sophisticated and essential feature that effectively preserves the freshness of your food. This advanced technology utilizes separate and independent cooling systems for both the refrigerator and freezer compartments, each carefully calibrated to maintain their own optimal conditions. By isolating these sections, the dual cooling system ensures that the humidity, temperature, and Odors within the fridge and freezer do not mix. This separation is crucial in preventing the unwanted transfer of Odors, thus preserving the flavour and quality of your food while also preventing freezer burn. With the advantages of dual cooling systems, your fruits and vegetables will stay crisper for a longer duration, and your frozen items will remain free from any freezer-related issues, resulting in extended shelf life and superior food preservation.

### **(b) Convertible Compartments**

The convertible compartments found in modern refrigerators offer unparalleled convenience and flexibility. These innovative storage spaces can be adjusted to transform from a refrigerator to a freezer or vice versa, allowing you to adapt to your changing storage needs. This feature is particularly useful when you require extra freezer space for special occasions or during the holiday season. It enables you to seamlessly switch between temperature zones, accommodating a wide range of items such as

perishable fresh foods and frozen goods. Convertible compartments are an absolute game-changer for individuals looking for versatile refrigeration options, guaranteeing that your refrigerator can adapt to your culinary preferences. Whether you are storing large quantities of fresh produce or stocking up on frozen meals, these compartments make it effortless to optimize your storage space for ultimate convenience.

### (c) **Air Purification**

Air purification is a pivotal feature in modern refrigerators, providing a breath of fresh air for both your food and your kitchen environment. Advanced filtration systems are integrated into the appliance to effectively eliminate unwanted odors and bacteria, ensuring that the inside air remains crisp and clean. These systems employ various technologies, such as activated carbon filters and air ionizers, to neutralize any unpleasant smells and pathogens. Not only does air purification maintain the quality and flavor of your stored food, but it also contributes to a healthier home environment. With this technology, you can rest assured that the air inside your refrigerator is free from contaminants, allowing your fresh produce and leftovers to stay as appetizing as the day they were stored.

## **7. Proposed Feature**

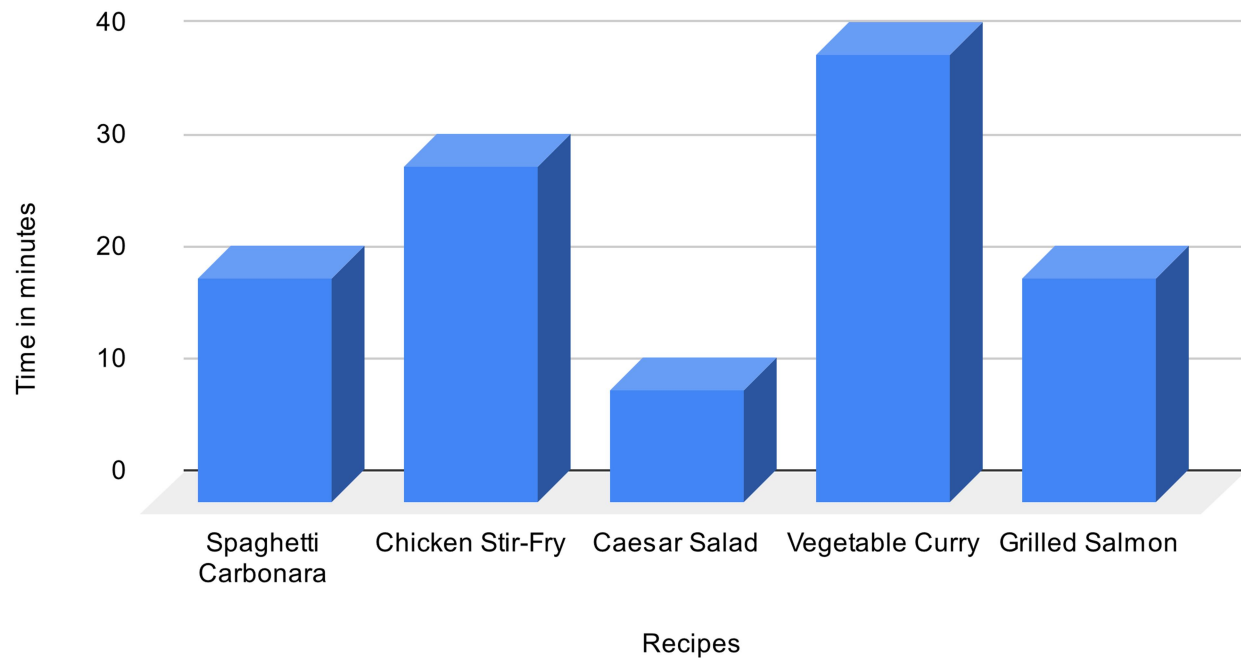
### **Suggestion of Food Recipes through the analysis of stored food items:**

By harnessing the power of artificial intelligence, data analytics, and connectivity, smart refrigerators can become proactive culinary assistants, offering users a personalized and delightful cooking experience. This proposal explores the potential of such a feature, its benefits, and the technological infrastructure required to bring it to life, so with the fusion of this technology, the smart refrigerator takes a significant leap toward becoming an indispensable companion for those seeking both nourishment and culinary inspiration.

This can be done by training a system with recipe manuals, for example: Making a Vegetable Curry requires Potatoes, Carrots, Peas, Bell Peppers, Curry Paste, Rice which has an average rating of 4.6 and a preparation time of 40 minutes.

Now, the system will use artificial intelligence to suggest food recipes in urgent needs just a like a human.

### Recipes Preparation Time



**Fig 4. An example dataset on Food recipes and their preparation times**

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