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Real-time Intelligence in Sustainable Restaurant Management

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Abstract: ***The growing field of real-time intelligence (RTI) in sustainable restaurant management addresses the imperative to enhance restaurant efficiency and sustainability through data-driven strategies. As the restaurant industry faces pressure to balance environmental impact with service quality, embracing modern technologies becomes crucial. This study aims to explore and assess the potential of RTI systems for managing reservations and predicting food demand in sustainable restaurants. The methodology involves rigorous desk-based research, drawing from reputable scholarly sources, industry reports, and credible online platforms. Findings highlight the multifaceted benefits of RTI, including data-driven optimization of labor, inventory, and green initiatives. RTI also optimizes table bookings and resource allocation, minimizing wait times and food waste for a more sustainable operation. However, data privacy concerns present challenges that demand comprehensive strategies, including privacy-by-design principles and adherence to regulatory standards. Future recommendations encompass cloud-based deployment, structural evolution, data and machine learning enhancements, and further refinements. This research contributes to advancing the integration of RTI systems to foster efficient, sustainable, and customer-centric restaurant management practices.***

Keywords: Real-time Intelligence, Sustainable Management, Supervised Learning, Gamification, Machine Learning, Efficiency

I. INTRODUCTION

The restaurant industry plays a significant role in modern society, offering culinary experiences and nourishment to a diverse customer base. As a hub for social gatherings, celebrations, and memorable moments, restaurants hold a special place in the hearts of people worldwide. However, in a fast-paced and competitive market, restaurant management has had to constantly adapt to discerning diners' changing needs. Restaurant owners and managers have long been committed to improving customer experiences while maintaining operational efficiency. Traditional methods of manual record-keeping, handwritten orders, and legacy accounting systems once formed the backbone of restaurant management. Despite their rich traditions, these methods were time-consuming and limited in their ability to provide real-time insights into business performance. During the late 20th century, the expedition for more efficient and data-driven restaurant management practices led to a significant turning point in the industry, marking the roots of real-time intelligence (RTI) systems. At the time, most restaurants used handwritten orders, inventory logs, and traditional accounting systems to run their businesses. Owners and managers made important decisions based on these handwritten records and their gut instincts. These processes were time-consuming, prone to errors, and limited in their ability to provide accurate and up-to-date information on the restaurant's performance. Recognizing the need for more efficient and data-driven management, engineers started designing applications that could automate and streamline restaurant operations as shown in Fig 1.

Fig. 1 Food demand prediction and restaurant management system

The pioneers in this field, like Gene Mosher, spearheaded the development of graphical POS software in 1986, introducing touch screen interfaces and coloured widgets. Following this, Microsoft launched the first POS software system for Windows in 1992, setting the stage for widespread adoption of restaurant technology [1]. As technology continued to advance, the capabilities of RTI systems expanded, allowing restaurants to integrate online ordering, reservation management, and customer feedback features. This enabled them to adapt to the changing needs and preferences of their patrons and make informed decisions to enhance customer experiences. Over the years, the adoption of RTI systems became more widespread, with large restaurant chains and independent establishments alike leveraging the power of real-time data to optimize their operations and drive growth. Today, real-time intelligence in sustainable restaurant management is a growing field that aims to use data and technology to improve the efficiency and sustainability of restaurant operations. Using RTI, restaurants can identify areas for improvement and create a more environmentally sustainable business model for the future. This technology enables better anticipation and management of reservations, leading to reduced food waste, higher customer satisfaction, and personalized marketing, dynamic pricing, and data-driven menu engineering, resulting in a more sustainable and successful restaurant management strategy. Many students at my college, including myself, have been having trouble recently that is causing disruptions in our academic pursuits. A challenge related to reservation and ordering processes has arisen, causing disruptions within academic sectors. Based on the findings of my investigation, due to the fluctuating number of customers, improper staff allocation has ensued, resulting in delayed orders that, in turn, have impeded students' punctuality for lectures. However, upon closer examination, this theory appears to apply only in particular regions and so requires further scrutiny. Climate change is another major topic that requires consideration in the present global setting. The industry is under increasing pressure to reduce its environmental impact while maintaining service quality. Restaurants will need to use current technologies to support their operations as the industry shifts to more sustainable practices.

Real-time intelligence (RTI) is a powerful tool that holds the potential to revolutionize the way restaurants handle reservation management and predict food demand. They can be very useful in areas such as reservation management and food demand forecasts. However, putting such a system in place is not without difficulties. One of the most pressing problems is ensuring that the system is accurate and dependable. This necessitates rigorous data analysis and the application of relevant statistical modelling approaches. Furthermore, it is critical to handle data privacy concerns. The collecting of data pertaining to customers' dining patterns and preferences is a matter of sensitivity, necessitating restaurant operators to ensure its security. To mitigate unauthorized access to data, it is common practice to employ encryption or other security mechanisms. Another important consideration when implementing a real-time intelligence system is the potential benefits that it can provide. By accurately predicting food demand, restaurant owners can avoid overstocking inventory, which can lead to food waste and decreased profitability. In addition, real-time intelligence systems can help restaurant owners to identify opportunities for cost savings and process improvements, which can lead to a more sustainable business. To achieve these benefits, machine learning and statistical modelling can be used to analyse the data and make accurate predictions about food demand and other key metrics. This can help to streamline restaurant operations, reduce costs, and provide a better experience for customers. This technology has helped prominent hospitality firms generate value. AccorHotels (2018) uses a Business Intelligence for Food and Beverage (BI F&B) system to evaluate revenues, inventory, and client preferences from its restaurants and bars. Real-time analytics from the BI F&B system helps Accor make menu, pricing, and marketing choices. MGM Resorts International launched MGM 2020 to streamline operations and tailor the visitor experience. Data analytics and machine learning evaluate real-time visitor behaviour and preferences to offer tailored suggestions and optimize operations like check-in and cleaning.

II. THE AIM AND OBJECTIVES

The aim of the research is to explore the capabilities and limitations of real-time intelligence (RTI) systems for managing reservations and predicting food demand in a sustainable restaurant setting, with the goal of developing and implementing an effective and efficient RTI system that improves operational efficiency, sustainability, and customer experience in the restaurant industry.

The objectives of the research are as follows:

1) Review literature and gain a deep understanding of various real-time systems.
2) Evaluate the capabilities and limitations of existing real-time intelligence systems.
3) Integrate the findings to develop and implement a real-time intelligence system.
4) Assess the effectiveness of the real-time intelligence system.
5) Propose recommendations for future research in the field.

III. JUSTIFICATION

The restaurant industry is currently facing significant challenges, including increased competitiveness, rising expenses, and a critical imperative to address waste reduction and improve sustainable practices. Conventional approaches may be ineffective and error-prone, resulting in waste, customer dissatisfaction, and financial setbacks. The COVID-19 pandemic has intensified these problems, causing restaurants to struggle and adapt. Real-time intelligence offers a solution by enhancing reservation management, forecasting demand, and minimizing resource wastage. In the context of restaurants, several challenges arise in maintaining sustainable operations while optimizing customer experiences. Firstly, there is the rising rivalry that constantly exerts pressure on restaurants to differentiate themselves and capture a loyal customer base. At the same time, the growing importance of addressing sustainability issues highlights the need to embrace environmentally sensitive methods that align with the values of conscientious consumers. In addition to these obstacles, there is the complex undertaking of manually managing a staff that requires a significant amount of labor, resulting in the consumption of vital time and resources. Moreover, the inherent fluctuation in client volumes daily presents a significant obstacle in achieving accurate demand forecasting, hence making traditional approaches insufficient. The requirement for agility and adaptation in restaurant management methods is heightened by the disruptive influence of external circumstances, as demonstrated by the exceptional impact of the COVID-19 epidemic. In the middle of these complexities, effectively managing the sensitive issue of reputation becomes of utmost importance, given the significant impact that online evaluations and feedback have on consumer decision-making. It is noteworthy that, despite the increasing accumulation of data by restaurants, there remains a prevalent challenge in successfully utilizing this data. The lack of utilization of data analytics inhibits the optimization of different facets of restaurant operations. Given the complex nature of these concerns, the incorporation of real-time intelligence solutions presents itself as a promising option, providing a holistic approach to effectively tackle these issues and establish a trajectory towards sustainable and resilient restaurant management.

Real-time intelligence systems present potential for aiding decisions with precise and prompt data. However, establishing such systems in sustainable restaurants is intricate, notably for small, independent ones that lack resources and expertise [2]. Furthermore, data privacy and security concerns pose challenges for restaurants in effectively gathering and utilizing data. Addressing these challenges within the restaurant industry requires innovative solutions that align with both sustainability and enhanced customer satisfaction. One pivotal solution involves the creation of a distinctive dining experience that sets an establishment apart, enticing customers through unique offerings and memorable interactions. In addition, harnessing the power of demand prediction through advanced analytics can significantly reduce food waste by accurately anticipating customer preferences and adjusting inventory levels accordingly. Complementing this, the implementation of a comprehensive content management system (CMS) streamlines restaurant operations, enabling efficient menu updates, online ordering, and seamless customer communication. Furthermore, facilitating prebooking options and establishing a robust online presence equips restaurants to cater to the evolving preferences of modern diners, enhancing convenience and accessibility.

Embracing adaptability, particularly exemplified by contactless solutions like card-less withdrawals, allows restaurants to swiftly respond to changing environmental factors, such as the need for minimal physical interaction due to the impact of COVID-19. Seamlessly managing seating arrangements and waitlists ensures efficient space utilization, reducing customer wait times and enhancing overall dining experiences. However, the true cornerstone of a sustainable restaurant lies in the integration of data-driven insights through a real-time intelligence system. Such a system empowers restaurants with invaluable real-time data, offering a holistic view of operations and enabling informed decision-making across various facets. This data-driven approach optimizes resource allocation, enhances service quality, and enables swift adaptations to changing demands. By orchestrating these multifaceted solutions, restaurants can successfully navigate the intricate landscape of sustainability and customer-centricity, fostering both operational efficiency and enhanced customer delight.

IV. RESEARCH QUESTIONS

1) How can real-time intelligence be used to improve the efficiency and sustainability of restaurant operations and what are the methods for collecting and analysing data in such systems?
2) What are the potential benefits and challenges of implementing a real-time intelligence system for managing reservations and predicting food demand in a sustainable restaurant setting?
3) How can data privacy concerns be proactively addressed and mitigated during the implementation and use of the system, while ensuring compliance with relevant data protection regulations?

V. ETHICAL CONSIDERATION

The research on real-time intelligence for sustainable restaurant management is guided by a set of ethical considerations that ensure the adherence to principles and norms of ethics. These ethical considerations not only uphold the integrity and value of the research but also demonstrate a commitment to responsibility and respect. Honesty, integrity, and reasonable research underpin this project. This study will present its findings without bias in design, data analysis, interpretation, or peer review. This empowers readers to assess the study's significance. Oversight errors will be minimized as well. To verify results, the report will be reviewed regularly. This ensures research credibility. Academic studies require a deep understanding of ideas' origins, the people who developed them, the factors that shaped them, and their historical context [3]. In adherence to ethical standards, this research will respect intellectual property rights by properly citing sources from articles, past papers, websites, journals, books, and other literature. This study uses pseudonyms to protect participant anonymity and maintain confidentiality [4]. This practice builds trust, integrity, and researcher-participant relationships [5]. Additionally, Participant safety is also a priority. The study will respect participants' dignity, privacy, and source confidentiality.

A. Ensuring Ethical Development

In developing a real-time intelligence system for sustainable restaurant management, ethical considerations play a vital role to ensure minimal harm to the users [6]. The Software Development Impact Statement (SoDIS) is made to identify potential negative consequences of a proposed project and to specify actions to mitigate those consequences [7]. To protect personal data, robust data storage and user sharing preferences are prioritized. The system ensures fairness and transparency for restaurants of all sizes. Accurate demand prediction and advice on sustainable sourcing and waste reduction reduce food waste and support industry sustainability. Inclusivity is a core aspect, with sharp contrast colors, larger fonts, and understandable language accommodating users of varying abilities. By upholding privacy, fairness, sustainability, and inclusivity, the system aims to create a trustworthy and responsible solution that boosts efficiency and promotes ethical restaurant.

VI. LITERATURE REVIEW

A. Research Methodology: Desk-based Research

Before implementing the Real-Time Intelligence (RTI) system for sustainable restaurant management, thorough desk-based research was conducted to ensure that the project's objectives align with relevant information and data. The methodology utilized involved extracting relevant and valuable information from reputable scholarly sources such as academic journals, industry reports, government publications, and credible online resources. Apart from the field or primary research, this approach, a form of empirical research, also known as secondary research, focuses on analyzing existing sources of information rather than collecting new data [8]. Several steps were taken to carry out this research effectively. The research question guided the investigation, and the identified sources were carefully assessed for credibility, relevance, and reliability. Library databases, academic search engines, and online platforms were used extensively to find the sources. Thorough examination and integration of the collected research material were conducted to effectively address the research inquiry. To maintain academic integrity, strict adherence to diligent citation and referencing was ensured throughout the entire process. The assessment of the sources involved a thorough examination of their credibility, relevance, and currency, leading to the incorporation of the most relevant and current information. Extraneous or replicated data was thoroughly removed, and the remaining information was systematically arranged in a suitable structure to facilitate subsequent analysis. The utilization of a desk-based research methodology played a crucial role in obtaining the requisite information and insights pertaining to real-time intelligence systems within the realm of sustainable restaurant management. Through the utilization of preexisting research and industry expertise, robust groundwork was laid to facilitate the creation of a pragmatic solution in the shape of a real-time intelligence system. The results and understandings derived from the literature review will make a substantial contribution to the existing knowledge on sustainable restaurant operations, particularly in the domains of effective reservation management and precise food demand prediction.

B. Marriott International

In the ever-changing world of hospitality, Marriott International stands tall as one of the largest and most influential hotel chains as it operates and franchises over 8,500 hotels, including Marriott, JW Marriott, Renaissance, Courtyard, Fairfield Inn, and SpringHill Suites, in nearly 138 countries and territories [9]. Over the years, the company has been at the forefront of pioneering initiatives, using innovative technologies and data-driven strategies to ensure their position as a leader in the hospitality realm.

1) Marriott's M Live

The company's proprietary system, M Live, collects and analyses data from a variety of sources, including social media, customer reviews, weather forecasts, and booking patterns. M Live enables to quickly identify trends and respond to events that may impact its business. Marriott used its M Live technology to carefully track the 2017 solar eclipse and evaluate hotel booking patterns in possibly affected locations. Marriott adjusted their pricing and promotion to capitalize on the expected demand increase using this data. This strategic change increased revenue and profitability and demonstrated Marriott's ability to use data to improve company results. [10]. M Live also helps Marriott respond rapidly to customer feedback and requests and gives Marriott real-time intelligence and insights to make better decisions and improve operations in a competitive industry.

2) Marriott's Group Pricing Optimizer (GPO)

Implemented by Marriott in late 2006, the Group Pricing Optimizer (GPO) serves as a sophisticated system aimed at enhancing hotel profitability and streamlining the sales process for both sales managers and customers. GPO utilizes price-elasticity models for different market segments, recommending optimal rates and negotiating ranges for group customers. Additionally, during negotiations, the system provides valuable data, including sleeping-room inventory availability, potential displacement of more valuable business, profitability analysis, and evaluation of alternative dates. Over its first two years of operation, GPO successfully achieved its goals of driving profitable revenue and enhancing the sales process.

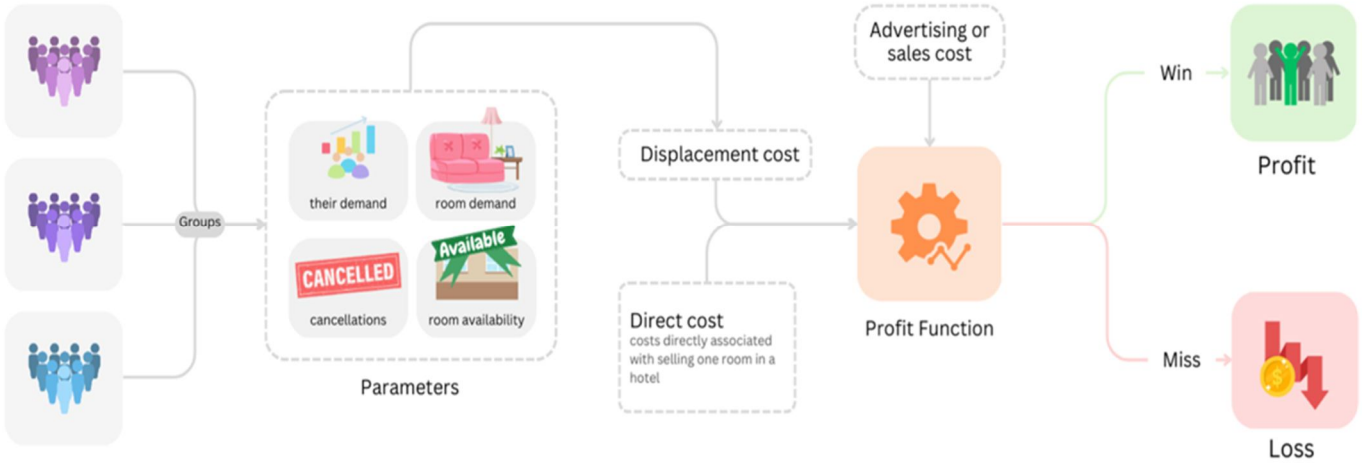

Fig. 2 Profit function simplified.

The cornerstone of GPO's success lies in its ability to calculate optimal prices for group hotel room reservations as shown in Fig 2. The profit function, a mathematical model used to calculate the expected profit from offering a specific price to a group customer for hotel room reservations combines the probability of winning a reservation bid with the corresponding profit. Estimating the displacement cost, which represents the value of business that might be lost if inventory is given to a specific group, is a significant challenge in the profit function. To address this, GPO relies on forecasts of individual and group customer demand, cancellations, room availability, and room demand for different stay dates. By solving optimization models, the system determines the forecasted maximum profit with and without the current group, providing an estimate for the displacement cost. Pricing curve estimation helps GPO determine customer price sensitivity based on occasion, group size, and season. Regression analysis is used to find win rate-related variables in a database of 800,000 group requests. Next, CART and CHAID tree algorithms group the data. Fitting pricing curves posed challenges in establishing a stable reference price and achieving curve sharpness. Nevertheless, a private reference price and "model with dependence" were employed to resolve these issues [11]. Marriott's GPO has revolutionized hotel revenue management and sales processes through innovative pricing models and advanced data analytics. Despite challenges, collaboration with field personnel ensured GPO's successful adoption. By providing real-time pricing responses, valuable data insights, and accurate forecasting, the system continues to drive profitable revenue and enhance the customer experience for Marriott hotels worldwide.

3) Marriott's One Yield and Total Yield

Revenue management has long been considered a critical aspect of the hospitality industry, and Marriott International has been a pioneer in implementing such systems for over 20 years. Their Revenue Management System (RMS) called One Yield has been widely adopted in nearly 97% of Marriott-owned hotels since 2010.

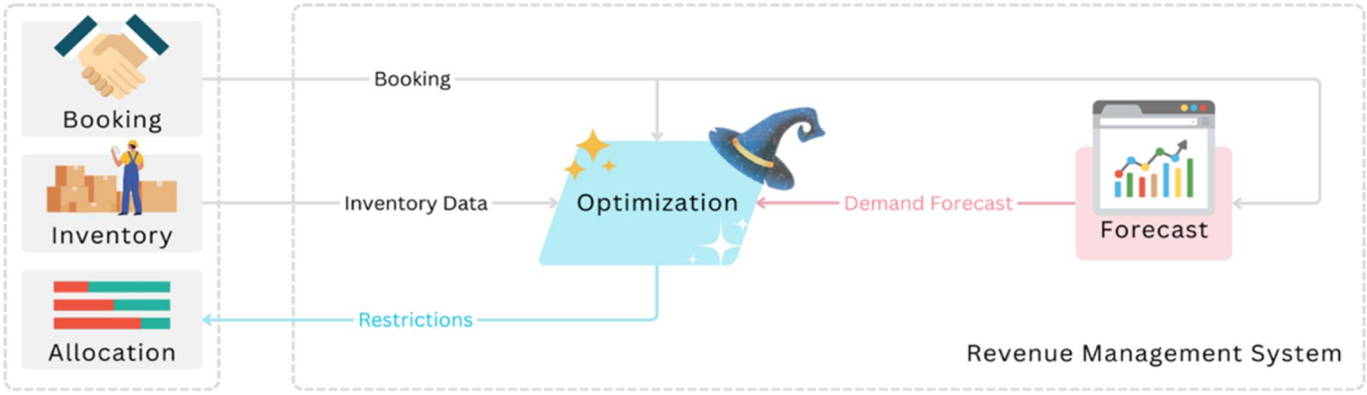

Fig. 3 Relation of Reservation (left) and Revenue management system.

One Yield is specifically designed for individual bookings, provides detailed demand forecasts, optimal inventory allocations, and a seamless reservation system interface as shown in Fig 3. With the reservation system handling a staggering 75 million transactions per year, it serves as a valuable repository of information about individual bookings. The core of a revenue-management system typically comprises a statistical model to forecast demand and an optimization model to generate optimal control policies based on inventory allocation. One Yield has been instrumental in managing millions of bookings annually, working primarily as a batch system to forecast demand for each rate category and length of stay up to 90 days in advance. These forecasts are then used to establish inventory allocations published to the reservation system. Marriott's ongoing efforts in revenue management have resulted in the implementation of the next generation of revenue-management systems known as the Consolidated Inventory/Total Yield system. This advanced system covers guest rooms and meeting spaces, optimizing revenue and profit for the entire hotel. By catering to both individual and group segments, it proves to be a powerful tool in maximizing revenue potential. The successful rollout of this system in the Eastern region of North America has demonstrated real business value within the first year, allowing hotels to optimize total revenue and profit while enhancing services for group and catering customers [12]. According to Bruce Hoffmeister, Global CIO at Marriott, the success of this ambitious project hinged on aligning business and IT priorities. As a result, the Consolidated Inventory/Total Yield system has no close competitors in terms of its comprehensive solutions. The system equips employees with the right information, empowering them to meet the expectations of group customers and secure the right business for the hotel.

C. Starbucks Corporation

Within the world of coffee retail, one name stands out as a widely recognized and omnipresent brand, captivating people globally: Starbucks Coffee. Starbucks began in Seattle, Washington, in 1971, and it has since become a global coffeehouse phenomenon, greatly influencing coffee culture worldwide [13]. Today, the company uses data analytics and technology to improve customer experiences, optimize store operations, and stay competitive. However, around fifteen years ago, it was not the case. Starbucks embraced data during the 2008 financial crisis, leading to a data-driven decision-making.

1) Starbucks' Location Intelligence for New Store

During the period from 2000 to 2008, Starbucks experienced blind expansion, neglecting core products, and facing in-store losses, which led to a decline in corporate growth year after year [14]. However, in 2008, when the financial crisis hit, the capital market and the retail industry suffered an unprecedented shock. To save Starbucks, CEO Howard Schultz had to make tough decisions. The company closed 600 underperforming stores in 2008 and 300 in 2009 to cut costs [15]. Schultz prioritized service and overcoming its effects. As part of this strategy, Starbucks used Esri's Atlas, a location intelligence tool, to later strategically open stores in specific locations [16]. The Atlas tool considered population, income, competitors, traffic, and proximity to existing Starbucks stores to recommend new locations. This data-driven approach accurately predicted store location economic performance.

2) From Beans to Bytes: How Starbucks Brew Data

Starbucks is a data company that also sells coffee [17]. The company's growth and customer relationship management depend on the collection of valuable insights from customers, stores, and coffee machines using advanced technologies such as AI, IoT, Big Data analytics, and blockchain. In the past, Starbucks used consumer data on at-home consumption and store ordering habits to introduce a grocery product line, including K-Cups and bottled beverages, expanding its brand presence, and offering consumers the pleasure of Starbucks at home [18]. However, since 2017, the company has been driving business growth through the Digital Flywheel Program, heavily relying on AI and data science. The program uses AI to suggest food and drinks to reward members based on factors like order history, weather, time, and birthdays [19]. The flywheel strategy focuses on customer acquisitions, spend-based rewards, personalized offers, and convenient ordering to boost sales, customer loyalty, and engagement [20]. In 2011, Starbucks ventured into big-data realm through the launch of its mobile app. The app gained momentum by offering app-based rewards points, known as stars, and today, the app has 31 million active users and handles over 100 million transactions each week [21]. Through the app, Starbucks has been collecting data on members' coffee purchases, including details about what, where, and when they make their transactions [22]. This process generates both qualitative and quantitative data with each interaction, providing valuable insights to create innovative solutions and deliver enhanced value to customers. Starbucks goes beyond its mobile app to leverage IoT in securely connecting its coffee machines. These machine collects data on each shot of espresso, including bean type, coffee temperature, and water quality, resulting in more than 5 megabytes of data during an eight-hour shift [23]. The guardian module, developed in collaboration with Microsoft, facilitates their secure connections with Azure Sphere, enabling remote recipe updates, reducing costs, and enhancing customer satisfaction through improved maintenance and customer engagement. Moreover, Starbucks adopts innovative solutions like Big Data and blockchain to offer supply chain transparency, enabling customers to trace the origins of their coffee beans through scanning codes on the packaging.

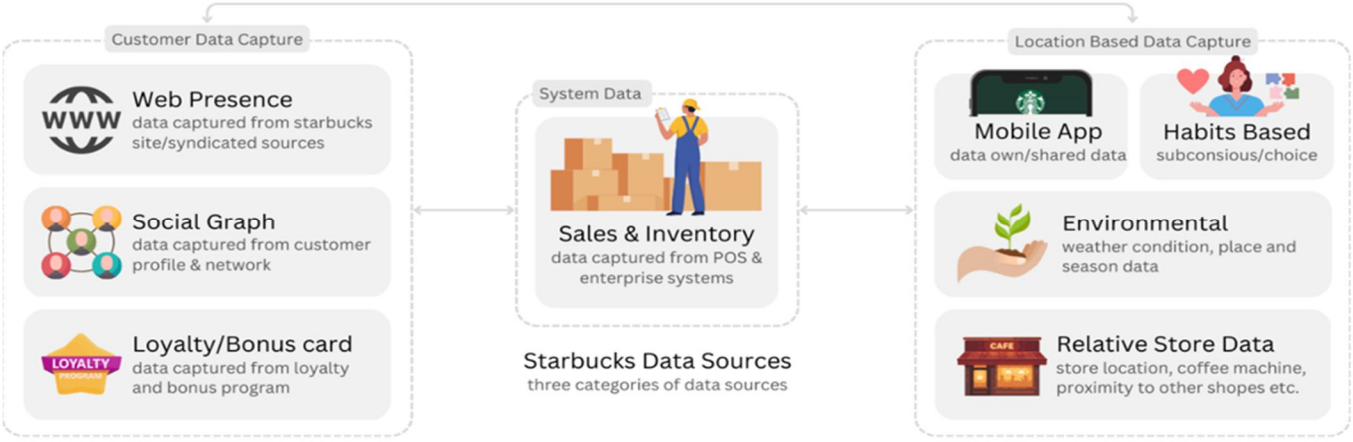

Fig. 4 Data source of Starbucks.

Introduced in 2019, Starbucks' internal AI platform, Deep Brew powers the company's personalization engine, optimizes labor allocations, and enhances inventory management within the stores. According to Brian Ames, Lead Manager Data Science, Analytics Ops at Starbucks, the platform helps them deploy models into production in their large organization [24]. Brian also describes that the platform's success is due to Starbucks' rich data and strong foundations, including the enterprise data analytics platform (EDAP) and data lake, which integrate diverse data sources, as shown in the Fig 4; inspired by Bradlow and colleagues' work [25]. Through a compute layer, the platform makes personalized suggestions using reinforcement learning across touchpoints like the mobile app, digital drive-thru, website, and social media [26].

3) Sustainability Initiatives at Starbucks

Starbucks is a leader in sustainable coffee sourcing. The company has heavily invested in green marketing and environmental sustainability, focusing on three areas: coffee, tea, and paper sourcing; product and personnel transportation; and outlet design and operational methods, including power and water consumption and waste recycling and treatment [27]. This promise to environmental sustainability exceeds the efforts by other large coffee companies, as reported by Starbucks. Nonetheless, the company faces criticism for potential greenwashing, as some assert that certain initiatives prioritize marketing and advertising over genuine environmental impact [28].

In 2004, Starbucks launched Coffee and Farmer Equity, a program that promotes ethical sourcing and long-term support for coffee farmers and communities (Starbucks, 2020). The program embraces the principles of Economic Transparency, Social Responsibility, Environmental Leadership, and Quality [29]. Through these practices, Starbucks ensures the production of quality arabica coffee, fair pricing, safe working conditions, sustainable agriculture, and premium rewards for farmers [30]. The company also supports coffee farmers worldwide with over $80 million and aim to supply $100 million in farmer loans by the end of 2025. In its 2012 sustainability report, Starbucks asserted that 90 percent of its coffee was ethically sourced through C.A.F.E. Practices. The 2014 sustainability report showed an increase, with 96 percent of coffee grown sustainably. In the recent 2022 report, Starbucks revealed an even higher figure, indicating that 98.2 percent of their coffee was now ethically sourced and verified through C.A.F.E. Practices. Contrary to greenwashing claims, Starbucks' commitment to sustainability and ethical sourcing has been proven by its practical actions and open reporting. The company's efforts to reduce carbon emissions in its coffee value chain and stores, implement sustainable packaging, promote circular economy, invest in regenerative agriculture, and support forest conservation, along with its focus on reducing dairy-related emissions and optimizing water use, demonstrate genuine dedication to sustainability and responsible practices [31].

D. OpenTable Inc.

Incorporated in 1998, OpenTable, part of Booking Holdings, Inc is a pioneering online restaurant reservation platform that allows diners to book tables in real time and gives restaurant operators tools to improve efficiency. This San Francisco-based company, founded by Sid Gorham, Eric Moe, and Chuck Templeton, has changed how people discover and experience restaurants. According to their website, over 80 million diners choose OpenTable each month at over 60,000 restaurants worldwide.

1) A Platform of Mutual Benefits

The platform provides mutual benefits to diners and restaurants. Diners experience convenient reservations, access to restaurant details, ratings, and nearby options. In contrast, OpenTable enables restaurants to adopt online reservations, digitizing their systems, and enhances their online visibility, potentially attracting new customers. The company addressed the chicken-and-egg problem by initially targeting restaurants, offering them a booking management system to reduce manual processes before attracting diners and capitalizing on cross-side network effects [32]. According to their 2022 press release, the platform has signed a global agreement with Marriott International to become their preferred restaurant technology provider, serving over 1,400 restaurants in Marriott hotels across 56 countries. The platform also offers a lighter version of the company's reservation system, which is purely web-based and aimed at restaurants that normally rely mostly on walk-in customers, enabling them to accept online reservations [33].

2) Data-Driven Dining with OpenTable

OpenTable's approach to enhancing dining experiences through data aligns seamlessly with the growing trend of data-driven decision making in the hospitality industry. By utilizing data analysis, the company gains valuable insights and creates captivating experiences, effectively applying the concept of data mining in the service sector.

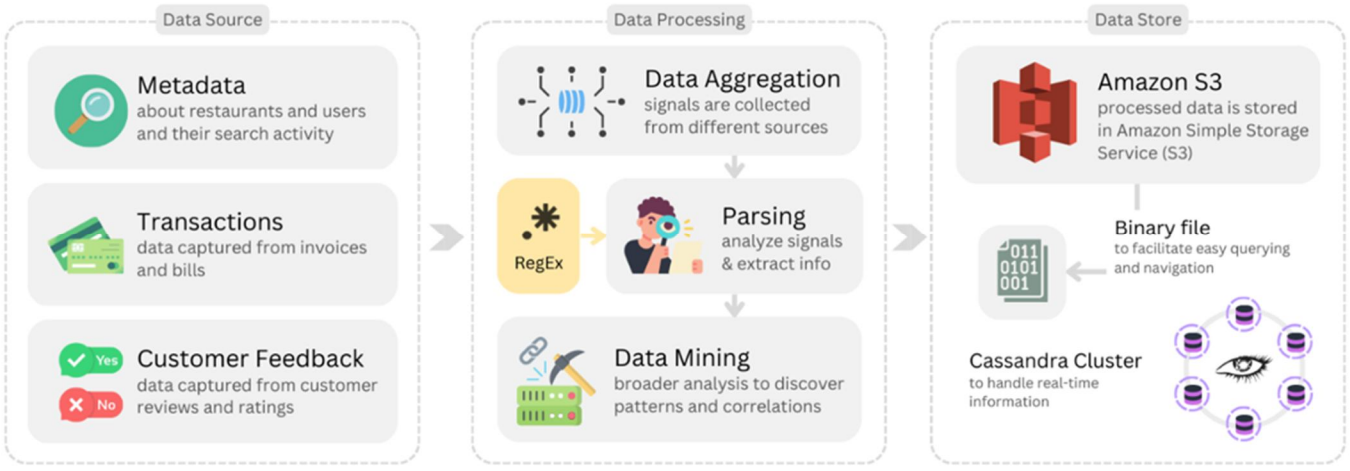

Fig. 5 Data analysis process of OpenTable.

OpenTable collects a wide range of data, including customer reviews, ratings, search activity, transactions, and metadata about restaurants and users [34]. According to Pablo Delgado, and as illustrated in Fig 5, Data Scientist at OpenTable, this data is then processed using a combination of techniques, including signal collection, parsing signals using regular expressions and data mining. Delgado also describes that the data is stored in Amazon S3, and binary files are created to facilitate easier querying and navigation. Real-time information is handled using a Cassandra ring, a distributed database system known for its ability to handle large amounts of data across many commodity servers [35]. In pursuit of understanding customer preferences, OpenTable employs sentiment analysis, a widely used technique in the realm of natural language processing. OpenTable also uses sentiment analysis to improve marketing and personalization by using customer reviews and sentiments [36]. Through sentiment analysis, companies can learn about customer preferences and improve their services.

3) OpenTable's Recommendation Engine

Recommendation systems are crucial in providing personalized suggestions to users. OpenTable's recommendation system is built on a process that involves the use of Spark models, collaborative filtering, neighbour-based approaches, and content-based exploration. Collaborative filtering is a method of making automatic predictions about the interests of a user by collecting preferences from many users. The system also employs a similarity measure called Jaccard similarity to compare restaurants. Matrix factorization is used for a model-based approach, where implicit preferences based on transactions and search frequency are considered instead of explicit ratings [37]. The final model is an ensemble of matrix factorization, item similarity, and blending with a parameter called alpha, according to Delgado.

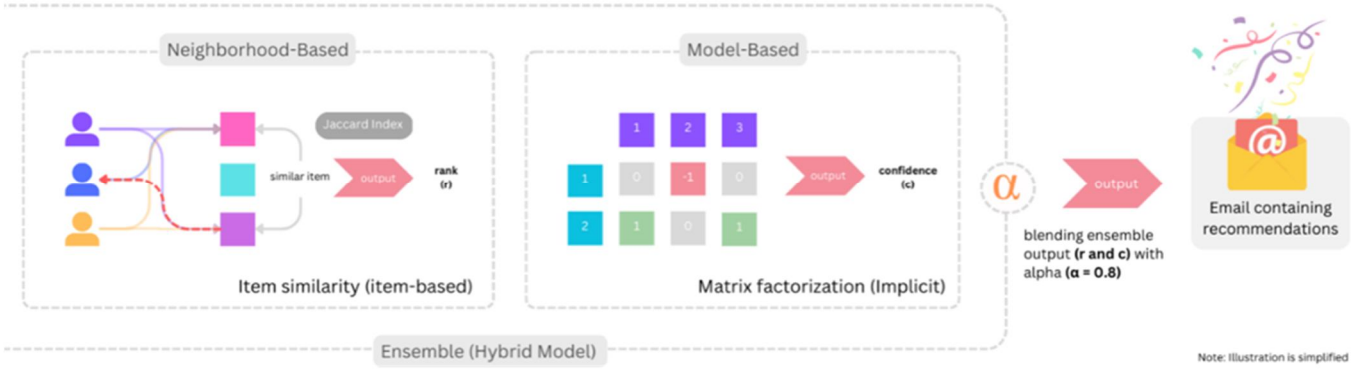

Fig. 6 Working of the collaborative filtering recommendation engine.

The recommendation architecture of OpenTable, as discussed by Jeremy Schiff, Senior Manager of Data Science at OpenTable, is a holistic approach that goes beyond collaborative filtering as shown in Fig 6, emphasizing the importance of data-driven recommendations in helping users find restaurants [38]. Schiff also emphasizes the importance of A/B testing and data analysis in validating these recommendations that highlight the role of controlled testing in improving decision-making in data-driven companies. Schiff discusses building offline models to predict metrics correlated with better A/B testing results, emphasizing model and metric optimization. This aligns with Provost and Fawcett's work on predictive modelling. Trust in these systems is emphasized by Schiff, as quality suggestions are irrelevant without user trust [39].

4) Other Intelligence Features

In August 2010, OpenTable, Inc. released Version 9.0 of its Electronic Reservation Book. The new version introduced an intelligence feature called Flex Mode which helps restaurants optimize seating and avoid overbooking by improving system navigation and table availability representation. The platform's search tool has also undergone a significant upgrade, transitioning from a simple restaurant directory to utilizing Elasticsearch, as revealed in an interview with Thomas Hunter, Principal Software Engineer at OpenTable. This implementation enabled users to conduct free-text searches, making the system more robust and user-friendly. The platform also enables restaurateurs to monitor reservations in real time, including access through Apple Watch, and grants consumers loyalty points with exclusive rewards at various restaurants within the OpenTable network [40].

E. Uber Eats

Uber Eats, a subsidiary of Uber Technologies, is a leading online food delivery platform. Established in 2014, the platform has successfully cracked various global markets, democratizing the way people order food. Operating in over 38 countries and reaching more than 6,000 cities, the service connects consumers with a diverse array of culinary options at their fingertips. The subsidiary connects customers to local restaurants via a mobile and web app for home delivery. The platform's success depends on its strategic use of technology, data analytics, and innovative logistics solutions, which have transformed traditional food service industry operations.

1) Uber's Real-Time Analytics: Charon

Real-time analytics has become a critical component in the operations of many businesses, particularly those that operate in the on-demand service sector. One such business is Uber, which leverages real-time analytics to drive decision-making and improve service delivery. Charon is an innovative system designed to manage demand at the merchant level by implementing real-time protocols. To achieve this, Charon relies on the "Long Request" (LR) metric, identifying live orders without a courier after 10 minutes [41]. The blog also reveals Charon's sophisticated architecture, which relies heavily on Uber's real-time analytics and data workflow management systems. Modern data-driven applications need a low-latency, scalable model to process real-time data efficiently and quickly [42]. Apache Pinot, a scalable distributed OLAP system, dominates Charon's operational framework. Charon uses this sophisticated system to perform real-time analytics streaming on large and complex datasets to gain timely and meaningful insights in dynamic environments [43]. The data sources for Charon mainly consist of granular order-level data from upstream microservices supporting the mobile app. This data is then processed in Apache Pinot for real-time analytics, facilitated by Uber's in-house platform, Databook, for efficient data management—a strategy documented by Li et al.'s research on the advantages of in-house platforms in handling extensive data volumes [44].

2) Uber's Streaming Analytics

In a video titled "Uber Tech Day: Powering Real-time Analytics at Uber," Jing Fan, a software engineer from Uber's Streaming Analytics team, provides an in-depth overview of Uber's real-time analytics system [45]. The video emphasizes the importance of real-time analytics in the context of on-demand services like Uber, where immediate action is expected. Fan describes that the data value changes over time, and the goal of streaming is to bring the business decision closer to the time the data is generated. This is especially important in the context of Uber, where immediate action based on real-time data is expected as shown in Fig 7.

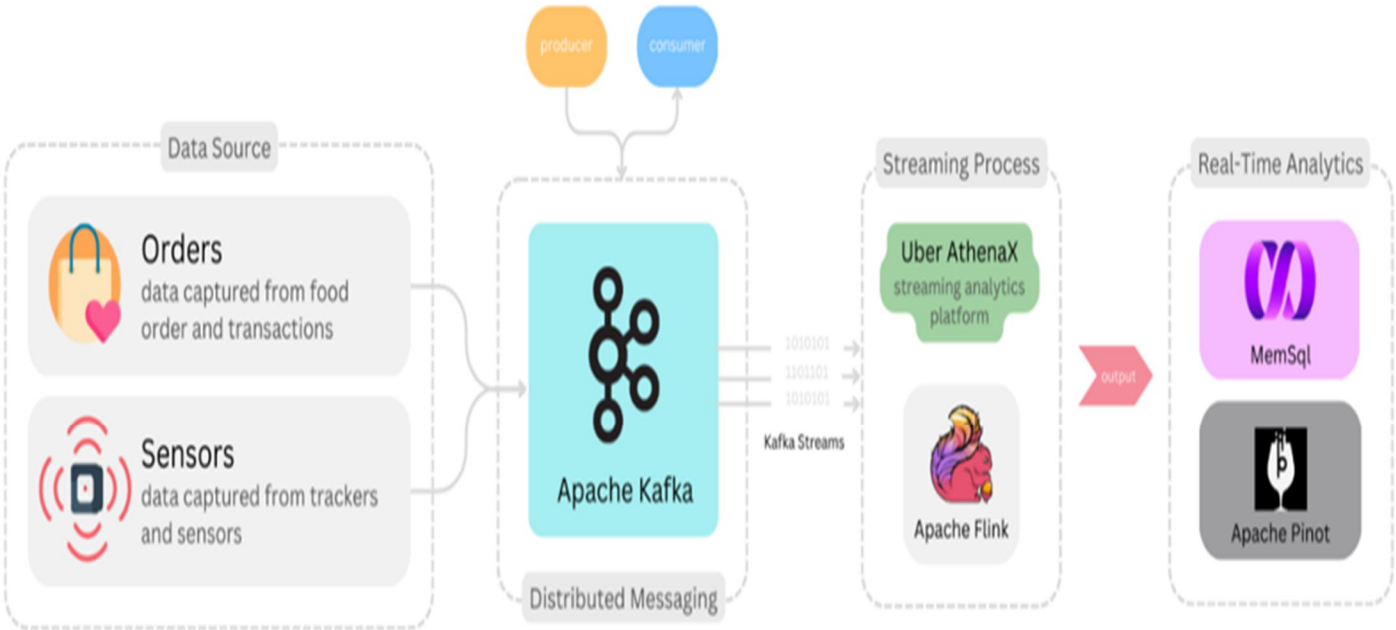

Fig. 7 Working of User Streaming Platform

Distributed messaging systems like Kafka are crucial for real-time processing of massive amounts of data [46]. Uber's real-time analytics system relies on Kafka to manage data persistence, scalability, and fault tolerance efficiently. The system also includes Escena Acts, an Apache Frank-based streaming processing platform. This platform allows users to create business logic like joining two streams and aggregating. According to Fan, the data transformation happens in the real-time analytics layer, composed of Pinot and MemSql. The Sequiera layer allows users to query data with low latency. The video also highlights Uber's real-time driver incentive system, providing drivers with visibility into their weekly earnings to enhance transparency. However, Fan mentioned that this system also presents technical challenges, such as end-to-end latency and data loss. These challenges were the main concern, as high latency is detrimental to real-time systems.

VII. DEVELOPMENT METHODOLOGY

For this project, a combination of Agile Kanban and the Agile Data Science methodology was wisely employed to formulate and construct a web-based real-time intelligence application. To initiate the development, the Agile Data Science approach was initially embraced, focusing on the creation of a machine learning model. This comprehensive methodology encompassed critical stages such as data collection, thorough data cleaning, exploratory analysis, feature engineering, systematic model development, and a continuous process of model evaluation to ensure its efficacy. Using Agile Data Science, the process went through different steps. In "Data Collection," appropriate data sources were methodically acquired and categorized. The "Hypothesis Generation" step then established project-guiding research questions and hypotheses.

"Data Cleaning" followed to ensure data quality and integrity. "Data Exploration" used visual and statistical methods to find patterns and insights. "Feature Engineering" selected and created relevant features. The "Modeling" step used machine learning methods, while the "Interpretation" phase drew conclusions from the model's outputs. The Agile Data Science Pyramid supported this framework with levels for data collection, cleansing, exploration, and feature engineering [47]. Subsequently, Agile Kanban was introduced to construct a content management system (CMS) for the restaurant and to seamlessly integrate the developed model into the system. Agile Kanban proved advantageous due to its visual task management, facilitating real-time tracking of progress and identification of bottlenecks.

The flexibility of the framework was pivotal in accommodating changing project requirements, and its continuous improvement philosophy facilitated early issue identification and resolution. Throughout the development process, the involvement of the research supervisor in the role of the product owner played a pivotal role in ensuring a close alignment between the application's development and the objectives of the research. This iterative collaboration involved regular feedback loops, where the research supervisor provided valuable insights and direction. At the culmination of each sprint, a comprehensive review meeting was conducted, during which the completed features were meticulously demonstrated and rigorously evaluated against predefined criteria. This interactive evaluation process facilitated the identification of any discrepancies, areas for enhancement, or adjustments required to refine the application's functionality and user experience.

A. Tools, Technologies, and Techniques

This project used several tools. Google was used for research and VS Code for coding. GitHub managed versions, code merging, and testing as the central repository. Figma and Canva helped me create high-quality visual assets, along with development tools. Postman made API testing and documentation easy by sending requests, checking responses, and writing detailed documentation. Microsoft Word wrote the documents, and Excel managed and converted the first set of data. Jupyter Notebook aided data analysis and model training. React.js, a component-based JavaScript library, was used for frontend development, along with Next.js for performance and SEO. Tailwind CSS enabled fast and consistent component development whereas SASS enhanced styling. Recoil managed component state changes. Node.js handled concurrent requests in a scalable, high-performance backend. Firebase is used as a secondary backend. Scikit-learn provided classification, regression, and clustering algorithms for the ML service. FastAPI wrapped the trained ML model and created the API endpoints. MongoDB, a flexible, scalable NoSQL solution, was chosen for data storage. This project employed iterative workflow techniques using Agile Kanban and CI/CD. Agile development emphasizes iterative, incremental development, allowing flexibility and adaptability throughout the project lifecycle. Iterative feedback and collaboration ensure project efficiency and user-centricity. CI/CD simplified deployment. CI/CD automates software development, testing, and deployment to reduce errors and guarantee releases. GitHub and Vercel were used for continuous integration and deployment.

VIII. DEVELOPMENT PROCESS

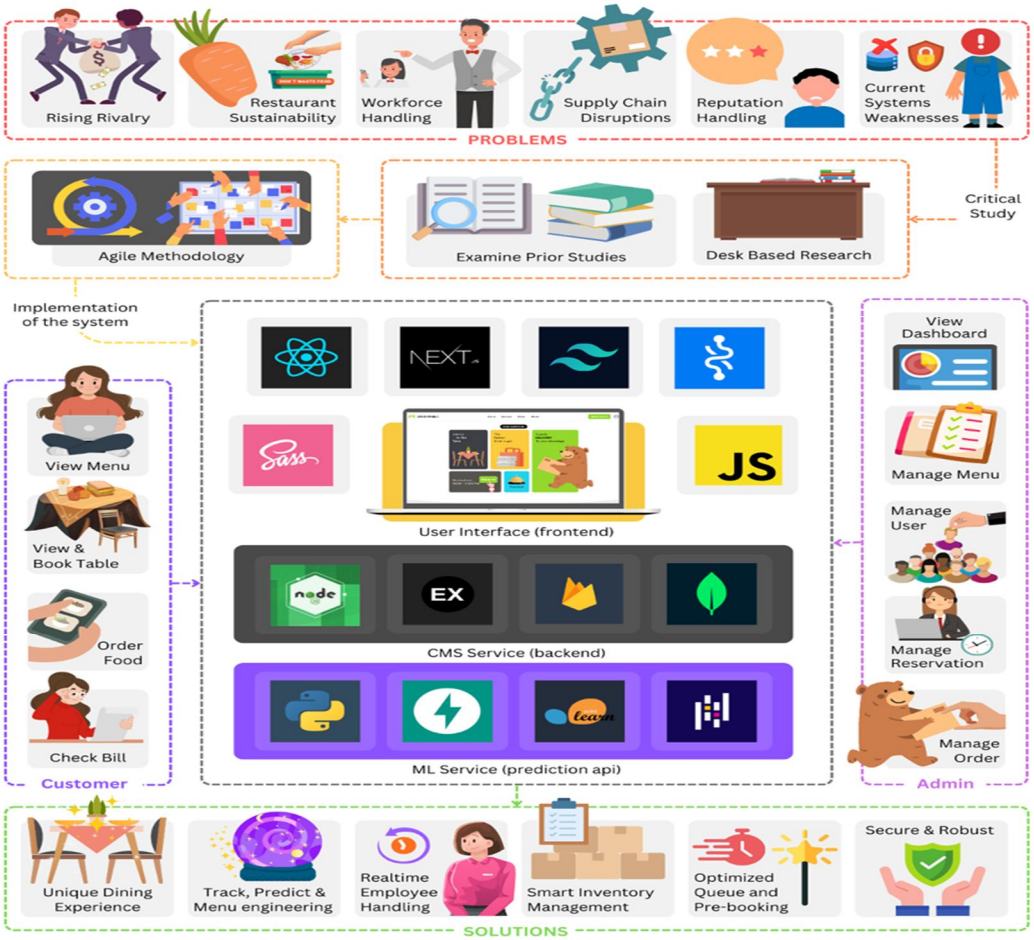

Fig. 8 Integration

A. *Inner Workings of the Software*

The core of the "green-table" application lies in its three interconnected components: the frontend, the CMS (Content Management System) backend, and the prediction service. This system synergizes to facilitate real-time intelligence in food sustainable restaurant management, offering users an intuitive and comprehensive platform for seamless interactions while empowering administrators with data-driven insights as shown in Fig 9.

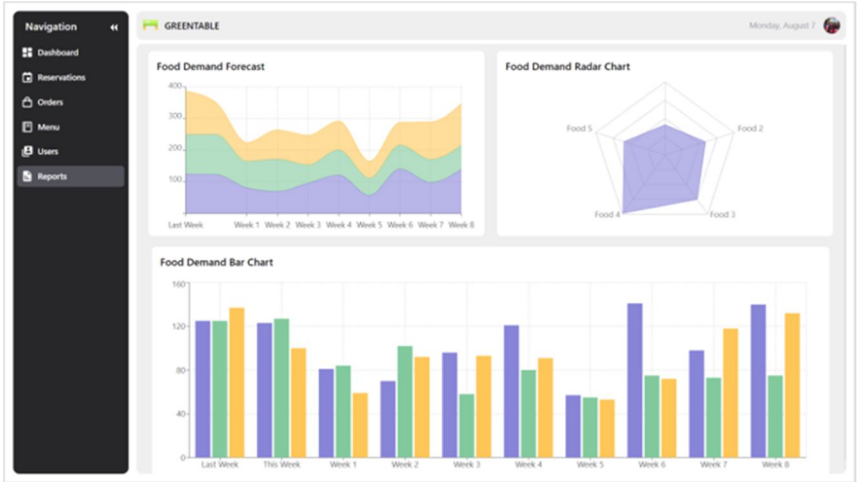

Fig. 9 Admin Panel Insights Frontend

At the forefront of the green-table experience is the user-friendly frontend, which encapsulates the system's functionality. This interface serves as the gateway for users, enabling them to effortlessly engage with various features. From the ability to conveniently login or register, to the flexibility of making reservations, viewing the food menu, and placing orders, the frontend streamlines the dining experience. Additionally, users can monitor their progress and engagement through the innovative "leaf" points system. These points, earned by successful reservations, orders, or referrals, can be redeemed for discounts or leveraged to ascend the leaderboard, fostering a sense of gamification. Administrators, on the other hand, handle comprehensive control through the frontend. They gain access to a robust dashboard that presents vital statistics encompassing reservations, overall food demand, and other critical metrics. The power to manage reservations, orders, staff, and generate reports is seamlessly integrated, enabling efficient oversight of operations. Area plots, radar charts, and bar charts help administrators make informed decisions to ensure sustainability and profitability. Bridging user interactions and system functionality, the backend orchestrates the seamless execution of requests from the frontend. This component stands as the backbone of the green-table ecosystem, deftly handling tasks ranging from user authentication and data storage to real-time communication. The backend dynamically communicates with the prediction service to ensure accurate food demand forecasts that drive the restaurant's operational strategies. Real-time reservation capabilities in the backend keep data current and improve user experience. It helps administrators manage reservations, orders, and staff, creating harmony. The backend, along with the frontend, connects users and administrators to the system's intelligence.

The powerful prediction service is key to the intelligence of the green-table, demonstrating the data-driven approach that underpins the restaurant management paradigm. This service propels useful estimates of food demand using supervised regression machine learning, which is critical for inventory management, waste reduction, and improved sustainability. The procedure began with the selection of XGBoost, a capable model discovered through extensive examination and comparison. Among the models, it had the lowest RMSE, indicating more accurate predictions as shown in Fig 10.

	Model	MSE	RMSE	Training Time
0	Linear Regression	99769.921826	315.863771	0.393824
1	Random Forest	56418.822261	237.526466	39.940171
2	XGBoost	51948.523434	227.922187	9.196249

Fig. 10 Model evaluation results.

The prediction service orchestrates a seamless process, encapsulated within a well-optimized model packaged as a .pkl file. This model is then made accessible through a streamlined API layer, made with FASTAPI. Six critical parameters, including week number, meal category, pricing data, promotional activities, and featured placements, serve as the inputs to the prediction API. This intricate orchestration culminates in a prediction of food demand, vital for prudent resource allocation and efficient planning. A separate health endpoint allows checks to ensure prediction service dependability. The prediction service supports the green-table system by providing real-time insights that make restaurant management sustainable.

IX. FINDINGS

A. *Research Question One*

It is evident that real-time intelligence (RTI) is altering restaurant operations and sustainability. Restaurants are tapping into vast data sources, employing artificial intelligence (AI), Internet of Things (IoT), big data analytics, and blockchain technologies to analyse and respond to trends rapidly. By integrating these technologies, restaurants can proactively manage resources, enhance customer experiences, and foster sustainability. One of the critical areas of restaurant operations that RTI can significantly enhance is management. Restaurants deal with a multitude of operational aspects, such as labor allocation, inventory management, strategic location planning, and pricing. Marriott's M Live project in 2017 is a good example of RTI use in management. The Great American Eclipse data helped them make good decisions. Similarly, Starbucks leverages IoT for data collection from embedded systems in their restaurants. The collected data offers insights into customer behaviour and preferences, enabling Starbucks to optimize labor allocations and enhance inventory management. Furthermore, RTI, combined with location intelligence, aids in strategic location planning for new branches, like Starbucks' approach. Following that, restaurants can use RTI to recommend optimal rates and negotiate ranges for group customers while considering various market segments.

Sustainability is another pivotal area where RTI proves beneficial. Restaurants increasingly invest in green marketing and sustainability campaigns to demonstrate their commitment to environmental preservation. By using RTI, restaurants can track and report their sustainability efforts in real-time, increasing trust and transparency. A prime example is Starbucks, which extensively reports its green initiatives, leveraging the power of RTI to collect data and relay the information to its customer base. Furthermore, RTI can help manage supply chains more sustainably by predicting demands accurately and preventing overproduction, which leads to waste. Food demand forecasting is essential to restaurant operations, ensuring they have the right ingredients at the right time. RTI can play a crucial role in solving the so-called "chicken-and-egg problem." For instance, OpenTable uses RTI to manage and predict demands, which allows restaurants to recommend dishes to customers based on available inventory. It also enables the optimization of seating and avoids overbooking by improving system navigation and table availability representation. In this way, RTI helps restaurants streamline their operations and reduce food waste. The methods for collecting and analysing data in these systems vary but often involve advanced tools provided by companies like Apache, Esri, Google, and AWS. Data sources are abundant, including customer reviews, ratings, search activity, transactions, and metadata about restaurants and users. Such rich data provides a sturdy foundation for making informed decisions. The use of A/B testing and data analysis validates recommendations, and building offline models helps predict metrics correlated with better A/B testing results. Additionally, real-time analytics and live metrics are used, like Uber Eats, to monitor order and track delivery in real-time.

To put it simply, real-time intelligence presents an array of avenues to enhance the efficiency and sustainability of restaurant operations. By collecting diverse data, analysing trends, optimizing labor and inventory allocations, and investing in green initiatives, restaurants can strengthen their position in a competitive market. Leveraging state-of-the-art technologies, implementing strategic location planning, and employing reinforcement learning and A/B testing further contributes to improved operations and customer satisfaction. Embracing real-time analytics and data-driven decision-making empowers restaurants to stay ahead of the curve and deliver exceptional dining experiences.

B. Research Question Two

Implementing a real-time intelligence system for managing reservations and predicting food demand in a sustainable restaurant setting offers several potential benefits. Firstly, such a system can optimize table bookings and resource allocation, leading to increased operational efficiency. By dynamically adjusting reservations based on real-time demand patterns, restaurants can minimize wait times for customers and reduce food waste, resulting in a more sustainable operation. Additionally, accurate food demand forecasting enables better inventory management, ensuring that the right amount of ingredients is ordered and used, further contributing to sustainability by reducing unnecessary waste. Furthermore, a real-time intelligence system can enhance the overall customer experience. By analysing customer preferences and behaviour, restaurants can personalize offerings and promotions, fostering customer loyalty and satisfaction. This personalized approach can also support sustainable practices by promoting locally sourced and eco-friendly menu items, thereby encouraging customers to make more environmentally conscious choices. For instance, if the system identifies a trend of customers showing interest in plant-based options, the restaurant can introduce more vegan dishes to cater to the growing demand for sustainable and healthy dining choices.

However, the implementation of such a system also comes with challenges. One significant concern is the data privacy and security of customers. To leverage real-time intelligence effectively, restaurants need to collect and analyse vast amounts of customer data, including reservation details and preferences. Ensuring robust data protection measures and obtaining consent from customers for data usage becomes critical to maintain trust and comply with regulations. Restaurant owners must be transparent about their data practices and assure customers that their data will be handled ethically. Additionally, the initial investment and technological readiness are challenges that need to be addressed. Adopting a real-time intelligence system may require significant financial resources for hardware, software, and staff training. Moreover, restaurants must have a reliable and stable IT infrastructure to support real-time data processing and analysis. This may involve collaborating with IT experts or partnering with specialized technology providers to ensure a smooth and effective implementation. It is essential for restaurants to conduct a cost-benefit analysis to assess the potential returns and long-term advantages of adopting such a system, considering the investment required. Overcoming these challenges is crucial to fully harness the potential benefits of a real-time intelligence system in a sustainable restaurant setting. By addressing data privacy concerns and making informed decisions about investments in technology, restaurants can successfully integrate and leverage real-time intelligence to improve their operations' efficiency, enhance sustainability practices, and deliver exceptional customer experiences. By embracing innovative technologies and adopting a forward-thinking approach, restaurants can play a vital role in promoting sustainable practices while remaining competitive in the dynamic and evolving food industry.

C. Research Question Three

In the implementation and use of real-time intelligence systems, addressing data privacy concerns is of utmost importance. Proactively mitigating potential privacy risks while ensuring compliance with relevant data protection regulations is essential to build trust with customers and protect sensitive information. One of the most effective strategies to proactively tackle data privacy concerns is adopting a privacy-by-design approach. This means incorporating privacy considerations into the very architecture and development of the real-time intelligence system. From the initial stages of system design, conducting comprehensive privacy impact assessments can help identify potential privacy risks. By recognizing and addressing these risks early on, organizations can put in place appropriate safeguards to protect customer data. This approach not only helps prevent data breaches but also promotes a culture of privacy awareness within the organization.

Transparency is another critical aspect of addressing data privacy concerns. Restaurant operators must clearly communicate with their customers about the data collection practices of the real-time intelligence system. This includes informing customers about the types of data collected, the purposes for which it is used, and the measures in place to protect it. Obtaining explicit consent from users before collecting their data demonstrates respect for their privacy and empowers them to make informed decisions about sharing their information. Additionally, data minimization is an essential principle to mitigate data privacy risks. Collecting and retaining only the necessary data is fundamental to reducing the potential misuse of personal information. By adopting data minimization practices, restaurant operators limit the amount of sensitive data they hold, thereby decreasing the attractiveness of their systems as targets for data breaches. Regarding data protection regulations, one of the key standards relevant to data privacy is the ISO/IEC 27000 family, particularly the ISO/IEC 27701 standard [48]. ISO/IEC 27701 provides guidelines for implementing and managing a Privacy Information Management System (PIMS) within the context of an organization's existing Information Security Management System (ISMS), governed by the ISO/IEC 27001 standard [49]. By adopting ISO/IEC 27701, restaurant operators can ensure they have the necessary controls and processes in place to protect personal data while complying with industry best practices and legal requirements as shown in Fig 11.

Fig. 11 Data protection regulations

To summarize, dealing with data privacy concerns in the context of real-time intelligence systems necessitates a multifaceted approach. To protect customer data and comply with regulations, a privacy-by-design strategy, transparency, data minimization, and ISO/IEC 27701 are essential [50]. Restaurant operators can reap the benefits of real-time intelligence systems while upholding their responsibility to protect customer data and privacy by incorporating these practices into their operations.

X. LIMITATIONS

The project is subject to several notable limitations that impact on its functionality and potential outcomes. Firstly, the system currently supports a restricted range of authentication methods, with only Google login available for users. Additionally, language support is limited exclusively to English, potentially excluding a wider user base. Furthermore, the application has not undergone comprehensive testing, and its SEO optimization remains unaddressed. Responsiveness is also constrained, primarily affecting the admin panel which is tailored solely for Tablet and Desktop use. Payment methods are limited to cash-on-delivery, potentially limiting user convenience. The model's predictive potential is hampered by a lack of data and, as a result, a limited number of prediction parameters. The absence of external factors such as weather, season, and events in the dataset may jeopardize the model's predictions. Finally, the deployment of the prediction service, especially the Machine Learning model, presents challenges that need to be addressed. These limitations collectively shape the boundaries of the project and highlight areas for potential improvement and expansion in the future.

XI. FUTURE WORK AND RECOMMENDATIONS

The future work and recommendations for this research primarily fall under four broad categories: Cloud-based deployment and optimization, Structural evolution, and application workflow, Data and machine learning model enhancements, and Further recommendations. The initial focus should be on transitioning the local environment to the cloud, enhancing the file upload mechanism for effective and compressed storage, and migrating backend firebase infrastructure to more enterprise-level platforms like AWS, Azure, or GCP. Furthermore, it is recommended to transition from the current monolithic architecture to microservices architecture. While the current monolith architecture may be sufficient for smaller restaurants, an uncoupled architecture is a more suitable approach for larger, well-established restaurant chains with multiple branches. For larger operations, a microservices architecture offers improved scalability, flexibility, and fault isolation. Microservices also reduce single-point-of-failure risk. Despite higher operational costs, this transition reduces service disruptions and potential losses. Another major improvement area is data and model refinement.

While the current model functions with a limited set of features and lacks some initially intended ones, such as weather and season, the goal is to train a more comprehensive model using restaurant invoice data. This dataset will include several factors like weather conditions, seasons, events, and specific food names at the time of reservation. However, it is essential to prioritize ethical considerations when sourcing such data, ensuring that personal identifiers are excluded from the dataset. Once these ethical concerns are addressed, the model can be retrained on the comprehensive dataset, leading to even more accurate and detailed demand forecasts, and significantly improving the model's predictive accuracy and granularity.

Moreover, this should be coupled with a move towards a model supporting incremental learning. Machine learning models that offer incremental learning capabilities, like the 'Prophet' model by Facebook, are particularly recommended. These models have the potential to adapt over time and generate more accurate forecasts by learning from new data as it becomes available. The initial training phase for these models would be as rigorous as before, but they will offer enhanced adaptability and accuracy in the longer run by continuously integrating latest trends and changes.

As restaurants generate large volumes of data continuously, a model that can be periodically retrained with new data would significantly improve prediction accuracy and adaptability. Another significant point for future work is the need to integrate a Test-Driven Development (TDD) environment into our current workflow. This shift is crucial to ensure that faulty code or flawed business logic does not reach the production stage. Employing a TDD approach within a Continuous Integration/Continuous Deployment (CI/CD) pipeline can dramatically enhance product quality and reliability. A dedicated mobile app is crucial as most users heavily rely on mobile devices. Adopting a 'mobile-first' approach ensures a seamless user experience, prioritizes speed, and optimizes touch controls. Even though the web app is responsive, a dedicated mobile app offers a tailored experience, captivating and retaining mobile users. Finally, the main emphasis should be on ensuring a robust dataset. The need for greater focus on data analysis and refining prediction algorithms cannot be overstated, especially given the challenges associated with sourcing ample data for training robust machine learning models.

XII. CONCLUSION

The research and implementation of a Real-Time Intelligence (RTI) system for sustainable restaurant management showcases the potential of data-driven technologies to revolutionize the industry. The growing challenges faced by restaurants, including competition, rising costs, and the need for sustainability, call for innovative solutions. The RTI system addresses these challenges by enabling better reservation management, food demand prediction, and resource optimization, leading to reduced food waste and improved efficiency.

The research was guided by ethical considerations, ensuring adherence to principles and norms of ethics. Thorough desk-based research laid the foundation for the project, using credible and relevant sources from library databases, academic search engines, and online platforms. Leveraging tools and technologies such as Nextjs, Firebase, FastAPI, Scikit-learn, and Pandas, along with agile Kanban methodology, facilitated the successful development of the system. The secondary features integrated into the system, ranging from privacy and security measures to gamification elements fostering user loyalty, contribute significantly to the comprehensive and seamless user experience. Looking ahead, recommendations for future work include cloud-based deployment and optimization, structural evolution and application workflow enhancements, improvements in data and machine learning models, and further refinement of the system. The research on Real-Time Intelligence in sustainable restaurant management contributes to the advancement of the industry, highlighting the transformative power of technology and data-driven approaches in creating a more sustainable and efficient restaurant ecosystem.

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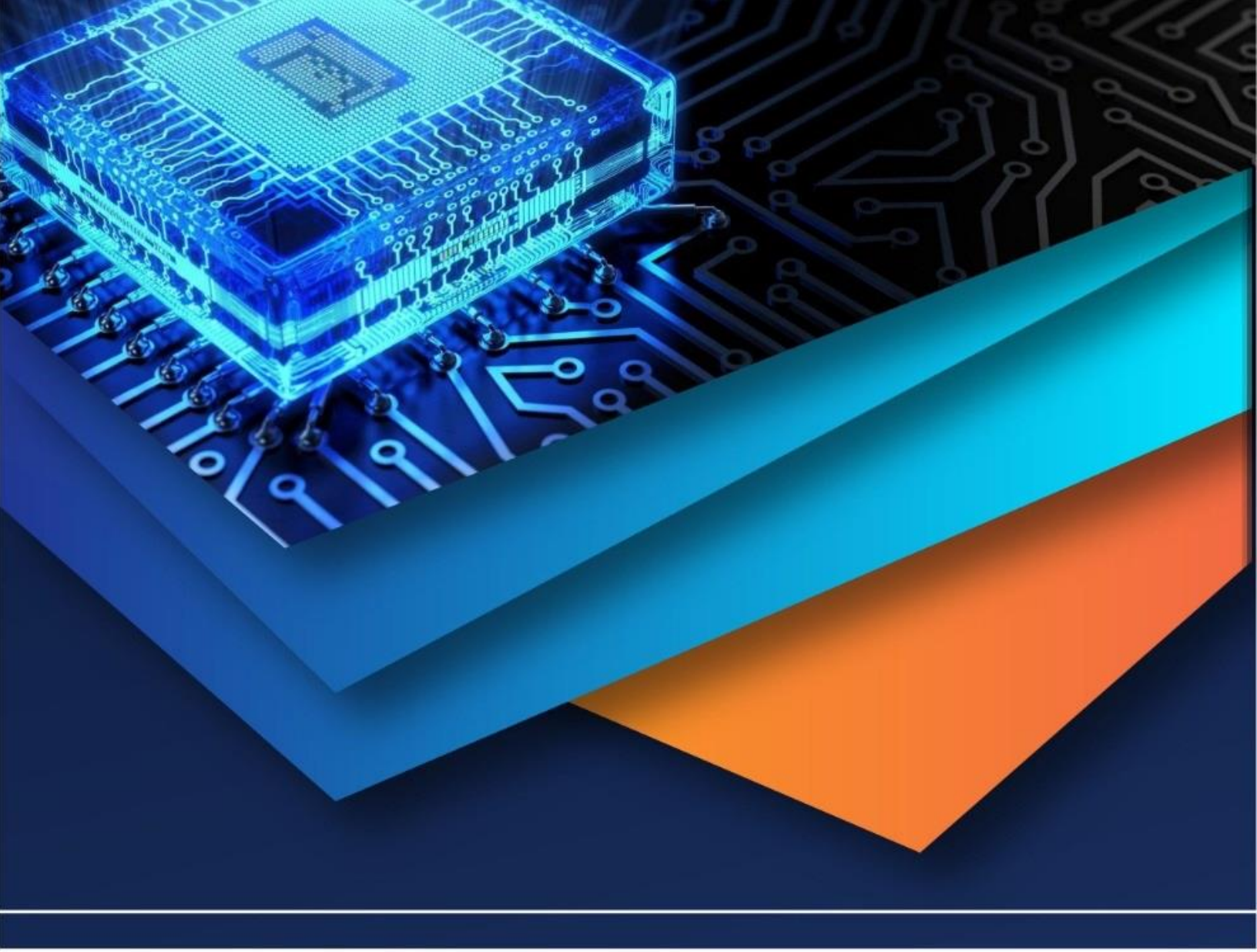

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