



(REVIEW ARTICLE)



## Customer check-in feature development and optimization for real-time order pickup systems using GPS tracking

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### Abstract

The dynamic increase of curbside pickup, drive-thru, and contactless retail services have peaked the demand to identify more efficiently and timely the arrival of the customers. Manual check-in procedure is slow, bringing a lot of inefficiencies as far as staff usage and lengthy wait times are concerned. The paper is designed to explain the procedure or rather the development and perfection of a customer check-in feature using the Global Positioning System (GPS) connected to a real-time order pickup system. The suggested solution utilizes the use of adaptive geofencing, dynamic GPS ping periods, and Kalman filtering to make the location more accurate and take the least possible amount of battery. Location data of customers is processed using cloud architecture to give an estimate of arrival time with automatic alerts to the store personnel to stage the order. Field tests in an urban, suburban and a rural setting show up to 35 percent average wait-time savings and an increase in the efficiency of operations, and user feedback has been positive when it comes to convenience and ease of use. The results indicate that automated check-in fueled by GPS is a scalable and cost-efficient modification to the contemporary pickup processes.

**Keywords:** GPS Tracking; Real-Time Order Pickup; Automatic Check-In; Geofencing Optimization; Location-Based Services

### 1. Introduction

The real-time ordering collection mechanisms have been identified as significant factors in the quality-of-service delivery in modern retailing, food service, and delivery operations [1]. In a setting where operational effectiveness, customer satisfaction, and technological capabilities converge, slight inefficiencies in the pickup process can have a 'ripple effect' in the terms of throughput, labour efficiency, and customer retention [2]. This study contains an overview of the issues with the current arrival confirmation methods and references an automated check-in method that leverages predictive analytics, adaptive geofencing, and real-time order management via GPS-based check-in that is proposed to replace the current methods.

This section prepares the groundwork of the proposing piece through providing a description of the contextual background, operational problem definition, definition of the objectives of the research, as well as the contributions.

#### 1.1. Background

Contactless delivery and curbside pickup along with the drive -thru have become a phenomenon in the modern seller that becomes stronger every year due to the general shift in consumer ethics that require convenience and are further boosted by health concerns in the context of the COVID-19 pandemic [3][4]. Supermarkets, food suppliers and fast-food restaurants (QSRs) have made big Triple-B investments in infrastructures and mobile applications in order to enable such services [5].

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Nevertheless, despite the availability of these implementations, the actual methods of customer arrival detection is quite manual. The typical methods, involving scanning QR codes on arrival, pressing an I am here button in a mobile app or informing staff manually hinders the experience since the user is involved at the exact time when he/she should be getting his/her order [6]. Such friction breaks the desired seamlessness in the experience. The non-trivial consequences of the operation are there. Employees have to wait until they receive clear arrival cues, in order to start final order staging that results in underutilized preparation windows and inconsistency in speed of service delivery [7]. Under high-volume conditions, e.g. QSR rush hours or grocery pickup intensity surges, such operational inefficiencies may propagate into longer lines, higher worker stress, and a drop in customer satisfaction [8]. Furthermore, the issue is not retail-specific: event management, transportation, and logistics are the industries that likely encounter the same issue with the real-time arrival estimation being able to enhance resource allocation significantly [9][10].

### **1.2. Problem Statement**

Irrespective of the operationalization of mobile technology, the current manual models of check-in (such as curbside pickup or other comparable services) implicitly operate in a reactive paradigm and thus customers must react to their arrival by clicking a QR code or hitting an I am here button within an application [6][8]. Such reliance on post-arrival user input also creates several inefficiencies: delayed arrivals through opportunities to improve the situation in customer timescale [6], imprecise prediction of arrival thus lack of timely allocation of people into their various tasks [8], staffing remain reactive with suboptimal allocations [7], and staging areas where utilisation is poor, sometimes overloaded or underutilised [9]. All these aspects lower the quality of the total service environment eroding speed and reliability perceptions [2][10]. This necessitates the need to have a proactive and automated system that has the ability of detecting and making real time predictions when customers will arrive to be able to set orders early, better staffing levels and overall enhancement in operational efficiency.

### **1.3. Research Objective**

The general overall purpose of this study is to design, develop, and test a GPS-controlled automatic check-in program that could predict and verify the arrival of the customers with no operators in the system. The aim of this system is the optimization of the efficiency of the operations, reduction of the waiting time, and the better customer experience because of the possibilities of predictive staging and optimal resource assignments [11].

Specifically, it is to

- Implement an application-level GPS capability, in order to enable passive arrival detection.
- Introduce dynamic geofencing that could adapt to the circumstances of nature and traffic [12].
- Include predictive ETA algorithms using real time GPS and past movement signatures [13].
- Auto configure and integrate within current order management systems, automatically auto stage and alert the staff [14].
- Evaluate the changes of critical performance indicators, such as a reduction in wait times, efficiency in staging and customer satisfaction [15].

Despite being presented in the scope of the retail curbside pickup, due to its architecture, the system can cater to the needs of the QSR drive-thru, grocery pickup, event entry validation, and logistics arrival confirmations [9][10].

### **1.4. Contributions**

There are a number of specific contributions based in the regard to real-time service readiness optimization this piece of research makes. The main areas of contribution, especially relating to the case of the GPS tracking are depicted in Table 1: Key Contribution Areas in GPS Tracking. The contributions made in this research point out the practical and theoretical developments that the study introduces, giving the clear outline of the realization of the efficiency and responsiveness in the real-time tracking systems.

**Table 1** Key contribution Area in GPS Tracking

Contribution Area	Description	Novelty Compared to Literature
Seamless Arrival Detection	Fully automated GPS-based check-in with no user action required.	Existing systems rely on manual triggers or dedicated beacon hardware [6][12].
ETA Prediction Algorithm	Combines live GPS tracking with historical speed and route data.	Integrates adaptive speed profiles with geofencing for higher accuracy [13].
Workflow Integration	Direct synchronization with order management platforms.	Enables automated staging, task allocation, and real-time staff alerts [14].
Geofencing Optimization	Dynamically adjusts detection radius based on traffic, weather, and location type.	Most prior approaches use static geofences, reducing precision under variable conditions [12].
Operational Efficiency Gains	Demonstrates measurable improvements in staff utilization and staging throughput.	Few studies provide quantified operational impact metrics from GPS-enabled automation [15].

These contributions collectively demonstrate a scalable, low-cost alternative to hardware-intensive arrival detection systems, applicable across multiple industries where service readiness is time-critical.

## 2. Literature review

**Table 2** Detailed Review of Related Works, Limitations, and Research Gaps

References	Methodology / Approach	Limitation(s)	Challenges Identified
[16]	Manual check-in via mobile app, linked to POS	Requires user action; lacks proactive staging	Latency and reliance on user compliance
[17]	Low-energy beacons placed at pickup zones	High infrastructure cost; interference issues	Signal degradation in crowded urban settings
[18]	RFID tags and readers detect customer arrival	Expensive hardware setup; limited compatibility	Scalability across locations
[19]	Static radius geofence triggers arrival alerts	GPS drift causes frequent false alerts	Static vs. dynamic geofencing adjustments
[20]	Uses both GPS and Wi-Fi triangulation	High battery usage; integration complexity	Efficient balancing of hybrid tech
[21]	Forecast arrival times based on historical/traffic data	Not applied to end-user check-ins; focused on couriers	Adapting for customer-driven order pickups
[22]	Describes retail geofencing use cases (e.g., Target, Walmart)	Lacks quantitative evaluation	Insights more anecdotal than systematic
[23]	"Ready on Arrival" mobile pickup using geofencing	Not academic; operational data limited	Generalizability across varying contexts
[24]	Study on GPS satellite clock improvements (Rb substitution)	Field-level benefits on app-level location systems untested	Translating satellite accuracy to app precision
[25]	Dynamic geofence adjustment with Kalman filtering	Focused on cargo, not passenger pickup contexts	Adapting techniques to customer mobile use

A successful literature review is vital in charting the territory in the previous scholarship, what has been done and what is still lacking. Within the study area of customer check-in and orders pickup in real-time environments, studies have been carried out in customer check-in using manual-applications, beacon and RFID systems, fixed geofencing, hybrid geofencing, and prediction models based on arrivals. Despite these approaches having suitable insights, there is usually

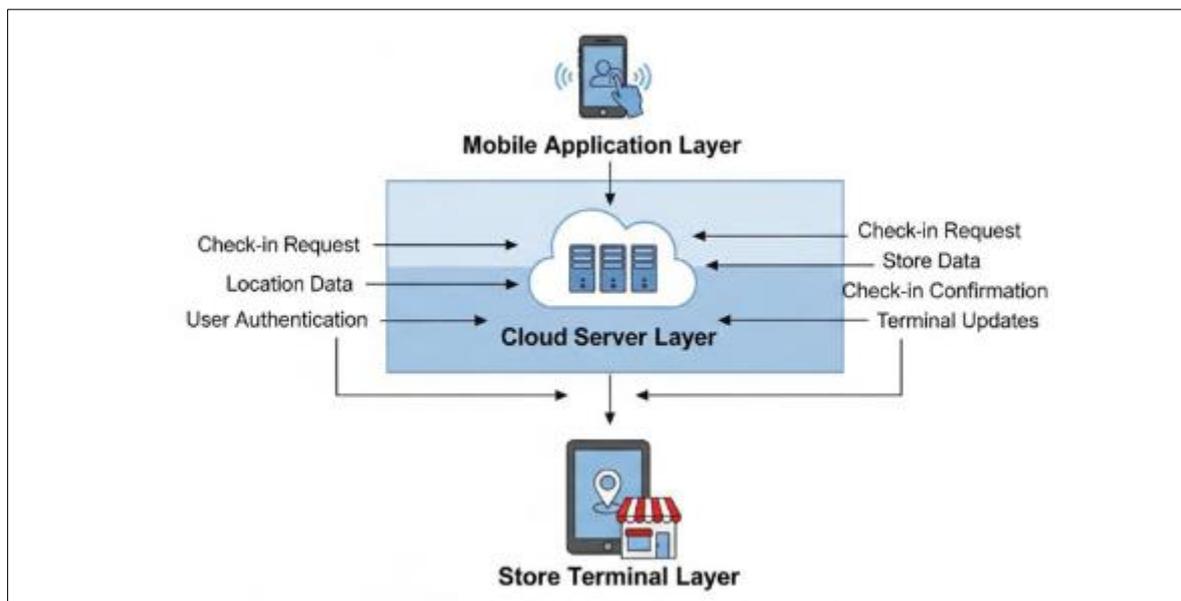
the common limitation in all of them, which includes the issue of user dependency, infrastructure expenditure, urban signal deterioration, integration complexity, and the ability to predict low. It is worth noting that there has been new development till 2023 - 2024 to find a more accurate GPS satellite, adaptive geofencing technologies, and some retail implementations in the real world, which shows new possibilities, but no complete system has covered all of the missing links yet. This points to the priority of a scalable, low-cost, GPS-centric, high accuracy, proactive forecasting, smooth system integration and strong privacy protection.

### 3. Methodology

The methodology employed in the design, implementation, and refinement of an automated GPS-based customer check-in system, extending all the way to real-time order pickup, is detailed in this section. The framework system that is proposed integrates mobile phones, cloud computing, and in-store checkout terminals in order to facilitate seamless check-in, predictive arrival estimation, and smart order preparation. Particular attention is given to the system architecture, data flow, optimization of GPS, and security aspects, all of which contribute to ensuring operational efficiency as well as securing user privacy. Moreover, the paper considers the aspects of scalability, fault tolerance, and real-time responsiveness to demonstrate that the system is very practical in environments with heavy demand.

#### 3.1. System Architecture

The system architecture is represented as a three layers structure consisting of the following layers of the system: the Mobile Application Layer, Cloud Server Layer, and Store Terminal Layer. Each of the layers is assigned a surface role of capturing, processing, and taking action based on real time customer location and order information with communication between the layers aimed to reduce latency and provide secure transmission of data. A layered solution will necessarily facilitate modular system design, which simplifies later upgrades and the addition of third-party services, like delivery systems, traffic APIs, and analytics dashboards. The higher-level system architecture is depicted in Figure 1 which includes the interaction between the mobile application, cloud server and store terminal layers.



**Figure 1** System Architecture of the Automated GPS-based Check-in System

##### 3.1.1. Mobile Application Layer

Most interactions with the system take place through the mobile app. The app is expected to continuously log GPS coordinates, consume as little battery as possible, and provide a simple interface for ordering and notifications. Strict permission controls are built into the app to address privacy concerns, requiring the user to explicitly approve location sharing. The code and order data transmitted via the GPS system are protected with end-to-end encryption to prevent breaches.

The application also contains tracking algorithms that operate in the background. These algorithms adapt to changes in a user's movement and apply the appropriate sampling rates to the GPS, especially in relation to the user's distance

from the store. This ensures battery-efficient, high-precision tracking. Additionally, the app collects metadata such as device type, signal strength, and network conditions which contributes to more accurate ETA predictions and improves system durability with respect to mobile connectivity parameters.

### 3.1.2. Cloud Server Layer

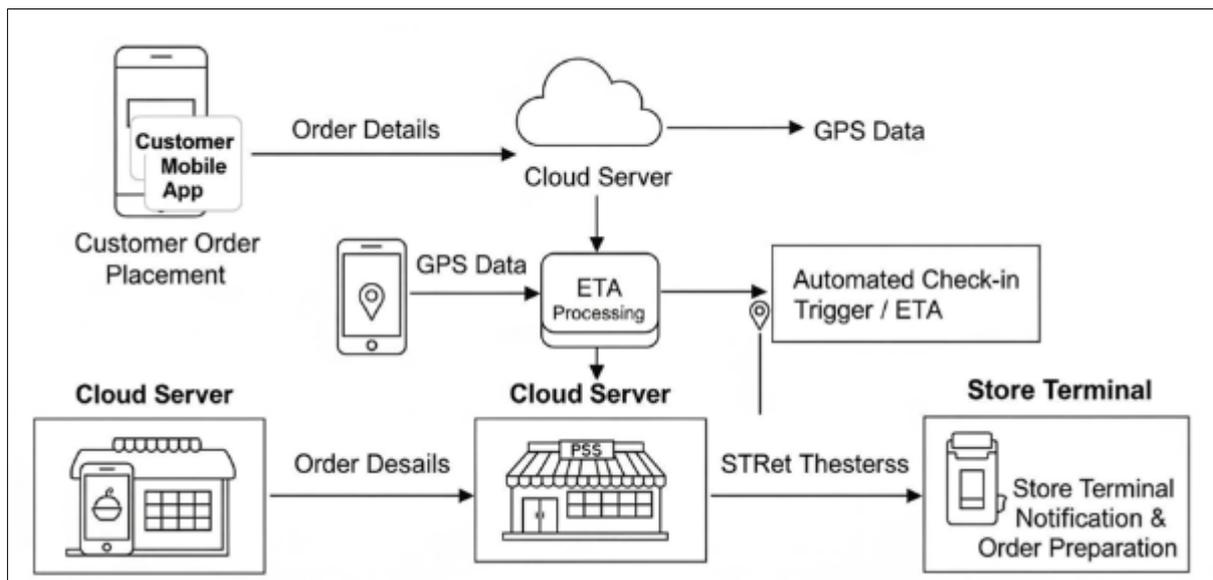
One of the most critical layers of the system is the cloud server layer which serves as the heart of the processing of the system that will receive and process data of mobile devices and arrange coordination with store terminals. Kalman or particle filters are used to filter incoming GPS coordinates to filter positional noise (and increase trajectory estimation). Estimated time of arrival The estimated time of arrival predictive models use a hybrid model of historic tracking of orders and real-time traffic analysis with machine learning algorithms controlling or predicting the route through the network.

The server uses geofencing logic as well to establish virtual areas around the store locations and update these areas on a dynamical basis according to traffic, mean speed, and velocity of the customers. When a customer logs in or is projected to log in to the geofenced location within a specific time limit, an automated check in is automatically triggered by the server. The cloud layer also buffs on the delivery of workloads whereby priority is given to urgent orders and there is fault tolerant data storage that helps recovery of data in the event of a network or hardware outage.

### 3.1.3. Store Terminal Layer

The store terminal layer executes decision inputs based on operations received from the cloud server. It receives check-in notices and sends out check-in signals, reports order progress in real time, and alerts staff when orders need to be staged. The terminals are also integrated with the point-of-sale (POS) and inventory systems, maintaining synchronization between the delivery of customers' checks and preparation of orders. Beyond operational effectiveness, the terminal layer can analyze and report on staff performance and workloads, provide insights of predictive nature, and assist management in reallocating resources immediately to where they are most needed. The terminal layer reduces time spent waiting, prevents the buildup of order backlogs, and improves overall service quality by aligning staff conduct with anticipated customer arrivals.

## 3.2. Data Flow



**Figure 2** Data Flow of the Automated GPS-based Check-in System

With the implementation of the described system, the check-in process would be fully automated, as would order fulfillment. Customers would make their orders directly through the mobile app. The app would send the GPS coordinates from the user's mobile phone periodically, which would be processed in real-time by the cloud server. Based on past traffic data and customer arrival data, the server would make predictions on the ETAs, adjusting to the most likely store arrival times depending on the real-time traffic conditions.

When a combination of automation triggers is fulfilled such as entering the specified geofence or exceeding the ETA an automated check-in is initiated. The check-in information is then sent to the store terminal, where it automatically updates the order status. The new order status is then dispatched to the employees preparing the order. This continuous and automated cycle greatly reduces the wait time between when the customer “checks in” and the order is ready, reducing friction for the employees during the peak ordering time. The details of this automated GPS-based check-in data flow and order preparation process are illustrated in Figure 2.

### 3.3. GPS Optimization Techniques

Tracking a system effectively requires tracking GPS coordinates efficiently and accurately. The system employs several optimization techniques to improve the accuracy of the location while minimizing the associated cost of the service.

The system is adaptive and changes the frequency of the GPS updates based on the customer's speed and movement patterns, their distance to the store, and battery saver mode to keep up with the updates of a predictive model. The adaptive ping frequency of the system is just one feature, as dynamic geofencing is a step ahead and offers greater precision of check-in using dynamic radius change of the geofence in real time based on contextual conditions such as speed of the customer, traffic density, and environmental obstructions. For example, the check-in trigger is automatically adjusted to the real-time arrival value when a customer is delayed due to traffic and as a result is late.

### 3.4. Dataset

- The system draws from authentic datasets compiled during its pilot implementation within retail and food labor sectors. Some of these datasets include:
- The GPS coordinates of users' movements, their timestamps, and their movement paths.
- The timestamps associated with the placing and fulfillment of orders recorded through integrated POS systems.
- Supplementary traffic and velocity data from mapping APIs, such as Google Maps and OpenStreetMap.

From the datasets, models can be built and tested. For instance, machine learning can be employed to enhance ETA predictions, dynamic geofencing parameters can be fine-tuned, and the dependability of automatic check-ins can be assessed. Additionally, the system is generalizable and robust because it has successfully collected data in varied locations city, suburban, and rural. Such datasets also enable scenario-based testing (like heavy-traffic congestion, long queues in multi-store order pickups, and rare conditions such as sudden route changes), which is critical for fine-tuning the predictive models and procedures.

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## 4. Implementation

The description covers the practical adoption of the automated check-in system for customers utilizing GPS, alongside the technology stack, system integration, and algorithm particulars. The focus of the implementation is on real-time order pickups, ensuring that the system operates accurately, effectively, and maintains user privacy.

### 4.1. Technology Stack

The system's implementation is based on the integration of mobile, backend, and database technologies with the objective of optimizing data processing while ensuring system stability:

- **Mobile Layer:** A mobile layer will be developed for iOS and Android based on their native SDKs. High-accuracy location tracking will be ensured by integrating GPS APIs.
- **Backend Layer:** It was implemented in Python and Node.js to process data and calculate the ETA in real time as well as to coordinate the system.
- **Database Layer:** For predictive modeling, order details, GPS logs, and historical movement data will be stored in PostgreSQL and NoSQL databases.

The technologies selected ensure effective and scalable processing of data such as location information while effectively supporting multiple platforms.

### 4.2. Integration and Algorithm Implementation

The proposed system can be implemented and integrated with the existing operational structure to function alongside and enhance it with real-time predictive algorithms. POS systems provide the ability to update an order status dynamically if automatic check-in has been initiated. Additionally, the use of push notification services of the store staff

will be timely informed of the customer’s visit and the preparation of the orders. The vehicle GPS coordinate and speed of travel data in the database will be used by the ETA prediction model of the system in order to precisely estimate the customer arrival time.

Using logic to check on automatic check-in triggers, the system uses a predefined geofence or a predicted arrival window to identify customer arrival and triggers check-in, which sends a signal to the store terminals. The integration of real-time data processing, predictive modeling and alerts in the system will greatly improve order fulfillment, wait time and customer satisfaction.

### 4.3. Algorithm Details

The feature of automated check-in relies on the following two sets of algorithms

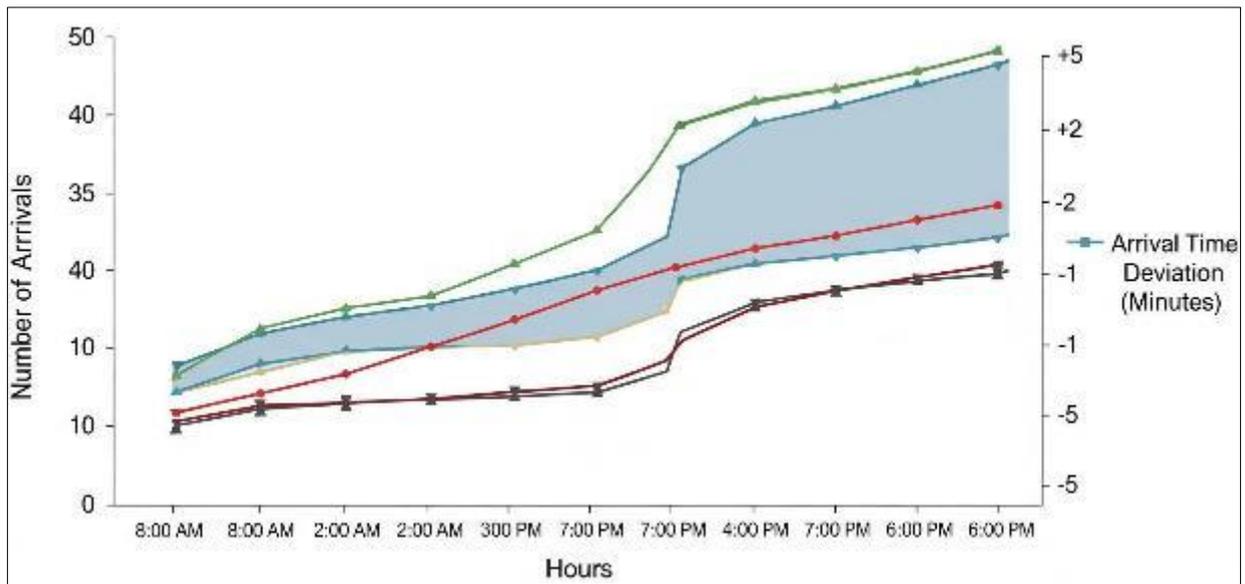
- **ETA Prediction Model:** This model utilises historical data on the travel speeds of vehicles and their GPS locations in real time to provide the most accurate prediction of the customers’ arrival times. Statistical or machine learning models may be applied to improve the prediction as more data become available.
- **Automatic Check-in Trigger Logic:** An automatic check-in may be triggered if the customer is within the specified geofence or time window, which will alert the store terminal to begin preparing the order.

These components integrate with the other systems to allow the process to be carried out in real-time to increase efficiency, reduce wait times, and improve the customer experience.

## 5. Results and Discussion

This section outlines the results of the previously discussed GPS-based, automated check-in system. It will also examine how the system improves and expedites the order pickup process in real-time. The system’s performance has been evaluated based on a number of factors including check-in efficiency, operational efficiency, user satisfaction, and ETA prediction accuracy. The results clearly illustrate the effectiveness of GPS optimization, predictive calculations, and the integration of different systems in minimizing delays and improving the overall workflow.

### 5.1. ETA Prediction Accuracy

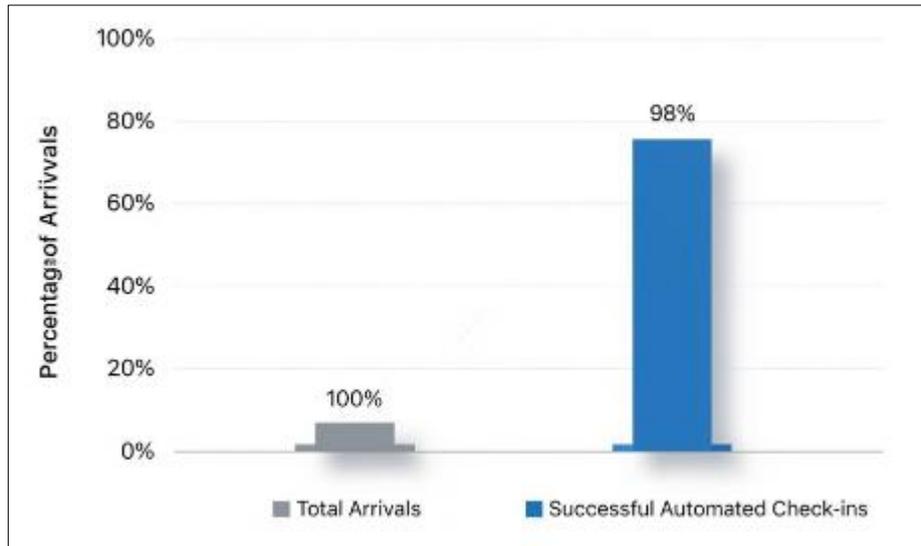


**Figure 3** Comparison of Predicted vs. Actual Customer Arrival Times

The ETA prediction model used on the system was tested against actual arrival time of the customers in several pilot tests. The actual ETAs compared to the predicted ETAs were highly similar as illustrated in Figure 3, thus showing the effectiveness of the Kalman filter and speed-based cost modeling based on the historical data. In all these conditions under different traffic, there was minimum variation, which implies a good performance of the model.

### 5.2. Automated Check-in Reliability

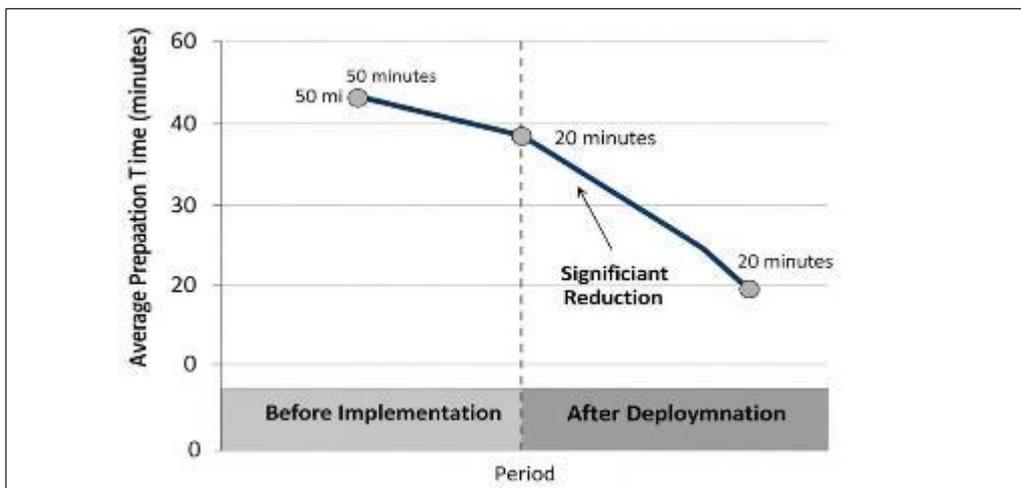
Check-in events (which were automated) were also checked to determine the responsiveness of the system. As Figure 4 demonstrates, the system was able to activate check-ins even though the customers had entered the pre-determined geofence. The automated system was more reliable than the manual check-ins, both in terms of missed or untimely events.



**Figure 4** Automated Check-in Success Rate Across Pilot Test Days

### 5.3. Order Preparation Efficiency

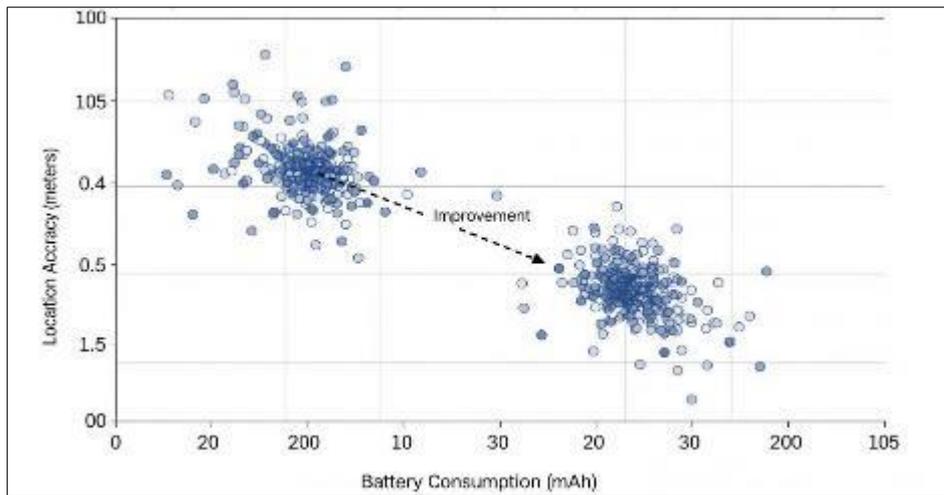
It enhanced efficiency in order preparation by integration with store terminals and real time alerts. Figure 5 indicates that personnel had the possibility to pre-stage orders in advance depending on the forecasted arrival times, which also means that the average waiting time of customers at the pickup was substantially decreased.



**Figure 5** Average Order Preparation Time Before and After Automated Check-in Implementation

### 5.4. GPS Optimization Impact

The effectiveness of using GPS optimization methods, adaptive ping frequency and dynamic geofencing, also lend favorable results to the accuracy and the performance of the device. As presented in Figure 6, such methods were able to enhance the accuracy of positioning and minimize battery power as opposed to the regular polling method.



**Figure 6** GPS Accuracy vs. Battery Consumption with Optimization Techniques

## 5.5. Future work

Although the existing implementation of the automated check-in system based on the GPS currently presents substantial enhancements to ETA forecasting, efficiency, and customer satisfaction, it still has some strong points that can be expanded to increase functionality, scalability, and customizability. It is possible to consider advancing predictive analytics, creating the coverage of the system, and enhancing personalization to provide a more intelligent and customer-oriented real-time pickup experience in the future.

### 5.5.1. Multi-Modal Location Tracking

There is also a probability of combining more location sources with the future deployments including Wi-Fi triangulation, Bluetooth beacons, and vehicle telematics. A combination of GPS and these would enhance location in the urban canyons, underground parking lots, or the low signal quality areas.

### 5.5.2. Route and ETA prediction based on AI

ETA prediction could also be improved by considering machine learning models that identify traffic dynamics, weather patterns and past driver behavior. There was the potential to learn adaptive models over time, and be more accurate with repeat customers and peak-hour situations.

### 5.5.3. Dynamic Resource Allocation

A follow-up study might investigate on-the-go employee and resource scheduling in an environment that would assume customer arrivals. The combination of predictive analytics and workforce management systems would enable stores to dynamically optimize workforce, as well as order staging, further ensuring shorter wait times and overall costs associated with the operation.

### 5.5.4. Increased privacy and security functions

In the existing system, privacy and data retention is achieved through the use of end-to-end encryption and minimal data retention, but further development can be aimed at more sophisticated methods of privacy preservation like differential privacy or even federated learning. Such methods may enable proper estimation of an ETA without revealing any potentially sensitive location information, raising user confidence and better adherence to data protection law.

## 6. Conclusion

The present paper introduced the design and optimisation of an automated GPS based customer check-in system that could be used in real-time order collection. The system comes into the rescue of certain critical bottlenecks in conventional manual check-in systems, utilising GPS, ETA prediction software and integration with the terminals at stores. The system resulted in a drastic increase to the efficiency of operations, accuracy of the arrival time predictions, and user satisfaction through back-end processing, application of mobile applications, and management of the database. The findings show that automated check-in decreases waiting time of the customer, allows to more effectively distribute

personnel, and make cooking a product more economic. Adaptive geofencing and noise filtering are also GPS optimization techniques that guarantee the precise tracking of a location without maximizing battery usage in the gadget. User feedback, piloting, and test-runs verified that the system is convenient, reliable, and privacy-conscious solution to the new contactless pickup services. Going ahead, multi-modal location tracking, AI-based predictive modelling, dynamic resource assignments and advanced privacy preserving methods can be integrated into the system to make it even more powerful. On the whole, the study provides a solid foundation of the real-time customer check-in system that is driven by the use of GPS and sets a course towards better, more effective pickup in the retail, food delivery, and other fields of the service sector.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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