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A mobile App-Based approach to profiling e-commerce users for detecting more convenient delivery time slots

Metodología de determinación de horas de entregas más convenientes en comercio electrónico a través de la caracterización de perfiles de usuario mediante aplicación móvil

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Abstract

The escalating complexity of B2C e-commerce logistics, particularly in last-mile delivery, coupled with the growing consumer preference for home delivery, presents a significant challenge: the need to reduce disruptions during the delivery process. These disruptions not only diminish perceived service quality but also escalate distribution costs and environmental emissions. This paper introduces a novel initiative to tackle delivery failures resulting from customer absences by enabling users to generate and share location statistics with delivery companies, contingent upon their explicit consent. This feature allows users to define a list of preferred locations for tracking, thereby enhancing coordination between customers and delivery providers. By fostering this collaborative approach, users gain greater control over their data, contributing to a more efficient and customer-centric e-commerce logistics ecosystem. Preliminary results demonstrate the application's potential to reduce delivery failures by up to 45%. This strategy not only mitigates disruptions and lowers costs but also helps minimize environmental impact.

Keywords: Business-To-Consumer, E-commerce logistics, geolocation, Last-Mile; user profiling.

Resumen

El aumento de la complejidad de la logística de comercio electrónico B2C, especialmente en la entrega de última milla, junto con la preferencia de los consumidores por la entrega a domicilio, supone un gran desafío: la necesidad de reducir las incidencias o fallos durante el proceso de entrega. Estas interrupciones no solo disminuyen la calidad percibida del servicio, sino que también aumentan los costes de distribución y las emisiones ambientales. Este artículo presenta una nueva iniciativa para abordar los fallos en la entrega debido a la ausencia de los clientes, permitiendo a los usuarios generar y compartir estadísticas de ubicación con las empresas de entrega, siempre que den su consentimiento explícito. Esta funcionalidad permite a los

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usuarios definir una lista de ubicaciones preferentes, donde se podrá realizar la entrega y sobre la que se realiza el seguimiento, mejorando así la coordinación entre clientes y proveedores en los servicios de entrega. En este enfoque colaborativo, los usuarios obtienen un mayor control sobre sus datos, lo que contribuye a un ecosistema logístico de comercio electrónico más eficiente y centrado en el cliente. Los resultados preliminares demuestran el potencial de la aplicación para reducir los fallos en la entrega en hasta un 45%.

Palabras clave: B2C, logística, comercio electrónico, geolocalización, última milla, perfiles de usuarios.

1. Introduction

Over the past decade, e-commerce has seen exponential growth, significantly transforming the business-to-consumer (B2C) retail landscape. This transformation has been driven by increased access to internet services, the convenience of purchasing goods from various digital devices, and the enhanced impact of marketing on social media platforms. The growth has accelerated even further since the COVID-19 pandemic, pushing both consumers who were previously unfamiliar with online shopping and many small and medium enterprises (SMEs) to quickly adapt to this digital environment. According to Eurostat (2024), 75% of internet users in the European Union engaged in online shopping in 2023, a notable rise from 57% in 2013. Additionally, Deloitte (2020) reports that, on average, 1.5 million e-commerce parcels are delivered daily in Spain.

However, this paradigm shift in commerce has introduced several logistical challenges (Acquila-Natale et al., 2019). one of the most significant being the lack of coordination between consumers and the delivery companies responsible for fulfilling orders. This coordination deficit often leads to failed delivery attempts, as consumers are frequently unavailable at their residences during designated delivery windows. As a result, distribution costs increase, and user experiences decline. In a study conducted by Lorenzo-Espejo et al. (2024a), various types of disruptions were analyzed, including missing information, incorrect addresses, customer absence, service rejection, service modification, lack of time, incomplete freight, and dubious disruptions. The findings indicate that the most significant disruption arises from customer absence, which, along with lack of time, accounts for 43.93% of disruptions in deliveries and 31% in pickup services. Notably, there is a clear difference in the timing of these disruptions: customer absence during morning slots (pickup and delivery) represents 52.23%, compared to only 23.29% in the evening, after 15:00. Figure 1 illustrates the percentage of customer absences analyzed by hour of the day, based on a study of approximately 2.7 million delivery services. This uncertainly suppose a cost to the service (Lorenzo-Espejo et al., 2024b).

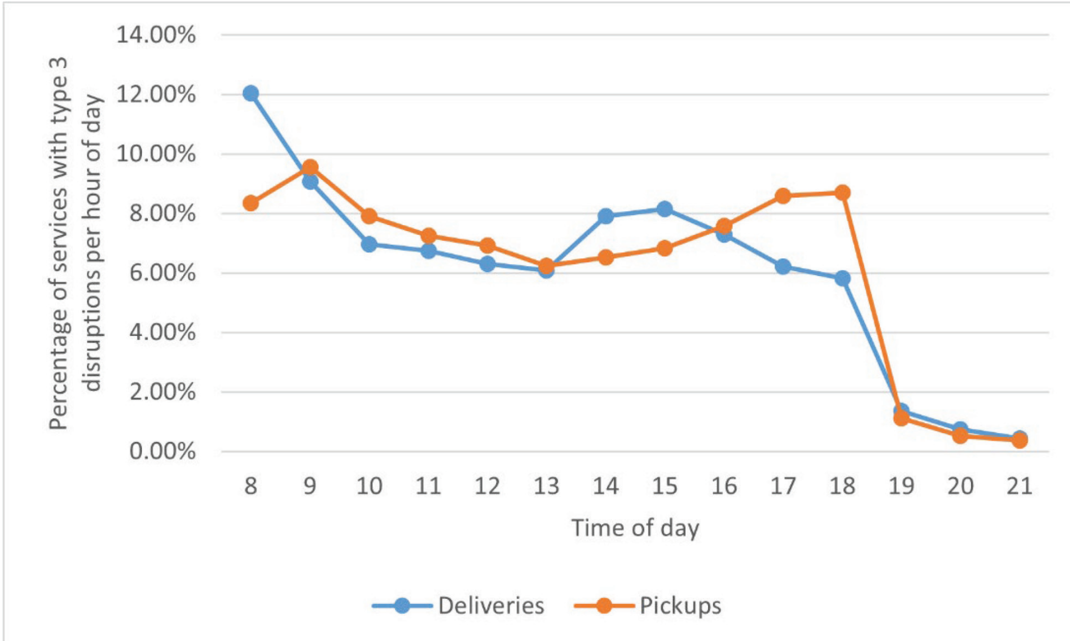
These results are in line with the research of van Duin et al. (2016), which suggests that the success of delivery services is influenced by the time slot and the availability of the customer during that period. Although the aggregate data suggests that successful service attendance is more likely later in the day, these trends can vary significantly depending on individual customer profiles and circumstances and may even fluctuate depending on the day of the week.

To address the lack of coordination between customers and couriers, various solutions have been proposed (van Duin et al., 2016): (1) offering alternative delivery points, (2) incorporating time constraints based on customers' slot-time preferences, (3) using customer data to predict availability, (4) promoting collaborative schemes, and (5) introducing emerging technologies such as drones, robots, or automated guided vehicles (AGVs).

This paper proposes and focuses on the development of an application designed to characterize a user's availability for product delivery, thereby mitigating inefficiencies and reducing resource waste associated with failed deliveries. The motivation for this work stems from three distinct perspectives: customer dissatisfaction due to delayed or missed deliveries, logistics companies facing increased operational costs from failed deliveries, and the environmental consequences of higher emissions resulting from these inefficiencies and redeliveries. By creating an application that facilitates better communication and information sharing between customers and courier companies, this research aims to optimize delivery processes, reduce delivery failures, and contribute to a more sustainable e-commerce ecosystem. The application has three main objectives:

(1) Characterizing customer habits to identify the most convenient delivery time slot for each customer, which may vary across different days of the week.
(2) Achieving real-time tracking in the period leading up to the delivery to increase the probability of a successful delivery.
(3) Creating a framework for more effective daily service planning based on customer preferences and courier availability.

Figure 1. Percentage of services with absence of customers per hour of day.



Source: Lorenzo-Espejo et al. (2024a).

The remainder of this work is structured as follows: Section 2 provides an overview of existing research and technologies related to last-mile delivery optimization and the challenges associated with failed deliveries. Section 3 presents the proposed methodology, illustrating the application architecture and functionality. Section 4 analyzes the results and discusses their potential impact on e-commerce delivery. Finally, Section 5 concludes the paper and outlines directions for future work.

2. Literature Review

The issue of last-mile delivery has been extensively studied and optimized over the decades, as it represents the most costly and unpredictable phase of the logistics chain, accounting for approximately 50% of total shipping costs (Joerss et al., 2016). Consequently, numerous studies have been conducted to address this challenge, particularly focusing on innovative concepts for last-mile distribution in urban areas, with the aim of reducing congestion, environmental damage, negative health effects, and improving customer satisfaction.

Several studies have sought to reduce disruptions caused by customer absence by utilizing alternative delivery points such as lockers or stores. For instance, Zhang and Lee (2016) examined the recent introduction of smart lockers as a solution for last-mile delivery. Although theoretical research on integrating this system with home delivery was still limited at the time, their study demonstrated the effectiveness of lockers as an alternative, a fact evidenced by their widespread adoption in recent years. Similarly, Orenstein et al. (2019) examined the flexibility offered by locker systems, highlighting the convenience of allowing users to choose from multiple locker locations. This flexibility, such as selecting between lockers near home, the workplace, or a shopping center, enhances convenience and can reduce delivery costs and times.

Buldeo Rai et al. (2020) analyzed locker usage in Brussels. The study found that most consumers resorted to pickup points after failed home delivery attempts, often choosing lockers that allowed them to combine parcel collection with other activities such as shopping. Despite the rise of lockers, customer preference remains strongly in favor of home delivery (DPD Group, 2020), provided the delivery occurs when the customer is available. In many cases, lockers are selected as a fallback option when the likelihood of successful home delivery is low.

Given the growing importance of sustainability in last-mile e-commerce logistics (Cullinane, 2009; González Romero & Prado-Prado, 2023), various studies have sought to demonstrate the environmental benefits of proposed alternatives. Buldeo Rai et al. (2020) emphasized the environmental advantages of pickup points over home delivery, while Mommens et al. (2021) investigated the sustainability of locker-based delivery compared to home delivery in Belgium. Their findings highlighted the role of regional and local factors in determining delivery outcomes, suggesting that home delivery is more sustainable in rural and suburban areas, whereas locker-based delivery performs better in urban settings. Therefore, the environmental impact of these solutions is not entirely clear. While they help reduce the number of trucks and overall mileage, they may also lead to an increase in customer trips to access lockers, depending on the distribution of alternative delivery points and how customers travel to them.

Other studies have investigated ways to improve last-mile delivery by reducing delivery time windows, which define the period during which a parcel can be delivered to a customer (Braysy & Gendreau, 2005). Xing et al. (2010) examined the impact of preferred delivery slots on last-mile deliveries. Additionally, some studies have explored the option of allowing customers to provide multiple delivery locations, further increasing the chance of successful deliveries (Moccia et al., 2012; Tilk et al., 2021), with some even enabling customers to express preferences between different alternatives (Escudero-Santana et al., 2022). These mechanisms give couriers greater flexibility in completing deliveries successfully.

Innovative approaches like mobile lockers or roaming deliveries have also been studied. Schwerdfeger and Boysen (2020) focused on optimizing locker locations based on customer presence patterns throughout the day. Their simulation and numerical analysis demonstrated considerable reductions in failed deliveries compared to fixed lockers, although implementation remains complex. Reyes et al. (2017) proposed a roaming delivery system that uses vehicle trunks to execute deliveries based on customer presence patterns, following a similar principle to mobile lockers. Rodríguez-Palero (2024) explored other technologies to facilitate urban deliveries in low emission areas, including electric vehicles like drone, pedal-assisted electric vehicle, ducktrain, etc.

Additionally, other studies, including this one, aim to determine the best time slots to guarantee successful deliveries at preferred customer locations (i.e., home). Seghezzi and Mangiaracina (2023) proposed leveraging the Internet of Things (IoT) and smart speakers to detect when customers are at home, thereby optimizing delivery routes based on customer habits. Tested in Milan, this solution significantly reduced failed deliveries compared to traditional methods. Similarly, Pan et al. (2017) used lighting consumption patterns to track customer presence and optimize delivery routes.

Özarık et al. (2021) and Voigt et al. (2023) explored how incorporating customer presence probabilities into route planning could result in up to 40% cost savings compared to traditional vehicle routing. Furthermore, collaborative strategies could help align customer preferences with courier availability (Yu et al., 2022; Muñuzuri et al., 2018).

These studies collectively highlight the significance of innovative approaches in solving last-mile delivery challenges, providing insights into sustainable and efficient solutions for the e-commerce logistics sector.

3. Proposed Methodology

The proposed solution entails the development of a mobile application that allows users to indicate their preferences for parcel delivery. The application collects and analyzes the user's location data to create statistics that help delivery companies coordinate their routes and schedules. It is designed to respect user privacy and security by encrypting the data and allowing users to control data sharing. The application can also, if the user allows it, be used for tracking in the moments prior to the delivery of the parcel, indicating in a more precise way the possibility of a successful delivery. Therefore, user characterization is fulfilled both periodically and in real time. The primary goal is to minimize failed deliveries, thereby improving customer satisfaction and reducing the environmental footprint of e-commerce logistics.

3.1. Development overview

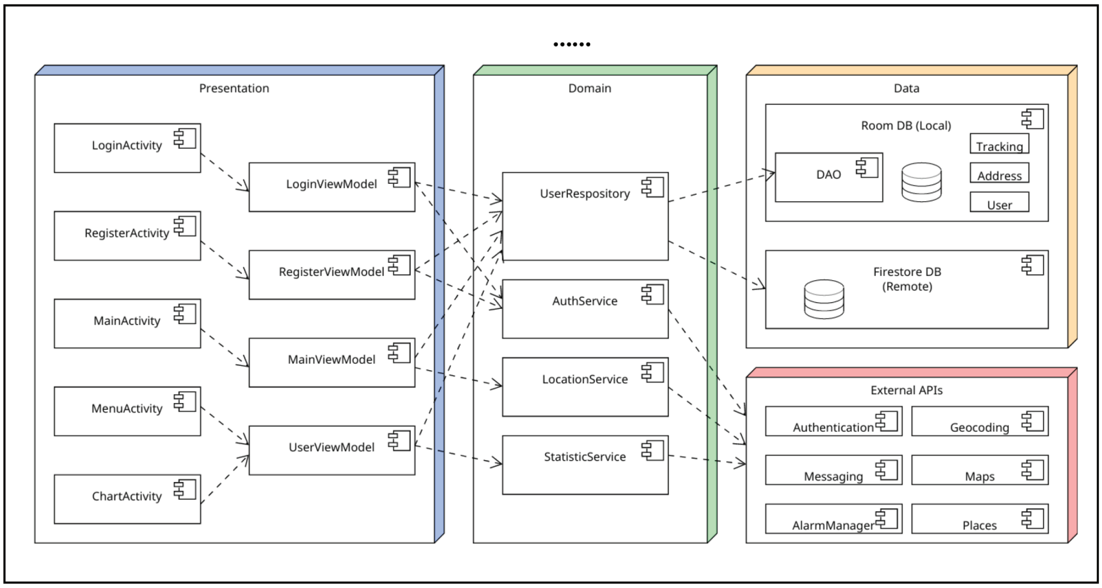
The application development process involved various technologies and tools to ensure a robust and user-friendly experience. It is important to note that this application serves as a demonstrator, meaning its deployment in production environments may require adjustments in the selection of technologies to fit specific contexts (Shwetha et al., 2023). The primary programming language utilized was Kotlin, known for its conciseness and compatibility with Android development. Android Studio served as the Integrated Development Environment (IDE), providing a comprehensive suite of tools for designing, coding, and debugging the application.

The architecture of the application, shown in Figure 2 as a component diagram, is built around the MVVM (Model-View-ViewModel) pattern and the DAO (Data Access Object) design. The design and implementation followed the guidelines provided by Google in Android Developers, specifically utilizing resources on ViewModels, app architecture, and data access with Room (Google, 2024a; 2024b; 2024c). This approach ensures a clear separation of responsibilities between the different layers of the app, making it more maintainable and scalable.

In the Presentation layer, the user interface comprises a series of activities that interact with their corresponding ViewModels. These ViewModels manage the presentation logic and act as intermediaries between the UI and the data layer. They handle user requests, retrieve data, and transform it into a suitable format for display. Additionally, the application utilizes AnyChart for dynamic data visualization, offering interactive charts that enhance user engagement. By adhering to Material Design 3 principles, the UI maintains a consistent and intuitive appearance, further improving usability and user satisfaction.

At the core of the application lies the Repository in the Domain layer, which bridges the gap between the

Figure 2. Component diagram of the application architecture.



ViewModels and the data sources. Following the DAO pattern, the Repository centralizes data access logic, ensuring that the ViewModels are abstracted from the specifics of data storage, whether from local or remote sources. This structure contributes to a more maintainable and testable codebase.

The Data layer includes both local and remote storage mechanisms. Room handles the local database, using DAOs to manage data operations. For remote data, Firestore provides real-time cloud storage, enabling seamless data synchronization across devices. Additionally, the app integrates external APIs, such as Google Maps, Geocoding, and LocationService, which function as external services rather than being encapsulated in the data layer. These services are critical for providing advanced mapping and location-based functionalities, but they remain separate from the core data handling mechanisms.

The communication flow between these layers is efficient, as ViewModels request data from the Repository, which decides whether to source it from Room, Firestore, or an external API. This setup ensures smooth interaction between layers while maintaining a clear separation of concerns.

The architecture also includes essential services such as user authentication, push notifications through Firebase Cloud Messaging, and real-time location tracking. These services are integrated as external components that enhance the app's core logistics features. Overall, this modular design contributes to the application's adaptability, maintainability, and scalability.

3.2. Functionality

The mobile application is designed to enhance e-commerce delivery coordination through user profiling. It begins with a user registration process where users can create an account using their personal and contact information. Once registered, users can log in to access the system and set their delivery preferences, including up to 4 different delivery addresses and times, as seen in Figure 3. The application also allows users to modify their account data, providing flexibility and control over their personal information.

One of the key features of the application is location tracking, which collects data for statistical analysis to improve delivery efficiency. It is important to emphasize that the user is not geolocated all the time, but rather periodic queries are made throughout the day. Furthermore, location information is never stored; it is only used to generate statistics regarding the customer's preferred delivery addresses.

The tracking service can be activated and deactivated by users as they want. For instance, a user may want to deactivate the service during the night and then activate again in the morning. To respect user privacy, the application also incorporates an automatic service shutdown feature that stops the tracking service at a specified time. In addition, it includes reminders for the activation of the tracking service that reach the user in the morning of the following day through a push notification.

Ultimately, the app provides users with the ability to manage statistics, offering them the option to view and send the collected data for better delivery route planning. Figure 4 contains an example of user statistics. It corresponds to a user with two preferred addresses, which are his home and workplace. The first screenshot of the application shows the statistics for a weekday. During the morning hours, the user is at the second location (work) with a high probability, whereas, during the afternoon hours there is a higher probability that he is near the first location (home). On the other hand, the second snapshot contains the statistics for

Figure 3. Selection of user preferences in the developed application.

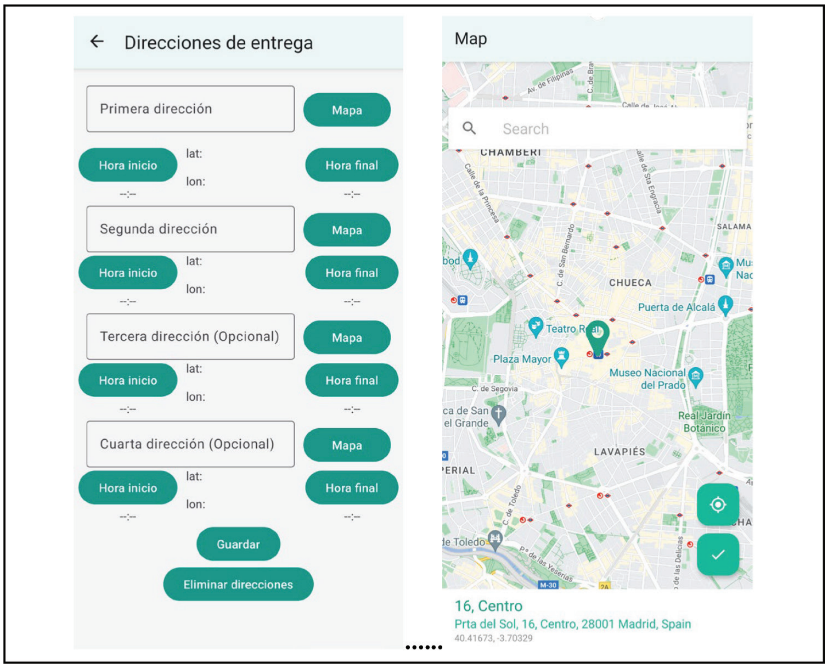


Figure 4. Example of the statistics section of the developed application.

Saturday, where clearly there is a high probability that the user is at home, decreasing considerably only during the evening hours.

This mechanism facilitates distribution companies in accessing information regarding users' availability at designated delivery points, fostering collaboration to reduce unsuccessful delivery attempts and enhance the overall user experience.

The application, along with its user manual, is available for download from the following repository: https://github.com/alejandroescudero/EntregAPP.

4. Results and Discussion

Functional and performance tests have been conducted with 15 users. The application has successfully collected and stored user data, demonstrating low battery consumption. An intuitive interface and timely notifications have been appreciated by users. Statistical analysis has revealed patterns related to delivery time preferences and common delivery locations.

Figure 5 shows the average pattern for each day of the week for one of the users participating in the study. The data were collected from two different locations (home in blue and work in green) over four weeks, between Monday at 8:00 and Friday at 17:00. The figure demonstrates how the user's habits

Figure 5. Tracking of a user with varying habits depending on the day of the week.

Figure 6. Tracking of a user with similar habits on weekdays.

Figure 7. Superposition of the habits of different users.

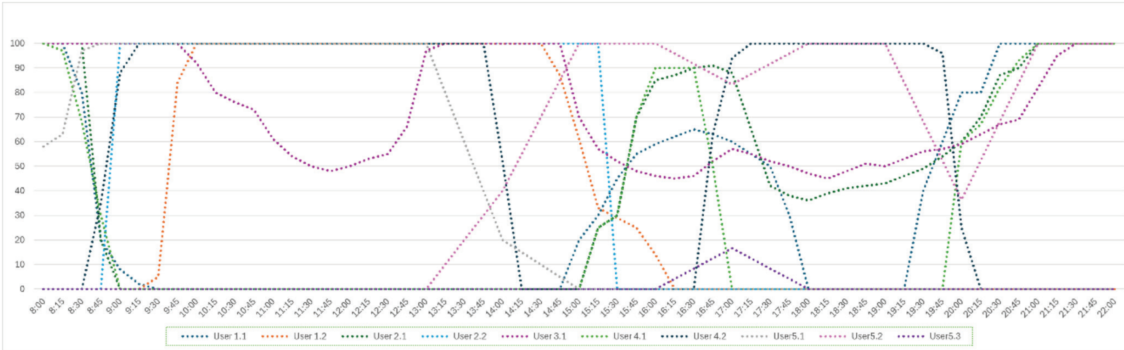
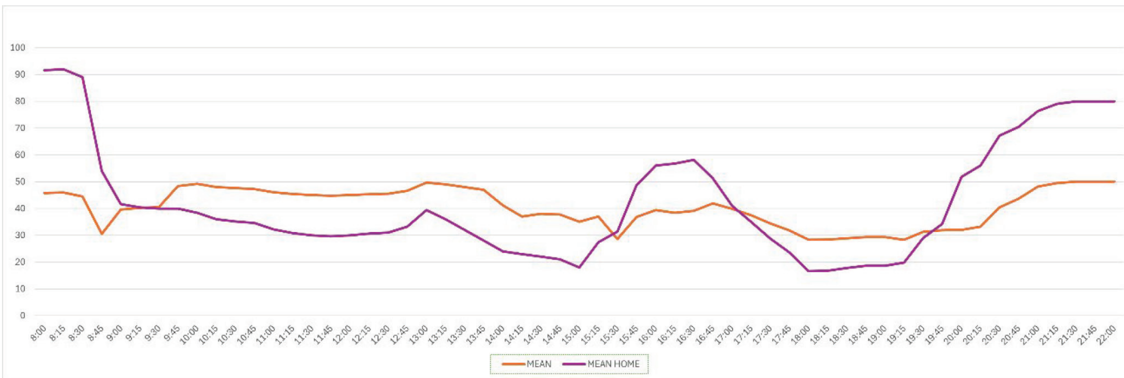


Figure 8. Mean probability of delivery success by hour: Comparison between home and alternative locations.



vary depending on the day of the week. After an interview with this user, it was confirmed that this figure accurately represents his routine. The user works from home two days a week, which explains why his delivery preferences differ throughout the week. Figure 6 presents the pattern of a user with consistent habits on weekdays, from Monday to Friday, with minimal variation in their routine throughout the week.

Each user exhibits distinct habits, often having higher probabilities of being at specific locations during certain times of the day. Figure 7 shows the overlay of the probability of being at some of the preferred locations for five different users, demonstrating that it is highly likely to identify alternative locations where effective deliveries (with a high probability of success) can be achieved.

Additionally, Figure 8 presents the mean probability of delivery success per hour of the day based on the habits of the user from Figure 7. This calculation was conducted considering only home locations as well as alternative delivery locations. The results show that the mean probability of successful home deliveries follows a pattern similar to the results in Figure 1. However, when all alternative locations are considered, the probability curve becomes more stable, indicating that a more constant delivery success rate can be achieved by offering multiple delivery points.

This information allows logistics companies to optimize delivery routes by identifying predictable time slots when users are consistently available. By focusing on these windows, couriers can reduce the number of missed deliveries (Lorenzo-Espejo et al., 2024c), thereby lowering operational costs, minimizing time wasted on unsuccessful attempts, and improving the rate of successful first-attempt deliveries.

Following the research line of Özarık et al. (2021) and Voigt et al. (2023), an experiment was conducted using the VRPTWDO (vehicle routing problem with time windows and delivery options) algorithm developed by Escudero-Santana et al. (2022, 2024). The experiment tested whether integrating statistical customer data, collected from volunteers, could help reduce delivery failure rates. In the simulated routes, customers were alerted 15 minutes before delivery to confirm availability at their chosen location.

Preliminary results showed that incorporating probabilistic data into route calculations reduced delivery failures by up to 45%, compared to using general morning or evening time slots. Additionally, the inclusion of alternative personal delivery points further improved the success rate by an additional 10%. This highlights the potential for combining real-time customer behavior data with advanced routing algorithms to improve logistical efficiency and customer satisfaction.

5. Conclusion

The proposed mobile application demonstrates substantial potential for addressing inefficiencies in last-mile parcel delivery by leveraging user-generated location statistics to profile e-commerce customers. By allowing users to control data sharing and define preferred delivery slots and locations, the system fosters better coordination between customers and delivery companies.

This solution not only enhances customer satisfaction by minimizing delivery disruptions but also reduces operational costs for logistics providers and contributes to environmental sustainability by cutting down on unnecessary re-delivery attempts. This enhances both efficiency and customer satisfaction while contributing to environmental sustainability by reducing the need for repeat trips.

The data gathered from users can be integrated into predictive algorithms, enhancing service reliability. For instance, delivery companies could prioritize these predictable slots for high-value or time-sensitive packages, ensuring faster, more accurate service. Furthermore, the application's ability to respect user privacy while providing valuable data insights strengthens its utility in real-world applications.

Future work should focus on expanding the user base to gather more comprehensive data and refining the underlying algorithms to further optimize delivery routes. By incorporating advanced technologies such as machine learning and predictive analytics, the system could adapt in real-time to dynamic customer behaviors, ultimately leading to a more personalized and efficient e-commerce logistics ecosystem. In conclusion, this approach paves the way for innovative solutions that enhance both logistical efficiency and customer-centric service in e-commerce deliveries.

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