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ORIGINAL

Integrated Customer Service System with Artificial Intelligence for Pharmacies

Sistema Integral de Atención al Cliente con Inteligencia Artificial para Farmacias

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ABSTRACT

This project addressed the issue of pharmaceutical care and management in community pharmacies, characterized by deficiencies in patient guidance, stock administration, and operational efficiency. Aiming to improve these aspects, an integrated system was developed, consisting of a mobile application for users and a desktop application for pharmacy staff. The solution included e-commerce functionalities, medication reminders, and a conversational assistant based on artificial intelligence, as well as tools for management and sales prediction. Although specific metrics were defined to assess the system's impact, they could not be applied in a real environment due to the academic nature of the project, time constraints, and the absence of a production context. Nevertheless, functional tests were carried out on each component, validating their technical and operational feasibility. The development process fostered the learning of emerging technologies and strengthened project management skills. It was concluded that the system is feasible and has the potential to significantly enhance customer service and internal management in pharmacies. Future implementation is recommended to validate its impact under real-world conditions.

Keywords: Pharmaceutical Care; Artificial Intelligence; E-Commerce; Inventory Management; Mobile Applications.

RESUMEN

El presente proyecto abordó la problemática de la gestión y atención farmacéutica en farmacias comunitarias, caracterizada por deficiencias en la orientación al paciente, la administración de stock y la eficiencia operativa. Con el objetivo de mejorar estos aspectos, se desarrolló un sistema integral compuesto por una aplicación móvil para usuarios y una aplicación de escritorio orientada al personal farmacéutico. La solución incluyó funcionalidades de comercio electrónico, recordatorios de medicación y un asistente conversacional basado en inteligencia artificial, así como herramientas de gestión y predicción de ventas. Si bien se definieron métricas específicas para evaluar el impacto del sistema, estas no pudieron aplicarse en un entorno real debido a la naturaleza académica del trabajo, las limitaciones de tiempo y la ausencia de un entorno productivo. No obstante, se realizaron pruebas funcionales sobre cada componente, las cuales permitieron validar su viabilidad técnica y operativa. El proceso de desarrollo favoreció tanto el aprendizaje de tecnologías emergentes como el fortalecimiento de competencias en gestión de proyectos. Se concluyó que el sistema desarrollado es factible y tiene potencial para mejorar significativamente la atención al cliente y la administración interna en farmacias, recomendándose su implementación futura para validar su impacto en condiciones reales.

Palabras clave: Atención Farmacéutica; Inteligencia Artificial; Comercio Electrónico; Gestión de Inventario; Aplicaciones Móviles.

INTRODUCTION

In an environment marked by digital transformation, community pharmacies must modernize their services to provide more efficient customer service and optimize their internal processes. This need has driven the search for innovative technological solutions in the sector. Khan et al.[1] identify limitations in traditional pharmacy systems, where tasks such as interpreting prescriptions, dispensing medications, and verifying doses and frequencies rely on manual processes and individual experience, which can lead to inefficiencies, errors, and delays. In response to these challenges, this project focused on developing an integrated system that encompasses various functionalities, using advanced technologies to improve efficiency and the customer experience in pharmacies.

Background

The authors Raza et al.[2] mention that the application of computers in pharmacies dates back to 1980. Since then, they have noted that technology has been utilized in various pharmaceutical activities, including data collection, retail pharmacy management, clinical research, drug storage, pharmaceutical education, and clinical pharmacy, among others.

In this context, several previous studies have explored technological solutions to improve customer service and optimize internal processes in pharmacies.

For example, recent research has highlighted the potential of using artificial intelligence in patient communication to answer questions via chat about medication use[1] and treatment monitoring systems with reminders[3] which could improve patient satisfaction and treatment adherence. Al Meslamania[4] mentions systems that, in addition to analyzing past sales and local health trends, can predict drug demand and ensure optimal inventory management, minimizing stockouts or excess inventory that could negatively affect profits. These studies support the importance and relevance of developing innovative technological solutions in the pharmaceutical sector.[5,6,7,8]

Description of the Problem Area

Pharmaceutical management and care in community pharmacies have significant shortcomings that affect various actors in the healthcare system. These shortcomings negatively impact the quality of service provided, the operational efficiency and profitability of these establishments, as well as the health and safety of patients.[9,10,11,12,13]

One of the main problems lies in the poor care received by users, who often do not have access to adequate pharmaceutical guidance.

This can lead to the incorrect use of medications, reducing the effectiveness of treatments and creating health risks. At the same time, community pharmacies face economic losses due to expired or slow-moving products, which represent a significant percentage of their total inventory.[14,15,16,17]

A determining factor is the presence of untrained staff, which limits the possibility of offering comprehensive and personalized pharmaceutical care. The lack of adequate training directly affects the quality of service and the ability of pharmacies to guide patients correctly.[18,19,20]

In addition, there are internal management failures, particularly in inventory, stock control, purchasing, and ordering processes, which contribute to operational disorder and unnecessary accumulation of medicines. On the other hand, low treatment adherence by patients, caused by a lack of understanding of the therapeutic regimen, side effects, or high costs, further exacerbates the problem.[21,22]

Taken together, these factors highlight an urgent need to improve pharmaceutical management in community pharmacies in order to optimize resources, ensure adequate customer service, and contribute to the proper functioning of the health system as a whole.[23]

How can a comprehensive technology system improve operational efficiency, customer service, and internal management in community pharmacies, given the current deficiencies in pharmaceutical counseling, inventory management, and treatment adherence?

Objective

To develop a comprehensive system for community pharmacies, consisting of a mobile application with e-commerce and automated assistance features using artificial intelligence, together with a desktop application for administrative management, to improve operational efficiency and accessibility to pharmaceutical products by at least 30 % during the first three months after implementation.

METHOD

Methodological Tools

This project is based on the Scrum agile software development methodology. This methodology aligns perfectly with the project's objectives because it "uses an iterative and incremental approach to optimize predictability and control risk" and also uses Sprints, which "are fixed-length events of one month or less to

create consistency," facilitating constant monitoring and evaluation of progress, ensuring that the expected results are achieved within the established deadlines.[5]

Software Tools

In the development of the comprehensive system for community pharmacies, various software tools will be used to address the different layers of the project, from user experience to business logic and data management. For the development of the mobile application, Android Studio will be used as the integrated development environment, taking advantage of the Kotlin language for its compatibility with Java and its modern syntax, which facilitates the creation of intuitive interfaces and functionalities such as orders, reminders, queries, and recommendations. This choice responds to the need to provide a fluid and accessible experience on Android mobile devices, which constitute the majority of the target market.

On the other hand, the web platform aimed at pharmaceutical staff will be developed using web technologies such as JavaScript, HTML, and CSS, using Electron Forge as a framework. This technology allows web applications to be packaged in desktop environments compatible with multiple operating systems, facilitating their implementation in pharmacy equipment without requiring constant access to a browser. Electron Forge also simplifies the software construction and distribution process, allowing for more efficient integration with local hardware.

Both platforms, mobile and desktop, will be connected to a central API developed with JavaScript using the Express.js framework on Node.js. This architecture will enable efficient communication between the client and the server, facilitating the management of requests such as order registration, inventory queries, and report generation. In addition, a chatbot based on Google's Gemini API will be integrated into this API, offering virtual customer service through natural language processing, providing personalized responses available 24 hours a day.

For the artificial intelligence part focused on sales forecasting, a separate API will be developed using the Python language, the Flask microframework, and the Prophet library. This combination allows the creation of a time series model that forecasts drug demand based on historical data, supporting pharmaceutical staff decision-making regarding restocking and planning.

Finally, the database supporting the entire system will be PostgreSQL, a robust, scalable, and open-source relational database management system. This tool ensures integrity and consistency in the handling of sensitive data such as order histories, inventories, user profiles, and records of interactions with the platform. The modular structure of the system, based on specialized and well-integrated tools, will allow for scalable, maintainable development that is aligned with the project's objectives.

Data collection

Direct observation in pharmacies was used to elicit requirements.

This selection is based on the need to obtain accurate and contextualized data on current practices and needs in the pharmaceutical environment. Personal observation allowed us to capture practical processes and situations in real time.

Project Planning

The activity plan designed to achieve the objectives of the work is presented below.

Fecha de inicio	Fecha de fin	Nombre
18/3/24	28/3/24	Selección de la temática
29/3/24	29/3/24	Título
1/4/24	3/4/24	Introducción
4/4/24	5/4/24	Justificación
8/4/24	10/4/24	Objetivos del Proyecto
11/4/24	17/4/24	Marco Teórico Referencial
18/4/24	24/4/24	Diseño Metodologico
25/4/24	1/5/24	Relevamiento
2/5/24	8/5/24	Proceso de Negocios
9/5/24	15/5/24	Diagnóstico y Propuesta
16/5/24	22/5/24	Objetivos, Límites y Alcances del Prototipo
23/5/24	24/5/24	Descripción del Sistema
27/5/24	30/5/24	Seguridad
31/5/24	5/6/24	Análisis de Costos
6/6/24	11/6/24	Análisis de Riesgos
12/6/24	13/6/24	Conclusiones
27/5/24	28/6/24	Demo

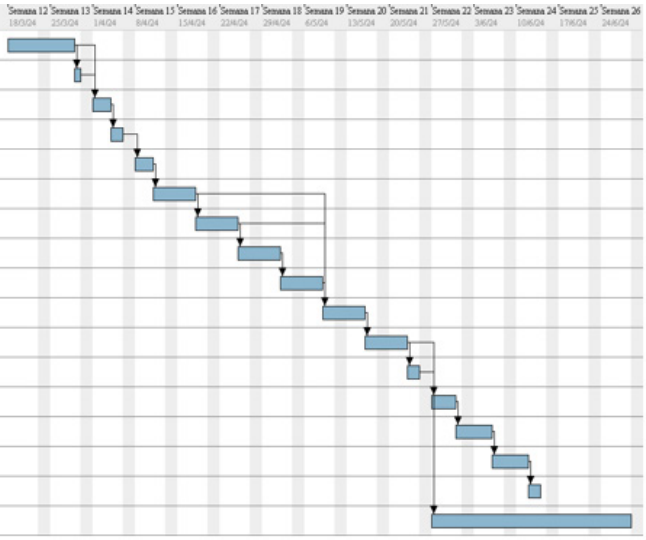

Figure 1. Gantt chart

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Survey

Structural Survey

Given that the project is intended for community pharmacies in general, the specific location will vary depending on where each one is located.

Functional Survey

The structure of a typical small community pharmacy is modeled.

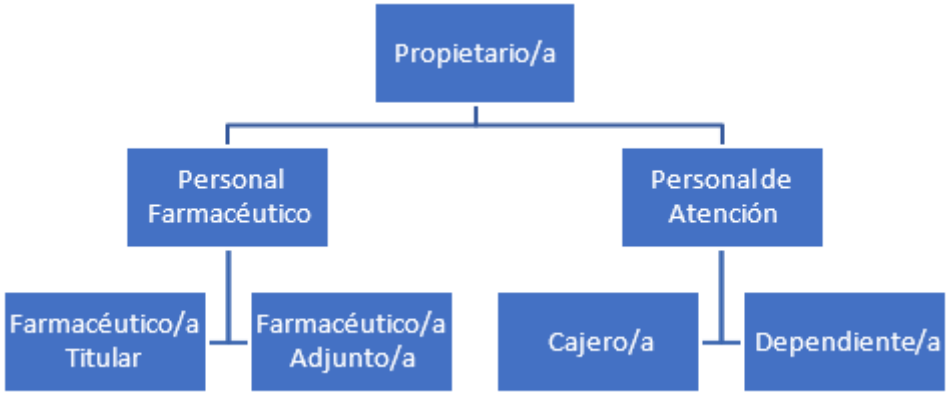

Figure 2. Organization chart of a small pharmacy

Functions of the areas

Owner

- Responsible for the overall management of the pharmacy, including financial administration, personnel management, and business strategy.

Pharmaceutical staff

- Head Pharmacist:
- Responsible for the technical management of the pharmacy and the dispensing of medicines.
- Supervises compliance with health and pharmaceutical regulations.
- Assistant Pharmacist:
- Supports the head pharmacist in their duties
- Assists in dispensing medications.
- Collaborates in stock management and ordering.

Customer Service Staff

- Cashier:
- Responsible for billing and cashier duties.
- Handles financial transactions and answers basic customer questions.
- Sales assistant:
- Assists with customer service and stock maintenance.
- Organizes and restocks products on shelves.
- Supports inventory and order management.

The processes surveyed are detailed below.

Process: Sale of Medication

Roles: Pharmacist and/or customer service staff

Steps:

1. Receive prescription.
2. Validate prescription information.
3. Check that the medication is in stock.
4. Enter medication record.
5. Purchase the requested medication.
6. Record the medication as dispensed.
7. Provide instructions for use to the user.
8. Accept payment and issue invoices. Deliver medication.

Process: Stock Management
Roles: Head Pharmacist, Assistant Pharmacist, Pharmacy Assistant
Steps:

1. Check medication inventory.
2. Record missing medications.
3. Place orders with suppliers.
4. Receive and verify orders.
5. Update inventory in the system.
6. Organize medications in the warehouse.

Process: Customer Service
Roles: Sales assistant, Cashier
Steps:

1. Greet the customer at the counter.
2. Assist the customer in finding products.
3. Provide information about medications and products.
4. Answer customer questions and concerns.
5. Process the purchase at the cash register (for over-the-counter products).
6. Accept payments and issue receipts.
7. Deliver products to customers.

Business Process

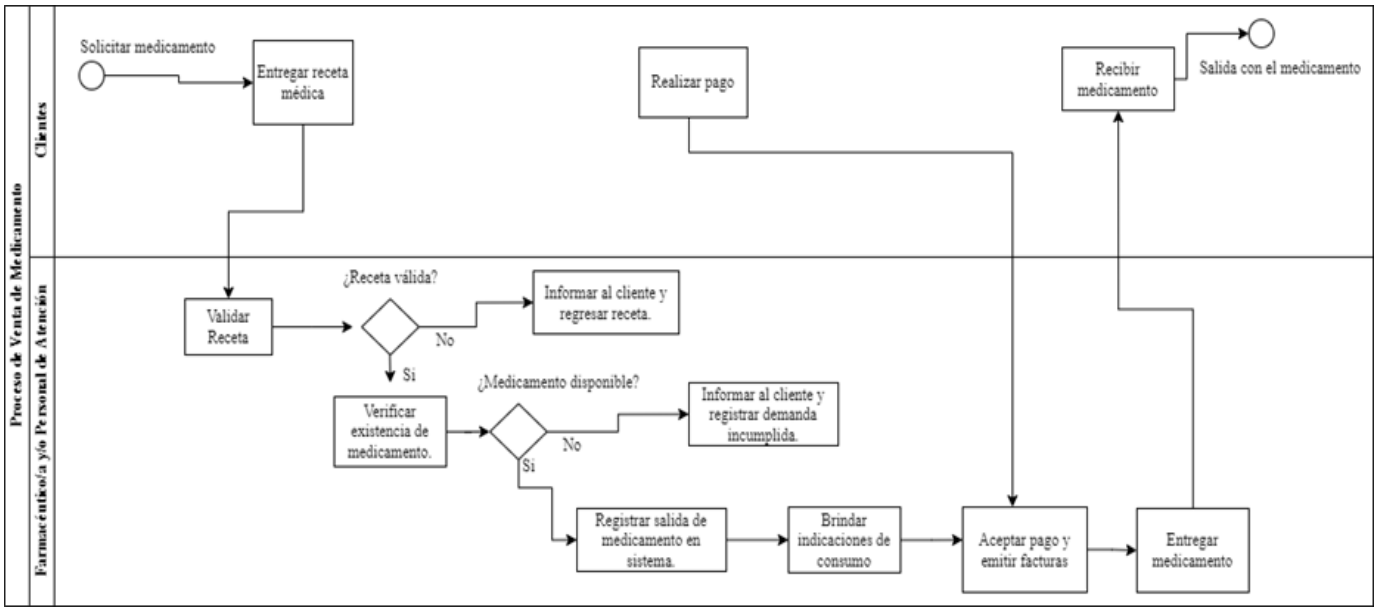

Figure 3. Medicine Sales Business Process

RESULTS

Diagnosis and Proposal
Diagnosis
The following is a diagnosis of the problems found in the processes surveyed and their causes.

Table 1. Diagnosis of the drug sales process

Process name: Sale of Medicines	
Problems	**Causes**
Errors in prescription validation	Staff do not have standardized procedures or sufficient training to correctly verify medical prescriptions.
Delays in dispensing	Tasks are performed using fragmented manual processes, which slows down service due to the lack of an agile workflow.
Poor customer service	Operational overload and a lack of clear role assignment reduce the quality of service provided to users.

Table 2. Diagnosis of the Stock Management Process

Process name: Stock Management	
Problem	**Causes**
Lack of critical medications	Replenishment is based on empirical observations without consolidated historical data or periodic inventory control.
Excess of undemanded medicines	No periodic product turnover analysis is performed, leading to an accumulation of slow-moving drugs.

Table 3. Diagnosis of the Customer Service Process

Process name: Customer Service	
Problem	**Causes**
Long waits for service	Appointments are not assigned based on actual customer flow and average service times.
Difficulty resolving queries	Staff lack ongoing training and up-to-date protocols to provide accurate answers.
Lack of access to up-to-date information	There are no mechanisms for quickly consulting relevant information about medications or treatments at the point of care.

Proposal

Based on the survey and diagnosis, we propose the development of a comprehensive management and care system for community pharmacies, consisting of a customer-oriented mobile application and a desktop application for pharmaceutical staff.

The mobile application allows users to purchase products and medicines, receive personalized recommendations based on their purchase history, validate prescriptions electronically, receive reminders about medicine consumption, and make inquiries through an artificial intelligence chatbot.

These features help improve the customer experience, reduce prescription validation errors, and ease the operational burden on customer service staff.

The desktop application facilitates internal pharmacy management through features such as automated inventory updates, real-time stock monitoring, and reports with predictive demand analysis.

This optimizes purchasing planning, prevents shortages of critical medications, and reduces excess slow-moving products.

Overall, the proposed solution seeks to strengthen key customer service, sales, and inventory management processes, promoting more efficient, personalized, and sustainable care in community pharmacies.

Objective, Limits, and Scope of the Prototype

Objective of the Prototype

To develop a prototype mobile application and desktop application that facilitates sales and customer service, as well as product and operations management by pharmacists, optimizing key service and administration processes in a community pharmacy.

Limitations

The prototype of the technological system will cover everything from the moment the customer makes an enquiry or places an order through the mobile application to the moment the pharmacy staff manages the orders and products through the desktop application.

Scope

Mobile application

- User registration and management.
- Chatbot queries.
- Medication reminders.
- Order placement.
- Order tracking.

Desktop application

- Product and order management.
- Sales forecasting.
- Report generation.

System description

Product backlog

Table 4. Product backlog

ID	User story	Priority	Points	Dependencies
HU-001	User registration	Registration	3	
HU-002	User management	Registration	3	HU-001
HU-003	Chatbot for queries	Sign up	5	HU-001, HU-002
HU-004	Medication reminders	Medium	4	HU-001, HU-002
HU-005	Ordering	Registration	6	HU-001, HU-002
HU-006	Order tracking	Average	4	HU-005
HU-007	Product management	High	5	
HU-008	Report generation	Medium	4	
HU-009	Sales forecasting	Average	6	

User stories

Table 5. User story HU-001

ID: HU-001	**Name: User registration**
Description	As a customer, I want to register with the application so that I can access all its features.
Acceptance criteria:	Given that I am on the home screen, when I select the "Register" option and correctly complete all the required fields on the form (name, email, password, password confirmation), the system should create my account and display a message confirming successful registration. Since I am on the registration screen, when I enter invalid data (e.g., incorrectly formatted email or mismatched passwords), the system should display specific error messages indicating which field requires correction and should not allow me to continue. Since there is already a registered account with the email address entered, when I try to register with that same email address, the system should prevent registration and display a message indicating that the email address is already in use.
Priority: High	Estimated story point: 3

Table 6. User History HU-002

ID: HU-002	**Name: User management**
Description	As a customer, I want to manage my personal data to keep my information up to date.
Acceptance criteria:	When I am in my user profile and edit my personal data (such as name, phone number, address, or password) and click "Save," the system should update the information correctly and display a confirmation message that the data was saved successfully. Since I am updating my data, when I enter invalid information (for example, a phone number with letters or a misspelled email address), the system should display specific error messages for each field with invalid data and not allow the changes to be saved until they are corrected. Since I made changes to my profile, when I try to exit the section without saving, the system should display a warning indicating that there are unsaved changes and ask me if I want to exit without saving or stay to continue editing.
Priority: High	Estimated story point: 3

Table 7. User History HU-003

ID: HU-003	**Name: Chatbot for queries**
Description	As a customer, I want to use a chatbot to ask questions about medications and services in order to obtain quick and accurate answers without the need for direct assistance from staff.
Acceptance criteria:	Since I access the chatbot from the app, when I ask a question related to a medication (e.g., "What is paracetamol used for?"), the system should display a relevant, clear, and understandable response based on validated pharmacological information. Given that I make an ambiguous or unclear query, when the chatbot cannot interpret the intent correctly, it should then request clarification or suggest related query options. Given that there is a connection problem with the language model API, when I try to send a query, the system should notify me of the problem and suggest trying again later or contacting staff. Given that the chatbot has a history of my previous queries, when I interact with it continuously, it should maintain the context within the same session to improve the consistency of responses.
Priority: High	Estimated story point: 5

Table 8. User Story HU-004

ID: HU-004	**Name: Medication reminders**
Description	As a customer, I want to set reminders for my medication so that I don't forget to take my medication according to the schedule.
Acceptance criteria:	1. Since I am in the reminders section, when I enter the required information (medication name, dosage, frequency, start time, and duration), the system must save the reminder correctly and schedule notifications according to the information entered. Since I have a reminder set up, when the specified time arrives, I should receive a push notification on my mobile device indicating which medication I should take and in what quantity. Since I access my reminders, when I select one to edit or delete, the system should allow me to modify the fields or delete the reminder and update the notification schedule accordingly. Since I try to save a reminder with incomplete or invalid data (for example, without selecting a time or without a medication name), the system should display an error message indicating which fields need to be corrected and not allow saving until the information is valid. Since I have multiple active reminders, when they overlap at the same time, the system should notify each one individually without overlapping or losing information.
Priority: Medium	Estimated story point: 4

Table 9. User History HU-005

ID: HU-005	**Name: Ordering**
Description	As a customer, I want to purchase medications through the app to save time and avoid unnecessary trips.
Acceptance criteria:	When browsing the product catalog, when I select one or more medications and add them to the cart, they should be displayed correctly in the shopping summary, including name, quantity, unit price, and subtotal. Since I have finished selecting products, when I access the cart and press "Checkout," I should be able to enter or confirm the delivery address, select the payment method, and see the total amount to be paid. Since I enter the required information correctly and make the payment, when the transaction is complete, the system should display a purchase confirmation message and generate an order number. Since I make a purchase, when it is registered, I should receive a notification or email with the order details, including products, address, and initial shipping status. If the purchase process encounters an error (such as a payment failure or product out of stock) when I try to complete the purchase, the system should clearly inform me of the reason for the failure and guide me on the steps to follow (for example, select another payment method or modify the cart).
Priority: High	Estimated story point: 6

Table 10. User Story HU-006	
ID: HU-006	**Name: Order tracking**
Description	As a customer, I want to track the status of my order so I know when it will arrive and can be available to receive it.
Acceptance criteria:	When I access the "My Orders" section and select an order, the system should display its current status (e.g., "Pending," "In preparation," "In delivery," "Delivered") along with the estimated delivery date and time. Since my order changes status, when it is updated (e.g., changes from "Pending" to "In delivery"), I must receive an automatic notification informing me of the new status. Since the order has a delay or problem, when this occurs, the system should display a message explaining the reason for the delay and, if applicable, a new delivery estimate. Since I place frequent orders, when I access the orders section, the system should display a list of previous orders with their historical statuses and allow me to filter by date or status. Since I try to view a non-existent order or one with a synchronization error, when I select that order, the system should display an error message indicating that access the order information at that time.
Priority: Medium	Estimated story point: 4

Table 11. User Story HU-007	
ID: HU-007	**Name: Product management**
Description	As a member of the pharmacy staff, I want to manage products in the desktop application to keep inventory up to date and avoid shortages or excesses.
Acceptance Criteria:	Since I am in the product management section, when I add a new product by entering all the required information (name, code, category, quantity in stock, expiration date, price), the system must correctly save the product and reflect it in the inventory database. Since I select an existing product, when I edit its information (e.g., change price, stock, supplier), then the changes should be saved correctly and available for future operations (sale, query, report). Since I try to save a product with incomplete or invalid information (e.g., empty fields, expired date, negative price), the system must prevent the save and display specific error messages indicating which fields require correction. Given that I perform a stock update, when I manually add or deduct units, then the system must update the total stock and record the movement with the date, type of operation, and responsible user. Given that other processes (such as sales or returns) affect inventory, when I access the product management section, then changes must be reflected in real time or with reliable system synchronization.
Priority: High	Estimated point in history: 5

Table 12. User History HU-008	
ID: HU-008	**Name: Report generation**
Description	As a member of the pharmacy staff, I want to generate sales and stock reports to analyze business performance and make informed decisions about purchasing and inventory management.
Acceptance criteria:	Since I am in the reports section, when I select the parameters (e.g., report type, date range, product category), the system should generate a document with the corresponding and updated information. Since I generate a sales report, when the report is presented, it must include at least: products sold, quantities, sale dates, revenue generated, and totals by category. Since I generate a stock report, when the system displays it, it must include: product name, current stock, minimum and maximum units defined, expiration date (if applicable), and alerts for products with low inventory. Since the report is generated correctly, when I want to save it, I must be able to export it in PDF or Excel formats. Since there is an error in the parameter selection (for example, invalid dates or no data available), when I try to generate the report, the system must display a clear message explaining the problem and suggest corrective actions.
Priority: Medium	Estimated story point: 4

Table 13. User Story HU-009

ID: HU-009	**Name: Sales forecast**
Description	As a pharmacist, I want to predict future sales to better manage stock, avoid stock shortages, and reduce excess products that are not in demand.
Acceptance criteria:	Since I access the prediction tool in the desktop application, when I select a date range and/or product category, the system should generate a report with sales predictions based on available historical data. Since I generate a forecast report, when the results are displayed, they must include the product name, expected units to be sold per period, trend (increasing/stable/decreasing), and forecast confidence level. Since there is not enough historical data for a product or category, when I try to generate the report, the system should notify me that the prediction cannot be made or indicate that the accuracy is limited due to lack of data. Since I generate a predictive sales report, when I view the results, I should have the option to export them in PDF or Excel format for analysis or printing. Since I make predictions regularly, when trends change compared to previous months, the system must reflect those changes in the graphs or comparisons, highlighting products with atypical behavior (demand spikes or drops).
Priority: Medium	Estimated point in history: 6

Sprint backlog

In this first sprint, we will focus on the basic functionalities so that the system can start operating, including user registration, the chatbot for queries, and order placement. This will lay the foundations of the system on which more functionalities can be added in future sprints.

Table 14. Sprint backlog

Sprint	User story	ID	Tasks	Priority	Estimated (hours)	Status
1	HU-001	0	Design database for users	Registration	4	Pending
		02	Implement the user registration interface	High	6	Pending
		03	Develop registration functionality	High	8	Pending
		04	Unit tests for user registration	Registration	4	Pending
1	HU-003	05	Design and integrate the chatbot	Sign up	6	Pending
		06	Configure responses	High	6	Pending
		07	Develop user interface for chatbot	High	4	Pending
		08	Unit and integration testing for the chatbot	Registration	4	Pending
1	HU-005	09	Design the database for orders	High	5	Pending
		10	Implement the purchase interface	High	8	Pending
		11	Implement the payment gateway	Registration	8	Pending
		12	Unit tests for purchasing functionality	Registration	5	Pending

Data structure

The data structure is described below using an Entity Relationship Diagram (ERD).

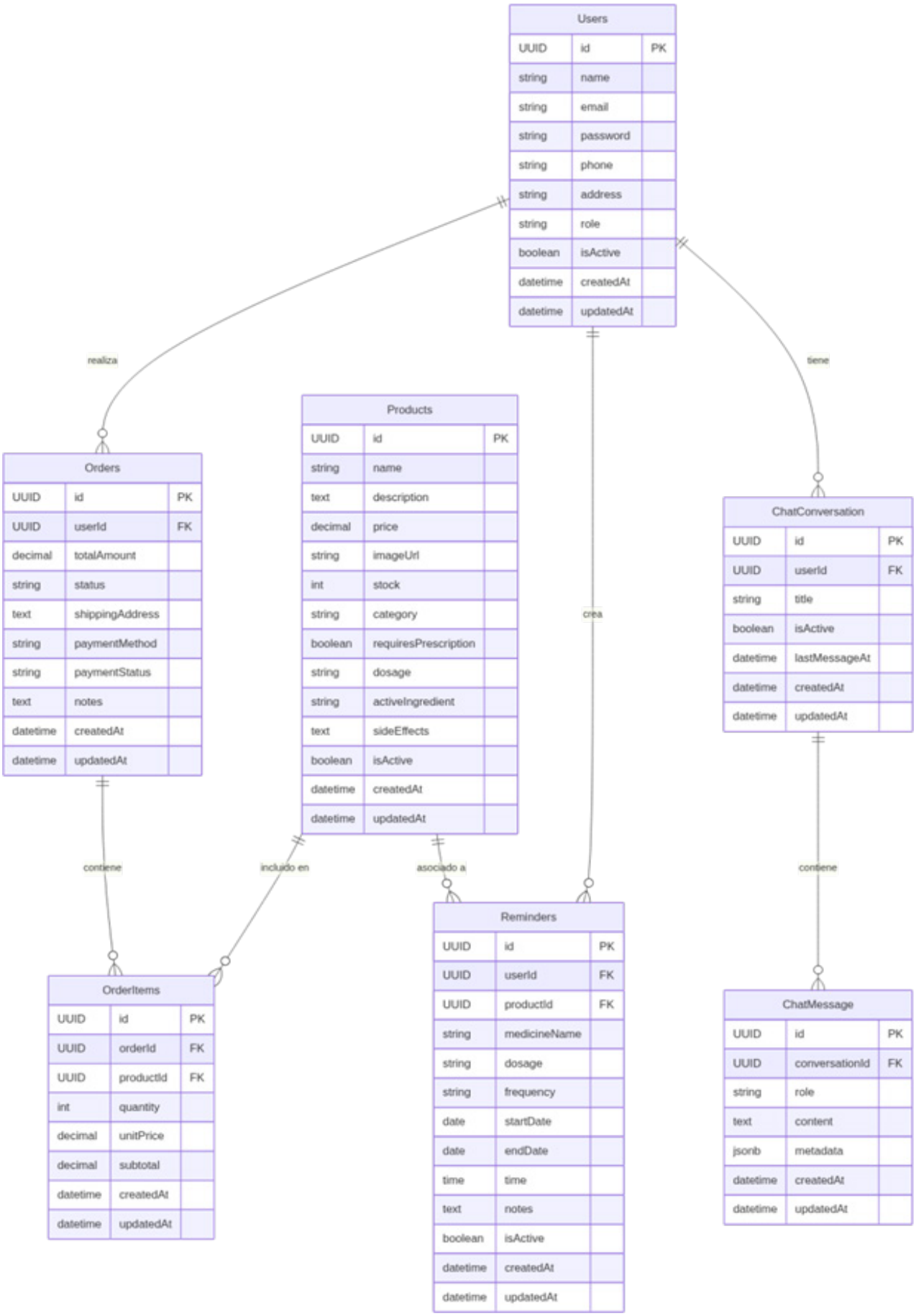

Figure 4. Entity Relationship Diagram

Screen interface prototypes

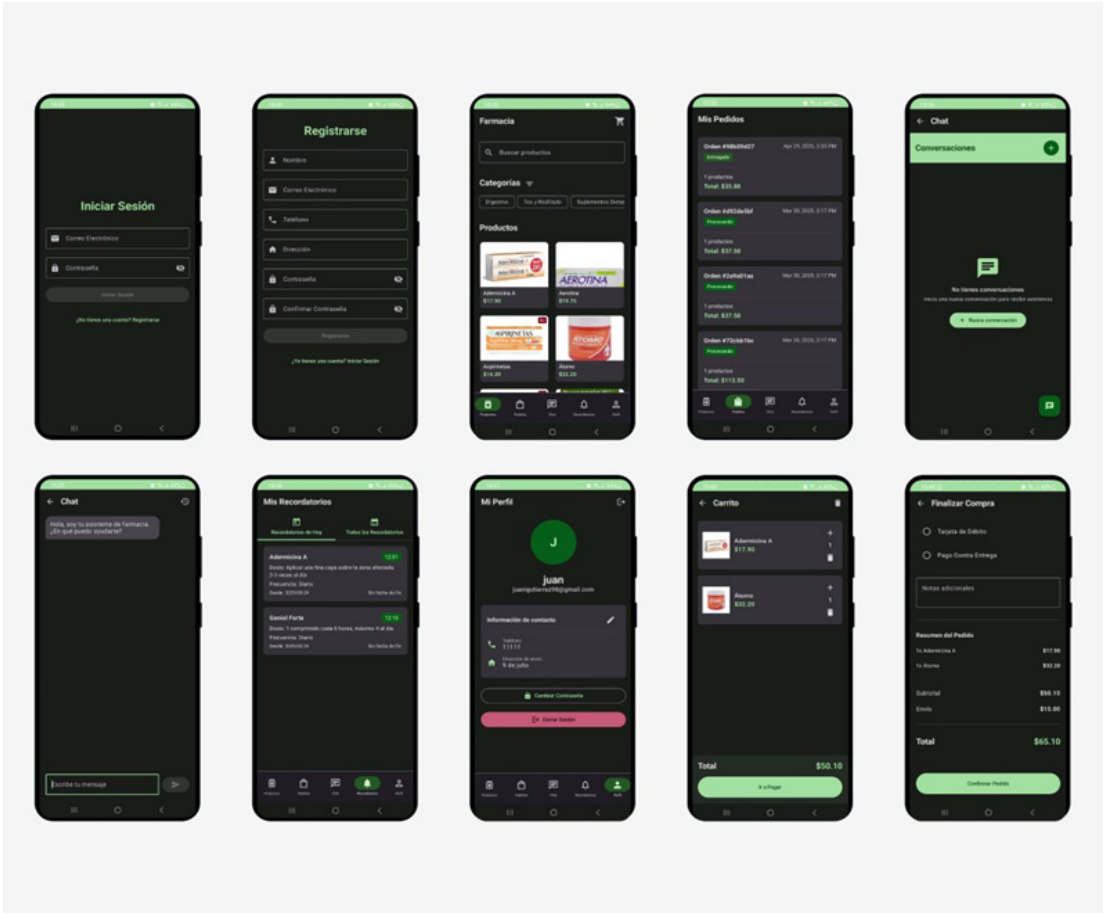

Figure 5. Mobile application

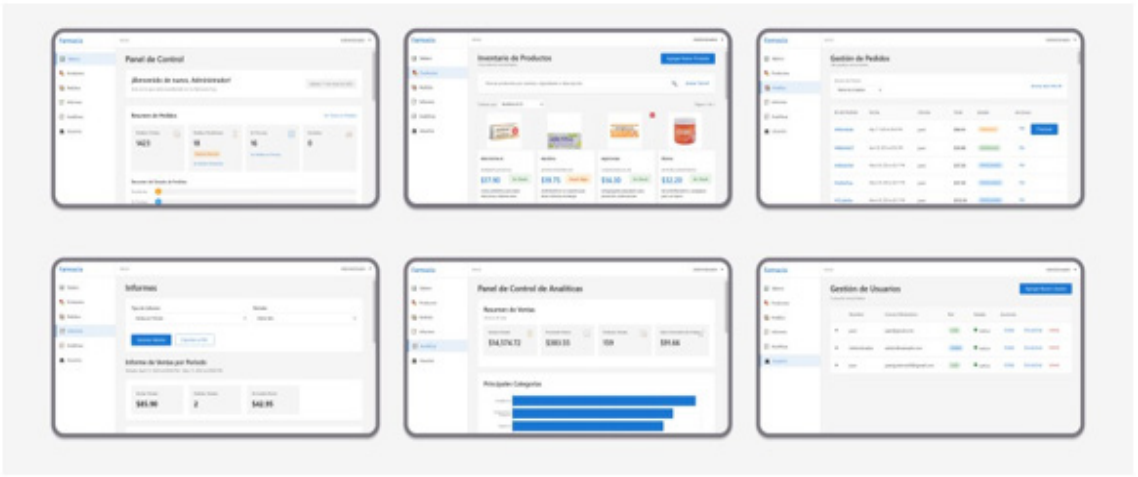

Figure 6. Desktop application

Architecture diagram

The diagram illustrates a distributed architecture composed of services deployed in the cloud. Users access the system through an Android application or a desktop application, both integrated into the presentation layer. These applications communicate with a main API, developed in Express.js, using the HTTPS protocol. This API manages the system logic and connects to a PostgreSQL database.

In addition, the desktop application interacts with a machine learning API developed in Flask, while the main API integrates with the external Gemini service. All business logic and data storage are centralized in the cloud, ensuring scalability, security, and a clear separation of responsibilities.

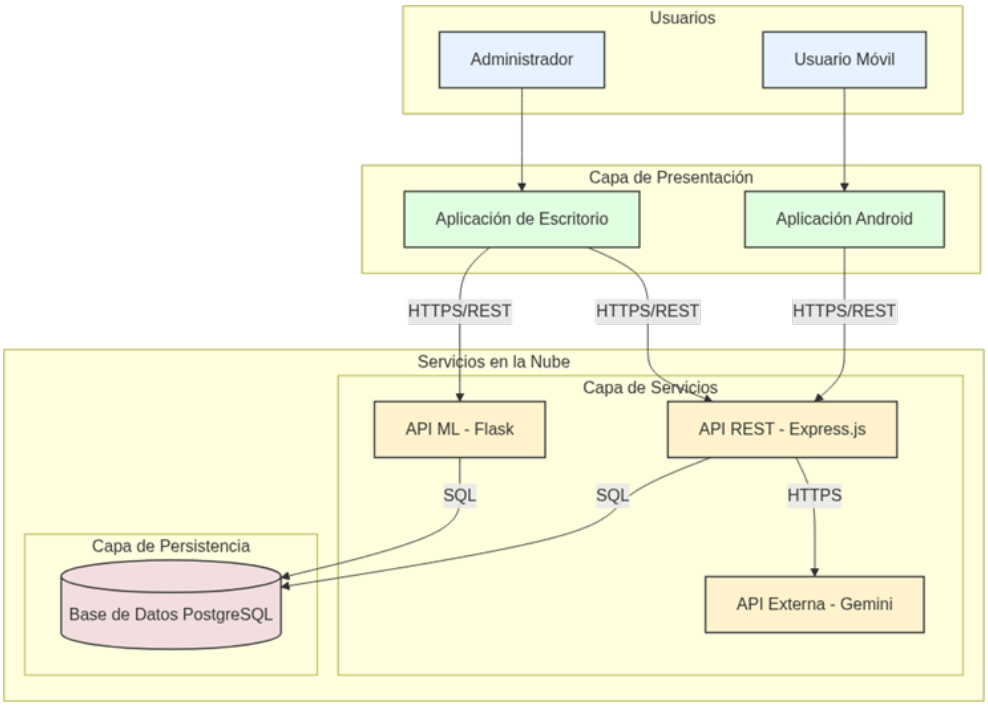

Figure 7. Architecture Diagram

Security

Access to the Application

A series of measures will be defined and implemented to protect users' sensitive information, ensure data integrity, and restrict access to features according to assigned permission levels.

First, the system will use an authentication mechanism based on personal credentials. To access the application, each user must register with their email address and a secure password. Strict password complexity policies will be applied to prevent unauthorized access:

- Minimum of 8 characters.
- Mandatory inclusion of uppercase letters, lowercase letters, numbers, and symbols.
- Passwords will not be stored in plain text, but will be encrypted using the bcrypt algorithm with salt, which will prevent them from being reversed even in the event of a leak.

To enhance the security of pharmaceutical staff and administrators, a two-factor authentication (2FA) system will be proposed. This additional layer of protection will require users to verify their identity using a temporary code generated by an authentication application, in addition to entering their credentials.

Access to the system will also be protected by session control based on JWT tokens, which will have a predefined expiration time. If the user remains inactive for more than 15 minutes, the session will automatically close. In addition, it will be possible to view active sessions and close them manually from the profile, giving the user complete control over their access.

To ensure that each user only accesses the functions that correspond to them, a role-based access control (RBAC) model will be implemented. Permissions will be assigned according to the user's profile:

- Customer: will only be able to access functions related to orders, queries, reminders, and product tracking.
- Pharmaceutical staff: will have access to stock management, customer service, sales, and reporting features.
- Administrator: can manage users and products and access all system functions.

From a technical standpoint, all sensitive operations and requests to the server will undergo server-side validation, which will prevent users from altering their privileges from the client or manipulating forms.

Communication security will also be a priority. All information exchanged between the client and the server will be transmitted via HTTPS protocols with TLS 1,3 encryption, ensuring data confidentiality and integrity, even on insecure networks.

In addition, defense mechanisms against common cyberattacks will be incorporated, such as:

- Temporary blocking of access after multiple failed login attempts (to mitigate brute force attacks).
- Parameterized database queries using an ORM to prevent SQL injections.

- Sanitization of user input to prevent Cross-Site Scripting (XSS) attacks.
- Inclusion of CSRF tokens in forms, where appropriate, to prevent Cross-Site Request Forgery (CSRF) attacks.

Finally, the password recovery process will also be designed with appropriate security measures. When a user requests to reset their password, the system will send a recovery link with a unique token and a limited expiration time (15 minutes). Only after validating this token will the user be able to enter a new password that meets the established criteria.

Information Backup Policies

Backup and availability policies will be established to ensure operational continuity, data integrity, and protection against unforeseen events.

Database backup and protection

The system will have an automatic and scheduled backup mechanism for the database, which will contain user information, products, transactions, recipes, reports, and configurations. These copies will be managed according to the following criteria:

Frequency

- Full backups will be performed daily, scheduled to run at 00:00.
- Incremental backups will be generated every 6 hours to minimize the loss of recent data in the event of possible incidents.

Storage

- Copies will be stored on remote, secure servers in the cloud, with geographic redundancy.
- A backup history for the last 30 days will be kept to allow recovery at different points in time.

Access security

- Only authorized personnel will be able to access the backups through multi-factor authentication (MFA).
- Files will be encrypted with the AES-256 algorithm and hosted on servers with both physical and logical protection.

Integrity verification

- After each backup, an automatic verification will be performed using checksums and scheduled audits to ensure its validity and recoverability.

Information availability

Given that the system must be available to both customers and pharmaceutical staff during extended hours or even continuously (24/7), mechanisms will be implemented to ensure high availability:

- Scalable cloud infrastructure with load balancing and continuous monitoring to ensure uninterrupted access.
- Geographically distributed servers that will ensure service continuity in the event of localized failures.
- Hosting providers with service level agreements (SLAs) exceeding 99,9 %, backed by failover mechanisms.
- Active real-time system monitoring, with alerts generated in the event of outages or performance anomalies.

Risk management

A comprehensive strategy will be planned to mitigate risks related to the availability, confidentiality, and integrity of information. Identified threats and planned countermeasures will include:

External attacks

- Implementation of a web application firewall (WAF).
- Continuous vulnerability scanning.
- Application of least privilege access policies.
- Constant updating of software and its critical dependencies.

Power failures or service interruptions

- Use of cloud infrastructure with redundant power backup (UPS and generators).
- Data replication on alternative servers.

Human error or system failure

- Regular training of authorized personnel.
- Detailed activity logs for auditing and error detection.
- Use of version control on the database and the ability to restore to previous states (rollback).

Natural disasters or unforeseen events

- Implementation of a Disaster Recovery Plan (DRP), which will include automated system reactivation in an alternative geographical region.

Cost analysis

For the estimation of project costs, all values have been expressed in Argentine pesos. The costs obtained initially in US dollars have been converted using the retail exchange rate of the Central Bank of the Argentine Republic on May 28, 2025, according to the rate published on its official website.[6] This rate was 1 180 00 pesos per dollar.

The estimated personnel costs are detailed below, based on the recommended fees of the Professional Council of Computer Sciences of the Province of Córdoba (CPCIPC), updated as of May 2025.[7]

Table 15. Estimated costs by role in the development of the system

Role	Monthly remuneration	Number of months	Subtotal
Functional analyst	$1 534 504,25	3	$4 603 512,75
UX/UI Designer	$1 786 211,22	2	$3 572 422,44
Backend Developer	$2 393 260,91	3	$7 179 782,73
Frontend programmer	$2 270 771,18	3	$6 812 313,54
QA Tester	$1 984 672,85	3	$5 954 018,55
Estimated total	-	-	$28 122 050,01

Minimal equipment is required for the development and internal testing environment. However, the system is designed to be accessed by customers from their mobile devices and by staff from desktop stations already available in pharmacies.

Table 16. Hardware Costs

Resource	Comments	Estimated cost
2 desktop PCs for pharmacy	Windows and 8GB RAM	$427 572
Android device for testing	Smartphone for testing	$350 000
Estimated total	-	$777 572

The following table details the software tools and services used in the development and implementation of the system, as well as their licenses and estimated costs.

Table 17. Software and Service Costs

Resource	Purpose	Type	Monthly Cost
Visual Studio Code	Development environment	Free	$0
JavaScript / Node.js / Express.js	Backend API for mobile app	Free	$0
Python / Flask	Backend API for prediction	Free	$0
Kotlin / Android Studio	Mobile app development	Free	$0
JavaScript / HTML / CSS / Electron	Desktop app development	Free	$0
PostgreSQL	Relational database	Free	$0
Google Cloud	API hosting, DB, backups, and AI	Paid	$187 024,5
Total estimated	-	-	$187 024,5

The following is a summary of the estimated initial costs for the development and implementation of the proposed system.

Table 18. Summary of estimated initial project costs

Item	Estimated amount
Human resources (development and QA)	$28 122,050
Software / Initial licenses	$
Cloud services (1st month)	$187 024,5
Hardware	$777 572,00
Total estimated	$29 086 646

Risk Analysis

Below is a detailed analysis of the risks identified in the project.

Table 19. Risks identified in the project

Type	Risk	Cause
Organizational	Delays in the project schedule	Poorly estimated times or insufficient resources
Organizational	Lack of stakeholder commitment	Low participation or limited interest in the project
Technical	Component integration failures	Incompatibilities between technologies or implementation errors
Economic	Unforeseen increase in project costs	Underestimation of resources or changes in service prices
Human	Staff turnover	Unexpected departure of key human resources
Technical	Low quality of the final product	Insufficient testing or undetected errors
Legal	Non-compliance with health or privacy regulations	Lack of adequate legal review during the analysis stage
Operational	Resistance to change among pharmacy staff	Lack of training or inadequate communication
Operational	Service interruptions due to infrastructure outages	Dependence on cloud services without backup
Legal	Misuse of sensitive data	Failure to implement security mechanisms

Once the project risks have been identified, a quantitative analysis is presented. To do this, the following quantitative risk assessment matrix was used

Table 20. Quantitative risk assessment matrix

				Severity (Impact)				
				Very low	Low	Medium	High	Very high
				1	2	3	4	5
Probability	Very high	90	0,9	0,9	1,8	2,7	3,6	4,5
	High	70	0,7	0,7	1,4	2,1	2,8	3
	Average	50	0,5	0,5	1	1	2	2
	Low	30	0,3	0,3	0,6	0,9	1,2	1
	Very low	10	0,1	0	0,2	0,3	0,4	0

The results allow us to prioritize the risks that could significantly affect the project's objectives.

Table 21. Quantitative analysis

Risk	Probability (P)	Impact (I)	Degree of exposure (P x I)	Percentage %	Cumulative %
Delays in the project schedule	High (0,7)	5	3.	21	21
Low quality of the final product	High (0,7)	4	2,8	17	38,4
Unforeseen increase in costs	Average (0,5)	5	2.	15,2	53,68
Component integration failures	Average (0,5)	4	2,0	12,2	65,88
Misuse of sensitive data	Low (0,3)	5	1,5	9,14	7
Non-compliance with legal regulations	Low (0,3)	4	1,2	7,31	82,33
Resistance to change among pharmacy staff	Average (0,5)	2	1	6.	88,4
Lack of stakeholder commitment	Average (0,5)	2	1	6,09	94,52
Interruptions due to infrastructure failures	Very low (0,1)	5	0,5	3,04	97,56
Staff turnover team	Very low (0,1)	4	0,4	2,43	100

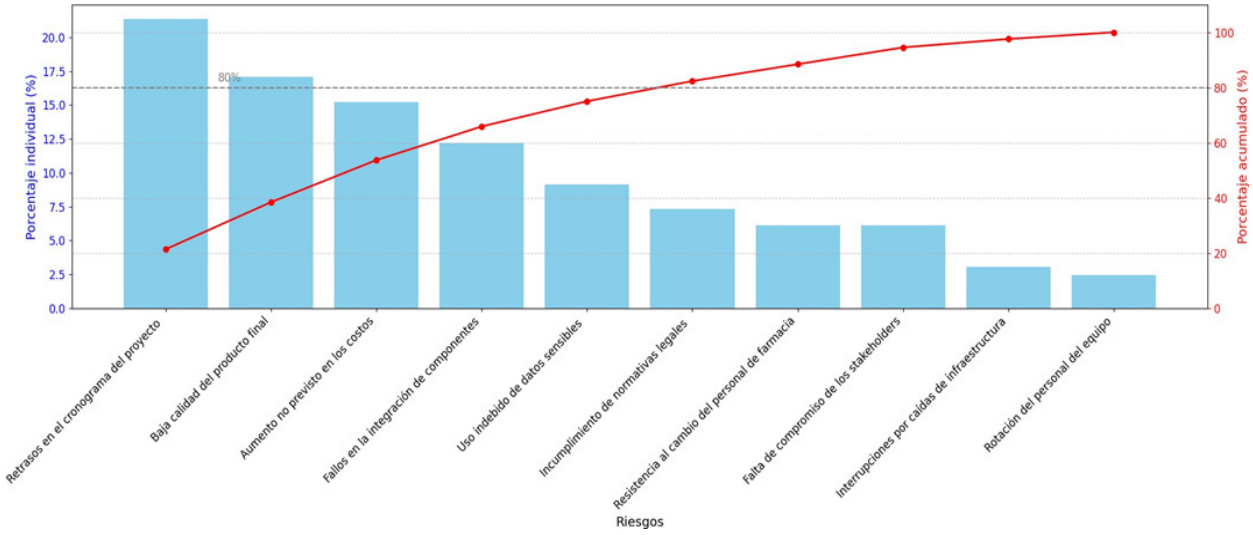

Figure 8. Risk Analysis - Pareto Principle

Applying the Pareto principle, risks representing approximately 80 % of the cumulative impact are considered. These risks are:

- Delays in the project schedule (21,34 %).
- Low quality of the final product (17,1 %).
- Unforeseen increase in costs (15,24 %).
- Component integration failures (12,2 %).
- Misuse of sensitive data (9,14 %).
- Failure to comply with legal regulations (7,31 %).

The following table details the contingency plan proposed for the risks previously analyzed.

Table 22. Contingency Plan

Risk	Contingency plan
Delays in the project schedule	Adjustment of the schedule and reassignment of critical tasks. Hiring temporary external support if necessary.
Low quality of the final product	Refactoring of key components. Implementation of a dedicated sprint for correction and quality validation.
Unforeseen increase in costs	Review of the budget and prioritization of features. Reduction of expenses on non-essential aspects or optional licenses.

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Component integration failures	Replacement of loosely coupled components. Automated documentation and testing to isolate errors.
Misuse of sensitive data	Implementation of incident response protocols. Temporary blocking of access and change of compromised credentials.
Non-compliance with legal regulations	Legal advice to adjust developments. Correction and reconfiguration of functions that do not comply with regulations.

CONCLUSIONS

This project, entitled "Comprehensive Customer Service System with Artificial Intelligence for Pharmacies," arose from the observation of a specific and widespread problem: the multiple deficiencies in pharmaceutical care and management faced by community pharmacies and their impact on both the quality of patient service and the operational efficiency of these establishments. This topic was chosen because of the possibility of developing a technological solution with a real impact on public health by improving key processes and promoting a more accessible, personalized, and effective care model.

The overall objective was to develop a comprehensive system consisting of a mobile application and a desktop application, aimed at improving operational efficiency and accessibility to pharmaceutical products. Although quantitative metrics were defined to evaluate the impact of the system (such as improvements in operational efficiency or accessibility), these metrics could not be applied in a real environment due to the academic nature of the project, time constraints, and the absence of implementation in a productive context.

However, functional tests carried out on the prototype validated the technical feasibility of each component, demonstrating that the system is feasible from a development and integration standpoint. These tests suggest that the system could have a positive impact if fully implemented. It is recommended that the defined metrics be applied at a later stage of implementation to confirm their impact under real conditions.

From a professional standpoint, this project allowed me to consolidate and expand my skills in software development, scalable architecture design, agile methodology application, and risk analysis. The integration of tools such as artificial intelligence, secure databases, and cloud services represented a technical challenge that drove my growth as a developer and systems analyst.

On a personal level, the project was an opportunity to deepen my ethical and social commitment to developing technological solutions for the healthcare sector. Understanding the needs of end users, translating those needs into functional requirements, and building an accessible and effective solution allowed me to develop greater empathy and a more comprehensive view of the professional role I aspire to play.

In short, this work met the technical and academic objectives established in the context of a final degree project and allowed me to grow both personally and professionally. It also provides a solid foundation for future stages of validation and real implementation, where the projected impacts can be measured and continue to contribute to the improvement of the community health system.

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None.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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