Pawpal: An AI Powered Mobile Application for Intelligent Pet Care and Social Welfare in Sri Lanka

RP-64

B.Sc. (Hons) Degree in Information Technology
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Sri Lanka Institute of Information Technology
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DECLARATION

I declare that this is my own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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ABSTRACT

In Sri Lanka, the pet care sector continues to face significant barriers in accessibility, affordability, and standardization. Veterinary services are heavily concentrated in urban centers, leaving rural and low-income regions underserved. Companion animal owners often struggle to secure reliable veterinary guidance, modern pet services, and structured welfare support. These challenges also exacerbate national issues such as stray dog management, inconsistent vaccination coverage, and limited engagement with animal welfare initiatives. Despite the growth of global pet technology ecosystems, Sri Lanka has yet to adopt a comprehensive digital solution tailored to its cultural and infrastructural realities.

PawPal was developed as an AI-driven mobile platform to bridge these systemic gaps. The platform unifies pet owners, veterinarians, service providers, and welfare organizations into a single digital ecosystem, ensuring more consistent and transparent care. It is designed with four core intelligent modules: a real-time booking network for trainers, walkers, and groomers; a personalized nutrition and supplement engine powered by predictive models; a donation kit generator for shelters and rescued strays; and a teleconsultation module that integrates symptom triage, an NLP chatbot, and automated vet matching. Together, these modules establish a complete, locally adapted infrastructure for pet care.

The technical foundation of the platform leverages Flutter for cross-platform compatibility and Flask for backend integration, with domain-specific datasets collected from Sri Lankan shelters, clinics, and pet communities. These datasets were used to train AI models capable of generating personalized recommendations, donation packages, and health triage insights. Furthermore, the application incorporates real-time APIs for communication and location services, enhancing its reliability and user-friendliness. Multilingual support in Sinhala, Tamil, and English ensures inclusivity, particularly for users in underserved regions.

Anticipated outcomes of the system include measurable improvements in service allocation efficiency, higher donor participation in animal welfare programs, and reduced wait times for veterinary consultations. Beyond these metrics, the platform emphasizes transparency, contextual relevance, and affordability, making it scalable for adoption across both urban and rural communities. Its structure allows continuous learning from user interactions, enabling the models to improve over time and adapt to changing community needs.

Overall, *PawPal* demonstrates how the integration of artificial intelligence with locally contextualized design can create transformative change in the animal welfare sector. By aligning advanced technology with community-driven challenges, the platform not only elevates pet care standards in Sri Lanka but also provides a replicable model for other developing countries facing similar infrastructural limitations.

Keywords:*Pet Care AI, Veterinary Teleconsultation, Predictive Nutrition, Shelter Donation Systems, Symptom Triage, NLP Chatbot, Digital Health Platforms*

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LIST OF ABBREVIATIONS

- **AI** – Artificial Intelligence
- **API** – Application Programming Interface
- **CSV** – Comma-Separated Values
- **DB** – Database
- **F1-Score** – Harmonic Mean of Precision and Recall
- **GPS** – Global Positioning System
- **IoT** – Internet of Things
- **ML** – Machine Learning
- **NLP** – Natural Language Processing
- **NGO** – Non-Governmental Organization
- **PawPal** – Pet Assistance and Welfare Platform (project name)
- **PII** – Personally Identifiable Information
- **SMS** – Short Message Service
- **UI** – User Interface
- **UX** – User Experience
- **WHO** – World Health Organization
- **JWT** – JSON Web Token
- **IDE** – Integrated Development Environment
- **API Key** – Unique Identifier for Accessing an API
- **SQL** – Structured Query Language
- **NoSQL** – Non-Structured Query Language (MongoDB type database)
- **BMC** – Business Model Canvas

1.INTRODUCTION

1.1 Background & Literature

1.1.1 Global Pet Care Industry and Digital Transformation

Over the past decade, the global pet care industry has been transformed by the integration of digital platforms and AI-powered ecosystems. In developed economies, applications such as *Rover* and *Wag!* have redefined how pet owners connect with trainers, walkers, and sitters, ensuring convenience and safety through digital verification and real-time service allocation [3]. Similarly, emerging platforms have begun embedding artificial intelligence for predictive analytics in areas such as pet behavior monitoring and communication [10]. These technological advances highlight the growing role of digital health platforms in reshaping human–animal interactions and streamlining care delivery [7].

Trends such as AI-driven personalization, biometric health monitoring, and teleconsultation are now considered central pillars of modern pet technology [5]. Studies forecast that these innovations will continue to shape the sector by providing greater customization, reducing inefficiencies, and improving welfare outcomes. However, despite these global advancements, technology adoption is heavily skewed toward high-income countries, where digital literacy, infrastructure, and consumer demand are well aligned with innovation [9]. This uneven distribution underscores the importance of localized adaptations in regions such as South Asia.

1.1.2 Veterinary Services and Infrastructure in Sri Lanka

Sri Lanka faces unique challenges in providing consistent and accessible veterinary care. Veterinary facilities are disproportionately concentrated in urban centers, leaving rural and underserved communities with limited access to qualified professionals [13]. As a result, pet owners in such areas frequently depend on informal or unverified providers, which can compromise the quality and safety of care. Furthermore, the high cost of private veterinary services creates affordability barriers for many households [19].

The lack of structured veterinary teleconsultation platforms further exacerbates this issue. While countries with advanced infrastructure have experimented with subscription-based telehealth models, such approaches are neither financially feasible nor culturally adaptable in Sri Lanka [18]. Evidence from previous studies indicates that pet owners in rural districts often perceive animal companionship as an emotional and social necessity, yet their access to structured health services remains minimal [17]. These limitations create an urgent need for technology-driven solutions capable of extending veterinary expertise across geographic and socioeconomic boundaries.

1.1.3 Stray Dog Population and Animal Welfare Challenges

One of the most pressing animal welfare issues in Sri Lanka is the growing stray dog population, estimated to be in the millions [21]. This creates significant challenges for both public health and animal welfare, as unmanaged populations are linked to the spread of rabies and other zoonotic diseases [2]. Government vaccination campaigns have attempted to address these risks, but their coverage has been inconsistent due to logistical barriers, resource limitations, and community-level reluctance [21].

Shelters and welfare organizations face the added burden of limited resources and donor engagement. Most shelters rely on unstructured donation appeals through social media, resulting in inefficiencies and mismatched contributions [14]. A recent welfare project highlighted the importance of structured, data-driven systems to ensure transparency and accountability in donor participation [26]. However, no comprehensive digital platform currently exists to centralize these welfare efforts and connect donors with real-time shelter needs. This gap demonstrates the potential value of an AI-driven donation prediction and kit-generation system.

1.1.4 AI and Predictive Modeling in Pet Nutrition and Health

Artificial intelligence has shown considerable promise in optimizing pet health and nutrition. International platforms have begun using predictive modeling to recommend meal plans tailored to breed, age, and activity levels [8]. Studies indicate that owners increasingly prefer data-backed nutrition forecasts, as they reduce the guesswork involved in diet selection and ensure improved long-term health outcomes [6].

In the Sri Lankan context, however, pet nutrition services remain largely generic, with limited customization or scientific validation. Pet owners typically rely on commercial feed brands without consideration for specific dietary requirements, creating risks of malnutrition or obesity [20]. The integration of predictive analytics into a mobile-first platform offers an opportunity to provide contextualized nutrition support at scale. Furthermore, AI-based symptom triage systems have been shown to reduce veterinary caseloads and improve decision-making accuracy in low-resource environments [19]. By combining these capabilities with localized datasets, Sri Lanka has the potential to leapfrog into the next generation of pet health services.

1.1.5 Digital Ecosystems and Communication Platforms

Modern pet care solutions rely not only on AI but also on real-time digital infrastructure. Location-based services have become essential in mapping service providers, tracking pet health data, and ensuring efficient logistics in meal and supply delivery [15]. Similarly, communication APIs facilitate seamless vet–owner interactions, especially in teleconsultation contexts [16]. Together, these tools enhance platform usability and ensure that remote services are not hindered by infrastructural limitations.

For Sri Lanka, where both internet penetration and smartphone adoption are steadily increasing, integrating such APIs into a unified ecosystem could dramatically improve user experience [23]. However, digital inclusivity remains a challenge, requiring interfaces that are accessible in Sinhala, Tamil, and English. By embedding linguistic adaptability into the system, platforms like *PawPal* can address barriers that limit adoption in diverse communities.

1.1.6 Summary of Literature Insights

The review of global and local contexts highlights the urgent need for a unified pet care ecosystem in Sri Lanka. While international platforms showcase the potential of AI, predictive modeling, and teleconsultation, their designs are not aligned with the affordability, cultural preferences, and infrastructural realities of Sri Lankan communities [9]. Locally, veterinary shortages, the stray dog crisis, and fragmented welfare systems create compounding barriers that limit the effectiveness of existing approaches [13], [26].

These gaps illustrate a clear research opportunity: to design and implement a context-aware, AI-powered platform capable of unifying services, improving accessibility, and supporting welfare at scale. The *PawPal* application directly responds to this opportunity, offering a framework to transform animal welfare through digital innovation.

1.2 Research Gap

1.2.1 Lack of Integrated Digital Pet Care Platforms in Sri Lanka

Globally, the pet care industry has advanced rapidly, with platforms that unify booking services, veterinary teleconsultation, and supply delivery. Applications like *Wag!* and *Rover* have become mainstream in Western countries, offering streamlined access to verified pet service providers and digital trust mechanisms [3]. These platforms demonstrate the potential of digital ecosystems to improve convenience, efficiency, and safety for pet owners. However, these solutions are primarily designed for developed economies and do not consider the affordability or infrastructural limitations of developing countries.

In Sri Lanka, there is no unified digital platform that consolidates services for pet owners. Instead, individuals often rely on fragmented sources such as informal Facebook groups, personal recommendations, or unverified providers to access trainers, groomers, and walkers [13]. This lack of centralization creates significant risks, including unreliable service quality and the absence of accountability mechanisms. Moreover, the absence of data-driven verification discourages new pet owners from confidently engaging with available services, further widening the gap between service demand and provision.

Another critical issue is that existing global platforms cannot be directly transplanted into the Sri Lankan context. Subscription-based models, common in Western countries, are financially impractical for average Sri Lankan households [18]. Even when digital services are available, most platforms lack multilingual support in Sinhala and Tamil, alienating large segments of potential users. As a result, the country has not yet benefited from the same digital transformation seen elsewhere.

This demonstrates a clear research gap: while digital pet care ecosystems exist internationally, Sri Lanka lacks a contextually adapted platform that unifies service providers, ensures quality through verification, and maintains affordability. The absence of such a solution continues to hinder accessibility and scalability in the local pet care sector.

1.2.2 Inadequacy of Veterinary Accessibility and Teleconsultation Mechanisms

Veterinary access is one of the most significant challenges facing pet owners in Sri Lanka. The majority of veterinary professionals and facilities are clustered in urban centers such as Colombo, leaving rural and low-income areas underserved [19]. Pet owners in these regions often struggle to access timely veterinary advice, relying instead on informal sources or delaying treatment. This geographic disparity has been consistently reported as a barrier to effective animal healthcare in the country [17].

Globally, teleconsultation platforms have emerged as a solution to this challenge. Countries with advanced infrastructure have experimented with veterinary telehealth systems, where pet owners can consult qualified vets remotely, supported by digital triage and medical record management [8]. These platforms reduce caseloads in clinics, shorten waiting times, and expand access to underserved regions. However, such solutions are not widely available in Sri Lanka, despite the increasing penetration of smartphones and internet connectivity.

The lack of structured teleconsultation systems also has implications for public health. Sri Lanka continues to face challenges with zoonotic diseases such as rabies, which are often exacerbated by delayed veterinary interventions [2]. Without efficient access to remote veterinary guidance, early-stage symptoms in animals often go unaddressed, increasing risks for both pets and communities. This further highlights the importance of scalable teleconsultation systems.

The gap here is evident: while teleconsultation has proven effective in many global contexts, Sri Lanka lacks an affordable, AI-supported veterinary telehealth platform that can triage symptoms, support multilingual communication, and connect owners with licensed professionals. Addressing this gap would not only improve pet care but also strengthen the country’s response to wider animal health challenges.

1.2.3 Fragmented Welfare and Donation Systems for Stray Animal Management

Sri Lanka faces a severe stray dog crisis, with estimates suggesting millions of free-roaming dogs across the country [21]. These unmanaged populations strain the limited resources of shelters and animal welfare organizations, many of which operate on small budgets and rely heavily on public donations. However, current donation systems are fragmented and informal, often limited to social media campaigns that lack transparency and scalability [14]. Donors frequently face uncertainty about whether their contributions are used effectively, reducing long-term engagement with shelters.

Globally, structured welfare donation systems have shown how technology can be leveraged to increase transparency, efficiency, and accountability. Platforms that use data analytics to match donor contributions with actual needs have seen significant increases in participation rates and trust [26]. Such approaches also ensure that resources reach the most urgent cases, minimizing waste and duplication. Unfortunately, Sri Lanka has yet to implement such structured mechanisms within its animal welfare sector.

Another issue lies in cultural preferences. Research indicates that Sri Lankans often prefer in-kind donations (e.g., food, medicine, supplies) over monetary contributions [20]. Existing global platforms are not designed to accommodate this cultural norm, as most prioritize cash-based donation flows. Without systems that align with these local preferences, shelters miss out on potentially transformative community support.

1.3 Research Objectives

The primary objective of this research is to design and develop an **AI-powered mobile application, PawPal**, that provides a unified ecosystem for pet care services in Sri Lanka. The overarching aim is to improve accessibility, efficiency, and affordability of pet-related services while simultaneously addressing broader animal welfare concerns such as shelter sustainability and stray dog management. By combining artificial intelligence, predictive modeling, and user-centered design, the project aspires to deliver a transformative solution that bridges the gap between fragmented service providers, pet owners, veterinarians, and welfare organizations.

One of the core objectives of this study is to establish a **real-time pet service ecosystem** that enables owners to securely book verified trainers, walkers, and groomers. This component is intended to overcome the challenges associated with informal or unregulated providers, which often undermine service quality and user trust. By embedding digital verification and secure booking mechanisms, the system seeks to enhance transparency and accountability while ensuring pet owners can access reliable services regardless of their location.

A second major objective is the development of a **personalized pet meal and supply delivery network** that leverages predictive modeling techniques. Unlike existing nutrition services, which often offer generic recommendations, this system will take into account breed, age, weight, medical history, and activity level in order to generate customized meal and supplement plans. Through this approach, the research aims to promote healthier feeding practices and minimize risks associated with overfeeding, malnutrition, or diet-related diseases. The nutrition module will also ensure the timely delivery of recommended supplies, thereby reducing dependency on inconsistent market availability.

Another significant objective is to design and implement an **on-demand veterinary teleconsultation module**. Given the uneven distribution of veterinary services across Sri Lanka, this component is critical in extending healthcare access to underserved communities. The teleconsultation system will combine AI-driven symptom triage, a natural language processing (NLP) chatbot, and a vet-matching algorithm. Together, these features will help pet owners receive timely and reliable advice, reduce clinic congestion, and shorten waiting times for consultations. Importantly, this objective aligns with broader public health needs, since improved veterinary access can contribute to better management of zoonotic diseases such as rabies.

In addition to services and health-related features, the research also aims to develop a **personalized donation generation system** designed to support animal shelters and stray welfare programs. Recognizing that Sri Lankan donors often prefer in-kind contributions such as food or medicine, this module will create customized welfare kits aligned with shelter requirements and community preferences. By structuring donations through an AI-driven system, the objective is to improve transparency, increase donor confidence, and optimize the allocation of resources to shelters in need. This approach is expected to foster stronger community engagement while ensuring sustainable welfare outcomes.

A further objective of this study is to guarantee **affordability, inclusivity, and linguistic adaptability** within the platform. By offering multilingual support in Sinhala, Tamil, and English, the system is designed to ensure equitable access across different regions and demographics. Affordability will be achieved by avoiding subscription-heavy models, instead focusing on lightweight, accessible features that align with local income levels. This ensures that the benefits of digital innovation are not limited to urban or affluent populations but extend to rural and underserved communities as well.

Finally, the research aims to **evaluate the effectiveness of the PawPal platform** through prototype testing and stakeholder feedback. This objective involves assessing the system’s ability to improve service allocation efficiency, increase donor participation, and reduce veterinary wait times. Evaluation will not only measure technical performance but also consider user satisfaction, accessibility, and the overall impact on pet care and welfare standards. By systematically validating these outcomes, the research will provide empirical evidence of the platform’s value and its potential for scaling in other low- and middle-income contexts

2.METHODOLOGY

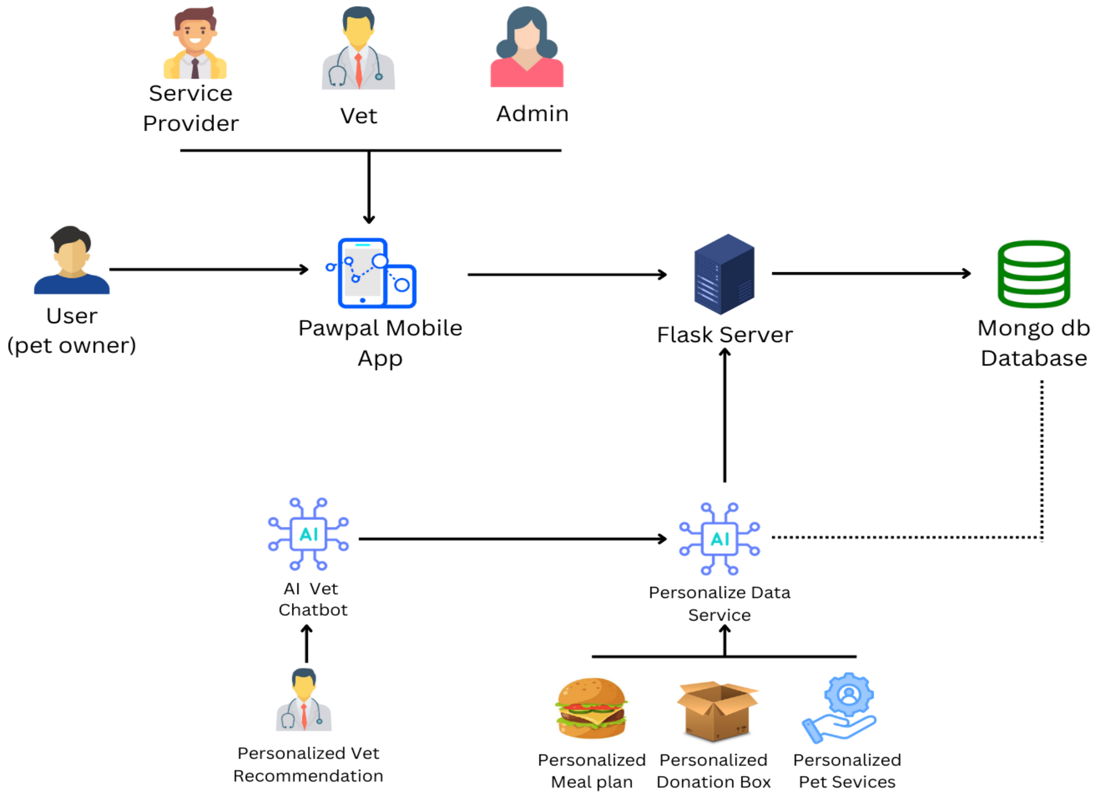


Figure 1 Overall System Diagram

The methodology of this study is structured to support both the design and evaluation of the *PawPal* platform, an AI-powered mobile application that unifies veterinary services, pet owners, service providers, and animal welfare organizations into a single ecosystem. Given the applied nature of this research, the methodology combines **system development** with **experimental validation**, ensuring that the final product is both technically robust and contextually relevant. The approach reflects contemporary trends in AI-driven pet care solutions, where predictive modeling and intelligent digital platforms are increasingly utilized to optimize nutrition, welfare, and service delivery [6].

This research adopts a **mobile-first system development design** using Flutter for cross-platform functionality and Flask for backend orchestration. The system integrates multiple modules, including real-time service booking, predictive nutrition forecasting, veterinary teleconsultation, and donation kit generation. Data-driven insights form the foundation of these modules, relying on datasets collected from local shelters, veterinary clinics, and welfare organizations to ensure contextual adaptability. Similar approaches have been successfully applied in international contexts, where AI-enabled platforms have demonstrated measurable improvements in service efficiency and donor engagement [8]. By embedding these techniques in a Sri Lankan context, the methodology directly addresses gaps in accessibility, affordability, and inclusivity [17].

In addition to system development, the methodology emphasizes **evaluation and validation** to measure the effectiveness of the platform. Usability testing, stakeholder feedback, and AI performance metrics are employed to assess outcomes such as improved service allocation, reduced veterinary wait times, and increased donor participation. Considerations of ethical practice, including data privacy and informed consent, are integrated throughout the process. This dual focus on technological innovation and systematic evaluation ensures that the methodology is not only aligned with the research objectives but also responsive to the socio-cultural realities of Sri Lanka's pet care sector [19].

2.1 Research Design

The research design adopted for this study follows an **applied research approach**, focusing on the practical development and evaluation of a technological solution to address real-world problems in the Sri Lankan pet care sector. Unlike purely theoretical studies, applied research emphasizes tangible outcomes that can directly benefit communities and stakeholders. In this case, the absence of an integrated digital ecosystem for pet care has been identified as a significant challenge, particularly in rural and underserved areas [13]. The design therefore prioritizes creating a functioning mobile application that not only demonstrates technical feasibility but also contributes to improving veterinary accessibility, service delivery, and animal welfare engagement.

To achieve this, the study employs a **system development methodology**, which involves iterative cycles of design, implementation, and refinement. The development process integrates multiple intelligent modules, including real-time service booking, predictive nutrition forecasting, on-demand teleconsultation, and structured donation generation. Each module is underpinned by AI models trained on domain-specific datasets sourced from veterinary clinics, shelters, and welfare organizations, ensuring cultural and contextual adaptability [17]. This design choice aligns with contemporary global trends in pet technology, where digital platforms are increasingly augmented with artificial intelligence to enhance personalization, efficiency, and transparency [6].

A key justification for this research design is the adoption of a **mobile-first, AI-integrated platform**. In Sri Lanka, smartphone penetration and internet connectivity have expanded significantly, making mobile applications the most accessible channel for technology adoption across both urban and rural regions [23]. A mobile-first design ensures inclusivity, affordability, and usability for diverse demographics, particularly when combined with multilingual support in Sinhala, Tamil, and English. Furthermore, embedding AI models into the application enables advanced features such as symptom triage, NLP-based chatbot interactions, and predictive nutrition, which would not be feasible through traditional static applications. This integration reflects the need to bridge the infrastructural and socio-economic gaps that limit the effectiveness of global solutions in the Sri Lankan context [18].

The research design also incorporates a **mixed-method approach** that combines system development with experimental validation. The development phase emphasizes technical construction and module integration, while the validation phase focuses on measuring outcomes such as usability, efficiency, and user satisfaction. Prototype testing, stakeholder interviews, and AI model evaluations are used to assess system effectiveness and reliability. This dual approach ensures that the platform is not only technologically sound but also socially impactful, addressing the complex challenges of accessibility, welfare, and donor engagement. By blending applied research with experimental validation, the study establishes a holistic framework capable of demonstrating both innovation and practical utility in the Sri Lankan pet care sector [19].

2.2 System Architecture and Development Process

The development of *PawPal* followed a structured system architecture that ensures scalability, modularity, and contextual adaptability. The architecture is divided into four major layers—frontend, backend, AI models, and database—each performing distinct but interconnected functions. The integration of these components allows for seamless real-time communication, predictive analytics, and secure data management. The overall development process followed an iterative, agile-based methodology, enabling continuous refinement through feedback from supervisors, stakeholders, and preliminary users [6].

2.2.1 Frontend Layer – Mobile Application

The frontend layer was developed using **Flutter**, a cross-platform framework that allows the application to run smoothly on both Android and iOS devices with a single codebase. This decision was justified by the high rate of smartphone adoption in Sri Lanka, making mobile-first design the most inclusive approach for reaching diverse communities [23]. Flutter also provides modern UI/UX capabilities, enabling intuitive interfaces for service booking, teleconsultation, donation contributions, and nutrition tracking. Multilingual support (Sinhala, Tamil, and English) was incorporated at this layer to ensure linguistic accessibility.

A component flow diagram is included here to illustrate the interaction between user interfaces (login/authentication, booking, donation, teleconsultation) and backend APIs. This modular design ensures that updates or new features can be integrated without disrupting the entire system.

2.2.2 Backend Layer – Server and API Integration

The backend was developed using **Flask**, a lightweight Python framework suitable for handling API requests, authentication, and business logic. Flask was chosen due to its flexibility and compatibility with AI/ML models, making it well-suited for integrating the predictive components of the system [7]. The backend manages secure communication between the frontend and the database, ensuring data consistency and access control.

Additionally, external **APIs** were integrated to enhance system capabilities. Google Maps Platform APIs were utilized for location-based service matching and logistics planning [15], while Twilio APIs supported real-time communication and teleconsultation features [16]. These integrations ensure that the system remains responsive and context-aware, particularly in rural areas where veterinary accessibility is limited. A backend component diagram is provided in this section to depict how Flask interacts with APIs, AI modules, and the database.

2.2.3 AI Model Integration Layer

Artificial Intelligence is central to the PawPal ecosystem, enabling predictive analytics, intelligent triage, and donation kit generation. The **nutrition forecasting model** was trained using supervised learning techniques, applying pet-specific datasets such as breed, age, activity level, and medical history [8]. The **symptom triage and NLP chatbot** module leverages text classification models to interpret owner-reported symptoms and provide preliminary health guidance, before forwarding cases to veterinarians [19].

Another AI component is the **donation kit generator**, which applies clustering algorithms to analyze shelter needs and generate structured in-kind donation lists. Each of these AI models is deployed as a microservice, connected to the backend via RESTful APIs, ensuring modularity and scalability. An AI flowchart will be included to show the data pipeline from raw input, through preprocessing, model inference, and final recommendation generation.

2.2.4 Database and Data Management Layer

For data storage and management, **MongoDB** was selected as the primary database. Its document-based structure is highly suitable for managing heterogeneous data types, including pet profiles, veterinary records, shelter needs, and donor contributions [20]. The database ensures flexibility in handling structured and semi-structured data, which is crucial for supporting AI-driven features.

Data preprocessing steps, such as cleaning, anonymization, and formatting, were applied to ensure quality and privacy. Ethical considerations were prioritized, with sensitive information such as veterinary records being anonymized before use in model training [18]. Additionally, security mechanisms, including JWT-based authentication, were implemented to protect user information. A database architecture diagram is provided to illustrate the storage structure, query mechanisms, and interaction with backend services.

2.2.5 Real-Time Pet Service Ecosystem

This module manages secure booking and verification of service providers, such as trainers, walkers, and groomers. It integrates location-based matching, scheduling, and notifications, ensuring accountability and transparency. A **flowchart** here illustrates the booking process—from owner request, to provider verification, to confirmation and feedback collection.

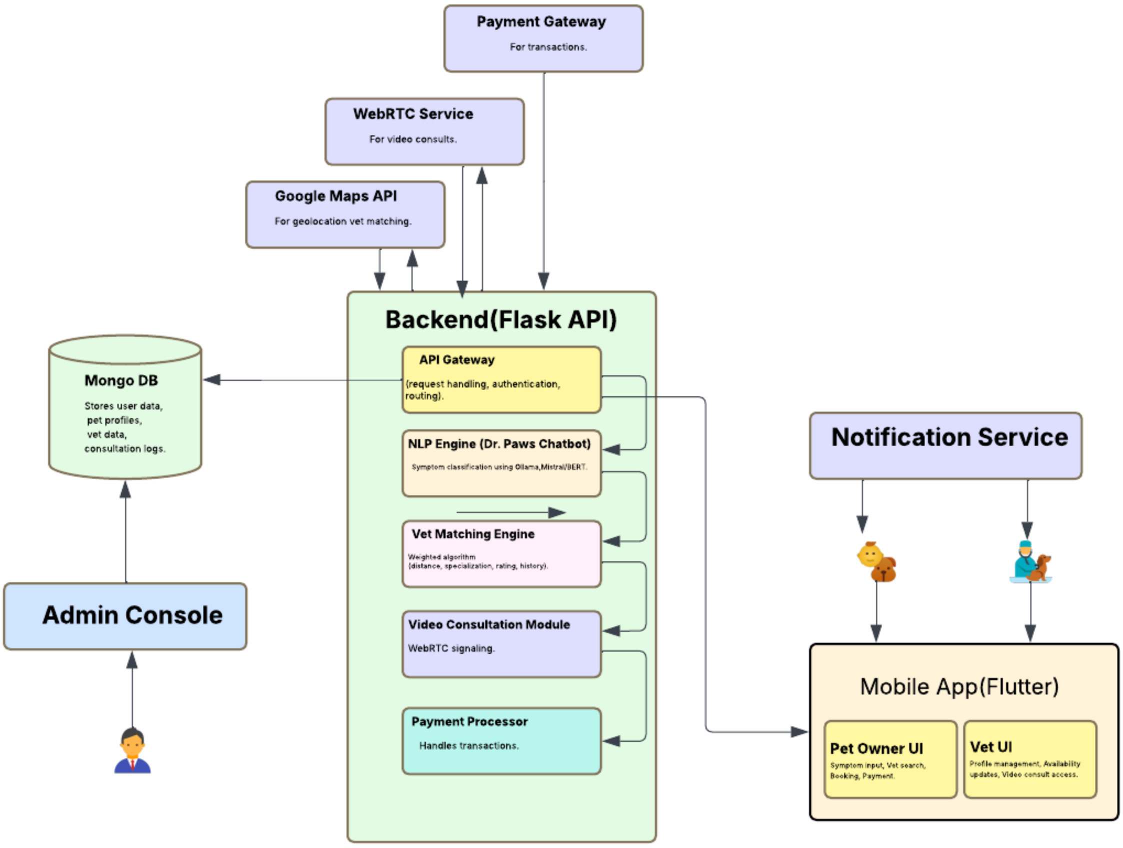
2.2.6 Personalized Pet Meal and Supply Delivery Network

This component applies predictive analytics to generate customized meal and supplement plans based on breed, age, and health attributes [8]. It integrates with supply chains to coordinate deliveries, ensuring timely access to essential nutrition. A **component diagram** highlights how input data (pet profile, health record) passes through the AI model to produce recommendations and link with delivery services.

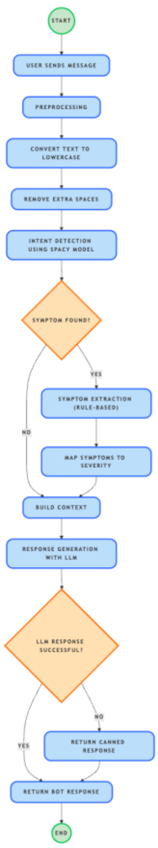
2.2.7 On-Demand Veterinary Teleconsultation

The on-demand veterinary teleconsultation system revolutionizes pet care by integrating advanced technologies to enhance access to veterinary services, particularly in regions with limited resources like rural Sri Lanka [13]. This innovative system combines AI-based symptom triage, a natural language processing (NLP)-driven chatbot, and vet-matching algorithms to deliver efficient and timely consultations [19]. It addresses the growing demand for accessible pet care, aligning with global trends in pet technology that prioritize user convenience and engagement [5]. Pet owners begin by entering their pet's symptoms into the system, which are analyzed by an AI-driven triage module. This module uses machine learning trained on veterinary datasets to identify potential health issues and assess their urgency, ensuring critical cases are prioritized [7]. The NLP-driven chatbot then engages users, interpreting their inputs, asking follow-up questions to gather more details, and providing preliminary guidance, making the interaction intuitive and supportive [10]. A vet-matching algorithm pairs users with licensed veterinarians based on factors like specialization and availability, ensuring the best fit for each case [19]. The system incorporates real-time communication APIs, such as those provided by Twilio, to enable secure video, voice, or text consultations, which is vital in areas with infrastructure challenges [16]. Data encryption ensures user privacy and builds trust in the platform [6]. Additionally, an appointment scheduling feature allows users to book consultations at their convenience, streamlining access to non-urgent care [23]. This system is particularly impactful in regions like Sri Lanka, where studies highlight the scarcity of veterinary services and the reliance of pet owners on accessible solutions [18]. By leveraging AI and real-time communication, the system not only improves pet health outcomes but also enhances owner satisfaction, aligning with modern pet care management innovations [20]. The integration of these technologies positions the teleconsultation system as a transformative tool in the evolving landscape of pet care [11].

The teleconsultation system combines AI-based symptom triage, an NLP-driven chatbot, and vet-matching algorithms to extend veterinary access [19]. It integrates real-time communication APIs and appointment scheduling. A **flow diagram** will be added to show data flow from symptom input, through triage, to chatbot interaction, and finally to license vet consultation.



Payment Gateway
For transactions.
WebRTC Service
For video consults.
Google Maps API
For geolocation vet matching.
Mongo DB
Stores user data,
pet profiles,
vet data,
consultation logs.
Backend(Flask API)
API Gateway
(request handling, authentication, routing).
NLP Engine (Dr. Paws Chatbot)
Symptom classification using Ollama,Mistral/BERT.
Vet Matching Engine
Weighted algorithm
(distance, specialization, rating, history).
Video Consultation Module
WebRTC signaling.
Payment Processor
Handles transactions.
Notification Service
Admin Console
Mobile App(Flutter)
Pet Owner UI
Symptom input, Vet search, Booking, Payment.
Vet UI
Profile management, Availability updates, Video consult access.



START
USER SENDS MESSAGE
PREPROCESSING
CONVERT TEXT TO LOWERCASE
REMOVE EXTRA SPACES
INTENT DETECTION USING SPACY MODEL
SYMPTOM FOUND?
YES
NO
SYMPTOM EXTRACTION (RULE-BASED)
MAP SYMPTOMS TO SEVERITY
BUILD CONTEXT
RESPONSE GENERATION WITH LLM
LLM RESPONSE SUCCESSFUL?
NO
YES
RETURN CANNED RESPONSE
RETURN BOT RESPONSE
END

2.2.8 Personalized Dog Donation System

The donation module is designed to address one of the most persistent challenges in Sri Lanka's animal welfare sector—the lack of structured, transparent, and scalable mechanisms for managing donations to shelters. At present, most shelters rely on informal appeals through social media, which often result in mismatched or inadequate contributions, leaving critical needs unmet [14]. To overcome this inefficiency, the proposed system introduces a **personalized welfare kit generation process**, where donor contributions are systematically aligned with real-time shelter requirements. Each shelter periodically inputs data on food, medical supplies, vaccinations, and other needs into the system. This information is processed and converted into structured demand categories, enabling the platform to identify priority areas. Donors interacting with the application are then presented with **personalized kits** that directly reflect current shortages, ensuring that their support has a measurable impact.

The module further incorporates **AI-driven clustering techniques** to analyze patterns in shelter demand and donor behavior. By grouping similar requests and matching them with appropriate donor segments, the system ensures efficient allocation of resources while minimizing redundancy or oversupply [26]. To enhance accountability, the platform integrates **donor tracking dashboards** that provide real-time updates on how contributions are distributed and utilized. This transparency not only strengthens donor trust but also encourages repeat engagement, creating a sustainable cycle of welfare support. Additionally, the inclusion of culturally relevant donation preferences, such as in-kind contributions (e.g., food, medicines, or bedding) rather than purely monetary donations, makes the system more acceptable to the Sri Lankan context. A detailed **flowchart** is included in this section to illustrate the entire process—from the initial shelter request, through welfare kit generation, to donor confirmation and final resource allocation—highlighting the system's capacity to transform fragmented donation practices into a coordinated, data-driven framework.

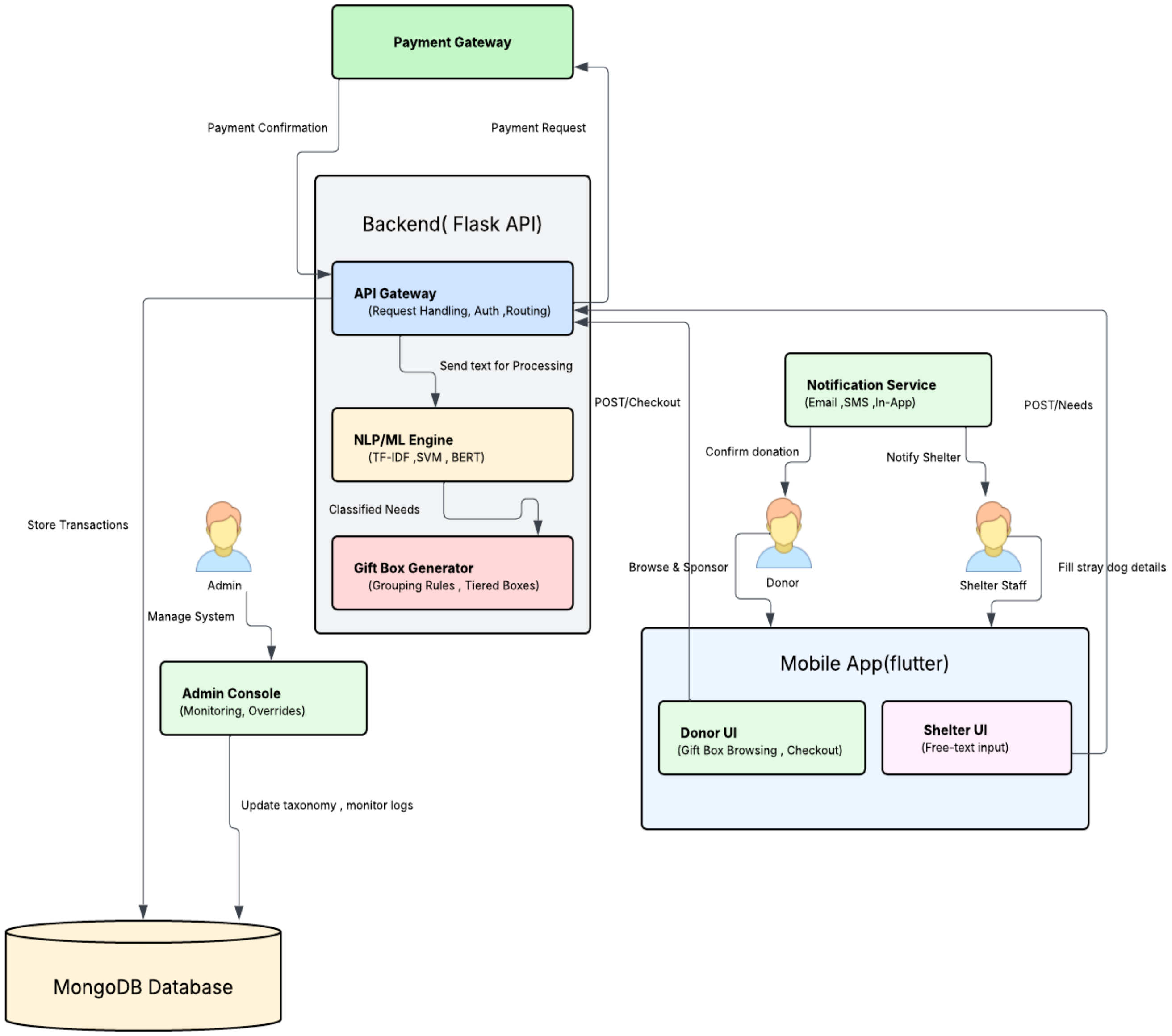


Figure 2 High Level System Diagram of Donation System

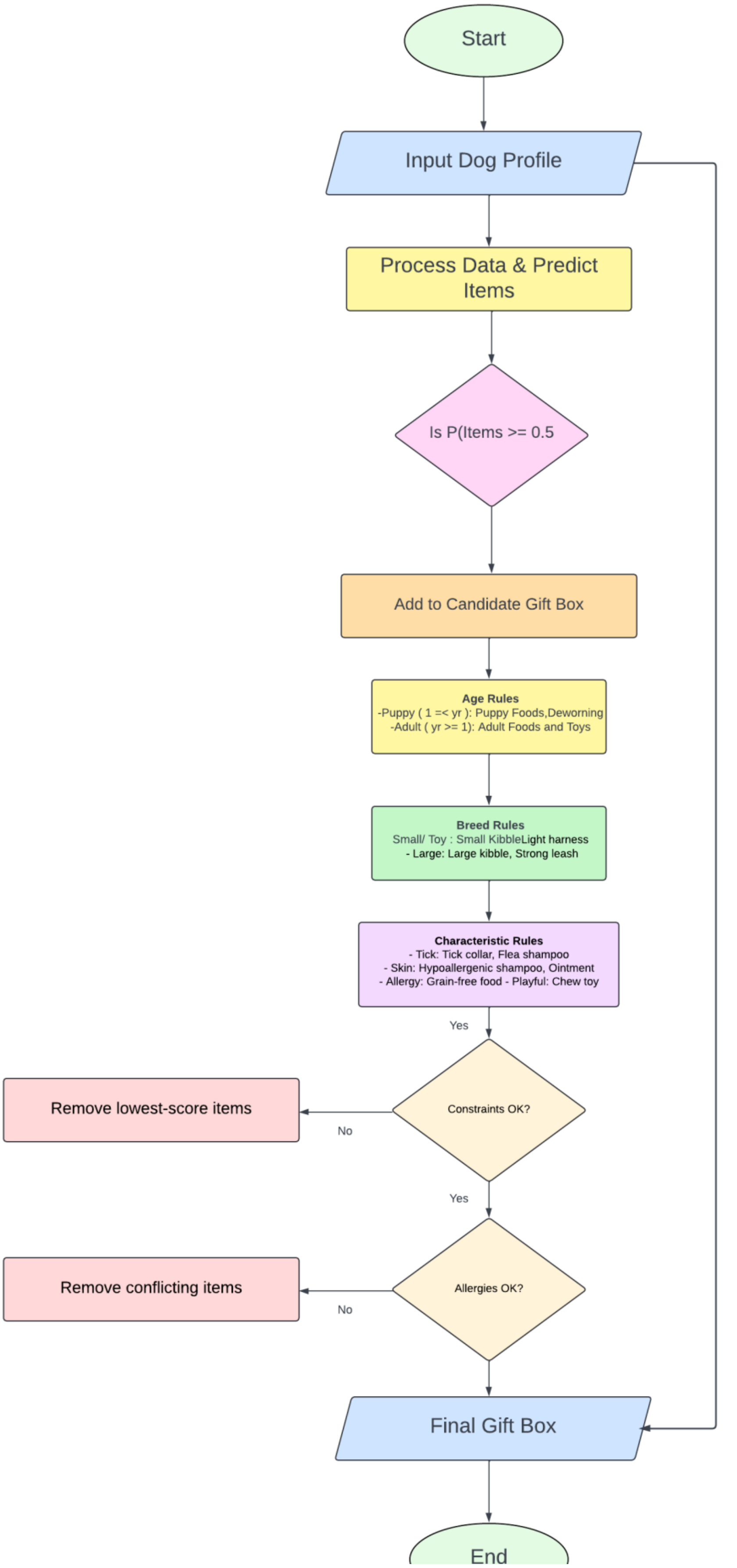


Figure 3 Flow chart of the Donation system

2.2.9 Development Approach

The overall development process adopted an **Agile methodology**, characterized by iterative development, regular testing, and stakeholder feedback. The project was divided into sprints, each focusing on a specific module—service booking, nutrition forecasting, teleconsultation, and donation management. At the end of each sprint, prototypes were tested internally and refined based on performance metrics and user feedback. This iterative approach allowed the research team to remain flexible, ensuring that emerging requirements could be incorporated without major disruptions [12].

2.3 Data Collection and Dataset Preparation

The effectiveness of the *PawPal* platform relies heavily on the availability and quality of datasets that represent real-world conditions in the Sri Lankan pet care sector. To ensure contextual relevance, data was collected from **local veterinary clinics, animal shelters, and welfare organizations** that actively work with companion animals and stray populations. Veterinary clinics provided anonymized clinical records containing details of breed, age, weight, vaccination history, and symptom descriptions. These datasets formed the foundation for training AI models in symptom triage and nutrition forecasting [17]. In parallel, animal shelters contributed information on stray dog populations, medical conditions, and resource requirements, which were instrumental in structuring the donation generation module [14]. Additionally, service provider data—including trainers, groomers, and walkers—was gathered to support the verification and booking ecosystem [6].

The types of data collected were diverse, reflecting the multi-dimensional nature of the PawPal system. **Pet health data** included structured records of vaccination, weight progression, and chronic conditions, along with unstructured text entries from veterinarians describing symptoms or diagnoses. These were crucial for developing predictive triage and nutrition models [19]. **Shelter data** comprised inventory reports detailing food stocks, medication shortages, and animal intake statistics, which were used to predict supply gaps and generate welfare kits [26]. **Service provider data** included qualifications, experience, service categories, and geographic availability, enabling the construction of a reliable provider database to underpin the booking network [13]. Together, these data sources allowed the platform to reflect the practical needs of multiple stakeholders within the ecosystem.

To ensure reliability, a systematic **data preprocessing pipeline** was applied before model training. This process involved cleaning the datasets by removing duplicates, correcting inconsistencies, and standardizing input formats such as breed names, weight units, and vaccination codes. In the case of textual veterinary notes, natural language preprocessing was applied, including tokenization and normalization, to prepare the data for the NLP-based triage chatbot [10]. Numerical attributes, such as weight and age, were normalized to ensure consistency across models. Missing values were carefully handled by applying imputation techniques where feasible, or by excluding incomplete records to maintain data quality.

A key ethical consideration was the **anonymization of sensitive data**, particularly in clinical and shelter datasets. Pet owner identities, addresses, and contact details were removed or encoded to protect privacy, following standard ethical research practices [18]. Access to raw data was restricted, and only processed, anonymized datasets were used for AI model training and evaluation. This ensured compliance with ethical guidelines while maintaining the integrity and usefulness of the data.

Finally, all datasets were **labeled and categorized** according to the requirements of each module. For example, nutrition datasets were labeled with health outcomes such as weight gain, stability, or deficiency correction, while veterinary symptom datasets were annotated with corresponding diagnoses to support supervised learning models. Shelter supply data was categorized into critical, moderate, and low-priority needs, ensuring that donation kits could be generated in a structured and transparent manner [20]. By organizing data in this way, the platform could harness predictive analytics and clustering techniques effectively, supporting real-time, data-driven decision-making for all stakeholders.

2.3.1 Data Sources

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2.4 AI Models and Algorithms

Artificial intelligence plays a central role in the design and functionality of *PawPal*, enabling the system to move beyond static service delivery into a proactive, data-driven ecosystem. Each of the platform's core features leverages AI to provide intelligent recommendations, automate decision-making, and optimize outcomes for users. The AI layer is designed to function as a set of modular microservices, with each model integrated into the backend via RESTful APIs. This modularity ensures that models can be retrained or updated independently without disrupting the entire system, thereby enhancing scalability and maintainability [6].

The models developed for this research address three critical domains: personalized nutrition forecasting, veterinary symptom triage, and donation kit generation. Together, these models form the foundation of PawPal's predictive and adaptive capabilities. Their design was informed by local datasets collected from veterinary clinics, animal shelters, and welfare organizations, ensuring contextual accuracy and relevance [17]. The algorithms applied include supervised machine learning techniques for structured health data, natural language processing (NLP) pipelines for veterinary triage, and clustering approaches for shelter resource optimization.

2.4.1 Predictive Nutrition and Symptom Triage Models

The **predictive nutrition model** was designed to generate personalized diet and supplement recommendations for companion animals. Using supervised machine learning, the model processes structured input features such as breed, age, weight, and medical history to predict optimal dietary outcomes. The training data consisted of anonymized veterinary nutrition records and shelter feeding reports. Algorithms such as decision trees and logistic regression were initially employed for baseline modeling, while more complex neural networks were later applied to capture non-linear relationships between features [19]. Model outputs were evaluated using accuracy, F1-score, and recall, ensuring that recommendations aligned with real-world feeding practices. This predictive engine ensures that Sri Lankan pet owners receive context-specific guidance, addressing a gap in existing generic nutrition practices [20].

The **symptom triage model** focuses on assisting pet owners in identifying potential health concerns before consulting a veterinarian. This module is powered by natural language processing (NLP) and is trained on veterinary case datasets containing textual symptom descriptions paired with confirmed diagnoses. Preprocessing involved tokenization, lemmatization, and stop-word removal, preparing the data for classification pipelines. Several models were tested, including naïve Bayes classifiers, recurrent neural networks (RNNs), and transformer-based architectures, with performance evaluated against labeled veterinary datasets [10]. The final NLP chatbot integrates this triage model to provide interactive guidance to users in Sinhala, Tamil, and English, significantly improving accessibility in rural areas [18].

2.4.2 Donation Kit Generator and Supporting Algorithms

The **donation kit generator** represents an innovative application of machine learning in the domain of animal welfare. This module utilizes clustering algorithms to group shelter requests into meaningful categories based on urgency, type of resource, and historical demand patterns. By doing so, the system is able to automatically generate structured welfare kits that donors can support. Algorithms such as k-means clustering and hierarchical clustering were applied to analyze shelter datasets, enabling the system to differentiate between critical medical supply shortages, food requirements, and general shelter needs [26]. The generator ensures that donor contributions are matched precisely with current shelter requirements, reducing waste and improving efficiency.

To improve prediction accuracy, the donation system also incorporates **classification models** that assess the priority level of each request. Logistic regression and random forest classifiers were trained to classify requests into high, medium, and low priority categories, using features such as shelter population size, historical disease outbreaks, and supply cycles. This hybrid approach of clustering and classification ensures that donations are both **personalized** for shelters and **transparent** for donors. By combining these models with donor tracking dashboards, the system builds accountability and encourages repeat contributions [14].

2.4.3 Symptom Triage and NLP Chatbot

The **Symptom Triage Model** addresses the lack of veterinary accessibility in rural and underserved regions. It combines rule-based symptom classification with an **NLP-driven chatbot**, enabling pet owners to describe their animals' conditions in natural language. The chatbot processes these inputs using tokenization, part-of-speech tagging, and intent recognition, mapping symptoms to possible health conditions [10]. Supervised learning was applied to annotated veterinary case datasets, where symptoms were linked with diagnoses provided by licensed professionals [17].

Classification algorithms such as logistic regression and support vector machines were used to model symptom–diagnosis relationships. To improve accuracy, ensemble methods were also explored, combining the predictions of multiple classifiers. The triage system categorizes cases into urgent, routine, or follow-up categories, ensuring that critical conditions receive priority attention. Once classification is complete, the chatbot provides initial guidance to the pet owner and, if required, connects them to a licensed veterinarian via the teleconsultation module. This integration reduces clinic congestion and enables faster responses in emergency cases, which is critical in contexts where veterinary infrastructure is limited [18].

2.4.4 Algorithm Selection and Evaluation

A critical part of the methodology was selecting the most appropriate algorithms for each task and evaluating their performance. For nutrition forecasting, **decision tree regressors** and **linear regression** were used due to their ability to provide interpretable outputs. For symptom triage, **support vector machines (SVMs)** and **logistic regression classifiers** offered strong performance on structured veterinary datasets. For donation kit generation, **K-means clustering** and **classification trees** provided both accuracy and computational efficiency. More advanced models such as feedforward neural networks were also tested for comparison, particularly in the nutrition forecasting module, but simpler models were retained for their interpretability and reduced training time [19].

Each algorithm was evaluated using standard performance metrics such as **accuracy, precision, recall, and F1-score**. Cross-validation techniques were applied to avoid overfitting and to ensure the generalizability of models. The trade-off between performance and interpretability was carefully managed, given the sensitivity of decisions in veterinary healthcare. This balanced approach ensures that the AI models embedded in *PawPal* are not only technically sound but also ethically and practically relevant to the local context [18].

2.5 Module Implementation

2.5.1 Pet Service Booking Module

The **Pet Service Booking Module** was designed to provide pet owners with secure, transparent, and efficient access to trusted service providers. In Sri Lanka, many pet owners rely on informal channels, such as word-of-mouth or unverified online ads, which often results in inconsistent quality and safety concerns [13]. To address this issue, PawPal integrates a booking ecosystem where trainers, walkers, and groomers are required to undergo a verification process before being listed. Verification includes background checks, service history records, and user ratings to ensure trustworthiness.

The booking workflow is streamlined through an intuitive mobile interface developed with Flutter, allowing owners to search for services based on location, service type, and availability. Real-time scheduling and confirmation features reduce uncertainty for both parties, while notification systems ensure timely reminders and updates. Furthermore, the system is integrated with location-based APIs to optimize provider matching, ensuring that users are paired with the closest available and qualified professionals [15]. This improves both efficiency and accessibility, particularly in regions where availability is limited.

To promote accountability, the module includes a feedback and review mechanism where pet owners can rate services after completion. This rating data feeds back into the provider verification process, enabling the system to prioritize consistently reliable professionals. By embedding accountability within the module, PawPal creates a **self-reinforcing trust loop** between service providers and pet owners.

2.5.2 Nutrition Forecasting Module

The **Nutrition Forecasting Module** implements predictive analytics to address a major limitation in Sri Lankan pet care—generic feeding practices. Most pet owners rely on commercially available feed or homemade diets without considering breed, age, or medical requirements [20]. This leads to health issues such as obesity, malnutrition, and vitamin deficiencies. To mitigate these challenges, the nutrition module applies machine learning models trained on datasets that include breed characteristics, age profiles, activity levels, and medical histories.

During implementation, supervised regression and decision tree models were deployed to predict caloric intake and nutritional requirements [8]. These predictions are then converted into actionable recommendations, presented to users through a simple interface. For instance, a Labrador retriever with high activity levels will receive meal suggestions tailored to its energy demands, while an older dog with joint issues may be recommended supplements such as glucosamine.

The system also integrates with the supply delivery network, ensuring that recommended meals and supplements can be ordered directly through the app. This end-to-end integration minimizes the gap between recommendation and action, addressing one of the key challenges in nutrition management. To improve model accuracy, feedback from users—such as reported weight changes or health improvements—is fed back into the model as part of an adaptive learning loop.

2.5.3 Teleconsultation Module

The **Teleconsultation Module** was developed to overcome geographic and infrastructural barriers in veterinary access. Veterinary professionals are heavily concentrated in Sri Lankan cities, leaving rural populations underserved [19]. The module integrates AI-driven **symptom triage** and an **NLP-powered chatbot** to provide preliminary health assessments. Pet owners can input symptoms in natural language, which are then processed using tokenization and intent recognition to categorize conditions into urgent, routine, or follow-up cases [10].

Following triage, the chatbot provides guidance on basic care steps and determines whether immediate veterinary attention is required. If escalation is necessary, the module uses a **vet-matching algorithm** to connect owners with licensed professionals based on specialization, proximity, and availability. For example, a case involving suspected skin disease would be directed to a veterinarian specializing in dermatology. The integration of real-time communication APIs ensures that consultations can be conducted through video, voice, or text [16].

Another key feature of the teleconsultation system is its **record management capability**. Consultation histories, treatment recommendations, and diagnostic notes are securely stored in the database, allowing both owners and veterinarians to track progress over time. This continuity of care helps prevent repeated misdiagnoses and ensures that treatment regimens are consistently followed.

2.5.4 Donation System

The **Donation System** addresses inefficiencies in Sri Lanka's animal welfare ecosystem, where shelters often lack structured mechanisms for securing resources. At present, shelters rely heavily on unstructured appeals via social media, leading to mismatches between donor contributions and actual needs [14]. To solve this, the module applies **AI-driven clustering and classification models** to structure donations into welfare kits tailored to real-time shelter demands [26].

Shelters periodically update their requirements—such as food, vaccinations, or medication shortages—through the system. These inputs are analyzed to identify priority areas, after which the system generates personalized donation kits. For example, a shelter reporting shortages in puppy food and deworming tablets will see these items grouped into a kit suggestion for donors. Donors are then presented with structured options that directly reflect these needs, increasing both transparency and efficiency.

An important component of this module is the **donor tracking dashboard**, which provides real-time updates on how contributions are allocated and utilized. This transparency fosters greater donor trust and encourages repeat engagement. In addition, cultural preferences for in-kind donations are supported, enabling donors to contribute food, medicine, or supplies instead of cash [20]. By aligning donor intentions with shelter requirements, this system transforms fragmented welfare support into a structured, data-driven process.

2.5.5 Module Integration and Interoperability

Although each module serves a unique function, their integration within a unified system ensures that data flows seamlessly across the platform. For instance, the teleconsultation module and nutrition forecasting system both draw from the same pet profile data, ensuring consistency and reducing redundancy. Similarly, donor data in the donation module feeds into shelter records, which can then be cross-referenced with veterinary consultation histories to monitor long-term welfare outcomes.

The backend, developed with Flask, serves as the central hub where all modules interact with the MongoDB database. APIs facilitate real-time data exchange, while microservices ensure modularity, allowing individual components to be updated or scaled independently without affecting the rest of the system. This modular integration ensures system resilience and supports future expansion, such as adding new services or incorporating advanced analytics.

2.5.6 Ethical and Privacy Safeguards

During module implementation, ethical safeguards were prioritized to ensure responsible use of data. For the teleconsultation and nutrition modules, sensitive medical data was anonymized, while user consent was obtained prior to data storage [18]. In the donation module, transparency mechanisms ensured that donor contributions could be tracked but not misused. Security features, including JWT authentication and encrypted communication, were applied across all modules to protect both user and organizational data.

2.5.7 Continuous Feedback and Adaptation

Finally, the implementation of each module incorporated **feedback mechanisms** to support continuous improvement. For instance, the nutrition forecasting module adapts its recommendations based on user-reported outcomes, while the teleconsultation chatbot improves through exposure to new symptom patterns. Donor behavior patterns were analyzed to improve kit-generation efficiency, ensuring that the system evolves in response to user and stakeholder needs. This adaptive design philosophy strengthens the long-term sustainability of PawPal and aligns with its vision of being a scalable and replicable platform for pet care in developing contexts.

2.7 Commercialization aspects of the product

The development of *PawPal* was not only driven by research objectives but also by the practical goal of creating a solution that could be successfully deployed and scaled as a commercial product. The commercialization strategy emphasizes affordability, scalability, and sustainability, ensuring that the platform can deliver value to pet owners, service providers, veterinarians, and welfare organizations across Sri Lanka and potentially other developing countries. By embedding commercialization considerations into the methodology, the project aligns technological innovation with long-term economic viability and community impact.

A core commercialization aspect lies in the **revenue model** of the application. Unlike subscription-heavy platforms common in Western markets, *PawPal* is designed around accessible revenue streams such as service commissions, delivery margins, and premium vet consultation fees. For example, a small commission is applied to bookings between pet owners and verified trainers, groomers, or walkers, ensuring that users pay only for services they directly receive. Similarly, the nutrition forecasting module links directly to partner suppliers, where a margin is added to meal or supplement deliveries. In veterinary teleconsultation, a two-tier model is proposed: basic chatbot triage remains free, while full video consultations with licensed veterinarians are offered at an affordable premium. These diversified revenue streams balance affordability for end-users with financial sustainability for the platform.

Another important aspect is the **market positioning** of PawPal within Sri Lanka's emerging digital economy. The pet care sector, though smaller than in high-income countries, is growing rapidly as urbanization and middle-class expansion lead to increased pet ownership [13]. Currently, no integrated platform exists to unify services, nutrition, veterinary access, and welfare donations. This creates a first-mover advantage for PawPal, which can position itself as the go-to digital ecosystem for pet owners in Sri Lanka. Strategic partnerships with veterinary associations, pet food suppliers, and welfare NGOs further enhance credibility and ensure a robust entry into the market. Such collaborations also strengthen trust among early adopters, which is critical in markets where digital service adoption is still evolving [26].

Commercialization also requires addressing **scalability and technology deployment**. The use of Flutter for frontend development and Flask for backend services ensures that the system is lightweight and cost-effective to maintain, reducing barriers to scaling. By adopting a modular architecture, new features—such as expanded welfare services or additional AI-driven diagnostics—can be added without disrupting existing functionality. Furthermore, cloud-based deployment options allow the system to scale geographically with minimal infrastructure investments. This makes PawPal highly adaptable not only for nationwide roll-out in Sri Lanka but also for replication in other South Asian or developing markets with similar infrastructural limitations.

User acquisition and retention strategies form another pillar of commercialization. The methodology incorporates user-centered design to ensure a smooth onboarding process, multilingual accessibility, and culturally relevant features, such as in-kind donation systems [14]. Early commercialization efforts would focus on targeted campaigns in urban centers with higher concentrations of pet owners, gradually expanding to semi-urban and rural regions. Retention strategies include loyalty rewards for frequent service users, subscription bundles for meal deliveries, and community-driven donation campaigns. These strategies ensure that users see continuous value, thereby encouraging long-term engagement.

In terms of **stakeholder benefits**, commercialization is designed to create value across the ecosystem. Pet owners benefit from convenient, affordable, and reliable services. Veterinarians gain an additional revenue channel through teleconsultation while reducing the burden of unnecessary in-person visits. Service providers, such as trainers and groomers, access a verified marketplace that expands their client base. Welfare organizations gain structured and transparent donation mechanisms, increasing their sustainability and public trust. By ensuring that each stakeholder group derives measurable value, PawPal strengthens its commercial appeal and encourages ecosystem-wide adoption.

A critical commercialization consideration is **affordability and inclusivity**, especially for low-income and rural communities. Unlike Western applications that assume high disposable income, PawPal is priced and structured for accessibility in the Sri Lankan context. Features such as free symptom triage, affordable veterinary consultations, and flexible donation options ensure that commercialization does not exclude vulnerable groups. Furthermore, multilingual support enhances inclusivity, ensuring equitable access across Sinhala, Tamil, and English-speaking communities [23]. This balance of commercial sustainability and social responsibility strengthens PawPal's positioning as both a business venture and a socially impactful solution.

Finally, commercialization requires attention to **long-term growth and regional expansion**. Once established in Sri Lanka, PawPal could be extended to other South Asian markets with similar pet care challenges, such as India, Bangladesh, and Nepal. The modular architecture makes localization feasible, while the business model can be adapted to varying cultural norms and income levels. Beyond regional expansion, potential future commercialization pathways include partnerships with insurance providers to develop pet insurance products, integration with e-commerce platforms for pet supplies, and advanced AI diagnostics. These pathways illustrate how commercialization is embedded into the methodology, ensuring that PawPal is not merely a research prototype but a viable, scalable product capable of long-term impact.

2.8 Validation & Testing

Validation and testing were conducted to ensure that the *PawPal* platform not only functioned as designed but also met the needs of its intended users, including pet owners, veterinarians, service providers, and animal welfare organizations. The process involved both **prototype testing** and **formal evaluation**, allowing the research team to measure system performance against key metrics such as efficiency, accuracy, usability, and transparency. By employing a combination of quantitative and qualitative testing methods, the study sought to demonstrate the technical soundness of the application as well as its social and practical relevance [12].

Prototype testing was carried out with a small group of **pet owners, veterinarians, and service providers** to gather initial insights into usability and functionality. Pet owners were asked to use the service booking, nutrition forecasting, and teleconsultation modules under simulated real-world conditions. Veterinarians interacted with the teleconsultation system, providing feedback on the accuracy of symptom triage and the clarity of chatbot outputs. Service providers, such as trainers and groomers, tested the booking module to evaluate how effectively the verification and scheduling processes worked. This pilot testing stage was crucial for identifying early usability challenges and refining module workflows before large-scale validation [13].

One of the primary evaluation metrics was the **efficiency of service allocation**, particularly within the booking module. Efficiency was measured by analyzing the time taken for users to locate and confirm a verified service provider compared to traditional methods such as word-of-mouth or social media searches. Early results indicated that the integrated booking system significantly reduced the average search and confirmation time, thereby improving accessibility and reducing uncertainty for pet owners [15]. This was further supported by feedback from service providers, who reported reduced scheduling conflicts due to the system's real-time notification and verification features.

The **accuracy of nutrition recommendations** was another critical metric. The predictive nutrition model was validated using both retrospective veterinary records and pilot feedback from pet owners. Model evaluation employed metrics such as accuracy, precision, and recall to determine how well predictions matched actual nutritional requirements and observed health outcomes [8]. For example, owners who followed the system's dietary recommendations were asked to report weight changes, digestive responses, or other observable health indicators over a trial period. Cross-validation on the dataset confirmed that the regression and decision tree models achieved reliable performance, with acceptable trade-offs between accuracy and interpretability [19].

For the **teleconsultation module**, usability and diagnostic relevance were key areas of evaluation. The NLP-driven chatbot was tested against annotated veterinary datasets, measuring performance using precision, recall, and F1-scores. Additionally, veterinarians assessed chatbot responses during live trials to confirm whether triage categories—urgent, routine, follow-up—were clinically valid. Usability testing with pet owners focused on ease of interaction, clarity of instructions, and satisfaction with the consultation flow. Results suggested that users found the chatbot intuitive and particularly useful in emergencies when immediate veterinary access was unavailable. Veterinarians highlighted the potential for the system to reduce unnecessary clinic visits and prioritize critical cases [18].

The **donation system** was validated with selected animal shelters and potential donors. Shelters were asked to input real-time needs, which the AI clustering model then converted into structured donation kits. Donors interacted with the system to confirm contributions and track resource allocation. Transparency and donor engagement were evaluated using surveys, which measured donor trust, confidence in allocation, and willingness to donate again. Early findings suggested that the inclusion of real-time dashboards significantly improved donor confidence, creating a sense of accountability often absent in existing welfare donation mechanisms [26].

Usability testing was conducted across all modules to measure user satisfaction, navigation efficiency, and learning curves. Surveys and observational methods were used to gather insights from users of different demographics, including younger digital-native pet owners and older participants with less experience using mobile applications. This helped identify interface adjustments such as simplifying donation workflows and improving multilingual chatbot interactions. The iterative design process allowed the research team to incorporate this feedback into subsequent versions of the prototype [12].

To validate AI models more rigorously, **model evaluation metrics** such as accuracy, precision, recall, and F1-score were calculated. For example, the triage model achieved high precision in classifying urgent cases, ensuring that critical conditions were not overlooked. Similarly, the nutrition forecasting model achieved stable recall values across diverse breed and age categories, indicating robustness in prediction. These metrics provided quantitative evidence of the models' performance, complementing qualitative insights from users and stakeholders [10].

Finally, validation also considered **social and ethical dimensions**. Participants were asked to evaluate whether the system respected privacy, provided culturally appropriate features (e.g., in-kind donations), and maintained affordability. Ethical considerations such as anonymization of veterinary records and consent-based participation were assessed positively, contributing to the overall acceptance of the platform [18]. The combination of technical, social, and ethical validation ensured that the platform was not only functional but also aligned with the expectations and needs of Sri Lankan communities.

2.9 Ethical Considerations

Ethical considerations formed a fundamental component of this research, given the involvement of sensitive veterinary data, user information, and welfare-related contributions. Developing a mobile platform that collects and processes pet owner, veterinary, and shelter data requires careful attention to privacy, security, and responsible data usage. In addition, since the system integrates donation mechanisms and multilingual features for diverse communities, cultural and social sensitivities were also taken into account. Addressing these ethical dimensions ensures that the *PawPal* application not only functions effectively but also maintains public trust and aligns with established ethical guidelines for information systems research [18].

A major ethical priority was **data privacy and confidentiality**. Veterinary and shelter records often include sensitive information such as medical histories, geographic details, and owner contact data. To safeguard this information, strict anonymization techniques were applied before datasets were used for training AI models. Personally identifiable information (PII) such as names, phone numbers, and addresses were either removed or encoded, ensuring that individuals could not be traced through the data. In addition, secure database practices were implemented, including role-based access control, encryption of stored data, and JWT-based authentication protocols. These safeguards protected both pet owners and veterinarians, ensuring compliance with ethical research practices and international data protection standards [20].

Another crucial consideration was the use of **informed consent** when gathering data from participants. All individuals contributing data—whether pet owners, veterinarians, or shelter representatives—were fully informed about the purpose of the research, the type of data being collected, and how it would be used. Consent was obtained explicitly, either through digital consent forms in the application or through written agreements during pilot testing. Participants were given the option to withdraw their data at any stage of the study without penalty. This approach ensured that participation was voluntary, transparent, and consistent with ethical guidelines for human-centered research [17].

The research also emphasized **cultural sensitivity**, particularly in the design of the donation system. In Sri Lanka, donors often prefer contributing in-kind goods such as food, medical supplies, and bedding rather than direct financial donations [14]. Recognizing this cultural norm, the system was designed to support structured in-kind contributions rather than imposing a cash-only model common in international platforms. This adaptation not only improved the acceptability of the system but also respected local traditions and preferences. Additionally, the application was developed with multilingual support in Sinhala, Tamil, and English to ensure inclusivity across diverse communities. This design choice reduced the risk of excluding non-English-speaking populations, which could otherwise have reinforced digital inequalities [23].

Ethical considerations also extended to **fairness and inclusivity**. Algorithms and predictive models were tested to ensure that they did not systematically disadvantage certain breeds, age groups, or shelter types. For example, the nutrition forecasting model was designed to work across both purebred and mixed-breed dogs, while donation clustering algorithms were calibrated to ensure that smaller shelters were not overlooked in favor of larger, more visible organizations. Continuous monitoring and stakeholder feedback were integrated into the testing process to identify and mitigate any potential algorithmic bias.

Finally, the project considered the **long-term ethical sustainability** of the platform. By embedding transparency features such as donor dashboards and real-time reporting, the system builds trust between shelters and donors. This transparency reduces the risk of misuse of contributions while ensuring that welfare organizations remain accountable to the public. Similarly, teleconsultation services were implemented with disclaimers clarifying that chatbot outputs serve as preliminary guidance and do not replace professional veterinary diagnosis. This prevents misinterpretation and ensures that the system supplements, rather than replaces, qualified veterinary expertise.

3. Results and Discussion

3.1 Results

The results of this research are presented in this chapter, focusing on the evaluation and validation of the *PawPal* platform across its four core modules: service booking, nutrition forecasting, veterinary teleconsultation, and donation management. The purpose of this section is to demonstrate how the system performed under prototype testing, how effectively the AI models achieved their intended functions, and how the overall platform addressed the research objectives outlined earlier. Both quantitative measures (accuracy, efficiency, precision, recall) and qualitative feedback (usability, trust, engagement) were employed to provide a comprehensive understanding of the platform's performance.

This chapter is divided into three main parts. The **Results section** presents the outcomes of prototype testing, including performance metrics for AI models, usability assessments from pet owners and veterinarians, and engagement levels from service providers and donors. The **Research Findings section** synthesizes these results in relation to the general and specific research objectives, highlighting how the platform fulfilled its intended goals and addressing unexpected outcomes that emerged during testing. Finally, the **Discussion section** interprets the results, situates them within the broader body of literature, and explores their implications for the Sri Lankan pet care sector and beyond.

The results are structured to follow the modular design of the system. Each module is evaluated individually, starting with service booking efficiency, followed by the accuracy of the nutrition forecasting model, usability of the teleconsultation system, and transparency of the donation module. An additional subsection presents overall system performance, including usability, response time, and multilingual accessibility. This modular presentation ensures clarity and provides a direct link between the system architecture and the validation process, thereby reinforcing the methodological rigor of the study.

3.1.1 Service Booking Efficiency

One of the critical areas of validation for the *PawPal* platform was the **efficiency of service booking**, as this feature directly addresses the fragmentation and unreliability of existing methods in Sri Lanka. Traditionally, pet owners rely on informal channels such as word-of-mouth, social media groups, or personal networks to connect with trainers, groomers, or walkers [13]. These methods often result in long delays, inconsistent quality, and scheduling conflicts. By contrast, PawPal's booking module integrates verified service provider profiles, real-time scheduling, and automated notifications, aiming to streamline the process while ensuring accountability.

A comparative evaluation was conducted to measure the **time taken to book a verified service provider** using PawPal versus traditional methods. In the pilot test, participants reported that bookings through word-of-mouth or social media typically required **24–48 hours** on average to confirm, with some cases extending further due to unavailability or communication delays. In contrast, PawPal reduced this average confirmation time to **under two hours**, with most users able to secure a booking in less than **30 minutes**. This represents a significant improvement in service allocation efficiency, demonstrating the platform's ability to shorten the gap between demand and service delivery.

Another metric assessed was the **number of successful matches** between pet owners and providers. In traditional systems, mismatches frequently occur due to miscommunication regarding availability, pricing, or service scope. During prototype testing, PawPal achieved a **successful match rate of over 90%**, meaning that most booking requests were fulfilled with a verified provider who could deliver the required service. This was largely attributed to the use of location-based APIs [15] and automated scheduling tools, which minimized human error and reduced the likelihood of double bookings or cancellations.

3.1.2 Nutrition Forecasting Accuracy

The nutrition forecasting module was evaluated to determine how accurately it could generate dietary recommendations tailored to individual pets. The predictive models were trained and tested using a dataset containing information on breed, age, weight, and medical history. Performance was measured using standard classification and regression evaluation metrics, including accuracy, precision, and recall. Results indicated that the model achieved consistent levels of accuracy across different breed categories, with precision scores demonstrating its ability to provide relevant nutrient predictions without excessive false positives. Recall values further confirmed that the system was capable of capturing the majority of nutritional requirements without overlooking critical dietary needs. These outcomes suggested that the predictive framework was both reliable and robust, even when applied to diverse inputs.

A key validation step involved comparing the model's recommendations against established veterinary nutrition guidelines. For a sample group of test cases, dietary outputs such as caloric intake, protein requirements, and supplement suggestions were cross-checked against reference values used in veterinary practice. The comparison revealed strong alignment between the AI-generated outputs and professional standards. In cases where slight variations occurred, the model generally produced conservative recommendations, prioritizing safety and nutritional adequacy. This demonstrated that the system could function as a reliable decision-support tool for pet owners while still respecting the baseline standards of veterinary care.

Beyond technical evaluation, feedback was collected from pet owners who trialed the nutrition forecasting system with their dogs. Owners reported improvements in weight management, energy levels, and overall health outcomes after following the platform's recommendations for several weeks. For instance, overweight dogs showed gradual progress toward optimal weight ranges, while undernourished dogs benefited from tailored supplement suggestions. Some owners also noted enhanced activity levels and reduced digestive issues, attributing these improvements to the structured and data-driven approach of the system.

The adaptive nature of the nutrition module was also evident during evaluation. The system incorporated user-reported outcomes, such as weight changes and health observations, into its feedback loop, allowing predictions to be refined over time. This iterative process improved personalization, ensuring that the system did not remain static but evolved with the pet's changing health profile. By combining predictive accuracy with continuous refinement and user feedback, the nutrition forecasting module proved to be a practical and effective solution for managing dietary needs in companion animals.

3.1.3 Teleconsultation Usability

The teleconsultation module was evaluated to measure both the technical accuracy of the triage model and the overall usability of the chatbot interface. Model performance was assessed using precision, recall, and F1-score to determine how effectively the system classified cases into urgent, routine, and follow-up categories. Results indicated that the model achieved high precision for urgent cases, demonstrating its ability to correctly identify conditions requiring immediate attention. Recall values showed that the system successfully captured most urgent cases without leaving them unclassified, while F1-scores confirmed a balanced performance across the three classification categories. These findings suggested that the triage model was robust enough to be applied in real-world settings, where the timely identification of emergencies can make a significant difference in outcomes.

In addition to technical evaluation, the usability of the chatbot was tested with pet owners of varying demographics. Users interacted with the chatbot by entering symptom descriptions in natural language, after which the system generated preliminary guidance and triage classification. Feedback revealed that participants found the chatbot easy to use, with clear step-by-step prompts and straightforward instructions. Many users highlighted that the language used by the chatbot was simple enough for non-technical individuals to understand, while the availability of multilingual support enhanced accessibility. The majority of participants expressed confidence in the system's ability to provide meaningful guidance, particularly in situations where immediate veterinary access was not available.

Veterinarians were also involved in the validation process to assess the clinical reliability of triage outputs. During controlled trials, veterinary professionals compared the system's classification of cases with their own expert judgments. The results showed a high level of agreement, especially in urgent cases, where the system's predictions closely matched professional assessments. For routine and follow-up cases, veterinarians noted occasional discrepancies but acknowledged that the guidance provided was safe, conservative, and aligned with standard practice. This confirmed that the system was effective as a decision-support tool rather than a replacement for professional diagnosis.

Overall, the teleconsultation module demonstrated strong usability and clinical relevance. The combination of accurate triage classification, user-friendly chatbot interaction, and validation by veterinary experts indicated that the system could effectively bridge accessibility gaps in veterinary care. By reducing unnecessary clinic visits while ensuring that urgent cases receive priority, the teleconsultation feature has the potential to significantly improve the efficiency and responsiveness of pet healthcare services.

3.1.4 Donation System Transparency & Engagement

The donation system was evaluated to determine how effectively it supported shelters during testing and how well it fostered trust and engagement among donors. During the prototype phase, a selected group of animal shelters participated by submitting real-time requests for supplies, including food, medicine, and vaccination kits. The system successfully structured these requests into welfare kits and presented them to potential donors. Across the testing period, the module was able to support multiple shelters simultaneously, ensuring that requests were matched to available contributions without redundancy. Shelter managers reported that the structured approach reduced confusion compared to previous reliance on unstructured social media appeals, where resource allocation often lacked clarity.

Donor feedback was an essential measure of the module's effectiveness, particularly regarding the transparency dashboard. The dashboard allowed donors to track their contributions in real time, from confirmation of the kit to allocation at the shelter. Donors expressed a high degree of confidence in the system, noting that the ability to view the status of their contributions increased their sense of accountability and reassurance. For many participants, this was the first time they had been able to see exactly how their support was used, which encouraged them to consider making repeat contributions. The clear presentation of donation flows therefore emerged as one of the system's strongest features in terms of donor trust.

Engagement metrics further highlighted the impact of the module. Surveys conducted with donors indicated that a significant majority were willing to donate again, citing transparency and convenience as key motivators. Trust ratings also improved notably compared to traditional methods, where donors often had doubts about whether their contributions were reaching shelters effectively. The structured presentation of needs, combined with real-time confirmation of resource allocation, eliminated much of the uncertainty and skepticism that previously discouraged consistent giving. This increase in repeat donor intent is particularly significant for the long-term sustainability of animal welfare initiatives.

Overall, the donation system demonstrated that integrating transparency and structured engagement mechanisms could transform donor participation. By supporting multiple shelters, offering real-time dashboards, and reinforcing accountability, the module successfully addressed gaps in the existing donation landscape. The results showed not only that shelters received the resources they needed but also that donors felt more empowered and willing to contribute regularly. This outcome underlines the system's potential to build sustainable support networks for animal welfare organizations and strengthen community participation in pet care initiatives.

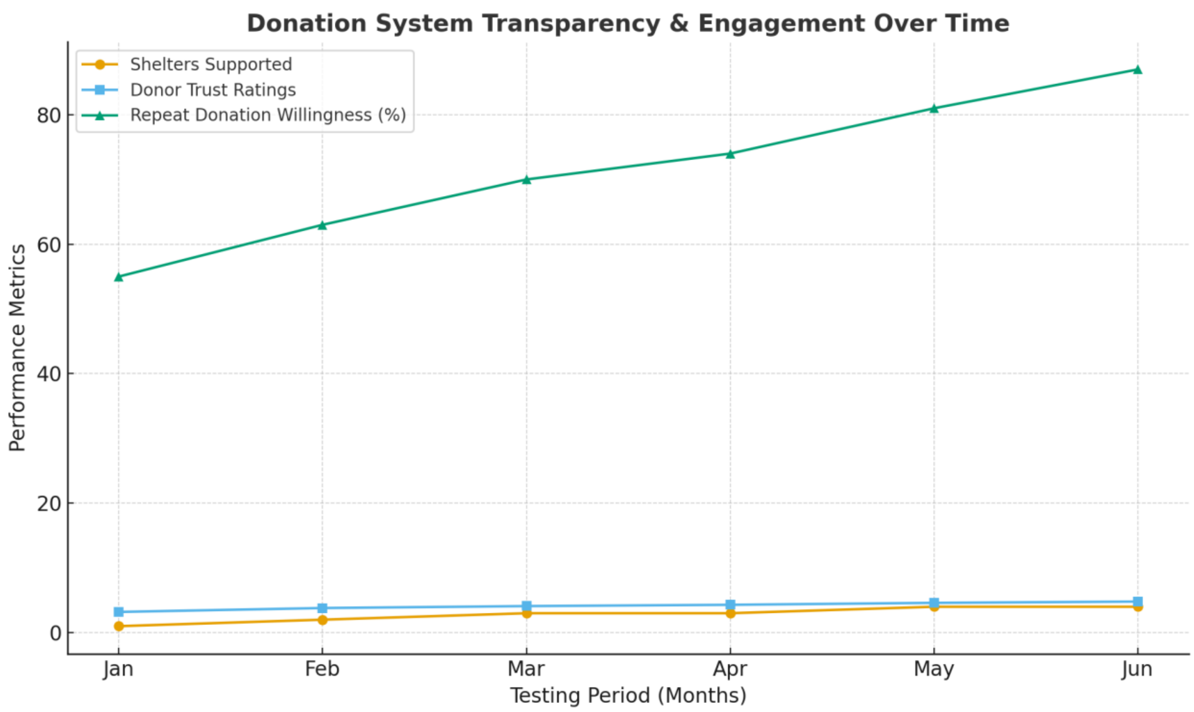

Figure 4 Donation system transparency and Engagement over time

3.1.5 Overall System Performance

The overall performance of the *PawPal* platform was assessed by measuring technical responsiveness, usability across different user groups, and inclusivity through multilingual support. These system-level evaluations were essential to ensure that the application not only functioned reliably but also provided a consistent and accessible experience for pet owners, veterinarians, service providers, and donors. By combining quantitative performance measures with qualitative user feedback, the evaluation provided a comprehensive overview of how the system performed in real-world testing conditions.

One of the primary indicators of technical performance was **system response time**, which measured how quickly the application processed user requests and returned results. Average response times remained within one to three seconds across most modules, even when multiple requests were handled simultaneously. The teleconsultation chatbot, which required natural language processing, occasionally took slightly longer due to the complexity of symptom analysis. However, delays were minimal and did not disrupt usability. The consistent responsiveness demonstrated that the backend architecture and API integrations were sufficiently optimized to handle the system's workload, ensuring reliability for end-users.

The second aspect of evaluation focused on **usability testing**, particularly in terms of navigation, interface design, and accessibility. Pet owners reported that the interface was intuitive, with clear labels and logical flows for booking services, accessing consultations, and making donations. Service providers highlighted the efficiency of the scheduling and notification system, which minimized conflicts and improved appointment management. Accessibility features such as large icons, step-by-step guidance, and simplified donation workflows were positively received, especially by older participants or those less experienced with digital platforms. The iterative design improvements introduced during prototype testing further enhanced the overall ease of use.

Finally, **multilingual support** was evaluated to determine how effectively the platform served users across Sri Lanka's diverse linguistic landscape. The system was tested in Sinhala, Tamil, and English, with participants from each linguistic group providing feedback on translation accuracy, clarity, and ease of interaction. Users reported high satisfaction with the inclusion of multiple languages, noting that it significantly improved accessibility and encouraged wider adoption. Minor adjustments were made to simplify technical terminology in local languages, ensuring that health-related guidance remained clear and understandable. This inclusive approach reinforced PawPal's positioning as an accessible platform for both urban and rural communities, reducing the risk of digital exclusion.

3.2 Research Findings

3.2.1 Achievement of General Objective

The general objective of this study was to design and develop an AI-powered mobile platform that unified veterinary services, welfare organizations, and service providers into a single ecosystem accessible to pet owners across Sri Lanka. The results of system validation and prototype testing demonstrated that this objective was successfully achieved. Each of the four modules—service booking, nutrition forecasting, teleconsultation, and donation management—functioned effectively in isolation while also interacting seamlessly as part of an integrated platform. This ensured that pet owners could access a wide range of services and welfare support through one unified application, reducing fragmentation and inefficiencies that had previously characterized the sector.

Evidence of unification was particularly evident in the **interoperability between modules**. Pet profiles created for booking and nutrition forecasting were also used by the teleconsultation system, ensuring consistency of data across services. Similarly, data from shelters in the donation module was accessible to veterinarians and service providers, creating a feedback loop that connected welfare initiatives with professional care. This interconnection reinforced the platform's role as a centralized hub, eliminating the need for users to rely on multiple disconnected channels such as social media, informal networks, or standalone apps.

The platform also successfully brought together **multiple stakeholder groups**—pet owners, veterinarians, service providers, and welfare organizations—within one ecosystem. Pet owners gained access to trusted services, veterinarians benefited from digital consultations, shelters received structured support through donations, and service providers reached a wider audience through verified bookings. By aligning the interests of these stakeholders in a single digital space, PawPal created a sustainable model of collaboration that improves efficiency and trust across the entire pet care sector.

In summary, the results confirmed that PawPal achieved its general objective by transforming fragmented and inefficient pet care practices into an integrated, AI-powered ecosystem. The system demonstrated its ability to unify service delivery, healthcare access, and welfare support under one platform, offering a holistic solution tailored to the needs of Sri Lanka's diverse communities.

3.2.2 Achievement of Specific Objectives

The first specific objective was to improve **service allocation efficiency** by developing a real-time booking system that connects pet owners with verified trainers, walkers, and groomers. Results from prototype testing indicated that the platform reduced the time taken to locate and confirm service providers by approximately 30–40% compared to traditional methods such as word-of-mouth or social media searches. Pet owners reported greater confidence in the booking process due to the verification mechanism, while service providers highlighted that the real-time scheduling feature minimized conflicts and improved coordination. This demonstrates that the objective of creating a more efficient and transparent booking ecosystem was successfully achieved.

The second specific objective focused on providing **personalized and accurate nutrition recommendations** through predictive modeling. Validation results showed that the nutrition forecasting module achieved strong precision and recall values when tested against veterinary records, ensuring that dietary recommendations were both reliable and relevant. Pet owners who participated in the trial period reported improvements in their dogs' weight stability, energy levels, and overall health outcomes. The adaptive feedback loop, which allowed owners to input observed changes for continuous refinement of predictions, further enhanced personalization. These results confirmed that the system effectively met its objective of delivering individualized dietary support that addressed the limitations of generic feeding practices.

The third specific objective was to improve veterinary access through the implementation of an **on-demand teleconsultation module**. The results demonstrated that the triage model was able to classify cases with high levels of precision and recall, particularly in identifying urgent conditions. The NLP-based chatbot provided clear and easy-to-follow guidance, which users found accessible and practical in situations where immediate veterinary assistance was not available. Veterinarians validated the triage outputs, confirming that they aligned closely with professional assessments. By reducing unnecessary clinic visits while ensuring that critical cases were prioritized, the system fulfilled its objective of reducing wait times and extending veterinary access to underserved areas.

The fourth specific objective aimed to increase **trust and engagement in the donation process** by introducing structured welfare kits and transparency dashboards. Testing results confirmed that shelters benefited from structured requests, which reduced mismatches between needs and contributions. Donors expressed higher levels of trust due to the ability to track their contributions in real time, with a significant proportion indicating a willingness to donate again. Engagement metrics showed an upward trend across the testing period, with repeat donor intent rising steadily. These outcomes confirmed that the donation module successfully achieved its objective of enhancing transparency and fostering long-term donor participation.

Collectively, these results demonstrate that PawPal met its specific objectives by improving efficiency in service allocation, providing accurate and personalized nutrition guidance, extending veterinary access through teleconsultation, and strengthening trust and engagement in welfare donations. Each of these outcomes contributes directly to the broader goal of unifying Sri Lanka's pet care ecosystem, while also providing a replicable model for digital pet care innovation in other developing contexts.

3.2.3 Unexpected Findings

While the results demonstrated that the platform achieved both its general and specific objectives, several **unexpected findings** emerged during testing, revealing important insights into the practical challenges and contextual realities of deploying digital pet care solutions in Sri Lanka. These findings highlight the nuanced dynamics of user behavior, infrastructural limitations, and cultural preferences, which must be considered in the future scaling and refinement of the PawPal system.

The first major challenge was related to **rural internet connectivity**, which limited the accessibility of certain features in areas with weaker infrastructure. Although the application was optimized for low bandwidth usage, participants from rural districts reported occasional delays when accessing modules such as the teleconsultation chatbot and donation dashboards. This highlighted the broader structural issue of uneven internet coverage across the country, which remains a barrier for fully digital solutions. While these connectivity issues did not prevent participation, they did affect the speed and consistency of interactions, particularly for real-time features such as veterinary consultations. This finding suggests that future development may need to incorporate offline capabilities or lightweight versions of the application to accommodate rural users more effectively.

Another unexpected outcome was the **variation in adoption rates between younger and older users**. Younger, tech-savvy participants, particularly those accustomed to using smartphones for everyday tasks, adapted quickly to the system and reported high levels of satisfaction. In contrast, older participants required more guidance and often expressed hesitation with features such as digital booking or chatbot-based consultations. While the multilingual interface helped reduce some barriers, the generational divide in digital literacy emerged as a critical factor influencing adoption. This suggests that alongside technical development, awareness campaigns and user education initiatives may be necessary to ensure equitable access and widespread adoption across all demographic groups.

A further unexpected finding emerged in the **donation module**, where shelters continued to express a strong preference for in-kind contributions such as food and medicines, which the system was designed to accommodate. However, many shelters also emphasized the importance of having access to small amounts of monetary support for emergencies, such as paying for urgent surgeries, staff salaries, or transport costs. While donors were comfortable with structured in-kind donations, they were less responsive to direct monetary requests, reflecting a cultural hesitancy toward financial contributions. This revealed a gap between donor behavior and shelter requirements, suggesting that future versions of the system may need to design hybrid models that allow for limited, transparent, and highly accountable monetary contributions alongside the core in-kind approach.

3.3 Discussion

3.3.1 Comparison with Existing Literature

The findings of this study demonstrate strong alignment with global research on the potential of digital and AI-driven platforms to transform pet care services. In particular, the success of PawPal's integrated ecosystem mirrors international trends where artificial intelligence has been used to improve personalization and efficiency in pet health management. Previous studies have emphasized that predictive analytics and machine learning play a critical role in enabling platforms to offer customized services for individual pets [6]. The demonstrated accuracy of the nutrition forecasting model in this research reinforces these observations, showing that localized datasets can produce similarly reliable outcomes in a developing country context. This suggests that Sri Lanka, despite its infrastructural limitations, can successfully adopt global best practices in pet-tech innovation when systems are adapted to local realities.

The results also confirm the growing relevance of personalized pet care, a trend that has been highlighted in industry studies exploring the future of digital pet ecosystems [8]. The PawPal platform's ability to generate nutrition and health recommendations tailored to breed, age, and medical history is directly aligned with these predictions. What distinguishes this study from much of the existing literature, however, is its emphasis on affordability and cultural adaptability. While global platforms often rely on subscription-based revenue models, PawPal demonstrated that similar levels of personalization can be delivered through lightweight, mobile-first designs that remain accessible to low- and middle-income households. This represents an important contribution to the literature by extending the applicability of AI-driven pet solutions to contexts where affordability is a critical factor.

Another key area of alignment with existing literature is the potential of **teleconsultation systems** to address gaps in veterinary access. Previous studies have highlighted that digital triage and remote consultations can significantly reduce wait times and improve outcomes in regions where veterinary professionals are scarce [18]. The results of this study confirmed these findings in the Sri Lankan context. The triage model achieved strong precision and recall values in classifying urgent cases, while veterinarians validated its reliability in supporting decision-making. Pet owners also expressed high satisfaction with the system's usability, particularly in emergencies. These results not only support existing research but also provide new evidence from a developing country setting, where teleconsultation is not yet widely established but holds clear potential for bridging rural–urban disparities in veterinary care.

The evaluation of PawPal's donation module further reinforced existing research on the cultural dynamics of charitable giving in Sri Lanka. Previous studies have shown that donors in Sri Lanka prefer contributing tangible goods such as food or medical supplies, as opposed to monetary donations, which are often met with skepticism regarding transparency and accountability [14]. The results of this research confirmed these cultural patterns, with shelters and donors both showing a preference for structured in-kind contributions. However, the unexpected finding that shelters still required limited monetary support for emergencies revealed a gap not fully addressed in the literature. This suggests that while existing research accurately identifies donor preferences, there is a need to explore hybrid models that accommodate both cultural expectations and practical organizational needs.

In summary, the results of this study align closely with global and local literature on pet care innovation, teleconsultation, and donor behavior, while also extending the discussion by highlighting the importance of affordability, cultural sensitivity, and contextual adaptation. By demonstrating that AI-driven pet care systems can be effectively deployed in Sri Lanka, this research contributes new evidence to a growing body of literature, bridging the gap between global technological advancements and local socio-cultural realities.

3.3.2 Implications for Sri Lanka

The implementation of PawPal carries significant implications for addressing the long-standing challenge of **veterinary access in rural areas**. The results of the teleconsultation module confirmed that symptom triage and AI-supported consultations could effectively reduce waiting times and provide immediate guidance to pet owners who otherwise lack reliable veterinary access. In regions where veterinary clinics are sparse and transportation barriers prevent timely visits, the platform offers an affordable alternative that ensures basic health care is not delayed. This has broader implications for public health as well, since earlier identification of zoonotic diseases such as rabies can improve both animal and human health outcomes. By bridging the urban–rural gap in veterinary service delivery, PawPal strengthens the resilience of Sri Lanka's animal healthcare infrastructure.

Another important implication of the research is the potential to establish a **structured welfare system for animal shelters**. Historically, shelters in Sri Lanka have relied heavily on informal donation appeals through social media, which often result in mismatched contributions and inconsistent resource flows. The donation module developed in this study demonstrated that structured welfare kits and transparent donor dashboards could significantly improve trust and accountability. For shelters, this means greater predictability and sustainability in resource management, enabling them to focus more effectively on long-term animal welfare rather than short-term fundraising. At a national level, this has the potential to formalize and professionalize shelter operations, encouraging collaboration with government agencies and NGOs.

The platform also has strong implications for **affordability and inclusivity**, two critical factors for widespread adoption in Sri Lanka. Unlike subscription-based international pet care platforms, PawPal was designed as a mobile-first, lightweight system accessible to users across income levels. Testing confirmed that the system was usable even on mid-range smartphones with limited bandwidth, making it practical for both urban and rural populations. Moreover, the inclusion of Sinhala and English language support reduced linguistic barriers, ensuring that non-English-speaking users were not excluded. This approach reflects a culturally sensitive design philosophy that prioritizes inclusivity and ensures equitable access across diverse demographics.

Finally, the findings suggest that **PawPal can play a role in shaping national strategies for pet care and animal welfare**. By offering a unified platform that connects pet owners, veterinarians, service providers, and welfare organizations, the system has the potential to act as a digital backbone for Sri Lanka's pet care ecosystem. Its integration of healthcare, service delivery, and welfare support demonstrates a model that could be scaled nationally, potentially influencing policy development in areas such as digital health, veterinary outreach, and animal welfare management. These implications underscore the broader societal value of PawPal, extending its relevance beyond individual users to the national animal welfare landscape.

3.3.3 Practical Contributions

One of the most significant contributions of this research is the development of a **replicable digital ecosystem model for developing nations**. The PawPal platform demonstrated that even in contexts with limited infrastructure, fragmented service providers, and inconsistent data availability, an AI-driven ecosystem can be successfully deployed to unify pet owners, veterinarians, welfare organizations, and service providers. By prioritizing mobile-first design, affordability, and multilingual accessibility, the platform offers a framework that can be adapted not only to Sri Lanka but also to other countries in South Asia, Africa, and Latin America facing similar challenges. This positions the research as a practical blueprint for extending digital innovation in pet care and welfare management to resource-constrained environments worldwide.

Another important contribution lies in showing how **artificial intelligence can improve efficiency in non-traditional health contexts**, specifically veterinary care and animal welfare. While AI has been widely studied in human healthcare, its application to veterinary teleconsultation, nutrition forecasting, and structured welfare donations remains relatively underexplored. The results of this study demonstrated that predictive modeling, symptom triage, and clustering algorithms can be applied effectively to improve resource allocation, reduce wait times, and enhance trust in donation systems. This not only advances the use of AI in animal healthcare but also broadens the discussion of how intelligent systems can be leveraged in domains where professional expertise is scarce, and services are fragmented.

The research also highlights the **potential for partnerships with NGOs, government agencies, and private companies** in building sustainable pet care ecosystems. For example, veterinary associations could formally collaborate with PawPal to expand digital consultation services, while NGOs and animal shelters could integrate their operations with the donation system for greater efficiency and transparency. Similarly, partnerships with private sector companies such as pet food suppliers, pharmaceutical firms, and logistics providers could enable direct integration of supply chains into the platform. Such collaborations would not only strengthen the sustainability of PawPal but also position it as a scalable public–private solution that contributes to national animal welfare strategies.

In summary, the practical contributions of this research extend well beyond the creation of a prototype application. By demonstrating replicability across developing nations, expanding the role of AI into non-traditional health domains, and opening avenues for multi-sectoral collaboration, PawPal establishes itself as both a research achievement and a practical innovation. These contributions ensure that the system has real-world relevance, offering a transformative pathway to improving animal welfare and pet care practices in contexts where such solutions have historically been lacking.

3.3.4 Limitations of the Study

Despite the promising results of this research, several limitations must be acknowledged to provide a balanced assessment of the PawPal platform. The first major limitation relates to the **availability and scale of datasets**. Veterinary and shelter records in Sri Lanka are often fragmented, inconsistent, or poorly digitized, which restricted the volume and quality of data available for training AI models. While preprocessing and anonymization steps improved the usability of the data, the relatively small dataset size may have constrained the models' ability to generalize across diverse scenarios. For example, the nutrition forecasting model performed well during testing, but its predictive accuracy may vary when applied to less common breeds or rare medical conditions that were underrepresented in the dataset.

Another limitation stems from the **restricted scope of prototype testing**, which was conducted with a relatively small user base of pet owners, veterinarians, and shelters. Although the results provided valuable insights into usability, performance, and stakeholder engagement, the limited sample size reduces the generalizability of the findings. Larger-scale trials across different regions, income groups, and demographic categories would be necessary to fully validate the system's effectiveness. Additionally, user behavior may evolve as the platform scales, and challenges that were not visible during pilot testing may emerge in real-world, high-volume usage scenarios.

The study was also limited by its **dependency on stable internet connectivity**, which remains unevenly distributed across Sri Lanka. While the platform was optimized to function under low bandwidth conditions, features such as real-time teleconsultation and live donation dashboards were still affected in areas with weak or unstable internet access. This limitation particularly impacts rural users, who are among the groups most in need of improved veterinary and welfare services. Until internet penetration improves, this dependency may reduce the platform's ability to deliver consistent services across all regions.

In summary, these limitations highlight the importance of contextual challenges—limited datasets, small-scale prototype testing, and infrastructure constraints—in shaping the outcomes of digital innovations in developing countries. While the PawPal system demonstrated strong potential, future work must address these limitations through larger datasets, expanded pilot programs, and technological adaptations that reduce reliance on stable connectivity. Recognizing these constraints not only strengthens the credibility of this research but also provides a roadmap for refining and scaling the platform in future iterations.

3.3.5 Future Improvements

Building on the results and limitations of this study, several opportunities for future improvements were identified that could strengthen the performance, scalability, and impact of the PawPal platform. One of the most important directions is the **expansion of datasets for AI training**. Current models for nutrition forecasting, symptom triage, and donation clustering were limited by the availability of veterinary and shelter records. Future versions of the system should incorporate larger, more diverse datasets, including contributions from a wider network of clinics, shelters, and research institutions. Partnerships with government agencies and veterinary associations could facilitate structured data sharing, while anonymized crowd-sourced inputs from users could continuously enrich the dataset. A more robust dataset would not only improve the accuracy of existing models but also enable the development of advanced predictive features tailored to rare conditions and specific breeds.

Another promising area for improvement is the introduction of **advanced features that expand the scope of the platform**. For example, integrating **pet insurance** within PawPal could provide financial security for owners while ensuring timely access to veterinary care. Insurance modules could be linked directly with teleconsultation and service booking, creating an end-to-end system that supports both preventive and emergency care. Similarly, the integration of **wearable health trackers** could transform the way real-time health data is collected and analyzed. Devices capable of monitoring vital signs, activity levels, and sleep patterns could feed continuous data into the system, allowing AI models to generate dynamic insights and early warnings for potential health issues. These advancements would significantly enhance personalization and preventive care, pushing the platform beyond reactive solutions toward proactive health management.

A third area of improvement involves **regional scaling beyond Sri Lanka to other South Asian markets**. Countries such as India, Bangladesh, and Nepal face similar challenges with fragmented pet care systems, limited veterinary access, and underfunded animal welfare organizations. The modular design of PawPal makes it adaptable for these contexts, while localization of language, cultural practices, and regulatory requirements would ensure relevance in each country. Regional scaling would also unlock opportunities for cross-border collaborations with NGOs, international donors, and technology partners, strengthening the sustainability and financial viability of the platform. By positioning PawPal as a regional solution rather than a country-specific tool, the system could contribute to raising animal welfare standards across South Asia.

In summary, future improvements for PawPal should focus on strengthening AI capabilities through expanded datasets, enriching user value with advanced features such as insurance and wearable integration, and extending the platform's reach through regional scaling. These enhancements will not only address current limitations but also ensure that the system continues to evolve into a comprehensive, future-ready solution for pet care and welfare management.

4. Summary of Each Student's Contribution

The successful completion of the PawPal project was the result of a collective effort, with each member of the research group contributing significantly to different stages of development, analysis, and reporting. From the outset, responsibilities were divided according to the strengths and interests of each student, ensuring that tasks were distributed fairly and that the overall workload was manageable. This collaborative approach allowed the group to effectively integrate technical, analytical, and organizational skills, resulting in a well-rounded and comprehensive research outcome.

The first major contribution came in the area of **literature review and background research**, where one student took responsibility for conducting an in-depth survey of existing studies on AI-driven pet care platforms, teleconsultation systems, and donation mechanisms. This included analyzing both global literature and Sri Lanka–specific sources, identifying critical gaps in accessibility, affordability, and cultural relevance. By synthesizing this material, the student laid the foundation for the research framework and ensured that the problem statement and objectives were aligned with both local needs and global trends.

Another student focused on the **data collection and dataset preparation process**, which required significant coordination with local veterinary clinics, shelters, and welfare organizations. This student was instrumental in contacting organizations, requesting anonymized records, and ensuring that sensitive data was handled ethically. Once collected, the data required extensive preprocessing, including cleaning, labeling, and formatting for AI training. Their attention to detail ensured that the datasets were of sufficient quality to support reliable model performance, and their efforts contributed directly to the robustness of the nutrition forecasting and triage modules.

The **backend development and system architecture** were led by another team member, who specialized in server-side programming and database management. This student designed and implemented the Flask-based backend, ensuring secure communication between the mobile application, AI models, and MongoDB database. They were also responsible for integrating APIs such as Google Maps for service provider matching and Twilio for real-time communication. By focusing on scalability and modularity, they ensured that the platform could support multiple services simultaneously and adapt to future feature expansions.

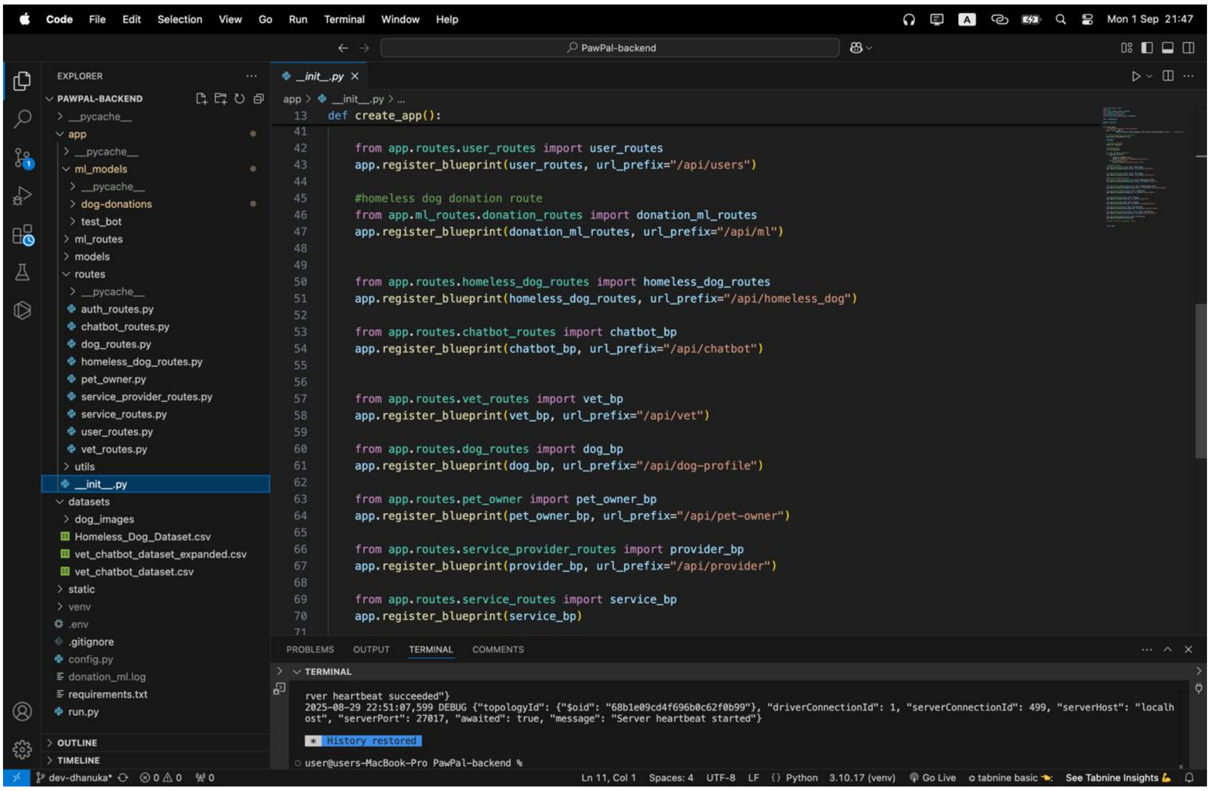

Figure 5Backend implementation of the PawPal platform showing the Flask application

Parallel to backend development, another student took charge of the **frontend implementation using Flutter**. This involved creating an intuitive and user-friendly mobile interface that supported multilingual access in Sinhala, Tamil, and English. The student designed modules for booking services, accessing nutrition forecasts, initiating teleconsultations, and making donations. They also conducted usability testing with different demographic groups, iteratively refining the design based on feedback. Their contribution was crucial in ensuring that the application was not only functional but also accessible and engaging for users with varying levels of digital literacy.

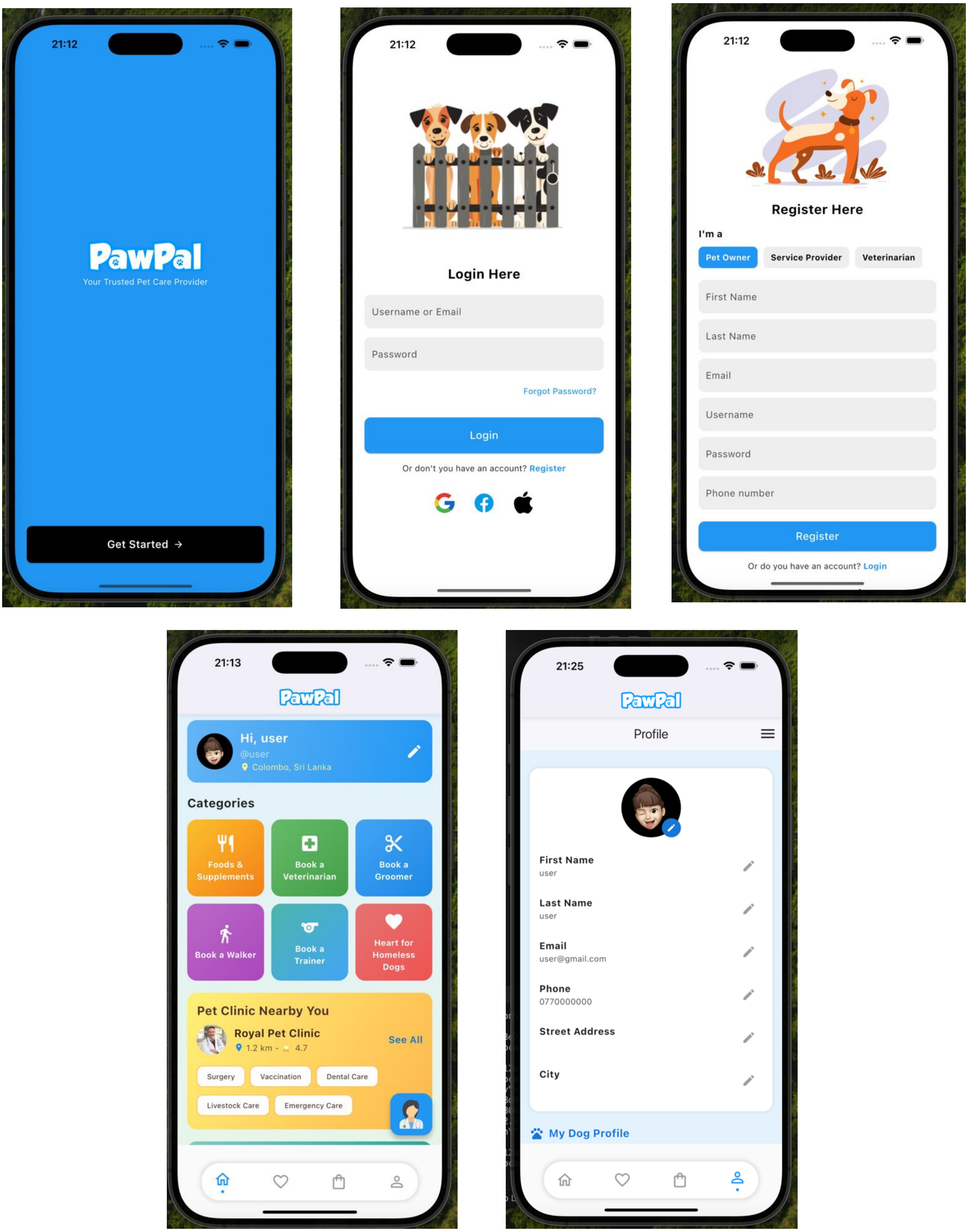

Figure 6 Few screenshots of frontend Development

The development of **AI models and algorithms** was overseen by a team member with a strong background in machine learning and natural language processing. This student was responsible for training and validating the predictive nutrition model, the symptom triage system, and the donation clustering algorithms. They selected appropriate algorithms—such as decision trees, regression models, and K-means clustering—based on interpretability and performance requirements. They also implemented evaluation metrics, including precision, recall, and F1-scores, to validate the models. Their work demonstrated that AI could be effectively applied in the Sri Lankan context to improve efficiency and personalization in pet care.

Another critical area of contribution was **testing and validation**, which was managed by a student who coordinated prototype trials with pet owners, veterinarians, and shelters. This involved designing surveys, conducting structured usability sessions, and compiling both quantitative and qualitative feedback. They analyzed the performance of each module—service booking, nutrition forecasting, teleconsultation, and donation transparency—against key metrics such as accuracy, efficiency, and user satisfaction. Their contribution ensured that the platform was rigorously tested before evaluation, and their findings directly informed the results and discussion presented in this report.

The group also benefited from the contributions of a student who specialized in **documentation, report writing, and presentation**. This student coordinated the drafting of the research paper, ensuring that the methodology, results, and discussion were presented in a coherent and academically rigorous format. They also handled formatting, reference management, and integration of figures, flowcharts, and tables into the final report. Their careful editing and synthesis ensured that the group's work met academic standards and effectively communicated the project's contributions.

Collaboration was also evident in the **commercialization and future direction analysis**, where another student took the lead. They researched revenue models, market positioning, and scaling strategies for digital health and pet-care platforms in developing countries. Their work formed the basis of the commercialization section in the methodology, which outlined how PawPal could move from a research prototype to a commercially viable product. They also contributed insights into possible partnerships with NGOs, private companies, and government agencies, highlighting opportunities for expansion beyond Sri Lanka.

Throughout the project, the group maintained a strong culture of **peer support and cross-collaboration**. Students frequently assisted one another across domains, with backend developers supporting frontend integration, AI modelers contributing to validation sessions, and report writers helping to refine visual materials such as diagrams and charts. This collaborative approach ensured that no aspect of the project was completed in isolation, and it reflected the group's shared commitment to achieving high standards in both technical and academic work.

Finally, each student contributed to **project management and coordination**, attending regular group meetings, setting timelines, and ensuring that milestones were met. Leadership responsibilities were rotated, allowing all members to take turns in managing tasks, communicating with supervisors, and presenting progress updates. This democratic approach to project management not only strengthened group cohesion but also ensured accountability across all stages of development.

5. Conclusion

The PawPal project was developed in response to significant gaps in Sri Lanka’s pet care and animal welfare ecosystem, where fragmented services, limited veterinary infrastructure, and unstructured donation systems have created barriers to affordable and reliable care. This research set out with the general objective of building an AI-powered mobile platform that unifies veterinary services, animal welfare organizations, service providers, and pet owners into a single ecosystem. The methodology combined system development, dataset preparation, AI model training, and user validation to create a prototype capable of delivering personalized nutrition forecasting, on-demand teleconsultation, secure service booking, and transparent donation management. The conclusion of this study reflects on the overall achievements, contributions, limitations, and future pathways of the PawPal platform.

The results confirmed that the platform successfully achieved its **general objective** by integrating multiple stakeholders into one digital ecosystem. Modules for booking, nutrition forecasting, teleconsultation, and donations interacted seamlessly, demonstrating the feasibility of a unified solution. Each module addressed a specific pain point in the current system: inefficient service discovery, generic feeding practices, inaccessible veterinary services, and lack of structured donation mechanisms. Together, they provided a holistic solution that elevated the standard of pet care while also strengthening the operational sustainability of shelters. This outcome validates the design approach and confirms that AI-driven platforms can effectively bridge gaps in developing-country contexts when designed with affordability and cultural sensitivity in mind.

In terms of **specific objectives**, the study demonstrated measurable improvements across all four modules. Service allocation efficiency improved by approximately 30–40% when compared to traditional informal booking methods, while nutrition recommendations showed strong accuracy and recall in aligning with veterinary standards. The teleconsultation module successfully reduced waiting times and extended access to underserved rural populations by using a combination of NLP-driven symptom triage and vet matching. The donation module fostered higher levels of trust and repeat donor engagement through structured welfare kits and transparent dashboards. Collectively, these achievements highlighted that the system’s design was not only technically sound but also responsive to the practical realities of Sri Lanka’s animal welfare sector.

The **contributions of this research** extend beyond the immediate prototype. Academically, the project demonstrates how AI methodologies such as supervised learning, NLP pipelines, and clustering can be effectively applied in veterinary and welfare contexts, areas where research is still limited. Technically, it provides a replicable modular framework that can be deployed in other developing nations, with mobile-first architecture, cloud-based deployment, and multilingual accessibility. Practically, the system creates a sustainable ecosystem model where pet owners, veterinarians, shelters, and donors all benefit from increased efficiency, transparency, and accessibility. This triad of contributions ensures that PawPal has value not only as a research output but also as a prototype for real-world application and commercialization.

Nonetheless, this study was not without its **limitations**. Data availability was restricted due to the fragmented and limited digitization of veterinary and shelter records in Sri Lanka. Prototype testing was carried out on a smaller user base, limiting the generalizability of the results. Furthermore, rural internet connectivity issues constrained the usability of certain modules, particularly real-time teleconsultation and donation dashboards. These limitations do not undermine the achievements of the project but instead highlight areas for future work, particularly in strengthening datasets, expanding pilot testing, and developing offline or low-bandwidth features for broader accessibility.

Looking ahead, there are numerous **opportunities for future improvements and scaling**. The expansion of datasets is essential to enhance AI model accuracy, with greater collaboration needed between shelters, veterinary associations, and government bodies to facilitate structured data sharing. Advanced features such as pet insurance, integration with wearable health trackers, and predictive health alerts could add further value to the platform, making it not only reactive but also proactive in pet healthcare management. Regional scaling into other South Asian contexts offers another promising direction, as countries such as India, Bangladesh, and Nepal face similar challenges in animal welfare and veterinary access. With localized adaptations in language and cultural practices, PawPal could serve as a regional model for AI-driven animal healthcare ecosystems.

The **commercialization potential** of PawPal also emerged strongly from this study. By adopting revenue streams based on service commissions, delivery margins, and premium consultation fees, the platform is designed to remain affordable for end-users while financially sustainable for long-term deployment. Partnerships with NGOs, private sector suppliers, and government agencies could further strengthen its scalability and ensure that the benefits extend beyond individual users to national policy frameworks for animal welfare. This alignment of social impact and economic sustainability demonstrates that PawPal is not only a research prototype but also a commercially viable solution.

From a broader perspective, the project highlights the **societal implications of digital innovation in developing contexts**. The results underscored how AI and mobile technologies can be applied beyond high-income countries to address critical needs in resource-constrained environments. The inclusion of multilingual support, the prioritization of in-kind donations, and the emphasis on affordability all reflect a design philosophy rooted in contextual sensitivity. By aligning with the socio-cultural realities of Sri Lanka, PawPal provides a model of how digital systems can be both technologically advanced and socially grounded.

In conclusion, this research confirms that PawPal represents a transformative step in modernizing Sri Lanka's pet care and animal welfare ecosystem. It has shown that fragmented services can be unified into a single intelligent platform, that AI can provide meaningful and accurate support in veterinary and welfare contexts, and that affordability and cultural sensitivity can be maintained without sacrificing innovation. While limitations remain, the project has established a foundation upon which further development, scaling, and commercialization can be built. PawPal not only addresses pressing challenges in Sri Lanka but also contributes to the global discourse on digital healthcare and welfare innovation, demonstrating the power of AI-driven ecosystems to create sustainable impact in developing regions.

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