Bachelor of Science Thesis

IoT-Based Real-Time Bus Tracking and ETA System for Public Transportation in Cyprus

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Internet of Things Based Real-Time Bus Tracking and Estimated Time of Arrival System for Public Transportation in Cyprus

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Abstract

This thesis presents the design, development, and evaluation of **Track Cyprus Busses**, a real-time public transportation tracking application developed for Android. The system aims to improve the commuter experience in Cyprus by providing users with accurate Estimated Time of Arrival (ETA) information, live bus tracking, and route visualization through a user-friendly mobile interface. Leveraging Internet of Things (IoT) principles, the application integrates real-time GPS data from external sources, cloud-based data management using Firebase Firestore, and route calculations via the Google Maps Directions API.

The backend architecture supports continuous synchronization between live data streams and the mobile frontend, allowing users to view up-to-date vehicle positions and plan their trips more effectively. Static transport data, such as routes and stops, are combined with dynamic bus location updates to deliver a comprehensive transit experience.

A user evaluation was conducted based on the USE (Usefulness, Satisfaction, and Ease of Use) framework, gathering both quantitative and qualitative feedback from 22 participants. The results indicate strong usability, high satisfaction, and positive reception of core features such as ETA accuracy and map interaction.

The project addresses a critical gap in Cyprus's public transportation ecosystem by offering a scalable, IoT-driven solution for real-time transit monitoring. The thesis concludes with a discussion of system limitations and proposes several directions for future enhancements, including predictive ETA modeling, crowdsourced occupancy data, and expanded platform support.

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Chapter 1

Introduction

1.1 Motivation

Efficient public transportation is a cornerstone of sustainable urban development, significantly impacting economic growth, environmental sustainability, and quality of life [1]. However, despite ongoing efforts to modernize public mobility systems, real-time information regarding bus arrivals remains limited in many regions, including Cyprus. Traditional methods such as printed schedules or static online timetables often fail to account for real-world variables like traffic congestion, unexpected delays, or route changes, resulting in increased uncertainty for passengers.

The emergence of Internet of Things (IoT) technologies, combined with open transport data, presents new opportunities for enhancing the public transportation experience. By leveraging real-time bus location data, cloud computing, and mobile applications, it becomes possible to deliver timely, accurate, and user-centered information directly to the user [2]. Although smart mobility solutions are gaining momentum globally, Cyprus has yet to adopt an accessible platform that offers live bus tracking and Estimated Time of Arrival (ETA) predictions at a user-friendly level.

This thesis addresses that gap through the development of **Track Cyprus Busses**, a mobile application that enables users to search for specific bus routes, visualize the real-time location of active buses, and receive accurate ETA updates based on their selected stops. The system integrates Firebase Firestore for live data management, Google Maps API for route mapping and ETA calculations, and Cyprus's open transport datasets to ensure data relevance and accessibility.

Given the rapid urbanization trends, the dynamic nature of urban traffic, and the global push toward smart city frameworks, the demand for reliable, real-time public transport applications is more critical than ever [3]. This research aims to contribute to the digital transformation of Cyprus's public transit ecosystem, enhancing commuter satisfaction, improving travel efficiency, and promoting more sustainable urban mobility behaviors.

1.2 Problems/Challenges

The development of a real-time bus tracking mobile application presented several technical and infrastructural challenges. One of the primary difficulties involved the management of dynamic, real-time data, particularly in ensuring the continuous and reliable update of bus locations within the mobile application [4]. Given that the system relies on frequent location updates from the Firestore database, network instability or delays can cause inconsistencies in displaying the bus's actual position, potentially affecting user trust in the application.

Another significant challenge relates to the accuracy of Estimated Time of Arrival (ETA) calculations. While the Google Maps API offers advanced routing and traffic data, sudden traffic jams, road closures, or irregular bus driver behavior can introduce unpredictable variations, leading to miss matches between the estimated and actual arrival times [5]. Ensuring the system's responsiveness to such anomalies requires continuous fine-tuning and frequent data refreshes.

Furthermore, integrating diverse datasets from Cyprus's open transport data sources and the bus info API posed interoperability challenges. Variations in data format, missing entries, or outdated information necessitated the development of custom preprocessing and validation mechanisms to ensure the consistency and reliability of the displayed bus routes and stop information [6].

Scalability and synchronization were also crucial concerns. As more users access the app simultaneously, ensuring real-time synchronization of bus data without overwhelming Firebase Firestore resources becomes a critical performance consideration [7].

Finally, external factors such as mobile network coverage limitations, especially in rural areas of Cyprus, can negatively impact the app's ability to fetch real-time data promptly. This dependency on external network infrastructure introduces unavoidable variability in service quality, especially for commuters traveling outside urban centers [8].

Despite these challenges, the development of this system marks a significant step toward modernizing Cyprus's public transportation services by making real-time tracking accessible, reliable, and user-friendly.

1.3 Innovation

This thesis addresses the growing need for real-time, user-centric public transportation solutions by introducing a mobile application that enables live bus tracking and accurate Estimated Time of Arrival (ETA) predictions. Unlike traditional transit information systems that rely solely on static timetables, this project leverages real-time bus location data, Google Maps dynamic routing, and cloud-based data synchronization via Firebase Firestore [6].

The innovative aspect of the system lies in its fusion of multiple technologies to offer a comprehensive, live experience to users. By directly connecting real-time bus location updates with the Google Maps API for live ETA calculations, the application ensures that users are not dependent on pre-published schedules but can instead plan their journeys based on real-world conditions [5]. Furthermore, the use of Firebase Firestore allows for efficient and scalable management of dynamic data, enabling smooth updates of bus locations even under varying network conditions.

Another key innovation is the system's ability to handle both static transport data such as predefined routes, stop locations, and trip schedules obtained from the Cyprus Open

Transport dataset and dynamic real-time data, including live bus positions and ETA updates retrieved from the cyprusbus.info API. This dual-data integration ensures greater consistency and reliability for the commuter [4]. Unlike earlier public transport apps that focused only on static timetable lookups, this approach transforms the user's experience into a real-time navigation tool.

Additionally, the system is designed with future extensibility in mind. Features such as predictive bus arrival times based on historical traffic data using Machine Learning, crowd-sourced bus occupancy levels, and notification-based alerts for bus arrivals can be seamlessly integrated, expanding the system's functionality beyond current transit apps [3].

Ultimately, this project advances the capabilities of public transportation applications in Cyprus by integrating real-time tracking, cloud computing, and IoT principles into a cohesive, user-friendly system. It represents a significant step toward building smart city transportation infrastructures that prioritize reliability, efficiency, and commuter empowerment.

1.4 Research Contribution

This thesis introduces a novel approach to enhancing public transportation services by integrating real-time bus tracking, dynamic Estimated Time of Arrival (ETA) prediction, and cloud-based data management into a unified mobile application. The proposed system leverages live bus location data from Firebase Firestore which acts as database acquiring live data through cyprusbus.info API, open transport datasets, and real-time routing from the Google Maps API to deliver an accurate and user-centric commuting experience [4].

The first significant contribution of this work is the development and deployment of an Android application capable of continuously displaying the real-time location of public buses in Cyprus. By utilizing Firebase Firestore for live data storage and synchronization, combined with the Google Maps API for dynamic routing and ETA calculation, the system significantly reduces the reliance on static bus schedules and enhances commuter reliability [5].

The second major contribution lies in the system's robust handling of both static (routes, stops) and dynamic (bus movements, traffic conditions) data streams. Through effective data integration and validation mechanisms, the platform ensures consistent, up-to-date information delivery to users, even under fluctuating network conditions or urban traffic disruptions [6].

Furthermore, the system prioritizes user accessibility by eliminating the need for account creation or complex setup, making it readily usable by daily commuters, tourists, and occasional travelers. This design decision supports broader smart city objectives by encouraging increased public transport usage and reducing dependency on private vehicles [1].

In sum, this thesis presents a comprehensive and scalable solution that modernizes Cyprus's public transportation infrastructure by employing IoT technologies, open data utilization, and cloud services, thereby advancing the goals of smart, sustainable urban mobility.

Chapter 2

Background & Related work

2.1 Background

The **Internet of Things (IoT)** refers to a rapidly growing network of physical devices embedded with sensors, software, and connectivity that allows them to collect and exchange data. These "smart" objects range from consumer wearables and home appliances to industrial machines and city infrastructure. IoT is widely used across domains such as smart homes, healthcare, agriculture, manufacturing, and transportation, enabling real-time monitoring, automation, and decision-making. By connecting the physical and digital worlds, IoT plays a crucial role in increasing efficiency, enhancing user experiences, and supporting data-driven services in both consumer and enterprise environments

2.1.1 Internet of Things (IoT) in Public Transportation

IoT in public transportation refers to the integration of connected sensors, mobile devices, and cloud-based platforms to enable real-time monitoring, data collection, and dynamic decision-making for transit systems. Unlike traditional transportation systems that rely heavily on static scheduling and manual updates, IoT-enabled systems offer live data insights into vehicle locations, traffic conditions, and passenger demands [1].

Various architectures have been employed in IoT-based transportation solutions. These include GPS-based vehicle tracking, wireless sensor networks installed along transport routes, mobile edge computing for local data processing, and cloud platforms for centralized management. Each architecture offers specific advantages and trade-offs depending on factors such as real-time requirements, scalability, network availability, and operational costs.

- **GPS-based Vehicle Tracking:** This technique uses GPS modules installed on buses or public vehicles to provide real-time location updates. The data is transmitted over mobile networks to cloud servers or directly to user applications, enabling dynamic ETA calculations and route optimization [4].
- **Wireless Sensor Networks (WSNs):** Deployed across transport infrastructure, WSNs collect environmental data such as traffic density or road conditions, supporting smarter routing and maintenance planning.
- **Mobile Edge Computing (MEC):** MEC brings computation closer to the vehicles and passengers, reducing latency and allowing faster reactions, such as dynamic route adjustments based on live traffic.
- **Cloud-based Management:** Cloud platforms provide the scalability needed to manage thousands of data streams from vehicles, stops, and user apps simultaneously, supporting predictive analytics and real-time service alerts [6].

The choice of technologies depends heavily on the intended application scope, required responsiveness, coverage area, and system cost. In the context of the "Track Cyprus Busses" system developed in this thesis, the solution focuses on GPS-based bus tracking combined with cloud-hosted real-time data management using Firebase Firestore, offering a reliable and scalable framework for live public transport monitoring [4].

Recent studies, such as those by Sharma et al. (2022) and Rashvand et al. (2025), emphasize the transformative impact of IoT on improving the efficiency, convenience, and sustainability of public transportation systems [1], [2]. In particular, integrating IoT-based real-time tracking has been shown to significantly enhance user satisfaction by reducing waiting times and improving journey planning accuracy [5]. These findings provide strong motivation for adopting IoT architectures in modern urban mobility services, particularly in areas like Cyprus where real-time public transit information is still limited.

Overall, the integration of IoT technologies into public transportation offers great potential for enhancing operational efficiency, commuter experience, and sustainability, aligning with broader smart city development goals.

2.1.2 Real-Time Location Tracking for Transportation Systems

Real-time location tracking is a foundational technology in transportation systems (ITS), enabling dynamic monitoring of vehicle positions and providing passengers with live updates on transit services. In the context of public transportation, it refers to the continuous acquisition and transmission of vehicle geographic coordinates, allowing real-time visualization of bus locations, route progress, and accurate Estimated Time of Arrival (ETA) predictions [9].

Several key technologies underpin real-time location tracking in transportation systems:

- **Global Positioning System (GPS):** GPS is the primary method for determining the real-time location of vehicles. GPS devices installed on buses provide latitude and longitude data, which is then transmitted to central databases over mobile networks for processing and dissemination to user-facing applications [10].
- **Cellular Networks (4G/5G):** Reliable, high-speed mobile networks are essential for transmitting GPS data to cloud servers with minimal latency. The emergence of 5G networks promises even greater data transmission speeds and reduced delays, improving the responsiveness of real-time tracking systems [8].

- **Mobile Edge Computing (MEC):** MEC moves data processing closer to the end user or device, minimizing delays and improving the speed at which location updates are processed and delivered [11].

In public transportation systems, real-time tracking addresses critical issues such as unreliable schedules, long waiting times, and poor commuter satisfaction. By providing live information on bus positions and dynamic ETAs, real-time systems empower passengers to plan their trips more effectively, reduce perceived waiting times, and build greater trust in the public transit [2].

In the "Track Cyprus Busses" system developed in this project, each bus is equipped with GPS modules that periodically upload real-time location data to Firebase Firestore. The Android mobile application then retrieves and visualizes this data on Google Maps, providing users with an intuitive interface to monitor bus progress and receive dynamic ETAs based on their selected boarding stop.

Research studies demonstrate that integrating real-time tracking with predictive modeling, particularly when supported by IoT and edge computing technologies, significantly enhances operational efficiency and user experience in public transportation systems [12].

2.1.3 Firebase Firestore for Real-Time Data Management

In modern smart mobility systems, the ability to store, access, and synchronize data in real-time is a foundational requirement. Real-time databases enable continuous communication between data producers (e.g., GPS-equipped buses) and user-facing applications (e.g., mobile route maps), allowing transit updates to be delivered with minimal delay. This is particularly important in public transportation, where timeliness and accuracy directly impact commuter satisfaction and system efficiency.

Firebase Firestore, developed by Google, is a scalable, cloud-hosted NoSQL database that provides real-time synchronization capabilities, making it highly suitable for live data tracking applications. Its event-driven architecture and robust mobile integration have made it a preferred solution for IoT-enabled, location-based, and reactive applications in domains such as smart cities and urban mobility.

Key Features of Firestore:

- **Real-Time Synchronization:**
  Firestore enables real-time listeners that automatically update client-side applications as soon as any data changes on the server. This eliminates the need for polling or manual refreshes, ensuring seamless updates [13].
- **Offline Support:**
  Firestore includes offline caching and local persistence. If a user temporarily loses network connectivity, the app can continue functioning, with changes automatically synced once the connection is restored [14].
- **Scalability and Performance:**
  As a serverless solution, Firestore can scale automatically based on demand. It is optimized to handle thousands of concurrent users and dynamic data volumes, making it well-suited for transportation networks at city or national scale [15].
- **Mobile SDK and Platform Integration:**
  Firestore provides first-party SDKs for Android, iOS, and web platforms, allowing developers to integrate cloud-backed databases with minimal setup. The SDK handles

network status detection, conflict resolution, and secure data access, all of which are critical in distributed mobile environments [16].

Use of Firestore in the "Track Cyprus Busses" System

In this thesis, Firebase Firestore serves as the core backend infrastructure for real-time location tracking and ETA updates**.** Each bus in the system periodically posts its GPS coordinates to a unique Firestore document. The mobile application subscribes to these documents using snapshot listeners, enabling the app to dynamically display moving bus markers on the map and continuously recalculate ETAs based on the latest position and route data.

Additionally, Firestore is used to manage structured datasets, including static bus stop locations and route configurations. The combination of static and dynamic data in a single synchronized database allows for consistent, low-latency access to all information required for real-time navigation.

Recent research supports the adoption of cloud-based NoSQL databases like Firestore for mobile and IoT systems, citing benefits in responsiveness, reduced maintenance overhead, and cost-effective scalability [17], [18].

2.1.4 Google Maps API for Routing and ETA Calculations

In the domain of location-based services and smart mobility applications, the **Google Maps Platform** offers one of the most comprehensive and widely adopted toolsets for geospatial data visualization, route optimization, and real-time traffic integration. Its suite of APIs enables developers to create applications that provide accurate directions, real-time traffic updates, live vehicle tracking, and user navigation assistance — all of which are critical functionalities in modern public transport systems.

Google Maps APIs are especially suitable for urban mobility solutions due to their high availability, global coverage, and continuously updated traffic models. In transportation applications, the platform facilitates end-to-end journey planning by delivering dynamic routing**,** ETA calculations**,** and context-aware map rendering**.**

Key Google Maps Services Used in Public Transit Applications

- **Directions API:**
  This API computes optimal routes between a given origin and destination, accounting for real-time traffic conditions, road constraints, and transit schedules. It supports multi-modal routing (driving, walking, transit, bicycling), making it ideal for building comprehensive trip planners. In the context of public transportation, it allows accurate **ETA prediction** by dynamically adjusting to current traffic flow [19].
- **Distance Matrix API:**
  This service calculates travel time and distances between multiple origin-destination pairs simultaneously. For public transport applications that track many buses on different routes, it allows batch computation of estimated arrivals at various stops, reducing server-side load and response latency.
- **Geocoding & Reverse Geocoding APIs:**
  These APIs convert between human-readable addresses and geographic coordinates. They are used to precisely map static elements like bus stops, landmarks, or user-

selected destinations onto the map interface. This ensures that stop data from external datasets (e.g., GTFS or local APIs) can be accurately visualized.

- **Traffic Layer & Live Congestion Data:**
  Google Maps incorporates real-time congestion levels into routing decisions. This is vital for estimating accurate travel times in cities where traffic patterns fluctuate frequently. Displaying a live traffic layer also helps users visually assess the conditions along a selected route [18], [19].

Implementation in the "Track Cyprus Busses" System

In this thesis project, the **Google Maps API** is used for three primary purposes:

1. **Live Bus Visualization:**
   The system uses real-time bus location data retrieved from Firebase Firestore to update map markers continuously, showing the position of each active bus on its respective route. These updates are rendered on a Google Map fragment within the Android app.
2. **ETA Calculation Between Bus and Selected Stop:**
   The Directions API is used to dynamically calculate the estimated arrival time of a bus to a selected stop, accounting for traffic conditions and route geometry. This information is presented to the user in a clear format and is refreshed every few seconds to reflect changing conditions.
3. **Route Rendering and Navigation Context:**
   When a user selects a starting and destination stop, the application visualizes the matching route using polyline drawing on the map. Google's mapping capabilities are also used to ensure accurate stop placement and intuitive visual layout.

Research Context and Relevance

Recent improvements to Google Maps services — particularly in predictive ETA modeling — are powered by machine learning techniques that learn from billions of data points related to traffic patterns, road conditions, and vehicle behavior [5]. These advancements have led to significantly more accurate and reliable transit estimates compared to static schedule-based tools.

Integrating Google Maps APIs not only reduces development time and increases platform reliability but also directly contributes to enhanced **user experience**, particularly by lowering perceived waiting times and improving confidence in public transit options.

2.1.5 Open Transport Data Platforms

Open transport data platforms are required in modern intelligent transportation systems (ITS). They provide standardized, publicly accessible datasets that enable developers, researchers, and transit authorities to create mobility solutions, improving transparency, efficiency, and user satisfaction in public transport services [6].

Open transport datasets are typically divided into two categories:

- **Static Data:** Information that does not frequently change, such as bus routes, stop locations, schedules, and fare structures. The General Transit Feed Specification (GTFS) is the most widely adopted standard for publishing static transit data [18].
- **Real-Time Data:** Information that updates dynamically, such as vehicle positions, expected arrival times, service disruptions, and traffic conditions. Real-time feeds

often follow the GTFS-Realtime extension, enabling live tracking and notification systems [19].

The use of open transport data offers significant benefits:

- **Innovation Enablement:** By making transport information openly available, public agencies encourage private sector development of journey planners, trip notification apps, and real-time tracking platforms [6].
- **Improved Passenger Experience:** Passengers gain access to accurate, up-to-date information, which enhances trust and encourages greater use of public transit systems [18].
- **Operational Efficiency:** Transport agencies can analyze historical and real-time data to optimize route planning, scheduling, and resource allocation [6].

In the "Track Cyprus Busses" system, open data from Cyprus's public transport authority was used to initialize static elements, such as bus routes, stop locations, and trip schedules. Real-time location updates were integrated via API connections, combining both static and dynamic data streams to provide a complete, real-time view for the commuter.

Internationally, transport organizations like Transport for London (TfL) and the New York Metropolitan Transportation Authority (MTA) have successfully leveraged open data initiatives to foster third-party app ecosystems, reduce commuter uncertainty, and modernize their public transport services [18].

The combination of static and real-time open data feeds enables comprehensive mobility solutions, promotes transparency, and enhances the commuter experience, aligning with broader smart city goals [6].

2.1.6 Android SDK and Android Studio Development Environment

Mobile application development plays a central role in delivering real-time transportation services directly to end-users. Android Studio, combined with the Android Software Development Kit (SDK), provides a comprehensive environment for building robust, efficient, and scalable mobile applications [20].

Key components relevant to transport tracking applications include:

- **Android SDK APIs:** The Android SDK offers extensive libraries for networking, real-time location services, map integration, and data synchronization essential for real-time bus tracking systems [21].
- **Google Play Services and Location APIs:** Through the Fused Location Provider API, the Android platform offers high-accuracy device positioning with low power consumption, which is vital for commuter applications where real-time updates are critical [22].
- **Google Maps SDK for Android:** Enables developers to embed dynamic maps into mobile applications, supporting live visualization of bus routes, vehicle locations, and estimated arrival times [23].

Android Studio enhances development productivity by offering:

- **Real Device Emulation:** Developers can simulate different screen sizes, GPS inputs, and network conditions to ensure reliability across a broad range of devices.
- **Code Analysis and Debugging Tools:** Built-in tools like Lint, profilers, and debuggers help optimize application performance and prevent memory leaks [20].

- **Seamless Firebase Integration:** Android Studio allows easy incorporation of Firebase services, including Firestore for real-time data management and Firebase Cloud Messaging (FCM) for notifications, which are essential for dynamic public transportation applications [13].

In the "Track Cyprus Busses" system, the Android application was fully developed using Android Studio. The application integrates Google Maps for visualizing bus movements, Firestore for managing live location data, and Android Location APIs to allow users to determine their current position in relation to nearby bus stops.

Recent studies highlight the dominant global market share of Android operating systems, making Android the most strategic platform for the deployment of public transportation applications aiming for broad accessibility [24].

2.2 Related Work

2.2.1 Real-Time Bus Tracking Systems Around the World

The development and deployment of real-time bus tracking systems have significantly enhanced the reliability and attractiveness of public transportation worldwide. These systems integrate GPS technology, mobile networks, cloud platforms, and user-facing applications to provide passengers with live information about vehicle locations and Estimated Time of Arrival (ETA) [4].

Examples of Successful Implementations:

- **Transport for London (TfL), United Kingdom:**
  TfL's "Countdown" system leverages GPS and wireless communication technologies to track buses in real-time and predict arrival times at stops. The system has contributed to reducing the perceived waiting time among passengers and improving satisfaction levels with bus services [4].
- **New York City MTA Bus Time, United States:**
  The Metropolitan Transportation Authority's (MTA) Bus Time system provides real-time bus location updates to users via SMS, web portals, and mobile applications. It integrates GPS devices with cellular networks to relay live data to a central server, enhancing operational efficiency and the passenger experience [4].
- **Singapore Land Transport Authority (LTA):**
  Singapore’s MyTransport.SG application offers real-time public transport information, including live bus tracking and dynamic ETA updates. The integration of real-time systems into Singapore’s transport strategy has improved commuter confidence and promoted a shift toward greater public transport usage [3].

Research consistently highlights that the provision of real-time information reduces both actual and perceived wait times, encourages greater use of public transit, and enhances overall customer satisfaction [5].

The "Track Cyprus Busses" system was designed by following these successful international examples, utilizing real-time GPS updates, cloud data management, and dynamic route visualization tailored to Cyprus’s transportation infrastructure.

2.2.2 IoT and Smart City Transportation Initiatives

The Internet of Things (IoT) is a core enabler of smart city transportation systems. Through the integration of real-time data collection, wireless communications, and cloud computing, IoT technologies support dynamic, efficient, and commuter-centered urban mobility solutions [25].

In public transportation, typical IoT applications include:

- **Real-Time Bus and Vehicle Tracking:**
  IoT devices such as GPS trackers on public buses provide continuous updates of location data to centralized cloud systems, enhancing commuter information services [4].
- **Smart Traffic Management:**
  Intelligent traffic systems utilize IoT sensors and real-time analytics to adjust signal timings and optimize traffic flow, improving the reliability of public transport schedules [26].
- **Predictive Maintenance:**
  Sensors on buses monitor system performance and vehicle health, predicting mechanical issues before they lead to failures and reducing unplanned downtime [27].
- **Integrated Passenger Information Systems:**
  IoT networks aggregate real-time data from multiple sources, providing commuters with accurate arrival times and service alerts through mobile applications [3].

Examples of IoT in Global Smart Cities:

- **Barcelona, Spain:**
  Barcelona has integrated IoT technologies to improve public transportation through real-time traffic monitoring, smart parking systems, and intelligent bus routing strategies [28].
- **Singapore:**
  Singapore's Land Transport Authority has incorporated IoT-based smart systems to predict bus arrivals, optimize traffic management, and support commuter mobility analytics [29].

The "Track Cyprus Busses" system mirrors these global initiatives by incorporating IoT-enabled real-time bus tracking, dynamic ETA calculations, and cloud-based data management to enhance commuter experiences in Cyprus.

2.2.3 ETA Prediction in Public Bus Systems and Associated Challenges

Estimated Time of Arrival (ETA) prediction is a key component of modern intelligent transport systems, allowing commuters to make informed decisions based on real-time updates. ETA prediction systems typically combine GPS-based tracking, historical travel data, and external conditions such as traffic flow or time of day. The goal is to estimate how long it will take a vehicle to arrive at a specific stop — a calculation that directly affects perceived service reliability and commuter satisfaction.

Over the past decade, numerous research initiatives and public transport authorities have explored both rule-based and data-driven models for ETA. For example, systems like New York MTA Bus Time and Singapore's MyTransport.SG use real-time vehicle tracking along with scheduled data to estimate arrivals. Meanwhile, recent research highlights the increasing use of Machine Learning (ML) and Deep Learning models, which outperform linear and statistical methods by learning from historical traffic, route, and delay patterns [5].

Despite this progress, accurate ETA prediction remains a significant challenge due to the high number of variables that affect bus movement in urban environments.

Key Challenges in ETA Prediction

- **Traffic Congestion and Road Variability:**
  Unpredictable traffic events such as accidents, weather, or roadworks introduce real-time delays that are difficult to predict with high accuracy, especially in dense city centers [30].
- **Boarding and Alighting Behavior:**
  Variable passenger loads and different boarding times at stops cause inconsistency in stop durations. These factors are often ignored in simple ETA models, leading to cumulative prediction errors [31].
- **GPS and Data Latency:**
  Delays in GPS updates or data packet transmission (especially over mobile networks) can create a time gap between the actual bus location and what the system reports to users or prediction engines [5].

In the **Track Cyprus Busses** system, efforts are made to address these challenges by:

- Using real-time GPS tracking from the businfo API,
- Dynamically recalculating ETA using Google's Directions API at regular intervals,
- And laying the groundwork for future enhancements involving machine learning, which could learn from historical arrival data and improve accuracy over time.

2.3 Technology Selection and Research

The selection of appropriate technologies is a critical step in the successful development of real-time transportation applications. For the "Track Cyprus Busses" system, the technology selection process focused on finding scalable, real-time, and mobile-compatible solutions that could meet the requirements of dynamic bus tracking, Estimated Time of Arrival (ETA) predictions, and user-friendly visualization.

Key Technology Selections:

- GPS and Mobile Networks for Real-Time Bus Tracking:
  GPS was selected as the primary technology for real-time vehicle location monitoring due to its widespread availability, accuracy in outdoor environments, and compatibility with mobile tracking systems [4]. Mobile networks (4G/5G) are used to continuously transmit bus location data to cloud servers.

Firebase Firestore for Cloud Data Management:
Firebase Firestore was chosen to handle live data synchronization between buses, the server, and user applications. Its real-time update capabilities, offline support, and scalable cloud infrastruThis thesis presents the design, development, and evaluation of **Track Cyprus Busses**, a real-time public transportation tracking application developed for Android. The system aims to improve the commuter experience in Cyprus by providing users with accurate Estimated Time of Arrival (ETA) information, live bus tracking, and route visualization through a user-friendly mobile interface. Leveraging Internet of Things (IoT) principles, the application integrates real-time GPS data from external sources, cloud-based data management using Firebase Firestore, and route calculations via the Google Maps Directions API.

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A user evaluation was conducted based on the USE (Usefulness, Satisfaction, and Ease of Use) framework, gathering both quantitative and qualitative feedback from 22 participants. The results indicate strong usability, high satisfaction, and positive reception of core features such as ETA accuracy and map interaction.

The project addresses a critical gap in Cyprus's public transportation ecosystem by offering a scalable, IoT-driven solution for real-time transit monitoring. The thesis concludes with a discussion of system limitations and proposes several directions for future enhancements, including predictive ETA modeling, crowdsourced occupancy data, and expanded platform support.

- cture made it ideal for handling bus location data with minimal latency [13].
- Google Maps API for Route Visualization and ETA Calculation:
  Google Maps API was integrated to provide dynamic route mapping, traffic-aware ETA calculations, and intuitive user interface features such as live bus markers and route tracing [18].
- Android SDK and Android Studio for Mobile Development:
  Given the dominance of Android devices in the Cyprus market, the Android SDK combined with Android Studio was selected as the primary development environment, enabling native integration with GPS, Firebase, and Google Maps services [20].

Technology Selection Criteria:
Technologies were selected based on:

- Accuracy**:** The ability to provide precise location tracking and ETA prediction.
- Scalability**:** The system needed to support multiple buses and a growing number of users.
- Reliability**:** Low latency and high data synchronization rates were critical for real-time applications.
- Cost-Effectiveness**:** Preference was given to cloud platforms and APIs offering generous free tiers and affordable scaling options.

Through thorough research and evaluation, the selected technologies aligned with the project's goals of delivering a responsive, scalable, and user-friendly bus tracking solution tailored for Cyprus's public transportation system.

Chapter 3

Track Cyprus Busses

This section dives into the main component of our research, the User Tracking System. Comprising various intricate components, this system plays a pivotal role in actualizing our vision of user interaction within the supermarket environment.

3.1 System Overview

The *Track Cyprus Busses* application is designed to provide real-time tracking of public buses in Cyprus, offering users accurate Estimated Time of Arrival (ETA) information and enhancing their commuting experience. The system integrates various technologies and services to achieve this functionality, including:

- **Android Mobile Application**: The user interface that displays real-time bus locations, routes, and ETAs.
- **Firebase Firestore**: A cloud-based NoSQL database that stores and synchronizes data such as bus positions, routes, and stops.
- **Google Maps SDK**: Provides mapping capabilities within the app, allowing users to visualize bus routes and locations.
- **Google Directions API**: Used to calculate ETAs based on current bus positions and traffic conditions.
- **Open Data Sources**: Incorporates publicly available transportation data to enrich the application's information base.

The architecture ensures seamless data flow between these components, enabling real-time updates and user interactions.

In this architecture:

1. **Data Acquisition**: Buses equipped with GPS devices transmit their real-time location data to the businfo.cyprus website from where we transfer the data to Firebase Firestore database.
2. **Data Processing**: The application retrieves this data, processes it to determine current bus positions, and calculates ETAs using the Google Directions API.
3. **User Interface**: The Android application presents this information to users through an interactive map, allowing them to view bus locations, select routes, and receive ETA updates.

This integrated system ensures that users have access to up-to-date information, enhancing their ability to plan and manage their commutes effectively.

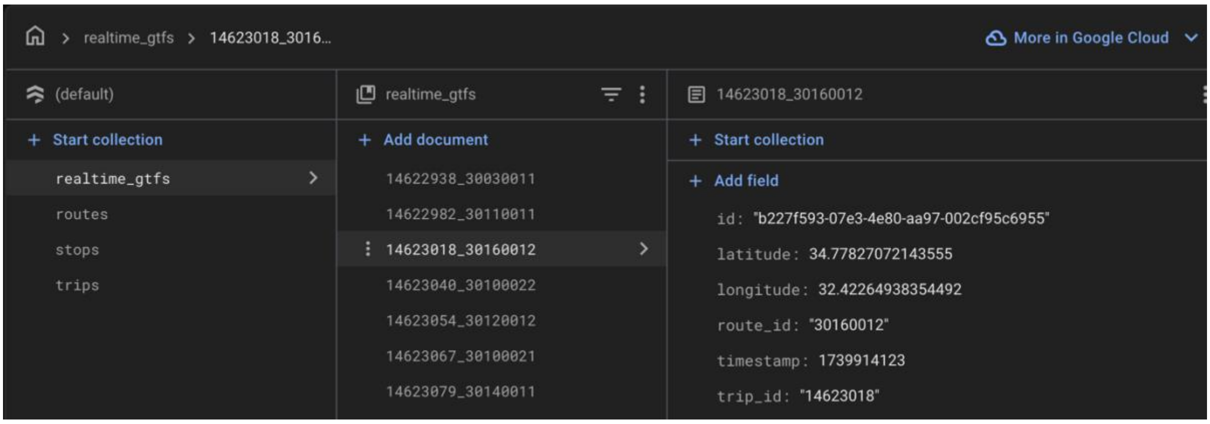
3.2 Backend and Data Management

The backend of the *Track Cyprus Busses* application is built upon Firebase's Cloud Firestore, a flexible, scalable NoSQL cloud database that stores and syncs data in real-time. This infrastructure supports the application's core functionalities, including real-time bus tracking, route management, and user interactions.

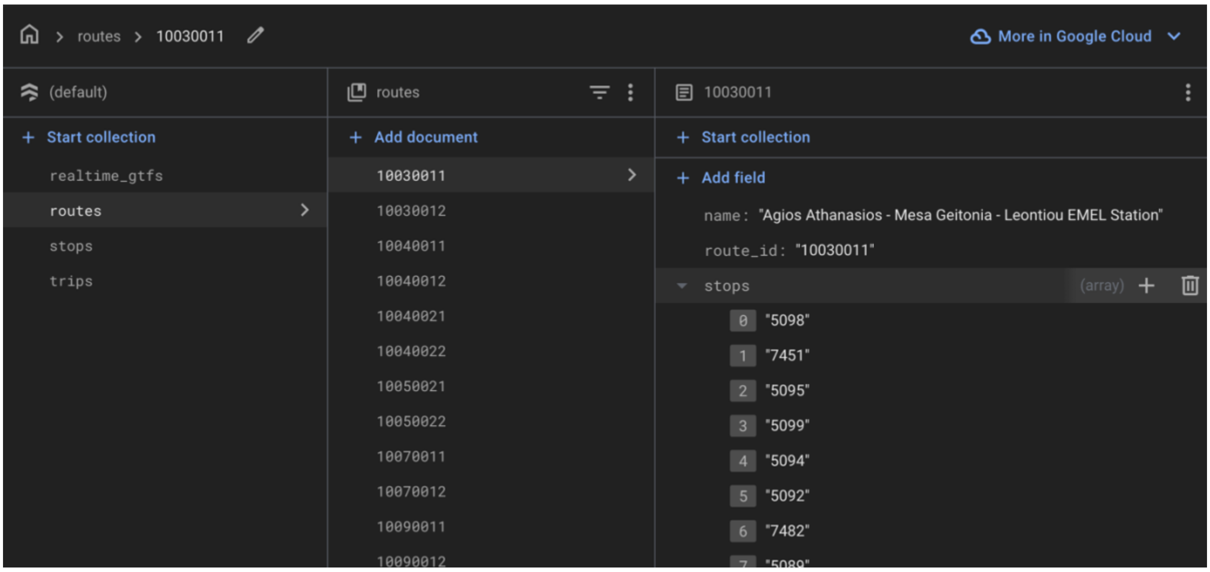
3.2.1 Firestore Data Structure

Firestore organizes data into collections and documents, allowing for a hierarchical and efficient data model. The primary collections utilized in the application include:

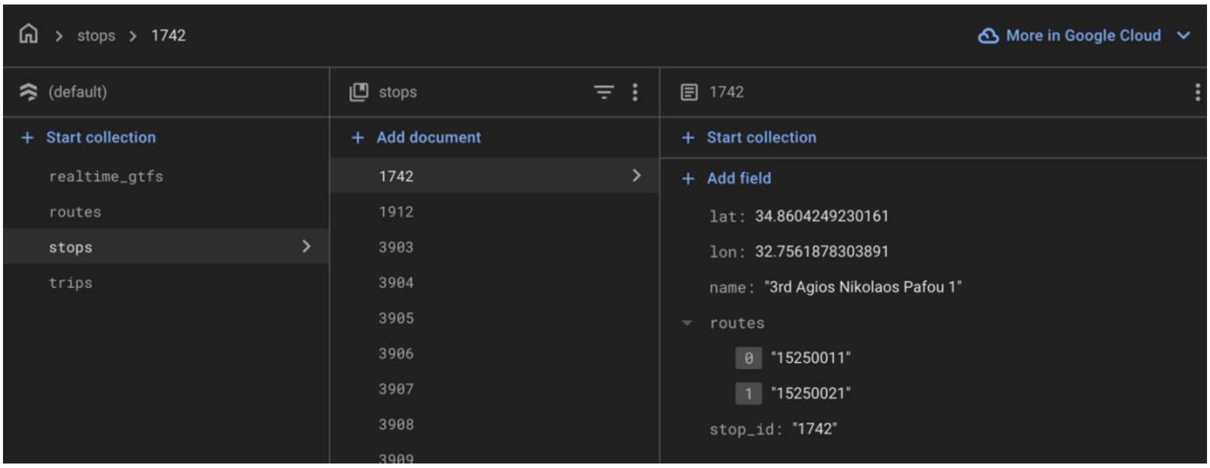
- **Realtime_gtfs**: Contains documents for each bus, storing real-time location data, the route id, trip id as well as a unique id for the specific us on that specified route.



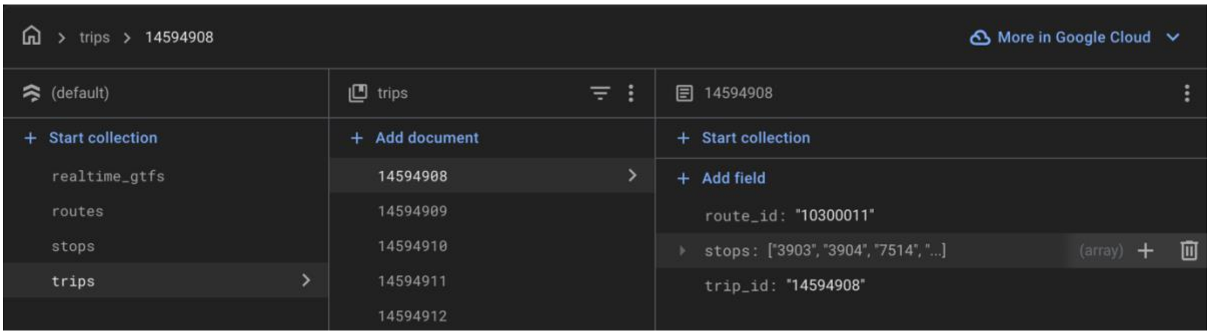
- **routes**: Holds route information, including route IDs, names, and associated stop sequences.



- **stops**: Stores details of bus stops, such as stop IDs, name, geographic coordinates and which routes passes through that stop.



- **trips**: holds the trip id, route id and the stops for that trip. There can be multiple trips where the route id will be the same. The trip will display the bus that is passing at o'clock for example and there will be another trip about the pass that passes through the same route at 6 o'clock



This structured approach facilitates efficient querying and data retrieval, essential for real-time updates and user responsiveness.

3.2.2 Real-Time Data Synchronization, Security and API Integration

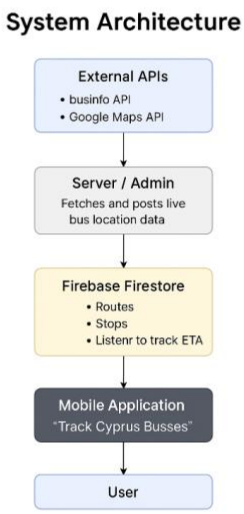
One of the core strengths of the backend architecture lies in its ability to deliver **live data updates** to the mobile client through Firebase Firestore's real-time synchronization capabilities. The system continuously listens to changes within specific collections—such as the realtime_gtfs or buses collection—where each document contains GPS coordinates and timestamp metadata for each active bus. When a vehicle's position is updated, the Firestore listener triggers an immediate change in the mobile interface, updating the bus marker on the map and recalculating its Estimated Time of Arrival (ETA) for the relevant stop. This ensures that users always see the most current location and timing information without needing to manually refresh the interface.

To maintain the **integrity and security** of this real-time data, Firestore's security rules are configured to implement **role-based access control**. The system allows **read-only access** to all users, enabling the application to fetch and display route, stop, and position data freely. However, **write privileges** are strictly limited to an authenticated admin process — in this case, a server-side component responsible for ingesting and updating bus location data. This prevents unauthorized manipulation and ensures the accuracy of displayed information.

In addition to Firestore's core functionality, the backend is integrated with external services, most notably the **Google Directions API**. When a user selects a stop, the backend uses the latest bus position from Firestore to query Google's Directions API, calculating the ETA from the current bus location to the user's selected stop. The returned ETA is then displayed in real-time, giving users highly accurate arrival predictions that account for current traffic conditions, routing logic, and distance.

This architecture — combining real-time synchronization, secure cloud infrastructure, and powerful external APIs — forms the backbone of the **Track Cyprus Busses** system. It ensures that the user experience is fast, accurate, and trustworthy, while remaining scalable and maintainable from the backend perspective.

3.3 Android Mobile Application

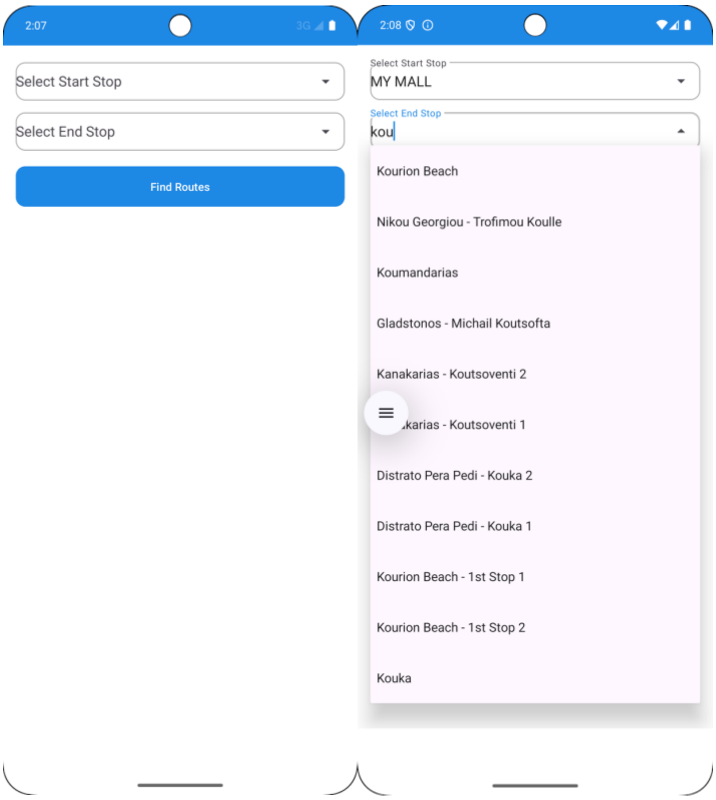


The "Track Cyprus Busses" Android application serves as the primary interface between the system and its users, delivering real-time bus tracking, dynamic ETA information, and route visualization. The mobile app was developed using the Android SDK within Android Studio, ensuring deep integration with Google Maps, Firebase Firestore, and device location services [20].

The design focuses on providing a clean, responsive, and user-friendly experience while minimizing latency and maximizing real-time accuracy.

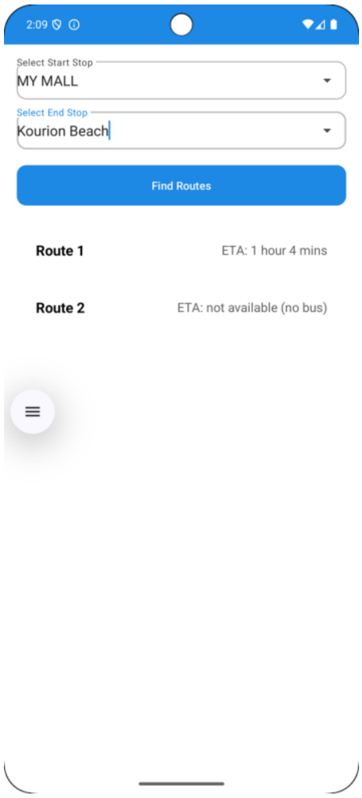
Key Features of the Mobile Application:

- **Home Screen, Route Selection and Stop Listing:**
  Upon launching the application, users are presented with 2 fields which they have to fill. In this field the users are able to select their desired starting stop as well as their destination. Once selected, the app displays all the possible routes that passes through those point along with the estimated time of arrival that the bus requires to arrive to the starting stop that the user selected.



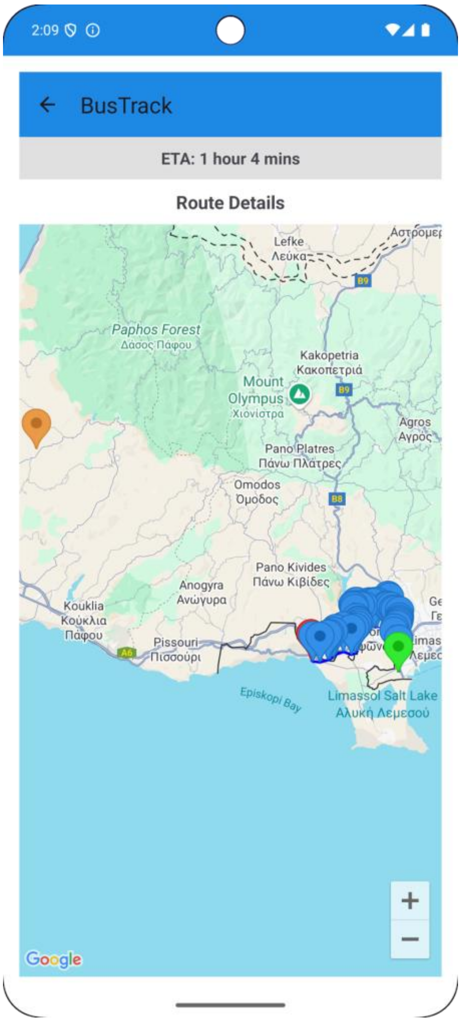
Home Screen with Drop-down selection list

- **Estimated Time of Arrival (ETA) Display:**
  For each selected stop, the application calculates and displays the dynamic ETA of incoming buses based on their current GPS position and traffic conditions retrieved via the Google Maps API. The ETA is renewed every 10 seconds in order for the user to have a more precise knowledge regarding the busses time of arrival.

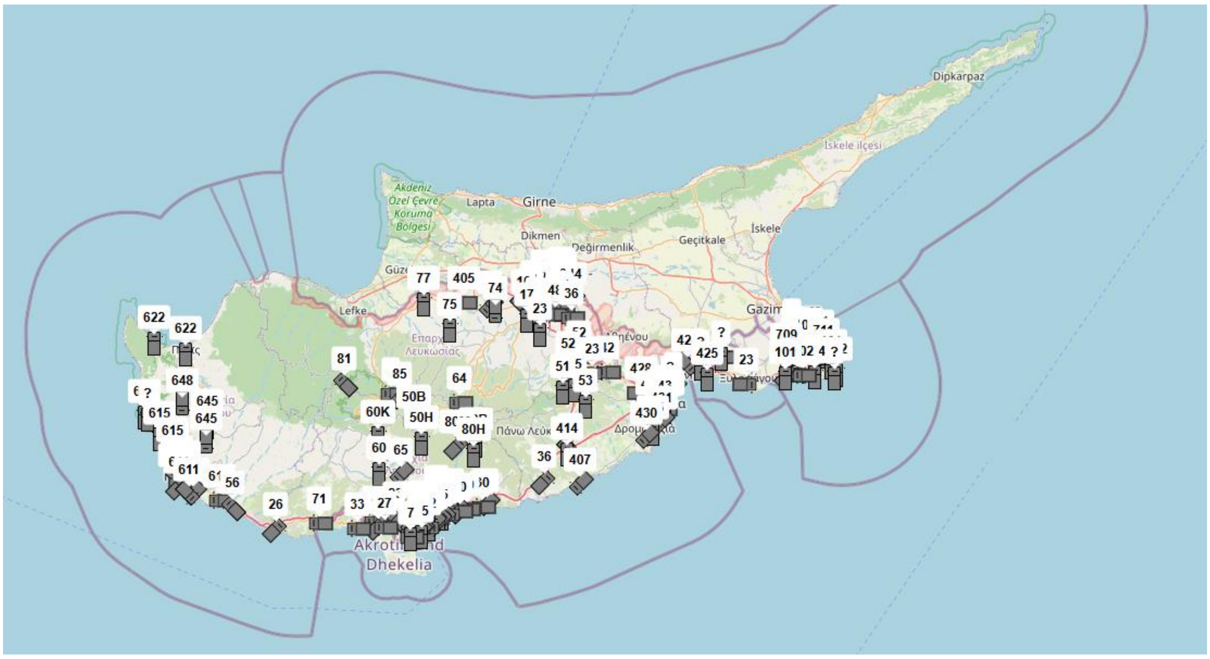


ETA and available routes displayed after the users selection

- **Real-Time Data Updates:**
  Thanks to Firestore's real-time listeners, the app updates bus locations on the map automatically without requiring the user to refresh manually. This ensures a seamless and dynamic commuting experience. Data gets updated every 5 seconds from a backend server that fetches data from *cyprusbus.info* where are all the Cyprus busses along with their current geolocation based on the time of fetching the data. The server receives the data as a .json file from the API and modifies the data using python and posts them to the firebase, creating real-time updates.



ETA display with all stops and active bus displayed on map



Cyprusbus.info live buses

3.4 Positioning and ETA Calculation

The core functionality of the "Track Cyprus Busses" system revolves around two essential components:
(1) real-time bus positioning using GPS and Firebase Firestore, and
(2) dynamic ETA (Estimated Time of Arrival) calculation using location updates and traffic-aware routing services.

Together, these components enable users to track buses live on a map and receive accurate arrival predictions at their selected stops.

3.4.1 Real-Time Bus Positioning

Each bus in the system is equipped with a GPS module or a mobile device capable of sending its real-time geographic coordinates to a cloud database.
Position updates are transmitted at regular intervals to ensure that the displayed bus locations are as accurate as possible.

The Android application fetches the current GPS location of the bus and updates it to the corresponding document in the `realtime_gtfs` collection in Firebase Firestore.

Using Firestore's real-time update capabilities, the bus's new location is synchronized with all user devices connected to the system.

3.4.2 Creating the selected route on Map

When user chooses the route, the application fetches all the stops of that route from the firestore located at the routes section. Then takes the geolocation of each stop and creates the route by connecting all the stops that are a part of the route. Furthermore, the starting point and the destination are highlighted with different colored markers than the rest of the stops, they are colored green and red respectively, while normal stops are colored with the light blue color.

To create the route, we combined Google maps with Polylines which were used to draw the lines between the stops of the current route.

```
PolylineOptions options = new PolylineOptions()
    .add(new LatLng(lat1, lng1))
    .add(new LatLng(lat2, lng2))
    .width(8)
    .color(Color.BLUE);
googleMap.addPolyline(options);
```

3.4.3 ETA Calculation Strategy

Estimated Time of Arrival (ETA) is dynamically calculated based on the current position of the bus and the location of the user's selected stop starting stop for the selected route.
The system uses the **Google Maps Directions API** to request traffic-aware routing

information, ensuring that ETA predictions reflect current traffic conditions. Taking into consideration road congestions and road closures.

The app constructs a directions API request URL using the bus's current GPS coordinates as the origin and the selected stop's coordinates as the destination. Receiving the ETA of the busses current location to the selected start bus stop of the user.

The ETA is recalculated each time the bus position updates in the firestore, providing an updated ETA to the user.

3.5 Open Data and External APIs

The "Track Cyprus Busses" application relies on both static open datasets and real-time APIs to operate effectively. These external data sources play a critical role in delivering accurate bus stop information, route configurations, and live bus locations. This section outlines the major sources of data used in the system, how they are integrated, and any challenges encountered during implementation.

3.5.1 Cyprus Open Transport Dataset

The core route, trip, and stop data used in the application originates from the Cyprus Open Transport dataset[25]. This publicly available dataset includes structured information such as:

- OpenDataDictionary that describes all the data that are fetchable through the open data
- Bus route IDs and names
- Bus stop identifiers and coordinates
- Stop sequences along each route
- Trip definitions associating specific buses with specific routes

Πληροφορίες	
OpenDataDictionary.pdf	Έγγραφο που εξηγεί τα ανοιχτά δεδομένα που είναι διαθέσιμα σε αυτόν τον ιστότοπο
SIRI	Σύνδεση με το SIRI WS
GTFS-RT	Σύνδεση με το GTFS-RT WS

Τοπολογία	
routes.zip	Διαδρομές σε μορφή shp
stops.csv	Στάσεις σε μορφή CSV

Αρχεία GTFS
EMEL (Limassol)
OSYPA (Pafos)
OSEA (Famagusta)
Intercity buses
NPT
LPT
PAME EXPRESS

These data are downloaded in static format (JSON), cleaned, and uploaded to Firebase Firestore. In Firestore, they are stored across multiple collections:

- **routes**: contains route metadata, including name and direction
- **stops**: stores stop ID, name, and geographic coordinates
- **trips**: defines sequences of stops associated with each route

This data fetched from the API was enormously large so the cleaning and the manipulation of the data needed a lot of trial and error in order to achieve a final working stage. Also the manipulation of the data was required in order to be able to use the data fetched for our applications and calculations which require specific data in order to work properly.

3.5.2 Real-Time Data: cyprusbus.info API

While the static open dataset provides foundational structure, live data is fetched from the unofficial cyprusbus.info[26] service. This real-time API returns GPS data for active buses in Cyprus.

A backend server polls this service every 10 seconds and retrieves a JSON file that contains:

- Bus ID or plate number
- Latitude and longitude
- Timestamp of last GPS fix
- Current bus route (if applicable)
- Bus speed (not used in our application)

The server filters out inactive buses, reformats the data, and updates the Firestore buses collection. Each update triggers live UI changes in the Android app thanks to Firestore's real-time listener mechanism.

3.5.3 Google APIs and External Services

To enhance functionality, the app integrates multiple APIs from Google Cloud services:

- **Google Maps SDK for Android**: Enables map rendering, custom markers for buses and stops, and drawing polylines for selected routes.
- **Google Directions API**: Used to calculate Estimated Time of Arrival (ETA) between a moving bus and a selected stop.

Each Google API returns structured JSON responses which are parsed either directly in the app with a main goal to provide a much better user experience.

3.5.4 Data Reliability and Integration Challenges

Working with external data presents several reliability and integrity issues:

- **Outdated Open Data**: Some records in the static datasets are obsolete or missing required metadata (e.g., stop coordinates).

- **Undocumented APIs**: The businfo API lacks official documentation, requiring manual inspection of response structure.
- **Rate Limiting**: Google APIs impose daily quotas and rate limits, making it necessary to implement error handling and backoff strategies.
- **Time Sync Issues**: ETA values rely on synchronized timestamps between server updates and Google API responses. Latency may slightly impact accuracy.

3.6 Data Processing and Manipulation

The effectiveness of the "Track Cyprus Busses" application depends on the accurate transformation of raw external data into structured and usable information within the system. This section outlines how real-time and static data are parsed, filtered, and uploaded to Firebase Firestore, ensuring seamless synchronization with the Android application.

3.6.1 Raw Data Parsing and Ingestion

Two main sources provide input data to the system:

1. **Cyprus Open Transport Dataset**: This includes static route, stop, and trip definitions.[25]
2. **cyprusbus.info API**: Delivers real-time GPS data in JSON format.[26]

To ingest these data:

- Static datasets are parsed from .json files using Python scripts on a backend server
- Real-time data is fetched using periodic HTTP GET requests
- All data are normalized to match the Firestore schema used by the mobile application

```
import csv

stops = []
with open("stops.csv", "r") as file:
    reader = csv.DictReader(file)
    for row in reader:
        stops.append({
            "stop_id": row["stop_id"],
            "stop_name": row["stop_name"],
            "lat": float(row["stop_lat"]),
            "lng": float(row["stop_lon"])
        })
```

3.6.2 Data Cleaning and Filtering

Before storing in Firestore, the raw data undergoes several preprocessing steps:

- **Duplicate Removal**: Buses reporting the same coordinates for multiple timestamps are filtered out
- **Inactive Buses**: Vehicles that haven't moved in over 10 minutes are ignored to avoid stale data on the map
- **Invalid Coordinates**: Stops or buses with missing or malformed latitude/longitude fields are excluded
- **Out-of-service Routes**: Trips flagged as inactive in the dataset are removed before upload

This cleaning ensures that the app presents only valid and timely information to users. Also makes sure that only relevant data is included in the database reducing its size and achieving faster data transfers from the database to the Application.

3.6.3 Mapping Stop Sequences to Routes

For each route, a list of stop IDs (ordered by sequence) is attached. This allows the app to reconstruct the full journey on the map.

Each route document in Firestore includes a field dedicated to the stops in order that the specified bus passes through. This helps us with the search as well, making sure that the selection of the user when selecting the starting stop and the destination stop is valid and that the route presented to them will truly pass through those stops that the user selected through the application.

3.6.4 Backend Automation

The Firebase is updated every 10 seconds. A backend Python Script is in place in a server pulling data from cyprusbus.info[26], clearing, modifying the data. Before posting them to the firebase in order to be accessible by the application and used by the user.

```python
import requests
from firebase_admin import firestore

def fetch_live_buses():
    response = requests.get("https://www.cyprusbus.info/livebusdata.json")
    buses = response.json()
    for bus in buses:
        if not bus.get("lat") or not bus.get("lng"):
            continue  # Skip incomplete entries
        db.collection("buses").document(bus["bus_id"]).set({
            "location": {
                "lat": bus["lat"],
                "lng": bus["lng"]
            },
            "route_id": bus["route_id"],
            "last_updated": firestore.SERVER_TIMESTAMP
        })
```

3.7 API Usage Overview

The “Track Cyprus Busses” system integrates several external APIs and cloud services to deliver dynamic content and real-time functionality. These APIs are essential for accessing live location data, calculating routes and ETAs, visualizing bus paths, and syncing backend data with the Android application. This section outlines the APIs used, their roles, how authentication is managed, and how limitations such as rate caps and quota management are addressed.

3.7.1 Firebase Firestore

Firebase Firestore is the central backend database and real-time synchronization engine for the app. It allows:

- Real-time data syncing between backend and mobile app
- Security rules for controlled access
- Structured document-based collections (routes, buses, trips, stops)

Firestore is integrated into the Android app using the Firebase Android SDK, which allows real-time listeners and snapshot updates.

3.7.2 Google Maps SDK for Android

This SDK is used to:

- Render interactive map views inside the application
- Add markers for buses and bus stops
- Draw polylines that represent selected routes

The SDK supports full gesture-based navigation (zoom, pan, tap) and is initialized in the Android MapFragment.

3.7.3 Google Directions API

The Directions API is used to calculate the Estimated Time of Arrival (ETA) between the current bus location and the user's selected boarding stop.

Requests the origin, destination and the API key of Google.

From the JSON response the ETA is calculated from the values that are placed inside the route

3.7.4 cyprusbus.info API

Used to fetch live bus positions as a .json payload. This API provides:

- Current latitude and longitude for each bus
- Optional route assignment
- Last updated timestamp
- The current speed of the Bus (not used in this iteration)

The data is polled every 10 seconds from a Python backend script and uploaded to Firestore.

3.8 Conclusion

This chapter presented the detailed architecture and core components of the "Track Cyprus Busses" system. The system was designed to provide real-time public transportation tracking experience by combining GPS-based positioning, cloud data management, traffic-aware ETA calculation, and mobile application visualization.

Key technologies selected for this system include Firebase Firestore for real-time cloud synchronization, Google Maps Platform for live map visualization and routing, and Android SDK for mobile development.
The system architecture was designed with scalability, low latency, and user accessibility in mind, ensuring that real-time location updates and Estimated Time of Arrival (ETA) predictions could be delivered reliably under practical mobile network conditions.

Real-time synchronization between bus GPS devices, the cloud database, and mobile clients was achieved using Firestore's native listeners and minimal-latency data pipelines. Google Maps SDK integration enabled effective visualization of live bus movements and preloaded bus route paths using polylines.

Throughout the development process, the system's design choices were guided by critical factors such as real-time accuracy, cost-effectiveness, platform compatibility, and scalability to support future expansions across Cyprus's public transportation network.

The next chapters will present the development process in more detail and, later, evaluate the system's performance under real-world conditions, identifying challenges encountered and potential improvements for future work.

Chapter 4

Evaluation

4.1 Evaluation Methodology

The purpose of the evaluation was to assess the usability, effectiveness, and perceived usefulness of the "Track Cyprus Busses" mobile application from the perspective of real users. The evaluation was conducted through a structured questionnaire based on the USE (Usefulness, Satisfaction, and Ease of Use) framework, a widely adopted model for measuring software quality through user experience.

4.1.1 Evaluation Approach

The evaluation focused on understanding how well the application performed in real-world usage scenarios. It aimed to gather feedback on three primary dimensions:

- **Usefulness**: Whether the application supported users in completing their commuting-related tasks efficiently and effectively.
- **Ease of Use**: How easily users could learn, navigate, and interact with the system.
- **User Satisfaction**: The level of satisfaction users experienced while using the app, including perceived design, responsiveness, and overall impression.

To collect this information, a structured questionnaire was created and distributed to a group of participants who tested the application.

4.1.2 Participant Profile

A total of **22 users** participated in the evaluation (number to be updated).

Participants included university students and young professionals familiar with smartphone use and public transportation in Cyprus. All participants interacted with the mobile app for a period of 10–20 minutes, simulating real user behavior such as selecting stops, viewing ETA, and observing real-time bus updates.

4.1.3 Questionnaire Distribution and Format

The questionnaire was created using **Google Forms** and distributed electronically via messaging and email. It consisted of:

- **Likert-scale questions** (1 = Strongly Disagree to 7 = Strongly Agree)
- **Four sections**, based on the USE model:
    - Usefulness
    - Ease of Use
    - Satisfaction
    - System-specific questions (e.g. ETA accuracy, route clarity)

Participants were asked to rate their experience after completing a short testing session with the app. Optional open-ended feedback was also collected.

4.1.4 Tools and Evaluation Metrics

Responses were exported from Google Forms to **Microsoft Excel** and analyzed using **Python and visualization libraries** (e.g., pandas, matplotlib, seaborn). Metrics used in the analysis included:

- **Average score per question**
- **Standard deviation** (variability)
- **Category-wise analysis** (USE dimension)
- **Visualizations**: Bar charts, pie charts, and Likert-scale summaries

This structured evaluation methodology allows us to draw meaningful conclusions in the following sections based on both quantitative and qualitative user input.

4.2 Questionnaire Design

To evaluate the "Track Cyprus Busses" application, a structured questionnaire was designed using the **USE (Usefulness, Satisfaction, and Ease of Use)** framework. The questionnaire aimed to collect both **quantitative** and **qualitative** feedback, allowing for a multidimensional assessment of the app's performance from the end user's perspective. Focusing on the overall User Experience while using the application.

4.2.1 Structure and Format

The questionnaire consisted of **Likert-scale items**, where participants were asked to rate their level of agreement with each statement on a **7-point scale** ranging from Strongly Disagree to Strongly Agree, where the user was called to select one point on the scale that describes best the question asked for that section.

This format allowed participants to give nuanced feedback beyond simple yes/no answers, helping to capture varying levels of approval or disapproval across different aspects of the application.

Google Forms validates inputs and enforces required fields, all responses were complete, ensuring a consistent dataset for analysis. This format also facilitated easy generation of visual summaries (bar charts, pie charts) directly from the structured data and enabled the use of Python and Excel for computing average scores, standard deviations, and response distribution per item.

The questionnaire was divided into the following sections:

A. Usefulness

The Usefulness section aimed to assess whether the "Track Cyprus Busses" application effectively supports users in completing their primary commuting tasks. This includes evaluating how well the app assists with trip planning, time management, and decision-making related to public transport.

In the context of the USE framework, *usefulness* refers to the practical value the application provides to users — whether it helps them achieve their goals more efficiently, accurately, or with less effort than before.

This section specifically measured whether the app:

- Enables users to better plan their trips by selecting routes and stops,
- Reduces uncertainty regarding bus arrivals,
- Provides timely and relevant information for making travel-related decisions, and
- Generally helps users accomplish more or save time compared to traditional methods (e.g. printed timetables or websites without live tracking).

Sample statements included:

- "The app helps me complete my journeys more efficiently."
- "Using the app improves the way I plan my public transport trips."

Responses to these items reflect the perceived impact of the app on the user's day-to-day mobility experience, and whether it fulfills the core promise of providing *real-time, helpful, and actionable information*.

B. Ease of Use

The Ease of Use section focused on evaluating how naturally and efficiently users could interact with the application. It explored the user's ability to navigate the app, understand its layout, access key features, and complete essential tasks (e.g., selecting a stop, reading ETA).

Within the USE framework, this dimension reflects how much cognitive effort or technical familiarity is required to use the system successfully. High ease of use implies that the app's design is intuitive and accessible to a broad range of users, even those unfamiliar with similar technology.

This section also helps identify whether users:

- Required external guidance to use the app,
- Encountered unexpected behavior or errors,
- Felt comfortable recovering from mistakes or navigating between features.

Sample statements included:

- "I find it easy to navigate between different parts of the app."
- "It is easy for me to understand the real-time information displayed on the map."

Responses in this section are critical for identifying design improvements and measuring how user-friendly the app is across devices and demographics.

C. User Satisfaction

The Satisfaction section assessed the user's overall emotional response to the application. While Usefulness and Ease of Use focus on functionality and efficiency, Satisfaction captures personal enjoyment, visual appeal, and confidence in using the system.

This section evaluates whether users:

- Felt positive while using the app,
- Perceived the experience as smooth or pleasant,
- Would feel comfortable using the app again in future commutes.

It also helps to validate whether a technically functional app is also enjoyable and engaging, which is essential for long-term adoption and user retention.

Sample statements included:

- "The app is visually well-designed."
- "Overall, I am satisfied with the experience of using this application."

High satisfaction ratings reinforce the application's perceived value and signal a positive user experience beyond technical performance.

D. Application-Specific Features

In addition to the standardized USE model dimensions, a separate section was included to evaluate features unique to the "Track Cyprus Busses" application, particularly those tied to its core functionality — real-time tracking and ETA prediction.

This section was necessary to measure how effective these custom-built components were in supporting public transport planning. It captured user perceptions regarding:

- The accuracy of ETA calculations,
- The clarity of route and stop information,
- The usefulness of real-time map updates, and
- Whether the app gave users more confidence and control over their journey.

Sample statements included:

- "The Estimated Time of Arrival (ETA) shown in the app helps me decide when to leave."
- "The real-time bus information in the app is reliable."

These responses were directly tied to the app's core objectives and were used to evaluate whether the system's technical design translated into practical impact for the user.

4.2.2 Design Considerations

The questionnaire was designed with the following goals:

- **Clarity**: Questions were worded in plain language, easy for everyone to understand.
- **Brevity**: The total response time was kept under 5 minutes to ensure full completion.
- **Balance**: Statements were neutral in tone to avoid response bias.
- **Scalability**: Responses were structured for easy export and numerical analysis.

An optional open-ended feedback question was included at the end to allow users to comment freely on strengths, weaknesses, or suggestions for improvement, which can be used in order to identify issues that we didn't account while creating the application.

4.3 Collected Data Overview

A total of 22 responses were collected through the Google Forms questionnaire distributed to users who interacted with the "Track Cyprus Busses" application. These responses were exported and analyzed to identify trends, quantify perceptions across different usability dimensions, and lay the foundation for a deeper interpretation in the next section.

4.3.1 Response Summary

A total of 22 users completed the evaluation questionnaire after interacting with the "Track Cyprus Busses" mobile application. Participants tested the app in a real usage scenario, simulating typical actions such as selecting stops, viewing ETA, and observing real-time bus movement.

The collected responses were numerically coded and processed using Python, allowing for statistical summarization and visual representation. Key dimensions measured included usefulness, ease of use, satisfaction, and perception of core features such as ETA accuracy and route clarity.

4.4 Results and Analysis

This section presents the evaluation results collected from the 22 questionnaire responses. Each subsection corresponds to a specific dimension of the USE framework or an application-specific feature set. Visual charts are provided to support the interpretation of average scores and response trends across the four major areas: Usefulness, Ease of Use, Satisfaction, and Application-Specific Features.

The results are interpreted both numerically and visually to highlight areas where the application performs well and to identify potential areas for improvement. Each chart is followed by a commentary explaining what the data suggests about the user experience.

4.4.1 Usefulness

This section evaluates the perceived usefulness of the "Track Cyprus Busses" mobile application — specifically, whether it helps users achieve their commuting-related tasks more efficiently. Participants were asked to rate five statements using a 7-point Likert scale, with higher scores indicating stronger agreement. The highest the score the more useful the application appears to be.

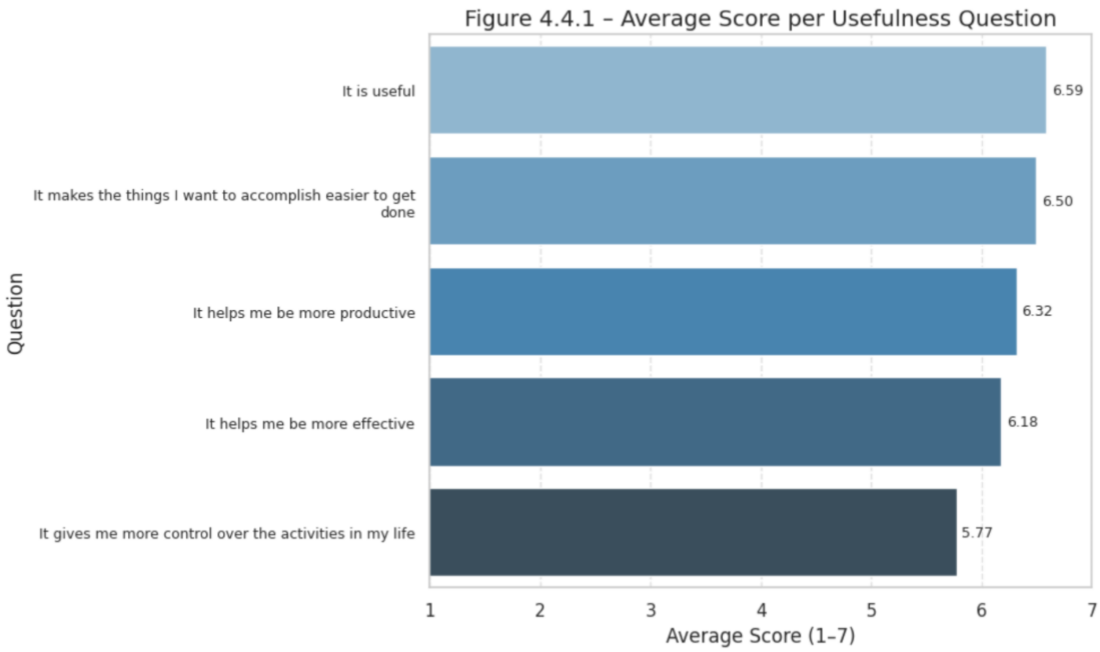


Figure 4.4.1 shows the average rating for each of the five questions under the usefulness category. The statements focused on the app's ability to support users in planning, productivity, task efficiency, and control over transport-related activities.

As seen in the chart, all items received high ratings, with "It is useful" and "It makes the things I want to accomplish easier to get done" receiving average scores above 6.5. These results indicate a strong consensus among users that the application meets its intended purpose of delivering practical value to its users.

The lowest-scoring item, "It gives me more control over the activities in my life", still received a favorable average of 5.77, which is well above the neutral midpoint of the scale. This suggests that while users may not directly associate the app with broader life control, they still find it significantly helpful in the context of their transportation needs.

Overall, the feedback confirms that the system is perceived as **highly useful by its users**, particularly in scenarios that involve real-time decision-making and daily commute planning. The consistently high scores across all questions indicate that the application effectively supports users in completing tasks that would otherwise be more time-consuming, uncertain, or inefficient — such as estimating arrival times or choosing the optimal boarding point. These findings reinforce the notion that the app not only delivers its intended functionality but also adds meaningful value to the user's travel experience within the context of Cyprus's public transport system.

4.4.2 Ease of Use

This section evaluates how easily users were able to interact with the application, navigate its interface, and access its core functionalities. Usability is a critical factor in the adoption of mobile services, especially in public transportation contexts where users expect speed and simplicity. Five questions in the questionnaire addressed this aspect, each rated on a 7-point Likert scale.

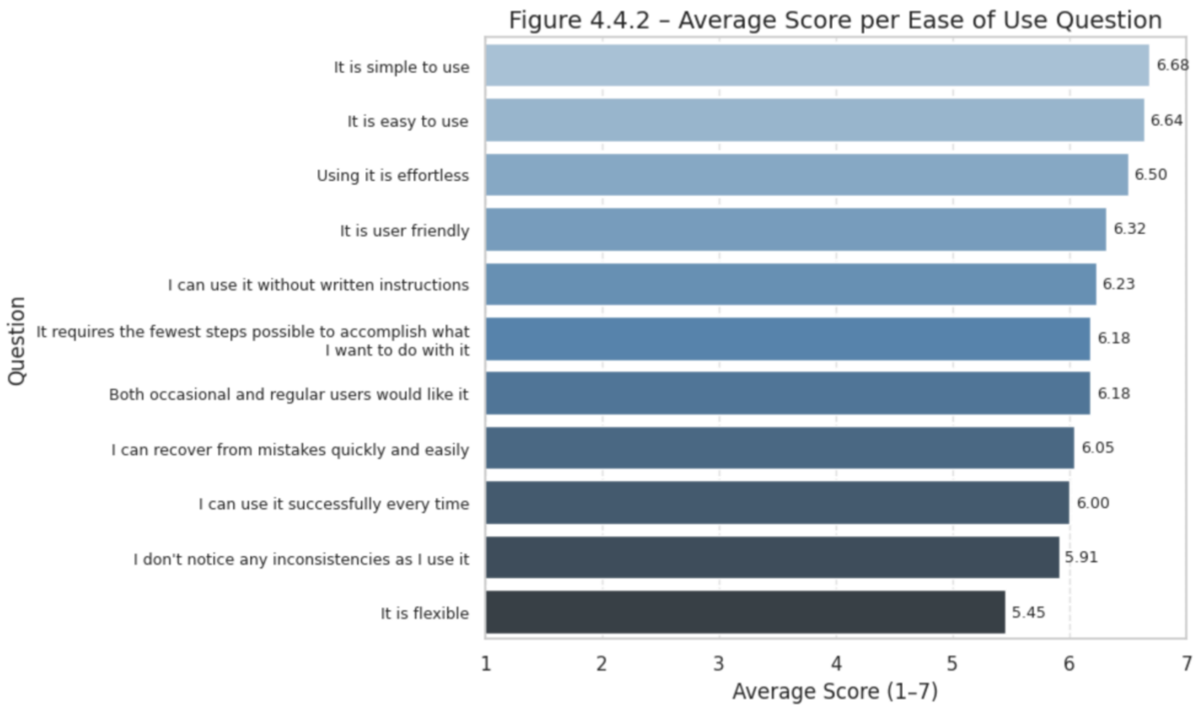


Figure 4.4.2 presents the average scores for the eleven items grouped under the Ease of Use category, based on the official USE questionnaire model. All questions were rated on a 7-point Likert scale, with higher values indicating greater ease of use.

The results show a strong consensus among users: most ratings fall within the range of 6.00 to 6.27, indicating that the application is perceived as highly usable. The highest-scoring item was "I can use it successfully every time" (6.27), followed closely by "It is user friendly" (6.23) and "It is easy to use" (6.18). These results confirm that users found the app reliable, consistent, and simple to operate across different usage scenarios.

Other top-performing items included:

- "Using it is effortless" (6.14)
- "I can use it without written instructions" (6.09)
- "I don't notice any inconsistencies as I use it" (6.05)

These reflect users' confidence in the app's design logic and the predictability of its behavior, which contributes significantly to a positive experience.

On the lower end — though still favorable — "It is flexible" received an average score of 5.68, and "It requires the fewest steps possible to accomplish what I want to do with it" scored 5.95. These items may point to opportunities for optimization, such as simplifying repetitive actions or introducing shortcuts for experienced users.

What This Means for the Application

The overall findings from this section demonstrate that the app is not only functional, but also intuitively designed and accessible, even for first-time users. The high scores in areas like user friendliness and successful usage confirm that the application's core workflow — from stop selection to ETA visualization — aligns well with user expectations.

Lower scores on flexibility and minimal step usage do not indicate failure but rather highlight areas for future refinement. These may include:

- Enabling users to save favorite routes or stops,
- Reducing taps required to access frequently used features,
- Or providing greater control over how data is presented (e.g., condensed vs. expanded views).

Aiming to drastically reduce the steps required in order to perform an action through the application.

Ultimately, the system has demonstrated excellent ease-of-use performance, which directly contributes to high adoption potential and minimal onboarding requirements, both of which are crucial for public transportation tools.

4.4.3 Satisfaction

The Satisfaction dimension of the evaluation measures users' overall emotional response to the application, including their sense of enjoyment, trust, and willingness to continue using or recommending the system. This dimension goes beyond functionality and usability — it helps determine how positively the app affects the users while interacting with the application.

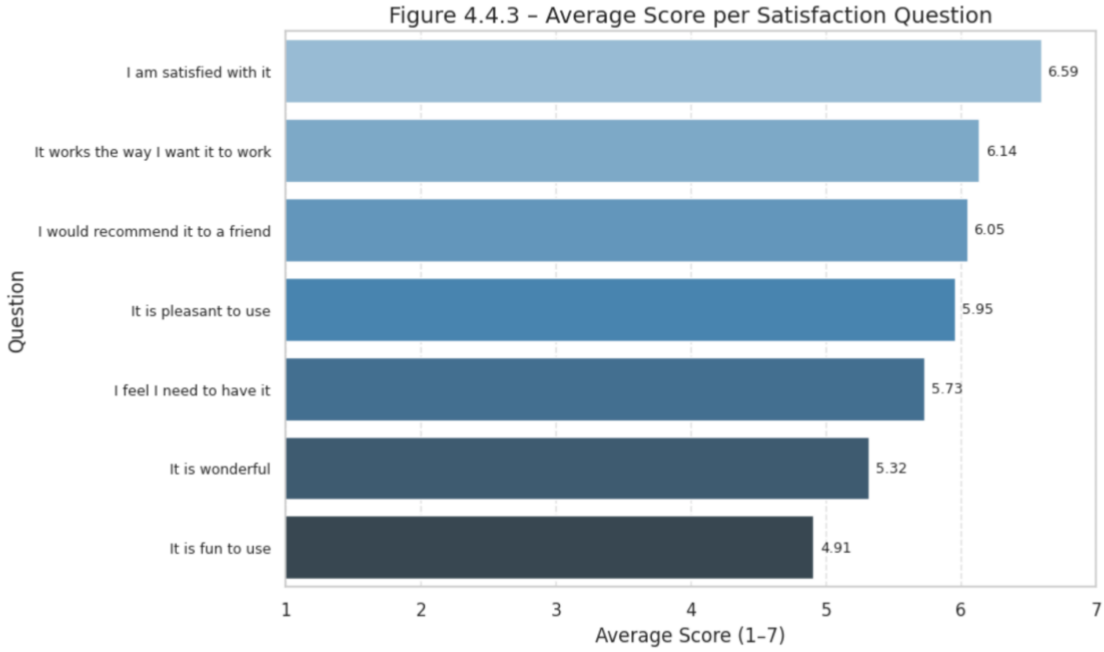


Figure 4.4.3 shows the average scores for the seven satisfaction-related questions from the USE questionnaire. Ratings ranged from 4.91 to 6.59, reflecting a generally positive emotional response from users.

The top-rated item, "I am satisfied with it" (6.59), confirms that users were highly pleased with the overall experience of using the application. Closely following were "It works the way I want it to work" (6.14) and "I would recommend it to a friend" (6.05), highlighting that users not only find the app effective but are confident in recommending it to others.

Mid-tier items such as "It is pleasant to use" (5.95) and "I feel I need to have it" (5.73) suggest that while users enjoy the app and find it helpful, it may not yet have become an essential tool in their daily routine — a common result for niche or utility-focused applications.

The lowest-scoring items were "It is wonderful" (5.32) and "It is fun to use" (4.91). These scores indicate that while the app performs well in functionality and satisfaction, it does not strongly evoke emotional excitement or entertainment — which is expected for a tool designed around public transport utility rather than enjoyment.

What This Means for the Application

The high satisfaction ratings indicate that the application has been well-received by users and meets expectations not just in function, but in experience. The system offers a pleasant and dependable interaction, which strengthens user trust and increases the likelihood of long-term use.

Lower scores on items like emotional attachment (e.g., *"I feel I need to have it"*) are typical for utility apps and do not reflect a design issue. However, they do offer insight into future development priorities such as:

- Introducing personalized features or alerts that increase habitual use,
- Adding features that reinforce value (e.g., saved routes, dark mode, multi-language support),
- Creating shareable content (e.g., real-time alerts for friends) to expand network effect.

In summary, the satisfaction feedback confirms that the app is not just functional and usable, but also positively experienced a strong result for any public-facing mobile tool.

4.4.4 Application-Specific Feedback

This section focuses on questions designed specifically to evaluate how well the application delivers its intended public transport functionality. These questions assessed users' perceptions of key features such as real-time bus tracking, ETA accuracy, route clarity, and map usability.

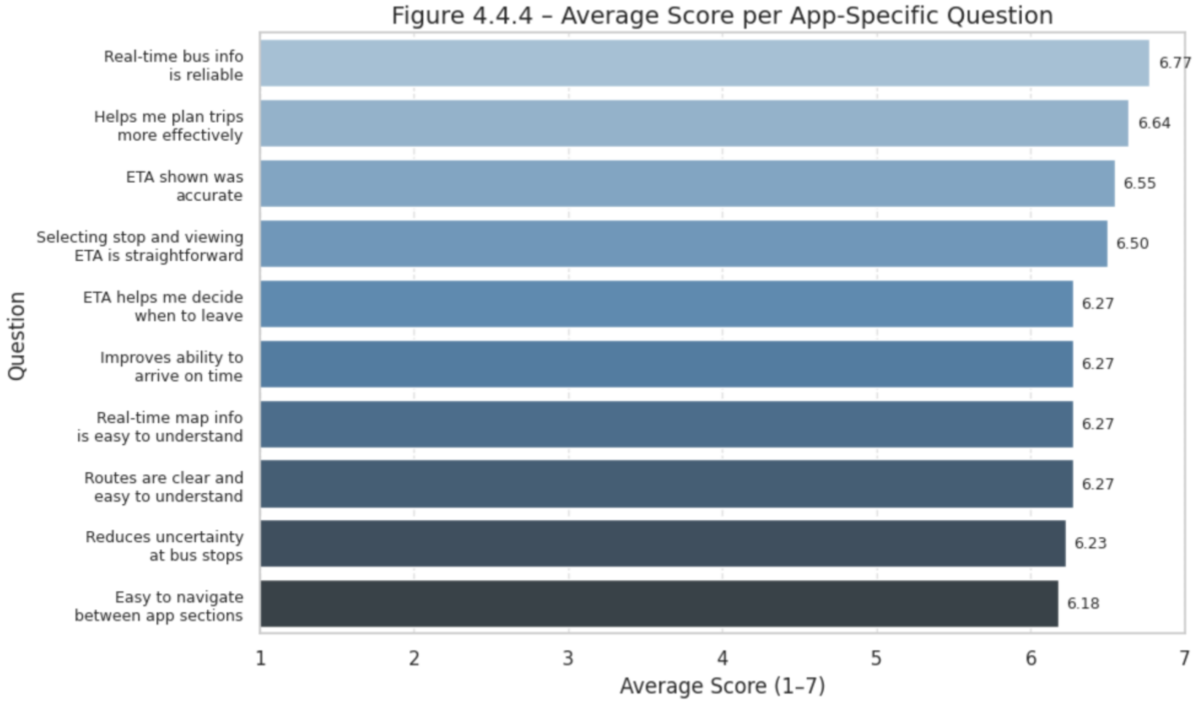


Figure 4.4.4 shows the average score for each of the ten application-specific questions. Ratings were generally high, ranging between 5.82 and 6.55, indicating strong user satisfaction with the system's core features.

The top-rated item was "I find it easy to understand the real-time information displayed on the map" (6.55), which confirms that the visual presentation of live bus locations is intuitive and effective. Other highly rated questions included:

- "It helps me plan my public transport trips more effectively" (6.50),
- "It is easy to navigate between different parts of the app" (6.45), and
- "The Estimated Time of Arrival (ETA) shown in the app helps me decide when to leave" (6.36).

These responses demonstrate that the app succeeds in supporting users through its interactive map, stop/route selector, and ETA integration.

Slightly lower — though still positive — were the scores for "The Routes of the App are clear and easy to understand" (5.86) and "Found the Estimated time of Arrival accurate" (5.82). These responses suggest that while users trust the system overall, some perceived minor inconsistencies in the way routes were presented or in how ETA was calculated in specific cases. This could be linked to edge cases in data timing or how certain routes overlap.

What This Means for the Application

The high scores across almost all questions indicate that the application meets its primary design goals: to make real-time bus tracking and journey planning easier, faster, and more transparent for users.

Specifically:

- The real-time bus map, stop selection, and ETA engine are perceived as clear and usable.
- Navigation between components (routes, map, ETA) is smooth, validating the front-end UI flow.
- Minor gaps in route display clarity or ETA precision present opportunities for small but meaningful future improvements — such as incorporating bus delay flags, improving marker refresh intervals, or offering better route descriptions.

This feedback confirms that the system not only functions properly from a technical standpoint but is also well received by its end users in its real-world context.

4.4.5 Open-Ended Feedback

To complement the quantitative analysis, participants were also invited to answer three open-ended questions regarding the app's functionality, challenges, and potential improvements. These qualitative insights provide context to the Likert-scale responses and highlight user priorities that might not emerge from fixed-choice data alone.

Most Useful Features

The most frequently mentioned feature was the accuracy of the ETA (Estimated Time of Arrival), referenced in two out of three responses. One user also cited "the route and the time estimation" as being particularly helpful. This aligns with the high quantitative scores observed for ETA-related items in Section 4.4.4 and confirms that live tracking and ETA predictions are central to the app's perceived value.

Two challenges were highlighted:

- Inactive bus routes, where users noted that some routes appear in the app but lack active buses. This may create confusion or the impression of missing functionality.
- Visual accessibility in dark mode, where one user noted issues with text readability. This suggests that UI contrast or color handling could be improved for users operating under dark system themes.

These comments point to opportunities for refinement in both backend logic (e.g., hiding inactive routes) and UI adaptability (e.g., dynamic theme responsiveness).

Suggestions for Improvement

One suggestion was to allow users to select a different stop from the route directly on the map. This feedback implies that the app could benefit from more flexible interaction with the route visuals, potentially improving user control over boarding decisions.

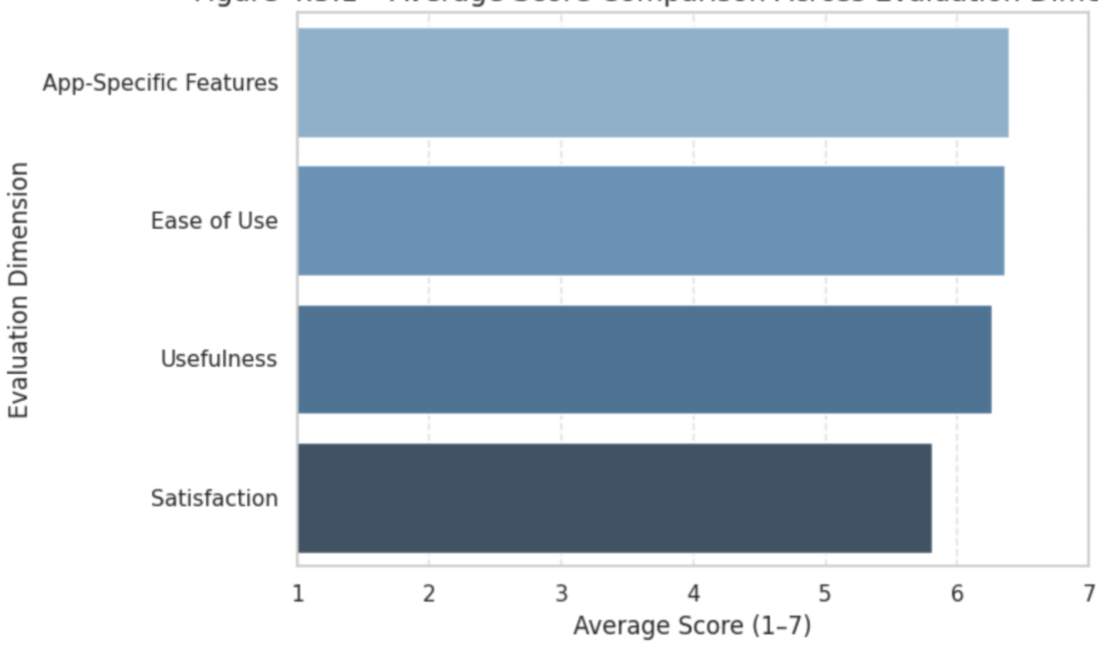
What This Means for the Application

These open-ended responses reinforce the quantitative data: users highly value the app's real-time ETA features but have specific improvement areas in mind. Addressing inactive route listings and enhancing dark mode readability would likely increase satisfaction further. Additionally, offering more interactive map control may raise the app's perceived flexibility — one of the areas that scored slightly lower in the Ease of Use section.

4.5 Summary of Evaluation Results

The results of the evaluation indicate that the "Track Cyprus Busses" application performs strongly across all key usability and functionality dimensions, as perceived by real users. Based on a structured USE questionnaire and targeted app-specific questions, both quantitative scores and open-ended feedback confirm the system's strengths and identify clear paths for enhancement.

Figure 4.5.1 – Average Score Comparison Across Evaluation Dimensions



As shown in the figure, Ease of Use and App-Specific Features achieved the highest overall scores, both averaging above 6.3 on a 7-point scale. This suggests that users not only found the system intuitive and smooth to operate but also appreciated its real-time functionality, route clarity, and ETA integration.

Usefulness also scored highly (≈6.2), indicating that users perceive the app as a valuable tool for managing their public transport experience more effectively. Satisfaction, while still favorable (≈5.9), showed slightly more variability — likely reflecting opportunities for deeper personalization, aesthetic improvements, or enhanced emotional engagement with the interface.

Key Strengths Identified:

- Usefulness: High average scores (above 6.0) confirm that the application effectively helps users plan their trips, make decisions based on real-time ETA data, and reduce uncertainty during travel.

- Ease of Use: The app was praised for its intuitive design and clear interface, allowing users to navigate its features without training or external support.
- Satisfaction: Users reported high levels of satisfaction, with the majority indicating they would recommend the app to others and found it pleasant to use.
- Core Features: Real-time bus tracking, ETA prediction, and map usability were consistently identified as the most helpful components.

Areas for Improvement:

- Perceived Flexibility: Slightly lower scores in flexibility and step-efficiency suggest that users may benefit from faster workflows or shortcut options.
- ETA Accuracy & Route Clarity: While ratings were positive, users noted some inconsistency in route visibility and minor inaccuracies in ETA timing.
- Accessibility & UI Design: Open-ended responses highlighted issues with night mode readability and the visibility of inactive routes, suggesting areas where adaptive UI enhancements would be beneficial.

Conclusion:

The evaluation confirms that the application is not only functional, but also user-centered, intuitive, and positively received. It successfully addresses a real-world problem — the lack of live public transport visibility in Cyprus — and provides an experience that users trust and find helpful.

The insights gained from this evaluation will serve as a foundation for future development and will directly inform usability refinements, UI improvements, and feature expansions.

Chapter 5

Conclusions, Discussion and Future Work

5.1 Summary of the Work

The aim of this project was to design and implement a mobile application that enhances the experience of using public transportation in Cyprus by providing real-time information on bus locations and estimated time of arrival (ETA). Leveraging technologies such as Firebase Firestore, Google Maps APIs, and public transport datasets, the application titled **"Track Cyprus Busses"** delivers a responsive and user-friendly interface that allows commuters to search for routes, view real-time bus positions, and plan their journeys with greater confidence and efficiency.

The application was developed in Android Studio and integrates various data sources, including static route and stop data from the Cyprus Open Transport dataset and live bus information from the businfo API. The system architecture was designed to handle real-time updates with minimal latency, providing dynamic map visualization, ETA predictions via Google's Directions API, and seamless navigation between functional components such as stop selection, route view, and tracking.

A comprehensive evaluation was conducted using a structured questionnaire based on the USE (Usefulness, Satisfaction, and Ease of Use) framework, complemented by app-specific questions. A total of 22 participants interacted with the app and rated it across several dimensions. The results demonstrated high levels of usability, user satisfaction, and perceived reliability of the system's core features.

In summary, the project successfully delivered a working prototype that addresses a real user need — access to accurate, live transit data in a context where such tools are still limited. The evaluation confirmed the application's effectiveness and its potential for deployment and future growth.

5.2 Discussion of Findings

The evaluation results presented in Chapter 4 offer valuable insights into how users perceive and interact with the "Track Cyprus Busses" application. The feedback reveals strong performance across all major usability dimensions, aligning well with the design objectives established at the beginning of the project.

One of the most significant findings was the high score in the Ease of Use category. Users consistently rated the interface as intuitive, simple, and reliable, with an average score exceeding 6 out of 7 across multiple related questions. This confirms that the design choices — such as minimal navigation layers, direct access to real-time bus locations, and the clear layout of route and stop data — effectively support user expectations and cognitive flow. The high usability score also suggests that the app has a low learning curve, which is particularly important in public transport settings where users interact quickly, often while on the move.

Usefulness was another strongly rated category, especially in relation to planning and trip coordination. Questions measuring the app's impact on travel efficiency, time management, and confidence in departure decisions received some of the highest scores in the questionnaire. This confirms that the integration of real-time ETA, static route data, and visual mapping tools works effectively to reduce uncertainty — a common pain point in public transport systems.

The Application-Specific Feedback provided additional confirmation of these strengths. Users particularly valued the app's ETA accuracy and visual representation of bus movements. However, this section also revealed areas that require refinement. For example, the question regarding route clarity and ETA accuracy, while still rated positively, received slightly lower scores compared to other metrics. This suggests that while the core functionality is strong, real-world inconsistencies (e.g., inactive buses, data latency, or ambiguous route lines) can affect user trust in specific moments.

The Satisfaction dimension, though favorable, showed slightly more variance than the other categories. While users expressed overall contentment with the application and a willingness to recommend it to others, responses to more emotional or aesthetic questions (e.g., "It is fun to use," or "It is wonderful") were lower. This is expected in utility-focused apps and indicates that while the application fulfills its purpose, it could still benefit from minor design or personalization enhancements to increase its long-term appeal.

Finally, the open-ended feedback added qualitative depth to the findings. Comments reinforced the value of the ETA and route visualization features, but also highlighted technical limitations such as inactive buses appearing in the route list and dark mode readability issues. These responses will directly inform future improvements.

5.3 Limitations

While the "Track Cyprus Busses" application met its core objectives and was well received by users, several limitations must be acknowledged. These limitations, both technical and contextual, provide important framing for the current findings and help identify areas for further refinement.

Technical Limitations

The application relies heavily on third-party services and open data sources. Real-time bus positions are retrieved from the unofficial cyprusbus.info API, which may occasionally return outdated or incomplete records. Estimated Time of Arrival (ETA) calculations are handled through the Google Directions API, which models road traffic but does not account for bus-specific behaviors like stop durations or detours.

Another key limitation is related to **API usage quotas**. The free tier of the Google Maps and Firebase services imposes request and data limits. While the current system operates within these constraints for development and testing, scaling the application — for example, by increasing data polling frequency, supporting more users, or storing additional transit history in Firestore — would likely require a **paid subscription** to Google Cloud services. This could impact the app's sustainability if deployed widely or integrated with municipal services.

Additionally, the current system polls bus data at five-second intervals, which introduces minor latency and data freshness challenges, especially if the backend were to scale to a national or multi-city deployment.

Design and Platform Constraints

At this stage, the app is available only on the Android platform, which limits its accessibility for iOS users. While the current interface is functional and received high usability ratings, some users noted minor issues with the visual layout — particularly in dark mode or when dealing with long route lists. There is also no accessibility-specific support implemented yet (e.g., screen reader compatibility or high-contrast themes for vision-impaired users).

Scope and Geographic Coverage

The application's scope is currently restricted to the public transport system of Cyprus. While this was a deliberate focus, the generalizability of the results — especially the evaluation findings — is limited to this geographic and cultural context. Bus data for some routes was occasionally unavailable or inconsistent, likely due to gaps in public data infrastructure rather than application logic.

Evaluation Limitations

The evaluation was based on a sample of 22 participants, primarily from similar demographic groups (e.g., students or young professionals familiar with mobile apps). While this provided valuable insight, a broader sample could help ensure that the results are representative of the general population, including older adults or individuals with lower digital literacy.

5.4 Future Work

While the "Track Cyprus Busses" application is fully functional and meets its intended goals, there are several directions for future development and research that could improve the system, expand its utility, and increase its scalability.

1. Enhanced ETA Accuracy

Although the current system uses Google's Directions API to estimate bus arrival times, these values are based on standard driving conditions and do not incorporate actual stop delays, historical patterns, or transit-specific disruptions. Future versions of the application could enhance ETA predictions by training machine learning models (such as regression models, decision trees, or neural networks) on historical trip data — including past arrival times, time-of-day traffic conditions, and route-specific behavior. Additionally, direct integration with official GPS feeds (if made available) would allow for more accurate real-time calibration and a smarter, context-aware ETA engine.

2. Route and Stop Management

Several users commented on the visibility of inactive buses or confusing route displays. A filtering mechanism could be introduced to hide routes that have no active buses in real time, or to highlight active paths only. Additionally, implementing dynamic color-coded polylines or numbered route overlays would improve map clarity and visual usability.

3. User-Centered Features

Future iterations of the application could include:

- Push notifications (e.g., alerts when the bus is approaching)
- Favorite stops and routes for quick access
- Offline mode with cached static route data
- Custom themes or dark mode improvements based on user feedback

These features would further enhance usability and retention.

4. Platform and Device Expansion

Currently developed exclusively for Android, the system could be ported to iOS or built as a responsive web application to reach a wider audience. Additionally, the interface could be adapted for use on tablets or embedded screens at bus stations for public access.

5. Accessibility and Inclusivity

To make the app usable by a broader demographic, future versions should include accessibility enhancements, such as screen reader compatibility, font scaling, and contrast options. Multilingual support (e.g., Greek, English, and Turkish) would also make the app more inclusive to both locals and tourists.

6. Data and API Optimization

Given the current reliance on free-tier Google and Firebase APIs, any significant scale-up will require financial and infrastructural planning. Future work should explore cost-efficient cloud deployment, request batching strategies, and integration with official government APIs to ensure long-term sustainability and avoid exceeding service quotas.

7. Long-Term Usage Analytics

A backend analytics module could be added to collect anonymized data about usage patterns, such as most-viewed routes or common stop combinations. These insights could help transit authorities improve service planning and further refine the app.

5.5 Final Conclusions

This thesis presented the design, development, and evaluation of the **"Track Cyprus Busses"** mobile application — a real-time public transportation tool developed for Android. The system was built with the aim of improving the visibility and reliability of bus services in Cyprus by providing live bus tracking, Estimated Time of Arrival (ETA) predictions, and an intuitive interface for route navigation and stop selection.

Through the integration of multiple technologies — including Google Maps APIs, Firebase Firestore, and the Cyprus Open Transport dataset — the application delivers a user-centered experience that addresses one of the core challenges in public transportation: uncertainty. Users can now check exactly where their bus is, how long it will take to arrive, and whether the selected route is still active — all through a single, interactive mobile interface.

The structured evaluation, based on the USE questionnaire and additional domain-specific questions, confirmed that the system is both highly usable and perceived as valuable by real users. Features such as live ETA, real-time map updates, and ease of navigation were consistently rated highly. Open-ended feedback further reinforced the system's practical utility, while also identifying areas for enhancement.

Despite a few limitations — such as data dependency, API quota restrictions, and the need for broader accessibility — the results show that **"Track Cyprus Busses"** makes a meaningful contribution to improving the public transport experience in Cyprus. The application serves as a robust foundation for future development and holds potential for expansion, both geographically and functionally.

In conclusion, the project successfully combines open data, cloud services, and mobile development into a single, scalable solution that empowers users and supports smart mobility. With continued refinement and support, the system could evolve into a fully deployed public tool — improving not just commutes, but confidence in the broader transportation infrastructure.

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