Development of a GPS Location Detection and Monitoring System for NU-APC Shuttle Service Using Android Application and Web Server

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Abstract

Shuttle service serves as a highly convenient mode of transportation for private institutions and companies seeking to travel between two locations. NU-Asia Pacific College offers a school shuttle service that accommodates students, parents, visitors, faculty, and staff who rely on public transportation from Lapu-Lapu St. to the main building of NU-Asia Pacific College. Currently, there is no existing monitoring system in place for the college's shuttle service. Consequently, several potential scenarios could arise, including unexpected incidents like hijacking or kidnapping, route changes due to refueling, unauthorized usage of the service, and insufficient capacity. To address these issues, a system has been developed that utilizes Google Maps to accurately track the shuttle's current location, capacity, and status. Additionally, the system automatically records each trip and generates historical analytics. The study's results demonstrate an impressive accuracy rate of 99.99989% in terms of GPS coordinates, thus confirming the system's reliability for real-time monitoring of shuttle activity at NU-Asia Pacific College and highlighting the significance of this technological advancement.

Keywords: *track monitoring system, transportation, web services, database, Google maps*

Introduction

Transportation is an essential aspect of contemporary society (Cascetta, 2015). In the Philippines, commonly utilized forms of public land transportation include tricycle, jeepneys, buses, and taxis (Thanatorn Chuenyindee, 2022). When people travel, it is crucial for them to stay informed about their current location, ensuring they are on the right track and aware of the distance remaining to reach their destination safely. Modern technologies, such as the Global Positioning System (GPS), play a significant role in providing secure transportation services like Grab, Uber, and Angkas.

Shuttle service proves to be an extremely convenient means of transportation between two locations (Collins Dictionary, n.d.), especially when one of the destinations is not easily accessible via public transportation. These shuttle services are reliable in terms of reaching their designated destinations within specific time frames.

Statement of the Problem

Undoubtedly, a glaring concern looms over the shuttle service operations at NU-Asia Pacific College – a concern that demands immediate attention and rectification. Astonishingly, the current scenario paints a disconcerting picture: a complete absence of any form of monitoring system for the shuttle service. This unsettling void in oversight gives rise to a series of potentially dire situations, each more alarming than the last. First and foremost, the specter of unexpected incidents, such as hijacking or kidnapping, hangs ominously over the entire operation. The absence of a monitoring mechanism magnifies the vulnerability, leaving both passengers and authorities in a state of helpless uncertainty. Adding to this unnerving landscape, the potential for abrupt route changes due to the mundane necessity of gas refilling emerges yet another lurking danger. Without a robust system in place, even the most routine operational alterations can lead to confusion, inconvenience, or worse. Compounding these concerns is the disquieting specter of unauthorized individuals exploiting the system for their own purposes. The lack of a vigilant eye allows for clandestine and unauthorized usage of the shuttle service, a perilous breach of security and propriety. Lastly, the dismaying realization of insufficient shuttle service capacity looms large, exacerbated by the absence of a mechanism to gauge and manage demand. Passengers left stranded due to capacity issues may find themselves questioning the very reliability of the service they depend upon. In the absence of a monitoring system, this multifaceted predicament deepens, highlighting a stark and urgent need for comprehensive oversight and rectification. The call for action resounds louder than ever, underscoring the pressing need to establish a robust and vigilant monitoring system without delay.

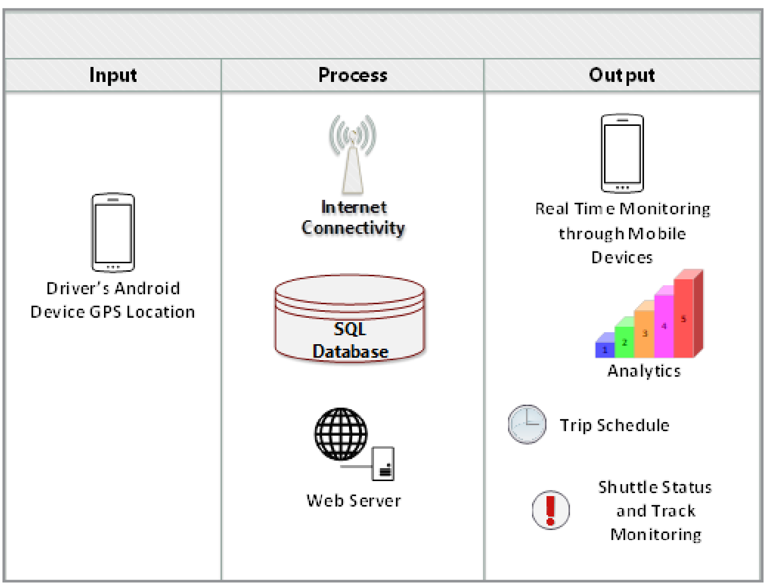
To address these concerns, the researchers propose the implementation of a

GPS tracking system utilizing an Android application through a web server. Separate Android applications will be developed for drivers and users, while administrators and users will have web access. Administrators will be able to monitor the current location of shuttle drivers and the number of trips made throughout the day via a web browser and the web server. Additionally, administrators will have access to historical data regarding the shuttle's capacity status. This data will aid in decision-making regarding the deployment of additional shuttles, based on the average daily trips for the corresponding day of the week over a four-week period (e.g., if today is Monday, the historical data will be from the last four Mondays).

Drivers will have access to the application to monitor their current number of trips and the shuttle's location. Students, faculty, and staff users can view the shuttle's current location by connecting to the Wi-Fi or using mobile data, either through the Android application or by accessing a public link within the APC main campus. The application will notify administrators if a shuttle deviates from the official route or enters an emergency status. The Administrator will be prompted to contact the shuttle driver, allowing them to verify the driver and passengers' status and determine the reason for the route change.

FIGURE 1

Conceptual Framework



The primary objective of this research is to develop a GPS Location Detection and Monitoring System for the APC Shuttle Service using an Android Application via a web server. The system aims to notify, detect, and monitor the shuttle's activity effectively. An end-user application will be meticulously designed and developed for Android devices using Android Studio, while non-Android devices will utilize PHP-HTML. Additionally, the system will generate comprehensive historical analytics based on daily time and shuttle trip capacity status to optimize overall shuttle service capacity. Rigorous testing will validate the system's accuracy in detecting and monitoring the precise GPS location of the shuttle, ensuring dependable notifications about its position on the designated track.

Objectives of the Study

The research project aims to enhance accessibility and efficiency by monitoring the shuttle's route, status, and location. Users can eliminate uncertainty about the shuttle's whereabouts and check its status through the Android application and website. Drivers will have access to monitor their shuttle trip schedules and communicate with administrators using the Android application.

The logistics staff and administrators will benefit from the web server application, enabling them to remotely monitor shuttle trip schedules, routes, and status. The generated analytics will assist in determining the required number of shuttles for specific scheduled times, minimizing inadequate shuttle service capacity daily.

Scope and Delimitations of the Study

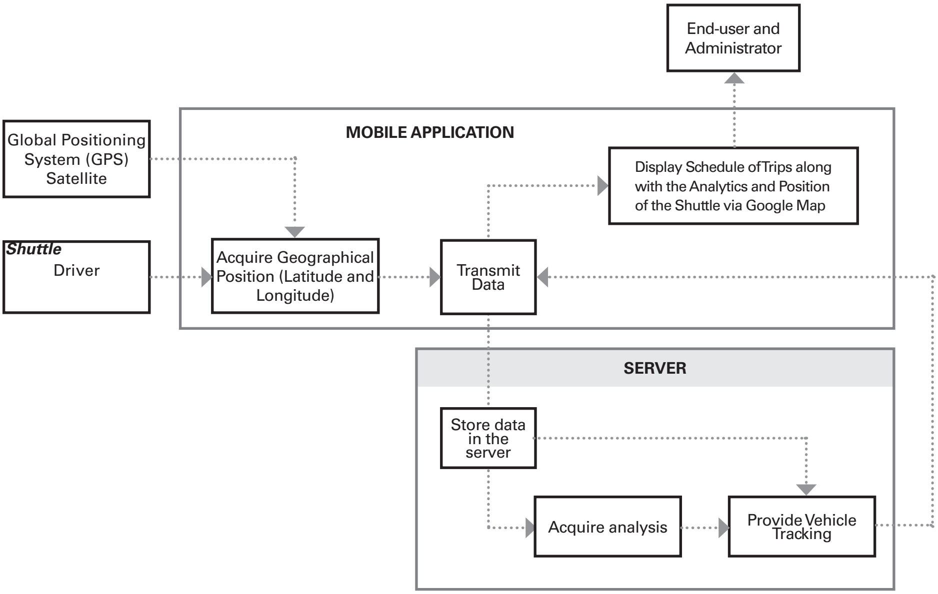
The project's scope includes monitoring the shuttle's current location through the user's Android application or the web application. Drivers will have a separate Android application allowing them to log in, set the shuttle's status, view the schedule and trip history, and select the capacity status before each trip. The GPS location received from the driver's Android phone will be transmitted to the server and displayed to all users (students, faculty, staff, logistics, and administrators) through the Android application and web server. Logistics and administrators will have the ability to register, enable, and disable driver accounts, view historical analytics based on time and shuttle trip capacity status, and receive notifications from the web server application if the shuttle deviates from its track and contact the driver.

Certain delimitations exist within the project. GPS location readings will be based on the driver's Android devices and transmitted via Wi-Fi or mobile data. Only APC students, faculty, and staff will have access to the application, while guests can only view the map on the APC main lobby. The shuttle's capacity status will be selected by the driver at the beginning of each scheduled trip. The shuttle's route will be limited between the terminals on Lapu-Lapu St. and the APC Main building. The shuttle's capacity status will be categorized as full, more than half, less than half, or empty. The driver will manually select the shuttle's status, which is limited to On Duty, Refilling Gas, or On Emergency Maintenance.

Software Application Design

FIGURE 2

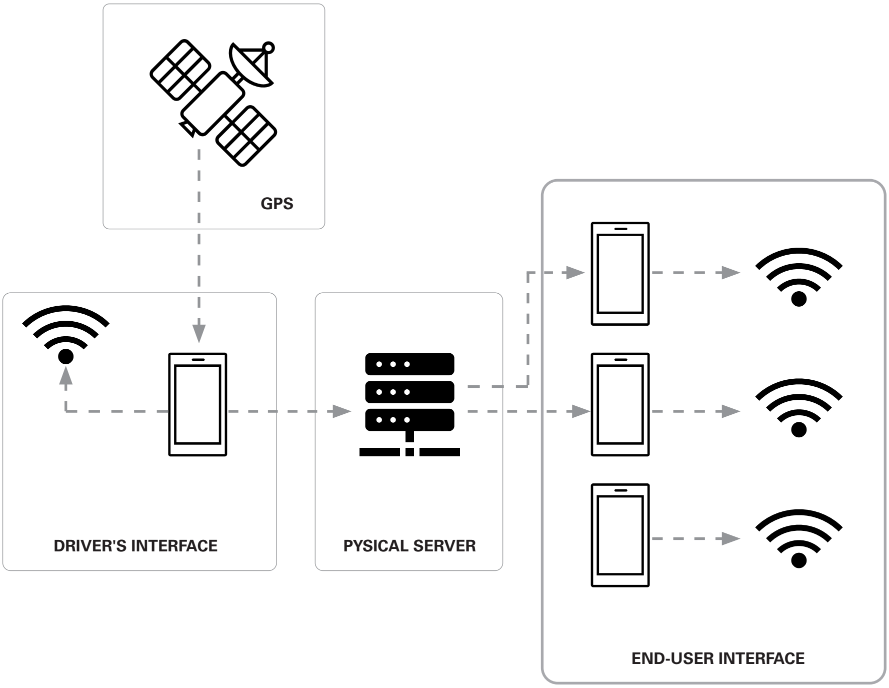
System Block Diagram



The block diagram illustrates the flow and components involved in the driver's mobile application and its connection to the GPS, as well as the subsequent transmission and storage of acquired position data on the server. It also demonstrates the comparison between the acquired position and the expected route position of the shuttle, incorporating the shuttle's analytics. Furthermore, the diagram showcases the functionality of the system in enabling vehicle tracking based on the gathered data, as well as the transmission of schedule and generated data to the end-user's application. Lastly, it highlights the system's ability to promptly notify the administrator in the event of a deviation in the shuttle's position.

FIGURE 3

High Level System Block Diagram



The high-level system block diagram shown in Figure 3 illustrates the interconnections within the proposed system. It showcases the various connections involved in the system through a graphical representation. The driver's device and the end-user's devices are both connected to the internet, depicted by a dash-line. The driver's interface retrieves the GPS location data from the device, which is then directly transmitted to the server. This data can be accessed and viewed by any end-user who is connected to the server through an Android application.

FIGURE 4

Driver's Application Flowchart

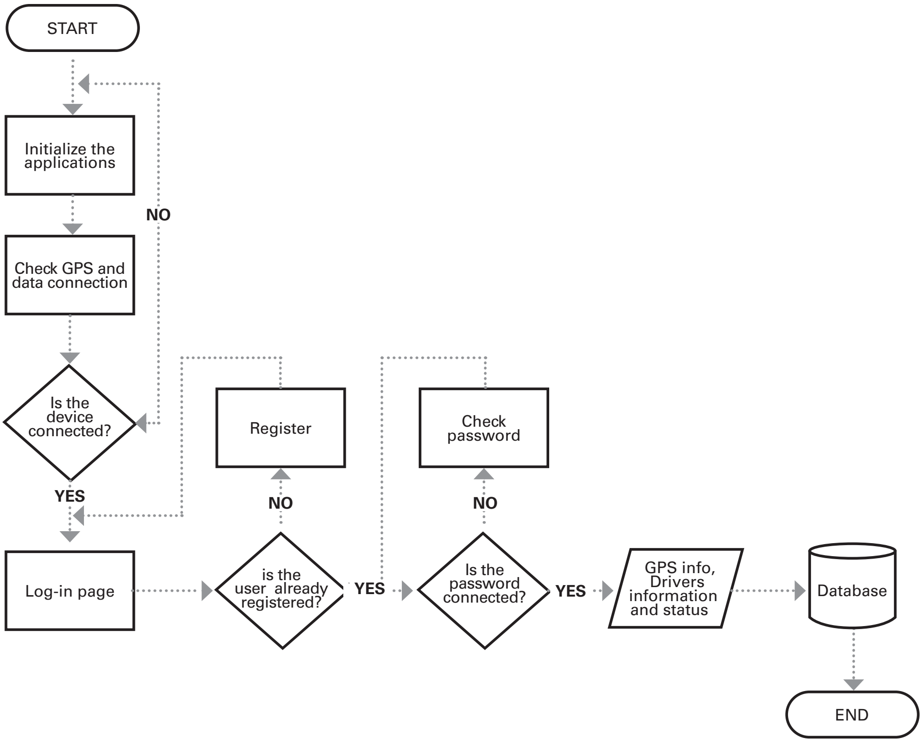


Figure 4 shows the flowchart of the application design for the driver. The application will first initiate the checking process for GPS and data connection. It is required that the device is connected to both a network and GPS. The user will then be directed to the login page, where they will have the option to register if they have not done so already. In the case of a registered user, a password must be entered, which should match the one stored in the database. Once successfully logged in, the application will transmit GPS information, driver's details, and status to the database.

FIGURE 5

User's Application Flowchart

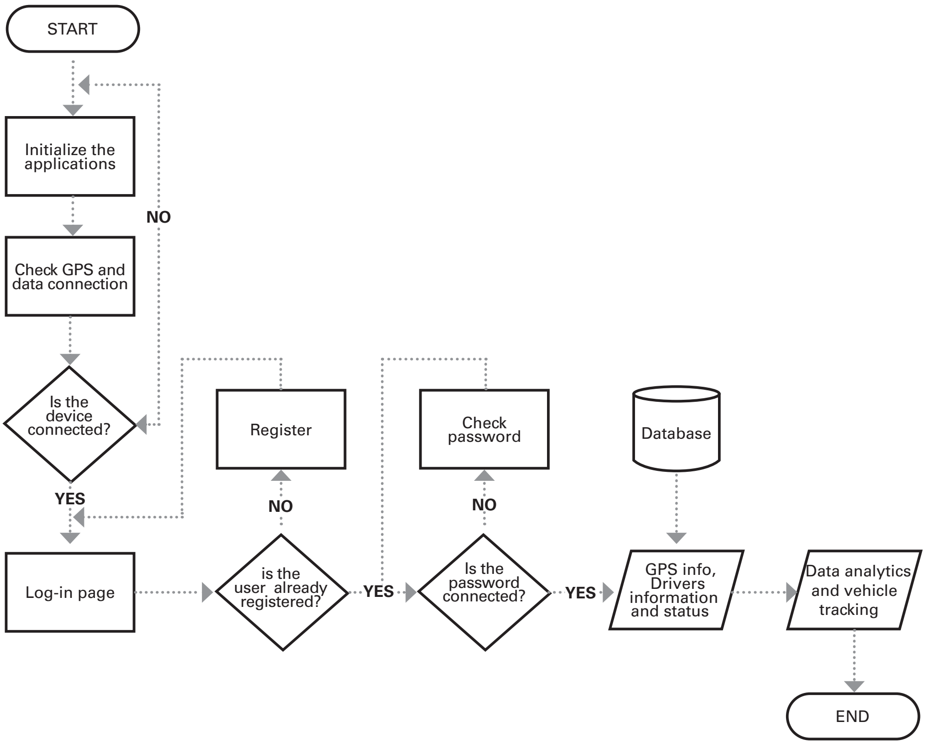


Figure 5 shows the flowchart for the application design for the user. The application will be initiated, and the first step involves checking the data connection. It is essential for the device to be connected to a network. Subsequently, the user will be directed to the login page, where they will have the opportunity to register if they have not already done so. For registered users, they will need to input their password, which must match the one stored in the database. Upon successful login, the application will retrieve the GPS information, driver's details, and status from the database. Additionally, the application will offer features for data analytics and provide vehicle tracking functionality.

FIGURE 6

Notification Flowchart

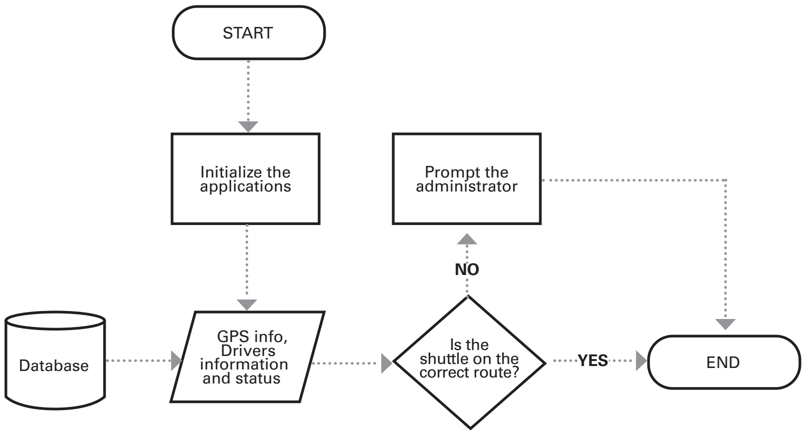
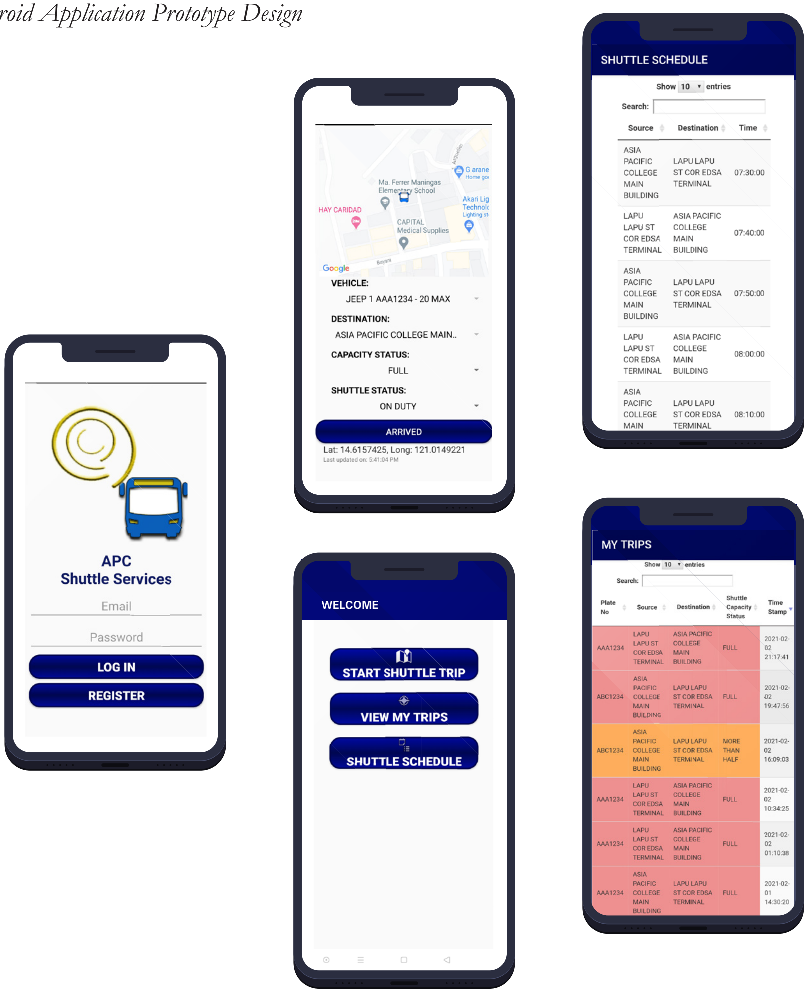


Figure 6 displays the notification flowchart, illustrating the sequence of events. The GPS information, driver's details (including the route and schedule), and the shuttle's status will be retrieved from the database. The application will then verify whether the shuttle is following the designated route. If the shuttle deviates from the expected path, the application will promptly notify the administrators.

FIGURE 7

Android Application Prototype Design



The android application is developed using Android Studio as the Integrated Development Environment (IDE). Figure 7 depicts a sample user interface (UI) for the application. In designing the UI, the researcher considers three key factors: development, visibility, and acceptance. Under development factors, considerations include the device, platform constraints, and available libraries. Android Studio offers an intelligent code editor that facilitates easy deployment on Android devices, while readily available libraries and tools effectively address development requirements.

FIGURE 8

Admin WebApp Modules Prototype Design

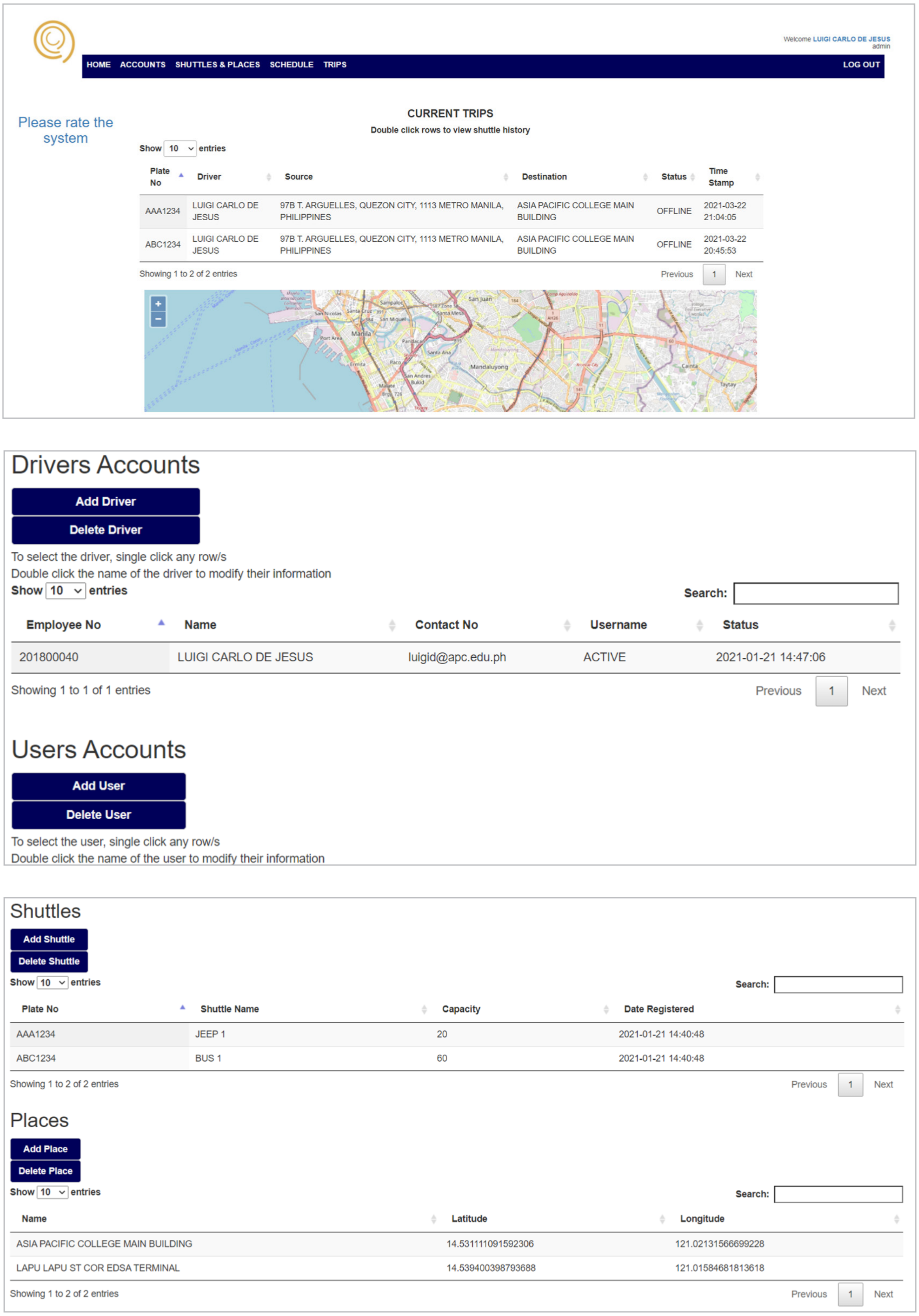


Figure 8 displays the preview of the website, which utilizes XAMPP for its Java Server Pages (JSP). The proponent chose XAMPP for its convenient deployment of Java and PHP-based applications, enabling efficient server deployment.

Visibility factors focus on the design of the interface, encompassing layout, typography, color, texture, and imagery. The design presented in Figures 7 and 8 takes all these elements into consideration. The arrangement of blocks and buttons is intentionally kept simple. User-acceptability will be assessed to determine the acceptance of the user interface. Factors such as organization, consistency, layout, navigability, simplicity, clarity, readability, and color will be tested for their impact on user- acceptance.

Testing and Evaluation

Tests were performed to validate the functionality of the application in accordance with the design specifications and desired objectives for design features: (1) accuracy, (2) reliability, and (3) user acceptability.

Accuracy

TABLE 1

Detection of GPS Location

Stopover	Google Map Latitude	Google Map Longitude	Application Latitude	Application Longitude	Lat Diff	Long Diff
1	14.5395580	121.0154001	14.5395356	121.0154112	0.0000224	-0.0000111
2	14.5393570	121.0147782	14.5393466	121.0147708	0.0000104	0.0000074
3	14.5327663	121.0193621	14.5326728	121.0192092	0.0000935	0.0001529
4	14.5317399	121.0199037	14.5317425	121.0199238	-0.0000026	-0.0000201
5	14.5315400	121.0207412	14.5315322	121.0207285	0.0000078	0.0000127

Table 1 presents a comprehensive overview of the outcomes stemming from an examination of GPS coordinates encompassing latitude and longitude. The assessment encompassed five distinct and randomly selected locations. The data, drawn both from the designated application and Google Maps, were meticulously analyzed, with a key focus on the absolute disparity between the coordinates furnished by the two sources. This rigorous evaluation of coordinate accuracy was conducted as part of a broader inquiry into the precision and reliability of the application's geographical measurements.

The accuracy of GPS location data is primarily determined by the geometry of satellite positions relative to the receiver's location on Earth. This relationship, known as Dilution of Precision (DOP), considers factors such as the number of visible satellites, their distribution across the sky, and their signal strength, collectively influencing the precision of the calculated position (Kaplan & Hegarty, 2006; Misra & Enge, 2006; Leick, 2004; Teunissen & Montenbruck, 2017).

Interestingly, the time of data acquisition, despite its seemingly significant role, has been found to have a minimal impact on the location's accuracy. This is due to the remarkable speed of light, which travels at approximately 299,792 kilometers per second (Kaplan, 2006). Consequently, the time required for GPS signals to traverse the distance from satellites to the receiver is negligible in comparison to other sources of error within the GPS system. Instead, the accuracy of GPS positioning is predominantly influenced by factors like atmospheric interference, multipath effects (signals reflecting off obstacles), receiver noise, and the geometric arrangement of the satellite constellation (Teunissen, 2017). Given these considerations, there is no requirement for the proponent to record the time of data acquisition.

Worth noting is the context within which this evaluation took place: the testing occurred against the backdrop of the global pandemic. The prevailing circumstances of the pandemic necessitated certain limitations, including a restricted number of shuttle trips to the designated locations for data collection. This scarcity of shuttle trips is a direct result of the challenges posed by the pandemic, which hindered the ability to carry out extensive fieldwork and gather a more extensive dataset.

Against these constraints, the application's accuracy in measuring coordinates emerged as a highlight of the investigation. By quantifying the absolute differences between the coordinates derived from the application and those sourced from Google Maps, a noteworthy level of precision was observed. Specifically, the results revealed a remarkable accuracy rate of 99.99989% across the five randomly selected locations.

This exceptional accuracy rate underscores the application's capacity to provide dependable and consistent geographical information, even in the face of the testing limitations imposed by the pandemic. Despite the reduced number of shuttle trips available for data collection, the application's performance remained impressive and indicative of its robustness in accurately determining latitude and longitude coordinates.

Table 1's depiction of the GPS coordinate assessment, coupled with the observed accuracy rate, underscores the application's reliability in geographical measurements. This achievement is particularly noteworthy considering the challenging circumstances of the pandemic, which led to a constrained number of shuttle trips and thereby highlights the resilience and effectiveness of the application's capabilities.

Reliability

TABLE 2

Shuttle's Location Monitoring

Stopover	Google Map Coordinates	Application Coordinates	Is the stop over within the route? (Y or N)	Did the application alert the administrator if the shuttle is not following the route? (Y or N)
1	14.5395580, 121.0154001	14.5395356, 121.0154112	Y	N
2	14.5393570, 121.0147782	14.5393466, 121.0147708	Y	N
3	14.5327663, 121.0193621	14.5326728, 121.0192092	Y	N
4	14.5317399, 121.0199037	14.5317425, 121.0199238	Y	N
5	14.5315400, 121.0207412	14.5315322, 121.0207285	Y	N
6	14.5381075, 121.0041301	14.5380556, 121.0041288	N	Y
7	14.5388898, 121.0109015	14.5388781, 121.0109129	N	Y
8	14.5391873, 121.0126406	14.5391769, 121.0126567	N	Y
9	14.5384847, 121.0070895	14.5384367, 121.0070996	N	Y
10	14.5384167, 121.0065977	14.5383797, 121.0066061	N	Y

Table 2 offers a comprehensive presentation of the outcomes stemming from a thorough testing regimen focused on GPS coordinates. These coordinates encompass both latitude and longitude data, which were derived from two distinct sources: the designated application and Google Maps. The testing effort encompassed a total of 10 diverse and randomly chosen locations, each serving as a unique point of analysis.

To facilitate a structured assessment, the 10 locations were further categorized into two distinct groups: "on track" and "out of track." The division was based on specific criteria related to geographic positioning. Five of the chosen locations were classified as "on track," meaning that they fell within the predefined range established for accurate tracking. The remaining five locations were labeled as "out of track," as they were deliberately situated approximately 100 meters beyond the designated map boundary.

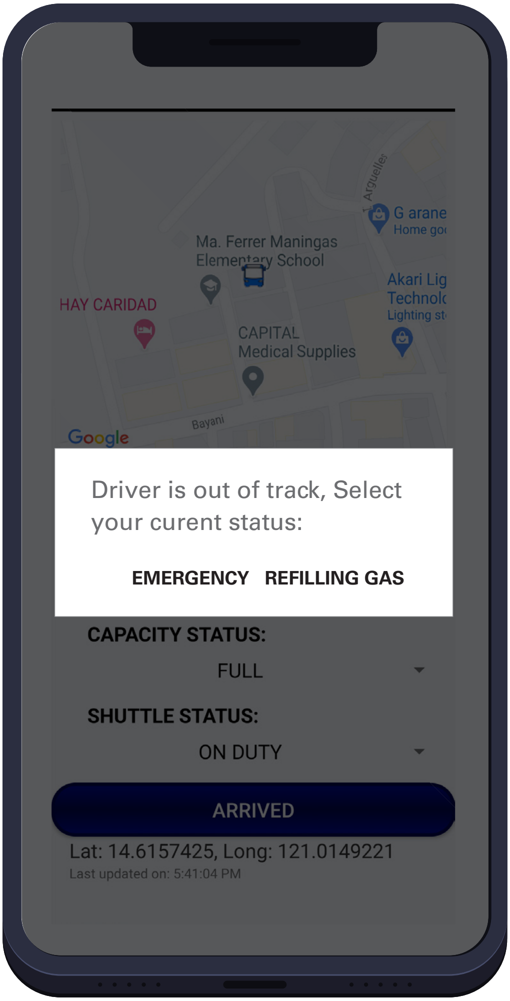
The testing methodology incorporates a proactive system to address scenarios in which the tracked location deviates from the intended track. When the system identifies that a vehicle's location has strayed beyond the established track boundary, it triggers a continuous series of notifications. These notifications are directed toward the driver and are facilitated through the application. The notifications persist until the driver takes deliberate action by manually updating their status. This action involves the driver pressing a designated button, a process that is visually represented in Figure 9 of the documentation.

This dynamic system of notifications and manual intervention is crucial for maintaining the integrity of the tracking process, especially in instances where a vehicle ventures outside the anticipated route. The system's responsiveness and real-time alerts enable drivers to promptly rectify any discrepancies between their actual location and the intended path.

Table 2 encapsulates the findings derived from a meticulous assessment of GPS coordinates across various locations. The inclusion of both on-track and out-of-track scenarios underscores the system's robustness in detecting deviations from the intended path. The implementation of continuous notifications and a manual update mechanism exemplifies the application's proactive approach to ensuring accurate tracking and enhancing driver engagement. This comprehensive approach contributes to the overall effectiveness and reliability of the tracking system, ultimately benefiting users and optimizing the navigation experience.

FIGURE 9

Driver Application Message Box Notification for Out-of-Track Status



User Acceptability

TABLE 3

User Acceptability Survey Result Summary

Elements	Average Rating
Organization	4.67
Consistency	4.67
Layout	4.57
Navigability	4.70
Simplicity	4.80
Clarity	4.67
Readability	4.77
Color	4.57
Average Rating	4.6775

Table 3 furnishes a comprehensive overview of the outcomes derived from an extensive Likert Scale survey, which was conducted to assess various elements pertaining to the application's user experience. The survey participants were prompted to rate each element on a scale that ranged from 1 (lowest) to 5 (highest), with the higher score indicating a more favorable evaluation. The provided ratings encompass a range of specific attributes that collectively contribute to the overall user perception of the application.

The obtained average ratings for each element reveal a notably positive assessment of the application's user experience. The highest average ratings were awarded to Simplicity (4.80), Readability (4.77), Navigability (4.70), and Organization (4.67). These scores are indicative of a high degree of user satisfaction in these areas, underlining the application's effectiveness in providing an intuitive and user-friendly interface.

Furthermore, the element of Consistency garnered an average rating of 4.67, demonstrating the application's ability to maintain a coherent and uniform user experience across various sections and interactions. Similarly, Clarity achieved the same average rating, affirming the clarity and effectiveness of the information presented within the application.

While most elements received notably high average ratings, two areas stood out with slightly lower scores. The Color category attained an average rating of 4.57, and the Layout category also received the same score. These scores, while still representing a positive evaluation, indicate that there may be room for improvement in terms of visual aesthetics and the arrangement of elements within the application's interface.

Notably, the survey results include outlier scores for the Color and Layout categories. Specifically, one user's feedback led to a notably lower score of 2 in these categories.

This user expressed a desire for a more visually engaging application, citing the perceived monochromatic nature of the interface as an area for enhancement.

Table 3 provides a comprehensive snapshot of user sentiment regarding various elements of the application's user experience. The consistently high average ratings across multiple attributes highlight the application's success in delivering a user-friendly, clear, and cohesive experience. While the Color and Layout categories received comparatively lower scores, the overall assessment of the application remains very positive, with ample scope for further refinement to address specific user expectations and preferences.

Summary and Recommendations

In line with the study's objectives, the implemented design functions yielded satisfactory and necessary results based on the evaluation data. Among these functions, location monitoring and stable data transmission are of utmost importance, requiring a smartphone with high-accuracy GPS and a reliable network provider. The accuracy of the system is crucial as it affects the quality of route monitoring, considering the potential interference from GPS satellites and wireless signals. Certain blind spots were identified in the Globe Telecomm network, particularly in areas with dense vegetation along Lapu-Lapu Street. Additionally, compatibility with non-Google Play devices, such as Huawei devices from 2019 onwards, should be considered.

Furthermore, the system demonstrated flawless execution, as confirmed by positive feedback from drivers, administrators, and users in the Likert Survey. Specific objectives were successfully achieved, with the DRIVER APP exhibiting a GPS location accuracy of 99.99989% and a reliability rating of 100%, both evaluated as Excellent. The utilization of a private server hosted by Hostinger.com contributed to the system's responsiveness and compatibility with PHP-based websites, ensuring zero network failures during data transmission. User acceptability, as assessed through surveys conducted with shuttle drivers and users, averaged at 4.6775, indicating a "Very Good" rating.

During the project development and testing phase, the proponent identified areas for improvement in the designed project. Due to the COVID-19 pandemic, certain issues could not be addressed during development. These identified areas can serve as valuable references for future researchers aiming to enhance similar engineering designs.

Firstly, it is recommended to enhance the user interface (UI) and code to ensure a more user-friendly and comprehensible navigation experience for all user types: drivers, users, and administrators. This improvement would facilitate easier learning and usage of the application.

Secondly, incorporating an estimated time of arrival feature in the passenger/ user application for each trip would be beneficial. This addition would provide users with an expected arrival time, enhancing their experience and convenience.

Thirdly, developing a method to count the total number of passengers on a trip would be valuable. This data could contribute to improved analytics and enable the creation of a prediction model. The prediction model could assist administrators in assigning the appropriate number of shuttles based on forecasted passenger numbers.

Additionally, enhancing the analytics charts by making them downloadable and adding an additional view would be advantageous for administrators. This improvement would facilitate the submission of reports and enhance data analysis capabilities.

Lastly, it is recommended to develop an application that supports Huawei devices released from 2019 onwards for obtaining GPS coordinates independent of Google Map Services. This would ensure compatibility and functionality across a wider range of devices.

By considering these recommendations, future researchers can build upon the existing project and contribute to its further enhancement

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