

Development of a National Travel Time and Delay Survey Methodology using Smartphone-based Data Collection System

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Abstract: One of the identified targets under the Department of Public Works and Highways (DPWH) Performance Governance System (PGS) Scorecard, is to promote both domestic and international trade through improvement of the capacity of priority corridors (N1 and Nautical Highways) with reduced travel time (in percentage of hours) as the primary measure. According to DPWH Department Order No. 38, Series of 2023, the target reduction in travel time is 4% and 8% in CY 2025 and CY 2028, respectively. As such, DPWH urgently needs an efficient and reliable system to accurately measure and assess the travel time and delay parameters along the N1 and Nautical Highways. This paper explores the development of a new national travel time and delay survey methodology using a smartphone-based data collection system.

Keywords: Travel time and delay, smartphone-based data collection, global navigation satellite system

1. INTRODUCTION

1.1 Background

In line with its commitment to realize *Ambisyon Natin 2040* and the *Philippine Development Plan 2023-2028*, the Department of Public Works and Highways (DPWH) adopted the Performance Governance System (PGS) as a strategy management tool to gauge the performance of the Department holistically and systematically in the implementation and monitoring of its policies, plans and programs. In the DPWH PGS Strategic Plan (StratPlan) for 2023-2028, now branded as *INFRAGENDA 2028*, the accomplishments of the Department are measured through a set of performance indicators.

One of the identified targets in the DPWH PGS Scorecard is to promote both domestic and international trade through improvement of the capacity of priority corridors (N1 and Nautical Highways) with reduced travel time (in percentage of hours) as the primary measure. According to DPWH Department Order No. 38, Series of 2023, the target reduction in travel time is 4% and 8% in CY 2025 and CY 2028, respectively. Figure 1 presents the measure profile and Figure 2 presents the map of the priority corridors.

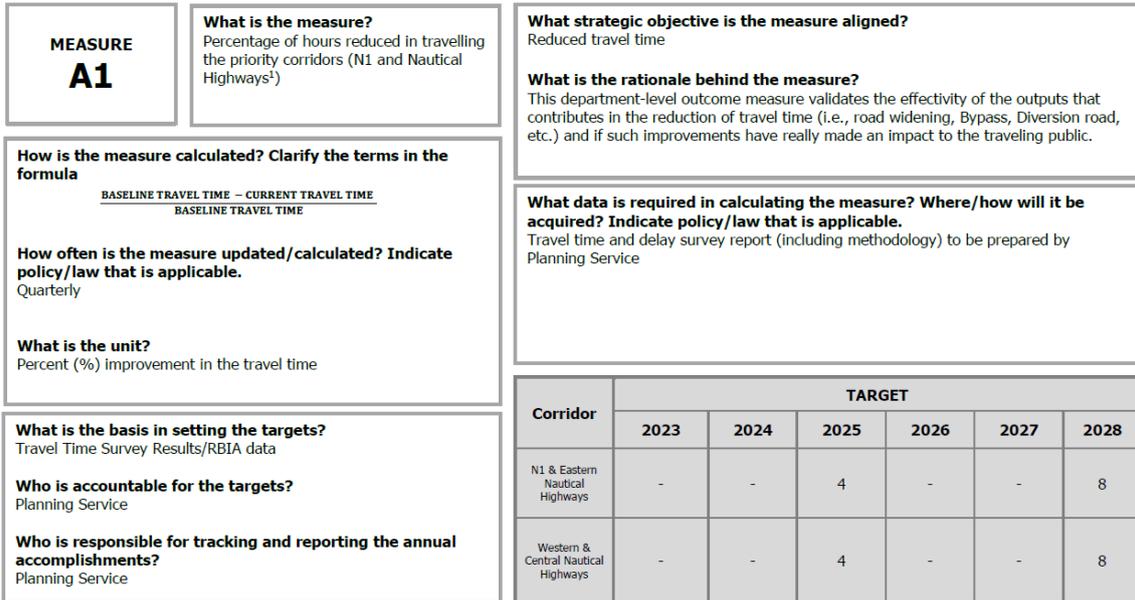


Figure 1. DPWH PGS Measure A1

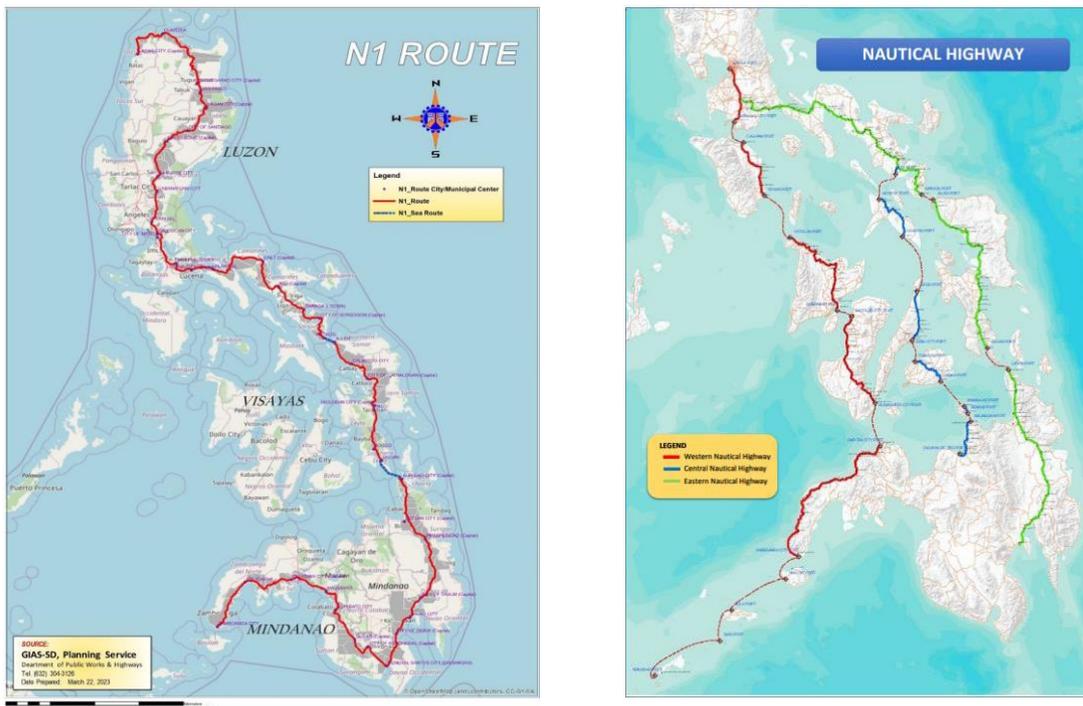


Figure 2. N1 and Nautical Highways Map

1.2 Rationale of the Study

Traffic congestion has been one of the most challenging problems concerning road traffic management in the Philippines. The cost of congestion for Metro Manila was first estimated to be about 100 billion Pesos annually (about 2 billion USD) or 2% of the country's GDP in 2000 (NCTS, 2000). This was computed primarily based on value of time of travelers or

commuters. Adjusting for inflation, Regidor (2012) estimated that the average annual losses incurred due to traffic congestion in Metro Manila reach over 137 billion Pesos as of 2011. Recently, a 2018 Japan International Cooperation Agency (JICA) study estimated that traffic congestion in Metro Manila costs the economy approximately 3.5 billion Pesos per day, a figure projected to rise to 5.4 billion Pesos by 2035 without changes. This cost includes factors like lost time, increased fuel consumption, and environmental impact. The costs arise from issues such as a high volume of vehicles, poor public transport, inefficient management, and rapid urbanization.

Due to its critical impact on the country's economy, traffic congestion is one of the major considerations in the assessment of potential road and bridge projects where DPWH aims to decongest and improve road traffic in the national road network by prioritizing projects for fund allocation that are prone to traffic congestion. To perform this, it is very important to establish and conduct measures that can provide reliable indicators of level of congestion.

One of the important parameters in studying traffic congestion is travel time, which is a direct measurement of congestion. Travel Time may be defined as the total elapsed time of travel, including stop and delay, necessary for a vehicle to travel from one point to another over a specified route under existing traffic conditions. Possible applications of travel time data include quantifying the overall congestion level along the chosen areas, identifying bottleneck zones in need of further study and developing future improvement projects. For example, Chen, et al. (2003) show that average travel time and travel-time variability are meaningful measures of freeway performance. In contrast, the Highway Capacity Manual (HCM) Level of Service (LOS) criteria do not capture the variability in travel time. Samal, et al. (2023) developed a Travel Time Reliability Congestion Index that accurately reflects the user experience in mixed traffic in order to identify the specific roadway attributes that contribute most to congestion. Finally, FHWA (2017) uses travel time data in identifying bottleneck zones by introducing data-driven methods to pinpoint exactly where and when traffic breaks down and provides a "playbook" of over 70 specific mitigation strategies.

There are several issuances and practices by the DPWH which require the collection of travel time and delay data, among others:

- INFRAGENDA 2028 Versa (DPWH D.O. 128, s. 2023)
- Road Conversion from Local to National Roads and Vice Versa (DPWH D.O. 112, s. 2024)
- DPWH Social and Environmental Management System Manual (DPWH, 2021)
- DPWH Highway Planning Manual 2012
- Conduct of various Feasibility Studies for Roads and Bridges

1.3 Research Objectives

The objective of the Study is to explore the development of a new national travel time and delay survey methodology using a smartphone-based data collection system.

3. TRAVEL TIME AND DELAY SURVEY

3.1 Floating Car Technique

Travel Time and Delay Studies are conducted to evaluate the quality of traffic movement along a route and determine the locations, types, and extent of traffic delays by using a moving test vehicle. This traffic engineering study method can be used to compare operational

conditions before and after roadway or intersection improvements have been made. It can also be used as a tool to assist in prioritizing projects by comparing the magnitude of the operational deficiencies (such as delays and stops) for each project under consideration.

When conducting a Travel Time and Delay Study, the Floating Car Technique has been the standard approach. In using this technique, the driver floats with traffic by passing as many vehicles as pass the test car. The idea is to emulate an average driver for each section of roadway. The advantages of the Floating Car Technique are its direct and accurate measurement of travel times and delays, and personal experience of the causes of delays. The main disadvantages are the large resources required for a comprehensive survey of a network, and problems of the survey vehicle exceeding the speed limit.

The Floating Car Method only surveys cars. Other vehicle types can be surveyed by following a selected vehicle. However, it is difficult to choose random vehicles to follow and the route of the vehicle is not known in advance. Safety may also be a problem, especially at high speed or in heavy traffic. The key definitions in Floating Car Technique are as follows:

- *Control Point (CP)*. A node at the beginning or end of a link, usually the stop line at a signalized intersection, but can be any physical feature, i.e., power pole. The stop line or physical feature selected within the intersection must be located in the same direction of travel. The control point may be different for each direction of travel. However, once a control point is chosen it shall be used for each run in that particular direction.
- *Delay (D)*. The elapsed time (in seconds) spent driving at a speed less than 5 kph.
- *Distance*. The length of a link or the length of a run.
- *Running Speed (RS)*. The test vehicle's average speed (in miles per hour) while the vehicle is in motion (does not include delay time) it can be calculated by the formula:

$$RS = \frac{Distance}{TT - D} \quad (1)$$

- *Running Time (RT)*. The elapsed time (in seconds) excluding delay spent driving a distance.
- *Special Control Points (SCP)*. Beginning and end points of the study route. They shall be located outside the influence of a signalized intersection or other highway feature which might cause delay. The vehicle must be at normal operating speed for the route when passing these points.
- *Stop (S)*. The average number of times per link or run that the test vehicle's speed falls below 5 kph. After a stop, an additional stop will not be recorded unless the speed first exceeds 30 kph.
- *Travel Speed (TS) or Average Speed (AS)*. The test vehicle's average speed (in kilometers per hour) over a distance.
- *Travel Time (TT)*. The total elapsed time (in seconds) spent driving a specified distance.

To conduct a Travel Time and Delay Survey, one must first define the study area by selecting all control points before beginning the study. The time periods recommended for studies are AM and PM peak hours as well as off-peak hours in the direction of heaviest traffic movements. These studies should be made during reasonably good weather so that unusual conditions do not influence the study. Also, since crashes or other unusual delays will produce erroneous results, any runs made during such an occurrence should be terminated and another run conducted. These studies should be conducted during average or typical weekday traffic conditions.

2.2 Existing Manual Method

The manual method requires a test vehicle, driver, observer, two stopwatches or one stopwatch with double sweep, distance measuring instrument, odometer, and two field forms. The typical number of runs is 5-6 on local practice. However, a minimum number of 3 runs may be considered acceptable. In other countries, the approximate minimum sample size is determined depending on the calculated average range in running speed and the desired permitted error. Figure 3 presents a typical Travel Time and Delay Survey Form used by DPWH.



DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
 PLANNING SERVICE
 PROJECT PREPARATION DIVISION

Travel Time and Delay Survey Field Sheet

DPWH QMS-4.12-14-Rev00

Route:		Direction		Date:							
Trips started at: (time)				at							
Trip ended at: (time)				at							
Name of Surveyor:											
CONTROL POINT	KMS	STOPPED	STARTED	TOTAL DELAY	CAUSES OF DELAY						
					1	2	3	4	5	6	7
					1	2	3	4	5	6	7
					1	2	3	4	5	6	7
					1	2	3	4	5	6	7
					1	2	3	4	5	6	7
					1	2	3	4	5	6	7
					1	2	3	4	5	6	7
					1	2	3	4	5	6	7
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					1	2	3	4	5	6	7
					1	2	3	4	5	6	7
					1	2	3	4	5	6	7
					1	2	3	4	5	6	7
					1	2	3	4	5	6	7
					1	2	3	4	5	6	7

Cause of Delay:

- 1 - Public Utility Vehicle Loading/Unloading
- 2 - Stop Sign/ Red Signal at Intersection
- 3 - Pedestrian Crossing
- 4 - Maneuvering vehicles such as parking, left turning or opposite turns
- 5 - Blocked by other vehicles such as heavy traffic ahead
- 6 - Road Construction/ Maintenance
- 7 - Others (explain)

Figure 2. Travel Time and Delay Survey Field Sheet

Several Travel Time and Delay Survey summaries can be computed as follows:

- *Kilometer (K)*. Distance in miles from one control point to the next.
- *Travel Time (TT)*. Time in seconds from one control point to the next.
- *Delay (D)*. The time in seconds of delay experienced from one control point to the next.
- *Totals*. The kilometers, travel time, and delay are summed vertically and written in the Totals area.
- *Running Time (RT)*. Total travel time minus total delay for each run.

Calculated Control Point to Control Point Averages

$$\text{Average Travel Time (ATT)} = \frac{\text{Sum of TT}}{\text{Total No. of Runs}} \quad (2)$$

$$\text{Average Travel Speed (ATS)} = \frac{K \times 3,600 \text{ seconds per hour}}{\text{ATT}} \quad (3)$$

$$\text{Average Delay (AD)} = \frac{\text{Sum of D}}{\text{Total No. of Runs}} \quad (4)$$

$$\text{Average Running Time (ART)} = \text{ATT} - \text{AD} \quad (5)$$

$$\text{Average Running Speed (ARS)} = \frac{K \times 3,600 \text{ seconds per hour}}{\text{ART}} \quad (6)$$

Calculated Route Averages

$$\text{Total Trip Length (TTL)} = \text{Total distance between all control points (km)} \quad (7)$$

$$\text{Travel Time Total (TTT)} = \text{Sum of travel times between control points for a run} \quad (8)$$

$$\text{Average Total Travel Time (ATT)} = \frac{\text{Sum of all TTT's}}{\text{Total No. of Runs}} \quad (9)$$

2.3 Probe Vehicle Data Collection System

The envisioned New Travel Time and Delay Survey Methodology will employ the use of a smartphone-based data collection system for cost-effective travel time and delay data collection. This method includes the integration of multiple technologies: satellite positioning systems (GNSS), wireless communication, geographic information systems. The basic principle implies a vehicle moving through the transport network and continuously sending data to the central monitoring center. The advantages of this method is the high transport network coverage. Figure 4 presents the key technological components of the probe vehicle data collection system capable of collecting Floating Car Data (FCD).

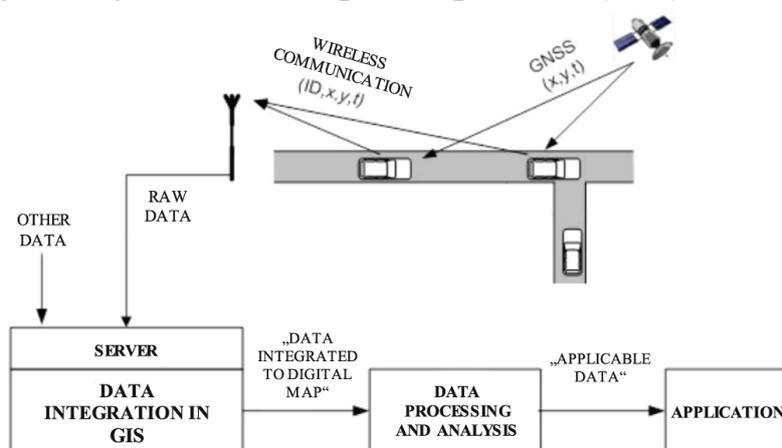


Figure 4. Probe Vehicle Data Collection System

The key components of the Probe Vehicle Data Collection System are as follows:

- *Global Navigation Satellite System (GNSS)*. A Global Navigation Satellite System (GNSS) consists of a constellation of satellites orbiting the Earth in very specific trajectories. For global coverage, it is estimated that a constellation requires 18 to 30 satellites. Navigation satellites provide orbit information and accurate timing (and other services) to radio receivers specifically designed to receive those satellite signals and decode the signal message contents. With the contents of the messages from at least four “visible” satellites, the position on or near most of the Earth’s surface can be calculated using a mathematical process known as trilateration.
- *Wireless Communication*. Systems using radio-frequency, infrared, microwave, or other types of electromagnetic or acoustic waves in place of wires, cables, or fibre optics to transmit signals or data. Wireless modems, microwave transmitters, and satellites make it possible to access the Internet from anywhere in the world. LTE (Long-Term Evolution) is a fourth-generation (4G) wireless standard that provides increased network capacity and speed for cellphones and other cellular devices compared with third-generation (3G) technology.
- *Central Server*. Telematics has emerged as a game-changer in the automotive industry, revolutionizing the way vehicles are monitored and managed. Telematics refers to the integration of telecommunications and informatics in vehicles, enabling the transmission and reception of data to monitor and track vehicles in real-time.

There are several GNSS constellations provided by the government around the world, including: BeiDou – China, Galileo – European Union, GLONASS – Russia, and GPS (originally Navstar GPS) – United States. In addition, there are some other systems that are engineered to service specific regions only, rather than offering a global service. These are referred to as Regional Navigation Satellite Systems (RNSS) including: IRNSS – India also known as NavIC, and Quasi Zenith Satellite System (QZSS) – Japan.

3. SMARTPHONE-BASED DATA COLLECTION SYSTEM

3.1 Data Collection Phases

Figure 4 presents the process of travel time and delay data collection using a smartphone-based data collection system.

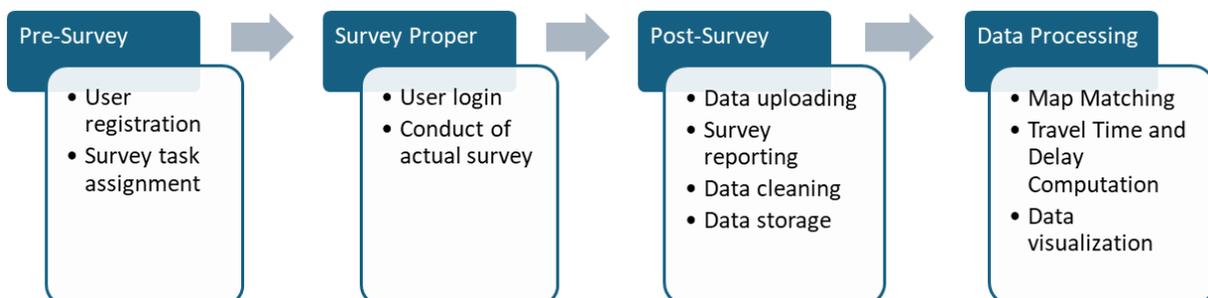


Figure 5. Data Collection Phases

3.2 Data Pre-processing

The resulting probe data is generally updated at intervals from as frequent as 1 second to a

couple of minutes. The data comes in NMEA 0183 format. After being interpreted and processed, the data includes information about the ID, Date and Time, Longitude, Latitude, Speed, Orientation and others. Table 1 presents the typical data fields and description of the probe data.

Table 1. Description of Probe data

Field	Example	Description
ID	221213582622	Unique Device ID
Date and Time	2021-3-22 13:20:15	Local Time
Longitude	123.499998	In Degrees
Latitude	10.0000	In Degrees
Speed	47	Units: km/h
Orientation	102	Units: degree

NMEA 0183 is a standard developed by the National Marine Electronics Association (NMEA) for communication between marine electronics devices like GPS receivers, sonar, autopilots, AIS (Automatic Identification Systems), and others. Sample NMEA 0183 sentence output is shown in Figure 6. The key features of this protocol are:

- Type: Serial communication protocol (ASCII text-based).
- Baud Rate: Typically, 4800 bps (can vary in some implementations).
- Format: One-way (talker → listener), point-to-point or multi-drop.
- Message structure: Sentences beginning with \$ or !, ending with a checksum.

```
$[TalkerID][SentenceType],[Data1],[Data2],...*[Checksum]<CR><LF>
Example: $GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,*47
```

Figure 6. Basic NMEA Sentence Format

The common Talker IDs and Sentence Types are tabulated in Tables 2 and 3, respectively.

Table 2: Talker IDs

Talker ID	Device Type
GP	GPS
GL	GLONASS
GN	Combined GNSS
AI	AIS transponder

Table 3. Sentence Types

Sentence Type	Description
GGA	Fix data
RMC	Recommended minimum data
GLL	Geographic position
VTG	Track made good, speed
GSV	Satellites in view
GSA	GNSS DOP and active satellites

Usually, the probe data is not good enough to be used directly. The errors and corresponding amending methods are as follows:

- Part of the location-data's error is too large to fix the estimating position to

corresponding roads. They are abnormal points (outlier) which should be removed.

- When under bridges, in tunnels, among tall and dense buildings and in other areas, GPS receivers can't receive the satellite signal, which lead to the data missing. We interpolate the missing points according to the vehicles' historical trajectory.
- The computed speeds of the probe system which are far greater or smaller than most of the speed on the same road at the same time. We drop those points, and interpolate it according to the speeds presented by points around.
- The position data is given using the WGS84 coordinate system, and the road network is often presented using other coordinate system. We unified them through coordinate transformation.

3.3 Map Matching

Due to the fact that the positioning accuracy of GPS data is limited, the survey vehicle cannot be located on the road accurately most of the time. As such, we should "clean" the data from inaccurate location points using Map Matching. The most commonly used map-matching algorithms are the Point-to-Curve and Curve-to-Curve algorithms.

The Point-to-Curve algorithm, which is considered to be uncomplicated, is suitable for situations where the road network to be mapped is simple, and it uses projection distance and angle between road and direction of the estimated point as constraint as shown in Figure 7.

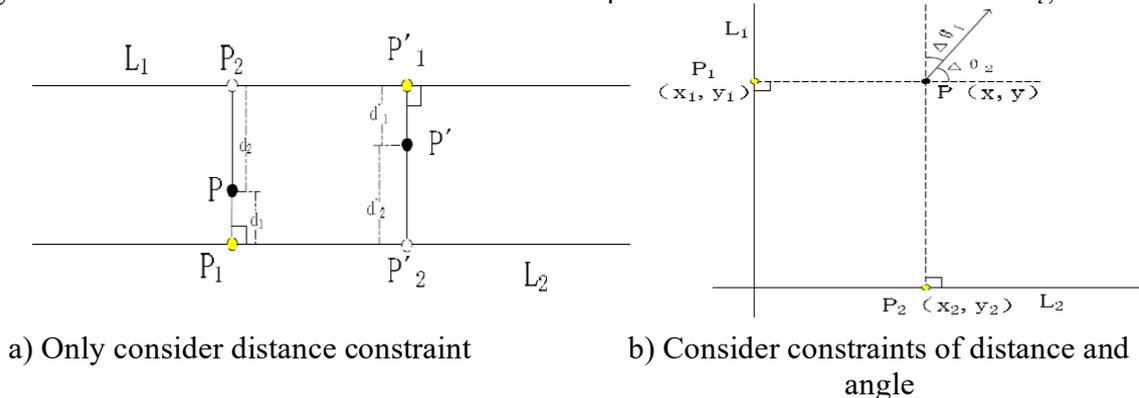


Figure 7. Point-to-Curve Map Matching Algorithm

The Curve-to-Curve Algorithm, which is considered to be a little complicated, is suitable for situations where the road network to be mapped is complex. The algorithm is a little complex but accurate in most of the time, and the matching rule is that the deviation between the trajectory of vehicle and the matching segment of road is smallest as indicated in Figure 8.

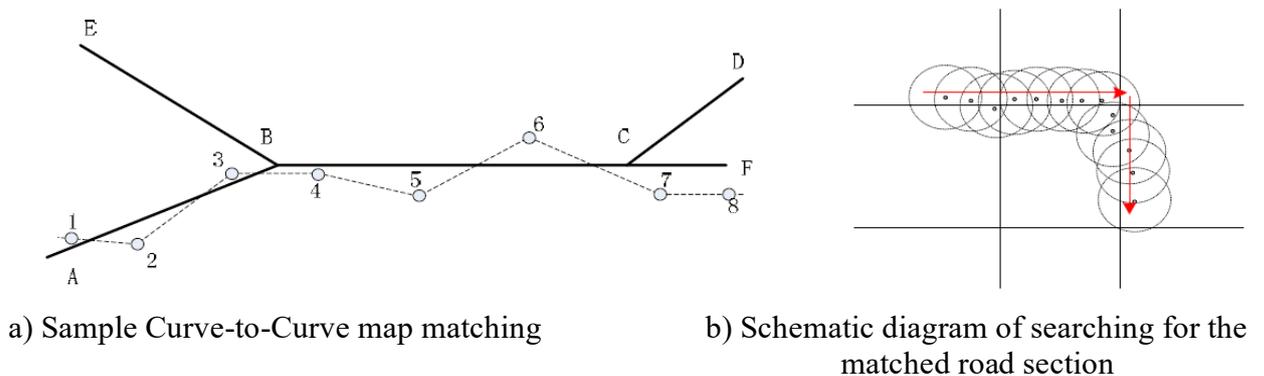


Figure 8. Curve-to-Curve Map Matching Algorithm

3.4 Travel Speed Estimation

After map matching, the probe data are corrected to match the road resulting in a continuous trajectory. According to the two successive location points' distance, l_j on the road and the interval ΔT between them, we can calculate the average speed as

$$\bar{v}_j = \frac{l_j}{\Delta T} \quad (10)$$

Thus, the average travel speed of one road can be computed as

$$\bar{v}_j = \frac{\sum_0^m \bar{v}_j}{m} \quad (11)$$

where road index number is i and the road contains m points.

3.5 Data Accuracy

Root-mean-square error (RMSE) is used to estimate positional accuracy. RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points.

Accuracy is reported in ground distances at the 95% confidence level. Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value. The reported accuracy value reflects all uncertainties, including those introduced by geodetic control coordinates, compilation, and final computation of ground coordinate values in the product.

Typically, the accuracy of a data set can be expressed by the comparison of the average of a data set with the actual position and it can be quantified with the Root Mean Square Error (RMSE), where:

$$RMSE = \sqrt{\frac{\sum (X - t)^2}{n}} \quad (12)$$

where:

X is an estimator of the central tendency of your observed data set

t represents the "true" value

n represents the number of observations

The difference between Accuracy and Precision is explained as follows:

- *Accuracy*: This refers to how close a geospatial measurement (like the coordinates of a location) is to its true, real-world position. High accuracy in geospatial data means that the recorded location of a feature on a map closely matches its actual location on the earth's surface.
- *Precision*: This refers to the consistency and resolution of the measurements. It's about the smallest level of detail that can be reliably recorded. High precision in geospatial data means the ability to measure and record small differences in location.

It is important to note that in the geospatial world, having high precision doesn't necessarily mean high accuracy. You can have a tool that precisely measures and records positions, but if it's consistently off from the true location (like consistently showing a position 10 meters to the north of where it actually is), it's precise but not accurate. Conversely, a tool might be generally accurate (getting you to the right street) but not precise enough to differentiate between closely spaced points (like different doors on the street). Figure 9 presents the classic illustration of Accuracy and Precision.

Several factors can affect the accuracy of GPS. Some of the most significant factors include:

- *Satellite Geometry*: The positioning of the satellites in the GPS network affects the accuracy of GPS measurements. When the satellites are positioned in such a way that they are close together, the accuracy of GPS measurements tends to be lower.
- *Signal Quality*: The quality of the GPS signal is an important factor in determining the accuracy of GPS measurements. A weak or noisy signal can lead to inaccurate measurements.
- *Atmospheric Conditions*: The atmospheric conditions at the time of the GPS measurement can affect the accuracy of the GPS reading. For instance, atmospheric conditions such as ionospheric delay can cause errors in GPS measurements.
- *Multipath Interference*: Multipath interference occurs when the GPS signal reflects off objects such as buildings, trees, and hills before reaching the GPS receiver. This can cause the GPS receiver to receive multiple signals, leading to errors in the GPS measurements.
- *Receiver Quality*: The quality of the GPS receiver is also an important factor in determining the accuracy of GPS measurements. High-quality GPS receivers are designed to minimize errors and improve accuracy.

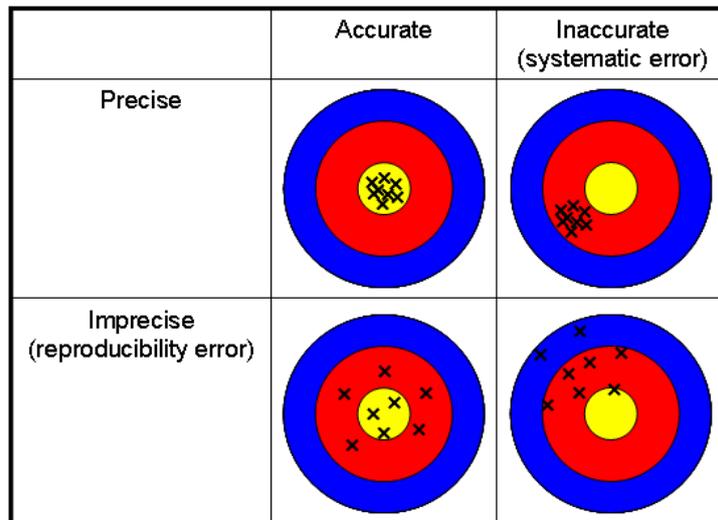


Figure 9. Factors Affecting GPS Accuracy

4. PROTOTYPE DEVELOPMENT

4.1 System Setup

Figure 10 presents an overview of the smartphone-based probe data collection system for capturing travel time and delay. The system consists of key components, namely:

- Mobile Application for data collection
- Web Application for survey task preparation and data uploading
- Backend/API Server for real-time monitoring
- IoT Telematics Device for capturing vehicle engine parameteris
- Database System for data storage, retrieval, and processing

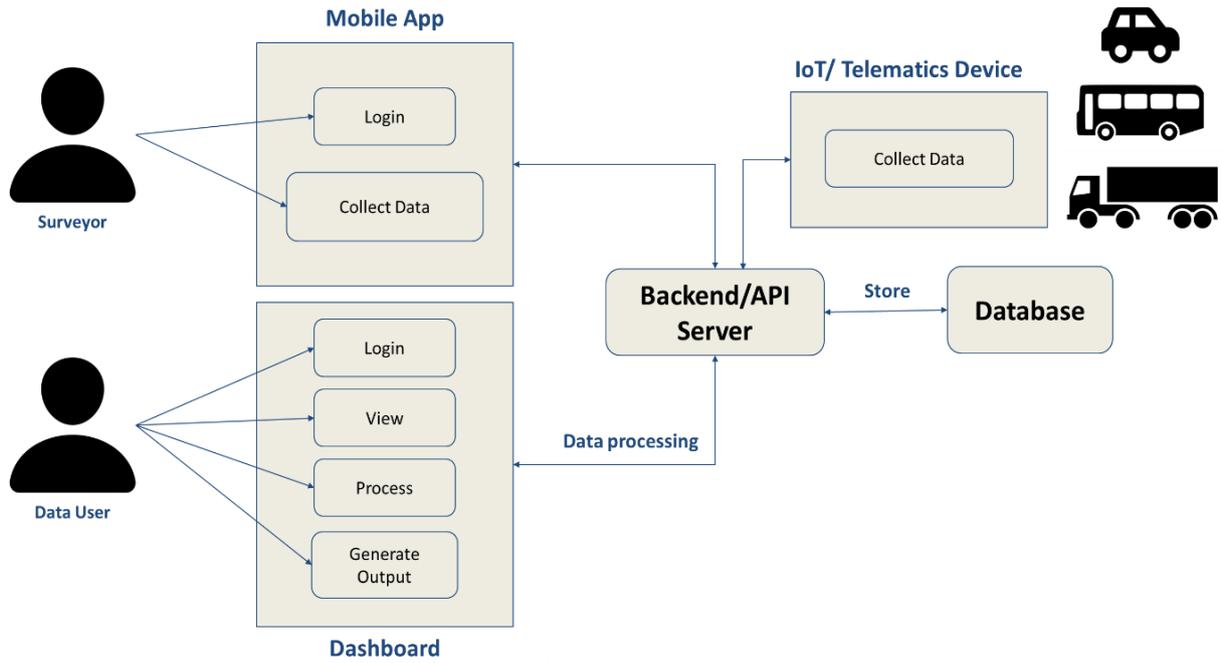


Figure 10. System Overview

4.2 Pre-Survey Phase

In the Pre-Survey Phase, the Survey Team Leaders, using the web application starts registering the surveyor detail and identifying their working region and route. This information interacts with backend systems for the storage of data. The system will generate a QR code then the surveyor receives the information. Figure 11 shows the activity diagram of the Pre-Survey Phase. Figure 12 shows the web application which prepares the survey task assignment.

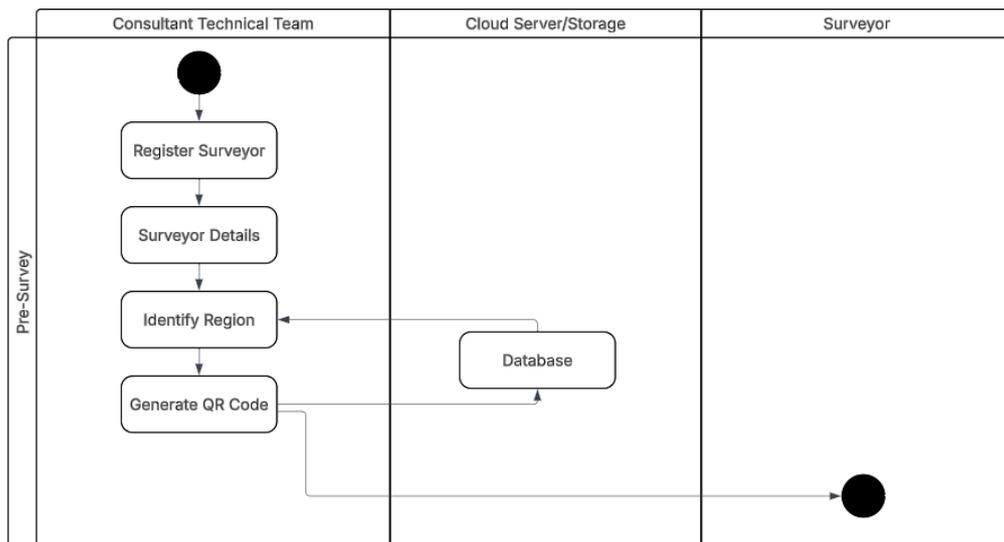


Figure 11. Pre-Survey Activity Diagram

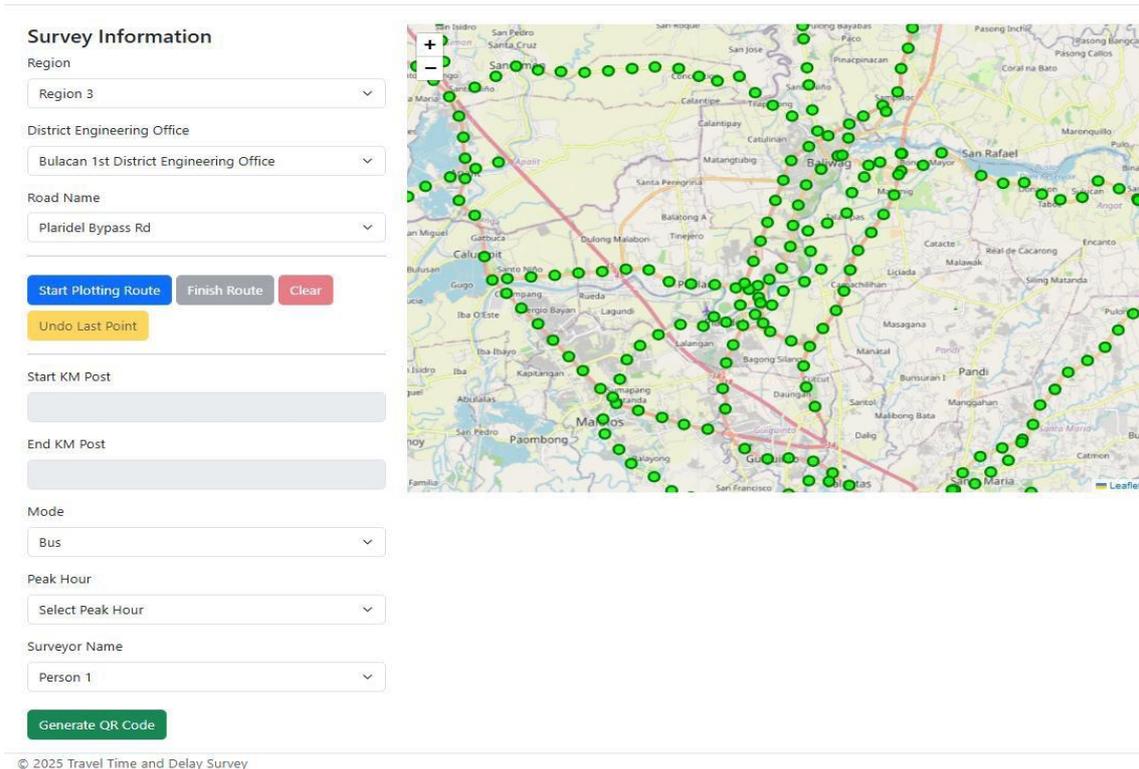


Figure 12. Survey Task Assignment

4.3 Survey Proper Phase

Prior to the survey, the surveyor inputs the username and password in the text field of the mobile application. Using the app, the surveyor scans the QR code generated by the Survey Team Leaders. This QR code consists of user details, assigned transport mode, route, and regions. Once scanned, the journey plan would pop-up to validate the survey plan information. After verification, the surveyor initiates the travel time and delay survey by clicking the “Start Tracking” button. Figure 13 shows the activity diagram for the Survey Proper Phase.

The mobile application collects data every second, stored in the local directory. It then sends it to the cloud server every minute to track the current location of the surveyor. As the surveyor approaches kilometer posts, the application provides alerts: at 500 and 200 meters away, a pop-up message notifies the surveyor of the approaching marker. When within 50 meters, mobile application rings or vibrates to notify the surveyor, then the camera automatically opens for the surveyor to take a photo. Photos captured are directly stored in a local directory of the application.

Meanwhile, when the surveyor experiences a delay on the road or if the speed of vehicle is less than 7 kph, the app rings or vibrates again, and a pop-up appears prompting the surveyor to select the cause of delay. After making a selection, the camera opens automatically, allowing the surveyor to capture supporting images, which are also saved locally.

After the travel time and delay survey, the surveyor will click the “Stop Tracking” and the collected data during the survey will be stored in the local database. The surveyor hands over the mobile phone to the Survey Team Leaders or Survey Data Analyst to download the gathered data. To transfer the data, the user selects “Upload Survey Data”, the application generates the zip file which consists of GPX file and geotagged image file.

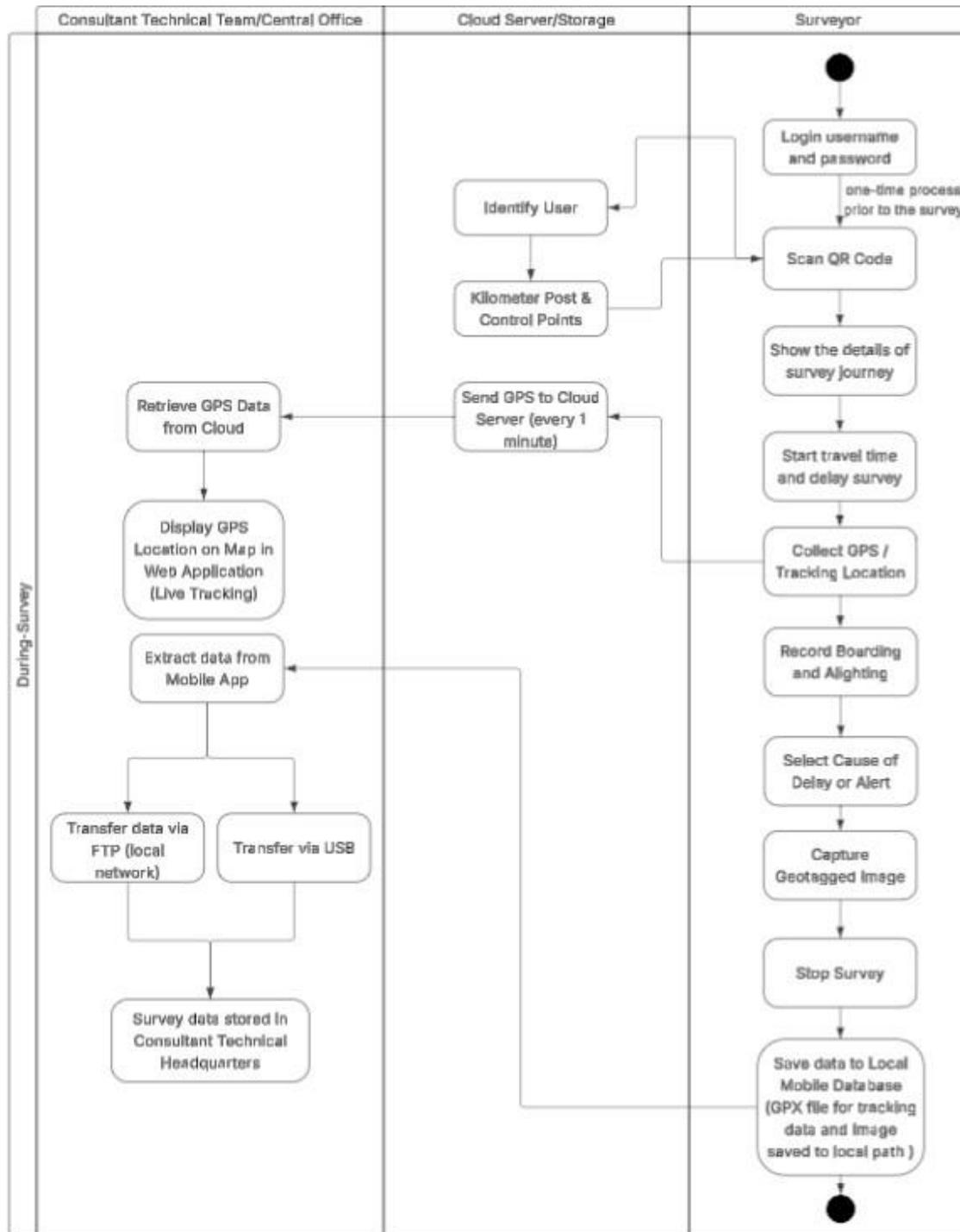


Figure 13. Survey Proper Activity Diagram

Figures 14 to 17 shows the screenshot of the app. Figure 13 shows the login screen of the smartphone app where the authorized user will provide their login credentials. After logging in, the user will be able to view their respective survey task assignment as shown in Figure 14. Figure 15 shows the operation of the app in terms of alert notification and image capture function. Finally, Figure 16 shows the screen for capture cause of delay.

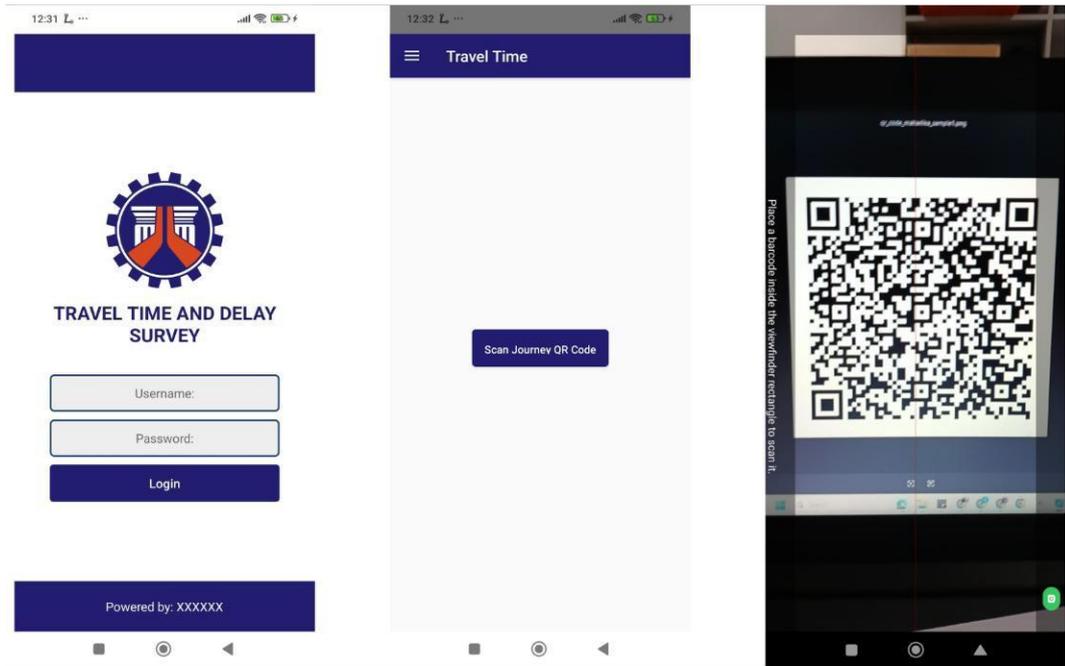


Figure 14. Login Screen

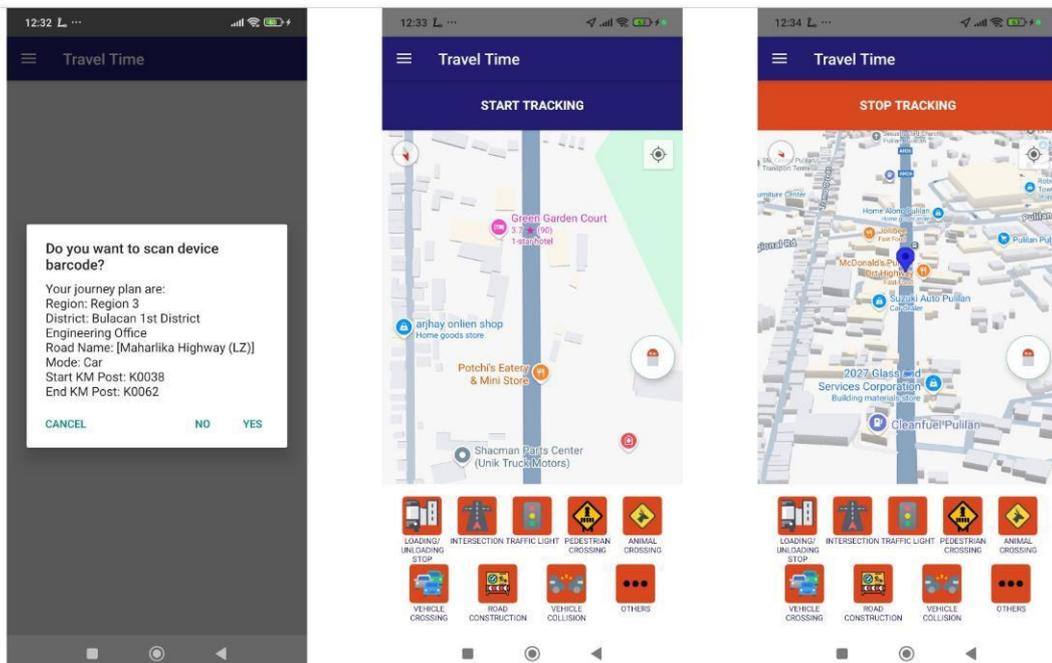


Figure 15. Task Assignment Details

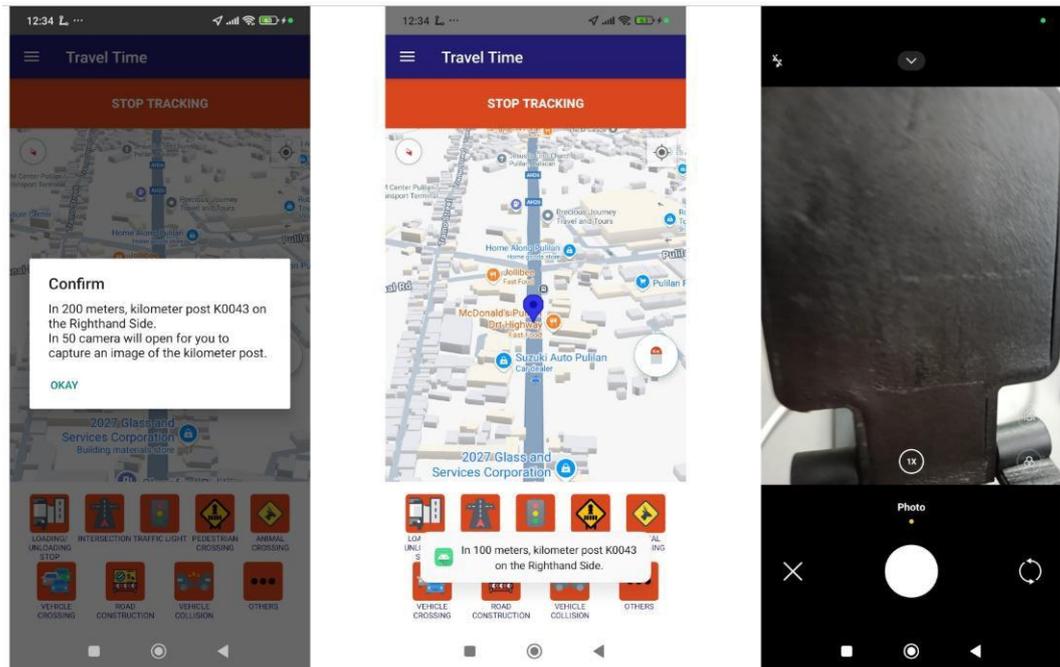


Figure 16. Alert Notification and Image Capture

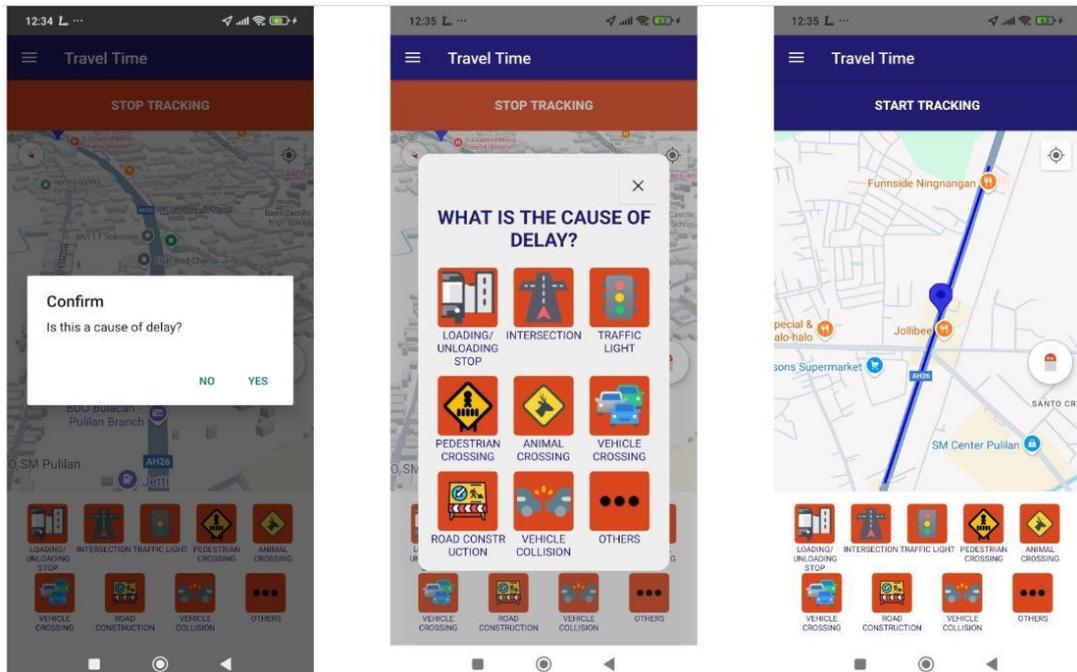


Figure 17. Capturing Cause of Delay

4.4 Post-Survey Phase

The post-survey process begins after the completion of The Travel Time and Delay Survey. This process involves compiling and analyzing the raw data, which includes GPX files, geotagged images (in ZIP format), and IoT data. The data is used to plot GPS maps with delay points and images, enabling detailed visualization and report generation. After processing,

both the raw data and the processed outputs are backed up and transferred to the Central Server for centralized storage, visualization, and reporting.

The post survey process steps are:

- Uploads raw survey data such as geotagged images and GPX files in ZIP format
- Plots GPS maps with delay points and images.
- Create the final survey report.
- Stores report data locally.
- Backs up and forwards both raw and processed data to the Central Server
- Performs centralized data visualization and reporting.
- Backs up all data to NAS (Network-Attached Storage).

Figure 18 shows the activity diagram for the Post-Survey Phase. Figure 19 shows the screenshot of mobile app for downloading the data.

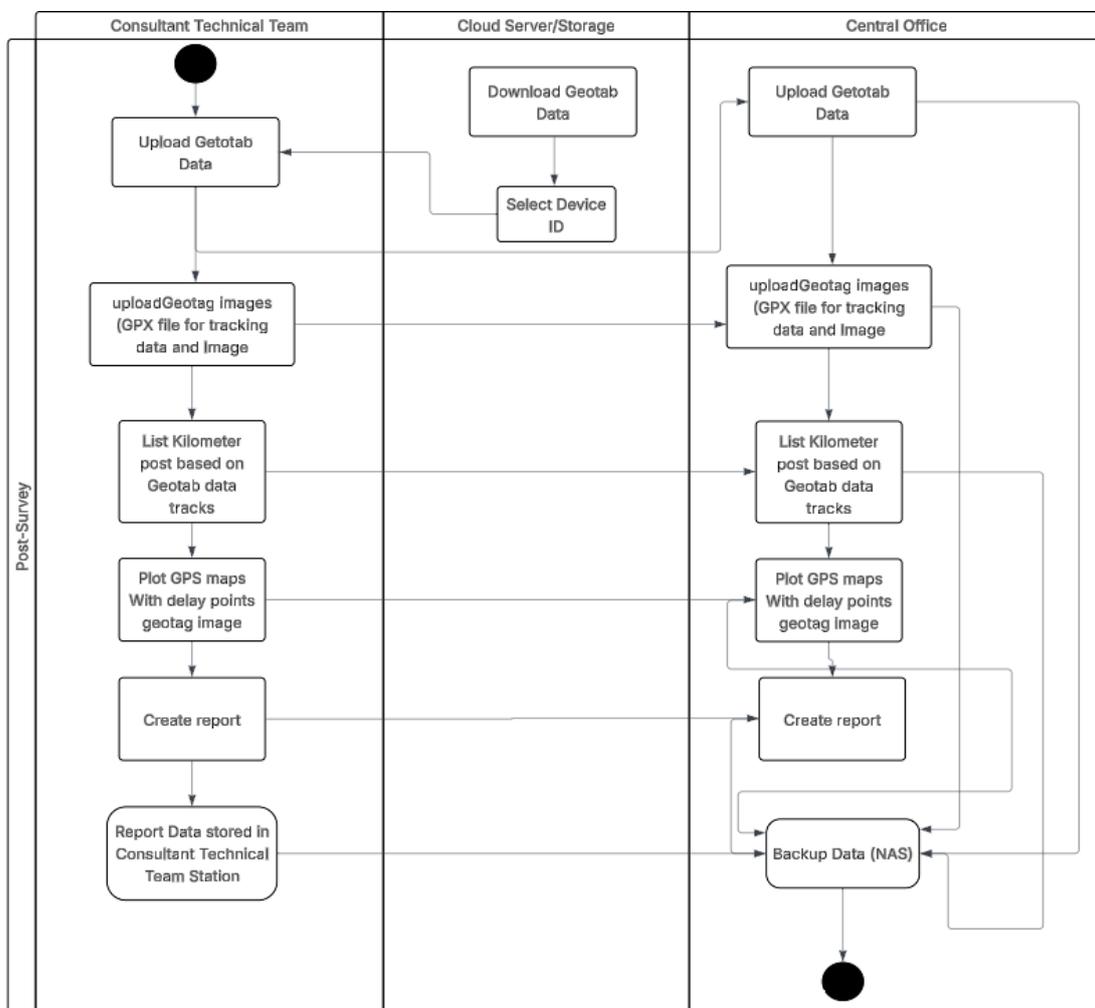


Figure 18. Post-Survey Activity Diagram

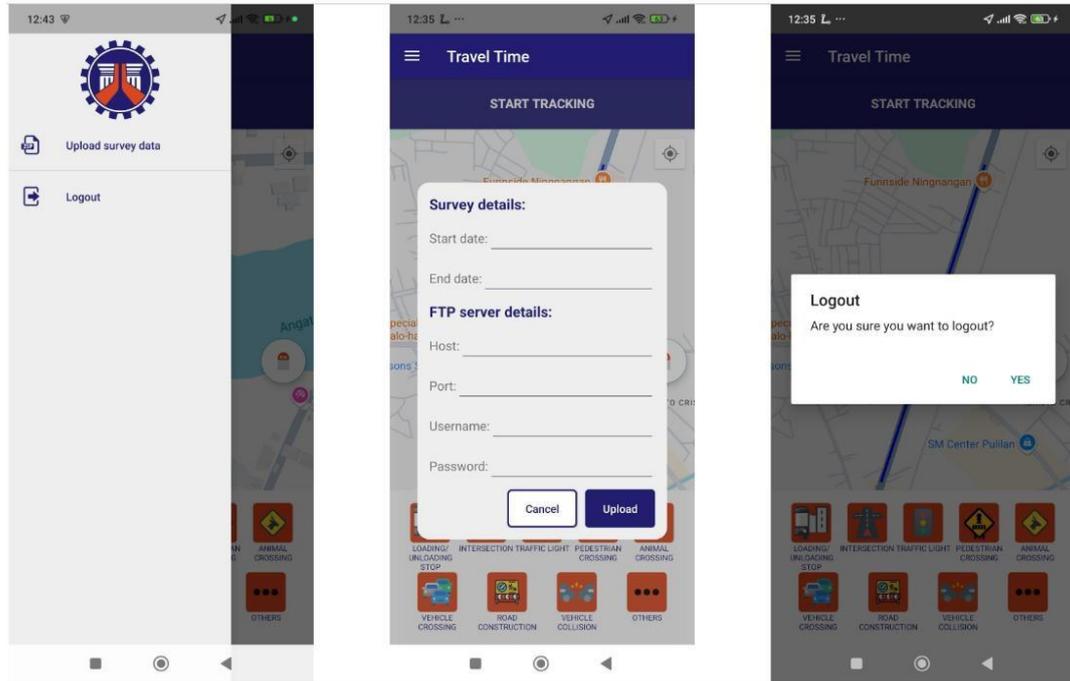


Figure 19. Data Uploading

4.5 Data Processing Phase

The data collected through the smartphone undergo a four-stage processing pipeline to ensure accuracy, reliability, and usability for travel time and delay analysis as indicated in Table 4. Figure 20 presents a typical screen for data visualization and analysis.

Table 4. Data Processing Pipeline

No.	Stage	Tasks
1	Data Preparation	<ul style="list-style-type: none"> Export GNSS trajectories as GPX files (timestamp, latitude, longitude, speed, control point, delay cause). Upload via FTP to Azure Cloud Storage, organized by route, date, and surveyor.
2	Data Cleaning and Validation	<ul style="list-style-type: none"> Remove outliers (speed > 150 km/h, distance > 200 m/s). Correct missing timestamps and duplicates. [Map Matching] Match points to control points and kilometer posts (≤ 70 m / ≤ 50 m). Verify delay events and geotag accuracy.
3	Travel Time and Delay Computation	<ul style="list-style-type: none"> Compute segment travel time, average speed, and delay ration (%). Identify delay events where speed ≤ 7 km/h for ≥ 5 seconds. Aggregate results into corridor-level summaries (N1, Nautical Highway).
4	Visualization and Analysis (Web dashboard)	<ul style="list-style-type: none"> Map: trajectory + delay points. Charts: travel time, speed, and delay distribution. Tables: detailed statistics per segment.

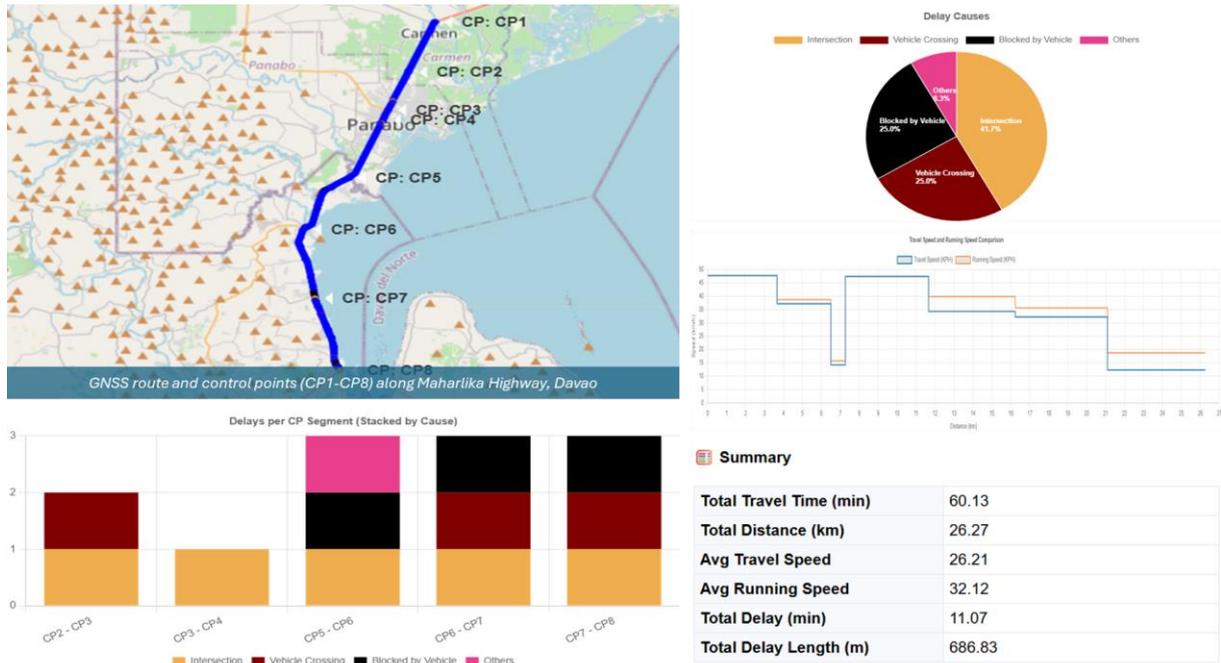


Figure 20. Data Visualization and Analysis

5. CONCLUDING REMARKS

It is recognized that traffic congestion has been one of the most challenging problems concerning road traffic management in the Philippines. Due to its critical impact on the country's economy, traffic congestion is one of the major considerations in the assessment of potential road and bridge projects in the Department of Public Works and Highways (DPWH). DPWH aims to decongest and improve road traffic in the national road network by prioritizing projects for fund allocation that are prone to traffic congestion. To perform this, it is very important to establish and conduct measures that can provide reliable indicators of level of congestion. This study presents a novel application of mobile application for modernization the collection of travel time and delay studies at a national scale.

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