

TRENDS AND DEVELOPMENT OF GPS TECHNOLOGY FOR ROAD SAFETY IN THAILAND

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1. INTRODUCTION

Road accidents are a leading problem in Thailand as they cause significant loss of life and economic damage. Such accidents may be caused by one of three factors or related issues: drivers, vehicles, and circumstances.

According to the World Health Organization (WHO), Thailand ranks number 2 in the world in the number of deaths caused by road accidents, with the death rate being 36.2 persons per 100,000 population. Libya, with a population of only 6.5 million, holds the distinction of being number 1 in road accident deaths. However, the traffic casualty statistics collected by Thai authorities are rather different from the WHO estimation. Two Thai agencies that collect traffic casualty statistics are the Ministry of Public Health, which recorded 15,045 deaths (22.45 per 100,000 population) in 2014, and the Royal Thai Police, which recorded 6,985 deaths (10.42 per 100,000 population) in the same year. Due to the huge difference in these statistics, the Department of Disease Control of the Ministry of Public Health in 2014 conducted a study to consolidate the statistics on road traffic deaths; it concluded that the number of deaths from traffic accidents in Thailand in 2013 was 20,029.

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Obviously, the collection of such statistics needs further improvement, preferably with a single agency being made responsible for compiling accurate statistics on road accident casualties.

Not only are traffic casualties important, but also the number of accidents as well as the causes of the accidents. Accident statistics provided by the Bureau of Highway Safety of the Department of Highways¹ have been showing a rise since 2012. The total number of accidents in 2016 was 15,579, and the top three causes of accidents were speeding (exceeding the speed limit), overtaking in a critical situation, and tailgating. These three situations accounted for more than one-third of the total number of accidents. All three causes can be considered as human errors, especially speeding.

Self-awareness and law enforcement can be applied in these cases, but these factors will not be completely effective as there are many limitations involved. Therefore, this article has two purposes: first, to show how Geographic Positioning System (GPS) technology can be applied to achieve better road safety, and second, to describe how GPS technology can be applied to various aspects of land transportation.

¹ <http://bhs.doh.go.th/statistic>

2. STUDY AND REVIEW OF THE APPLICATION OF GPS TECHNOLOGY

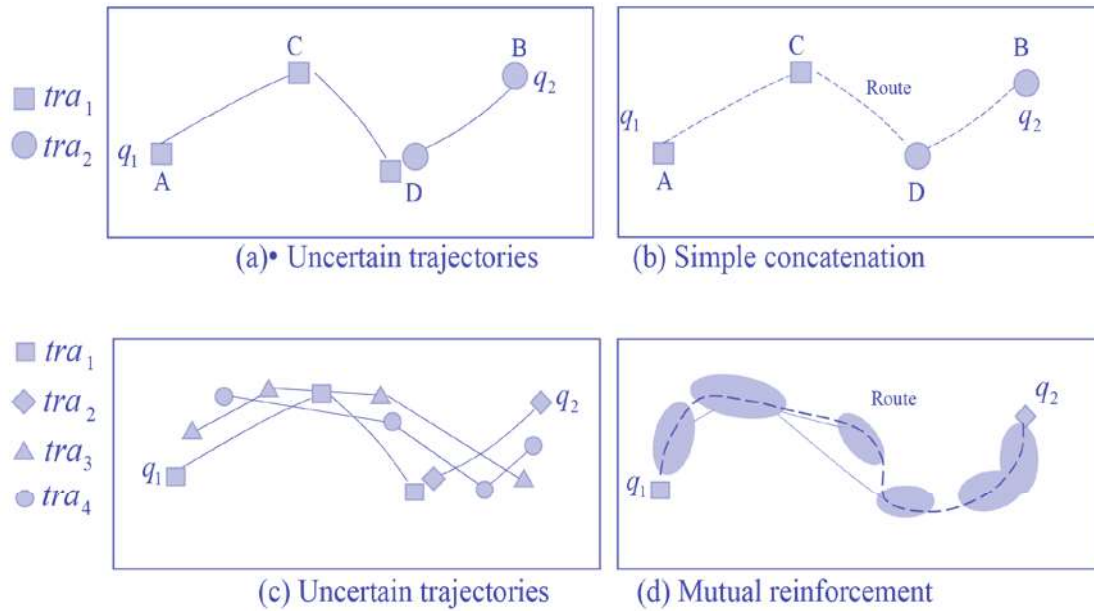
A study of driver behaviors through the use of GPS produces general data on road accidents, such as location, direction, and speed. However, development of applications for road safety control is necessary for conducting behavior analysis. Therefore, the authors reviewed various research studies relating to GPS applications in Thailand and abroad, using GPS technology as a development tool so that this project would be effective and reliable. The details are described in the following sections.

2.1 Discovering pattern-awareness routes

Wei et al. (2012) proposed a method to determine the best route to reach multiple destinations by collecting GPS data from each destination before considering the user's preferred route and then summarizing the most appropriate route from the determined starting point to the ending point. Such data can be applied to create the best road map based on the user's preferred routes.

Moreover, Wang et al. (2008) proposed the novel non-parametric Bayesian model, dual hierarchical Dirichlet processes (Dual-HDP) to detect unsupervised abnormal activities, which are based

Figure 1: Discovering pattern-awareness routes from trajectories to create the best road map



on deviations from other activities. To make the system easier to understand, data are clustered into smaller regions, and each region is checked to detect any abnormality, as shown in Figure 2.

However, the pattern used to detect abnormal trajectories can be applied well to detect human errors in driving. Ge et al. (2011) used GPS data from taxis to analyze routes and identify whether the trajectory was abnormal (i.e., taking a shortcut, or detour). Also, abnormal trajectory detection can be used to detect tricky drivers. First, the system considers the preferred route between two locations. Distance and time should be similar to the preferred routes. A taxi taking a different route would be suspected of cheating the passenger by taking a longer detour.

2.2 Travel time estimation

The authors reviewed a project of the Expressway Authority of Thailand on travel time analysis based on vehicles' speed and density; they then developed an algorithm to analyze travel time based on data from the GPS data source of taxis. Basically, the details, including latitude, longitude, speed, heading, and time-stamp, are sent back to the server in real time. The system then compares these data with routes on the map to identify the

Figure 2: When data are clustered into regions, abnormalities are detected if object B takes a different route

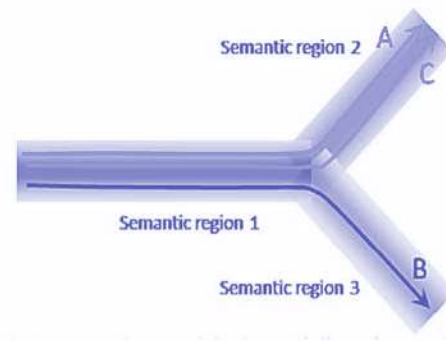


Figure 3: Sample of abnormal trajectory detection

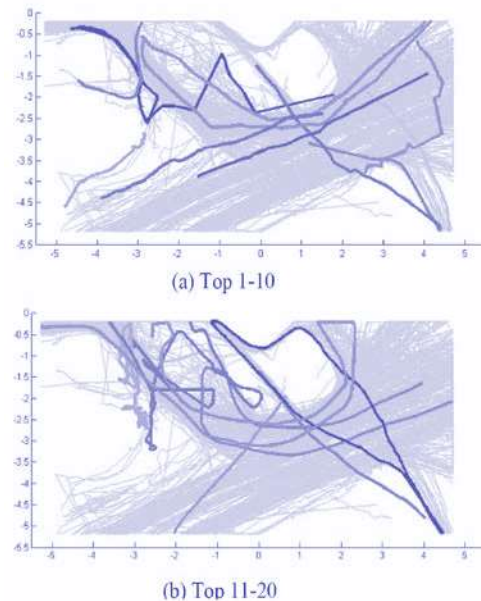
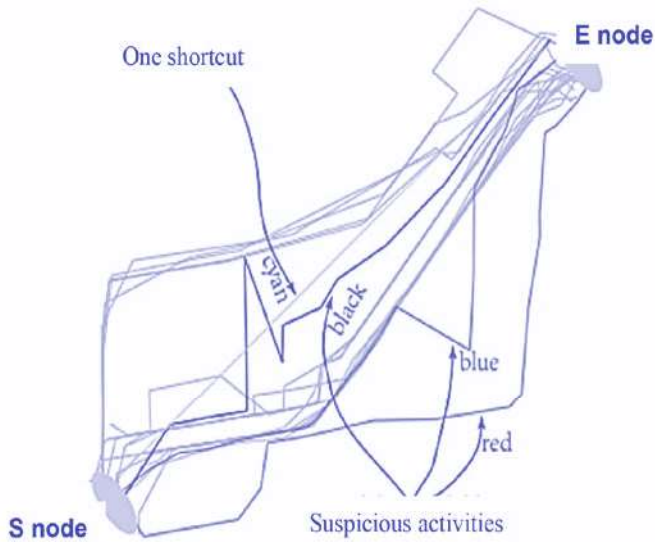


Figure 4: Example of a suspect trajectory taking a detour



vehicles' location. Routes are divided into what are called "links." For example, the route from Bang Khun Thian to Bang Kru is considered as "1 link." Location and speed data from the taxis' GPS is used to estimate travel time, which requires two types of data:

- (a) Spot speed — The system filters and aggregates a vehicle's real speeds in a certain link sent from GPS to estimate travel time: for example, the time between 10:00 a.m. and 10:05 a.m. Twenty records of location data are sent from the taxi's GPS in Bang Khun Thian, i.e., the Bang Kru link. These data are used to estimate travel time in the link, as shown in Table 1.

Table 1: Spot speed data sample for estimation

| GPS_ID | Latitude | Longitude | Time-stamp (May 15, 2012) | Speed (km/hr) |
|---------|-----------|------------|---------------------------|---------------|
| 1311042 | 13.581726 | 100.867721 | 10:00:13 | 84 |
| 1310992 | 13.581680 | 100.867248 | 10:00:14 | 114 |
| 1311751 | 13.581893 | 100.867095 | 10:00:22 | 45 |
| 65679 | 13.582565 | 100.861358 | 10:00:26 | 77 |
| 1311401 | 13.583236 | 100.860351 | 10:01:07 | 63 |
| 1310969 | 13.582931 | 100.859588 | 10:01:25 | 69 |
| 1311751 | 13.583587 | 100.858612 | 10:01:32 | 80 |
| 65878 | 13.583694 | 100.858566 | 10:01:06 | 92 |
| 1311791 | 13.583969 | 100.854690 | 10:02:11 | 32 |
| 65890 | 13.584228 | 100.854324 | 10:02:58 | 89 |
| 65723 | 13.584457 | 100.854217 | 10:02:44 | 78 |
| 1310992 | 13.584487 | 100.854049 | 10:02:18 | 118 |
| 65679 | 13.584213 | 100.853500 | 10:03:55 | 64 |
| 1311106 | 13.584274 | 100.853286 | 10:03:00 | 74 |
| 1310969 | 13.584518 | 100.852249 | 10:03:17 | 69 |
| 1311365 | 13.584625 | 100.851654 | 10:03:29 | 74 |
| 65746 | 13.584625 | 100.851654 | 10:04:32 | 84 |
| 1311854 | 13.584915 | 100.850662 | 10:04:59 | 23 |
| 1311542 | 13.584915 | 100.850601 | 10:05:23 | 57 |

- (b) GPS link — These data can be acquired only when the data are sent from the same taxi in the same link more than once during a certain period. This means that there is displacement of a taxi that gives two different locations at two specific times, as shown in Table 2.

Table 2: GPS link data sample

| Link_ID | GPS_ID | Lat1 -Long1 | Lat2-Long2 | Time1 (May 16, 2012) | Time2 (May 16, 2012) |
|---------|---------|-----------------------|-----------------------|----------------------|----------------------|
| 1649 | 51288 | 13.6911 100.52476 | 13.69136 100.52516 | 17:36:16 | 17:36:43 |
| 3820 | 1311502 | 13.75369 100.56437 | 13.75366 100.56381 | 17:35:20 | 17:36:01 |
| 1912 | 1310852 | 13.81317 100.62178 | 13.79470 100.61286 | 17:35:18 | 17:36:54 |
| 1912 | 1310852 | 13.80320 100.61680 | 13.79470 100.61286 | 17:35:18 | 17:36:07 |
| 1650 | 51288 | 13.69171 100.52571 | 13.69203 100.52615 | 17:35:13 | 17:35:43 |
| 2728 | 1311326 | 13.89981 100.54121 | 13.89942 100.54244 | 17:34:38 | 17:35:24 |
| 1934 | 1311277 | 13.74197 100.63064 | 13.74075 100.62464 | 17:34:37 | 17:36:02 |
| 1934 | 1311277 | 13.74133 100.62760 | 13.74075 100.62464 | 17:34:37 | 17:35:23 |
| 2727 | 1311326 | 13.89942 100.54244 | 13.89926 100.54298 | 17:33:53 | 17:34:38 |
| 1907 | 1310852 | 13.78596 100.60882 | 13.77705 100.60749 | 17:33:52 | 17:34:38 |

After “spot speed” and the GPS link are known, travel time can be estimated using the following equation.

$$v = s / t$$

In order to acquire the most accurate traffic data, it is necessary to filter out abnormal data in three steps.

The first step is “time-window filtering,” in which the location and speed obtained from a taxi are filtered. Any abnormality caused by GPS and by vehicles unable to move in congested traffic are removed. Thus, the actual travel time is obtained. For example, in high-traffic flow situations, the speed of some vehicles may be more than 160 km/hr, while that of others may be zero. In such cases, that taxi might be parked or waiting for a passenger. Therefore, the data from its GPS would be filtered by the time-window filtering facility.

Another example of time-window filtering of the speed of vehicles is shown in Table 3. The standard deviation of this data set can be found using the following equation:

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

The speed obtained is $\bar{x} \pm \sigma$.

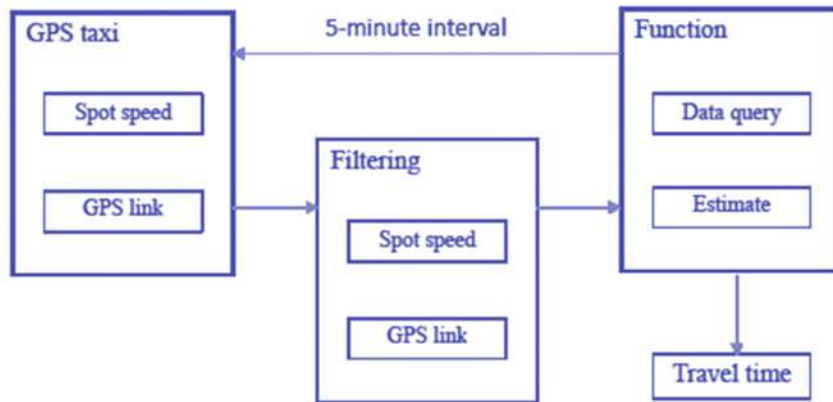
This time-window is used in the next step, which produces a data set ranging from 57 to 64, from 69 to 80, and from 84 to 92 km/hr.

After time-window filtering, the data undergo dynamic stratified sampling before the travel time estimation is applied. In cases when the data are widely distributed, the system will narrow the data ranges of the sample and randomly sample the same amount of data from each range to estimate the travel time. For example, there are 14 data points in the set after time-window filtering, namely 57, 63, 64, 69, 69, 74, 74, 77, 78, 80, 84, 84, 89, and 92 km/hr. The system therefore divides the speed data into three ranges and randomly picks speeds from the range with the least number of data points to calculate the average. In this case, the sample of ranges is shown in Table 3. Sampling obtained from the speed range of 57-68 (least number of data) is three. According to Table 3, the system samples data from each speed range and calculates the average

Table 3: The data samples from each data range

| Speed range (km/hr) | Number of data points | Data from sampling (km/hr) |
|---------------------|-----------------------|----------------------------|
| 57 - 68 | 3 | 57, 63, 64 |
| 69 - 80 | 12 | 69, 74, 80 |
| 81 - 92 | 4 | 84, 89, 92 |

Figure 5: Travel time estimation procedure



to estimate speed. As a result, the average speed in the Bang Khun Thian – Bang Kru link is 74 km/hr, and the travel time is equal to 10 minutes.

The flow of the algorithm for travel time estimation is shown in Figure 5, starting from the spot speed data collected and the GPS link. The data are collected every 5 minutes. After that, the application in the database requests data and passes them through the filtering process to obtain data for calculating in the last step of travel time estimation for 5-minute intervals.

3. APPLICATION OF GPS TECHNOLOGY FOR IMPROVING ROAD SAFETY IN THAILAND

The Department of Land Transport under the Ministry of Transport is the main department in Thailand for maintaining effective transportation and road safety, including traffic discipline, for the

general public. In 2011, the Department launched a project called “Study on GPS Installation in Public Transportation.” The main objective was to study, analyze, and design a public transportation control system architecture (composition, responsibility, and system connectivity) for the Department’s GPS Transit Management Center. The application included inspection of the transit system to ensure that it complied with the Center’s objectives, raised safety awareness using GPS, and engaged all parties.

In 2013, the project called “The GPS Transit Management Center Establishment Project for Safety Monitoring” was launched. At first, it was applied to trucks hauling dangerous goods, and buses owned by the Transport Co., Ltd., through an announcement requiring the installation of GPS by January 1, 2015. The operation of the project showed that it could effectively control drivers’ behavior in terms of speed. The Department of Land Transport subsequently (in late 2015) announced a regulation

Table 4: Statistics on vans with GPS installed as of January 31, 2017

| Vehicle type | Number of registered vehicles | Number of vehicles that require GPS | Number of vehicles with GPS installed |
|------------------------------|-------------------------------|-------------------------------------|---------------------------------------|
| Public transportation | 151,281 | 84,573 | 26,771 |
| Fixed route | 77,788 | 26,346 | 6,510 |
| – Type 1 | 19,226 | 5,138 | 1,036 |
| – Type 2 | 8,913 | 8,913 | 3,553 |
| – Type 3 | 12,295 | 12,295 | 1,799 |
| – Type 4 | 37,354 | 0 | 122 |
| Unfixed route | 61,274 | 58,227 | 20,131 |
| Personal | 12,219 | 0 | 130 |
| Trucks | 1,056,068 | 394,361 | 91,361 |
| Unfixed route | 275,169 | 117,204 | 55,117 |
| Personal | 780,899 | 277,157 | 36,244 |
| Others | | | 21,191 |
| Total | 1,207,349 | 478,934 | 139,323 |

Source: GPS Management Control Center, Department of Land Transport.

requiring that all forms of public transportation and trucks must install GPS onboard under the project entitled “Nationwide Confidence with GPS Onboard.”

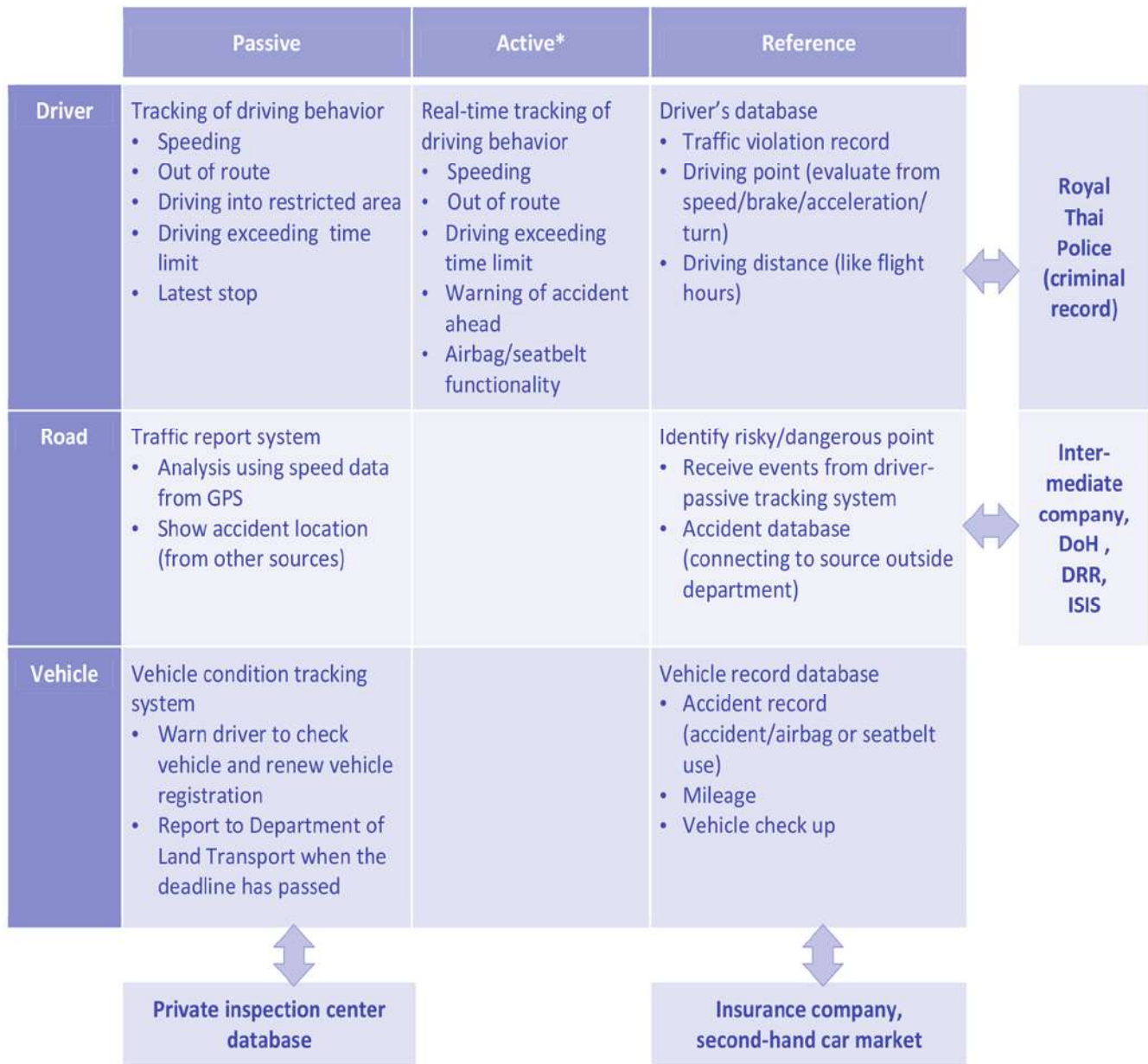
Under the project, all types of public transport and vans (except buses with two rows of seats, type-4 buses, and type-1 provincial buses), as well as trailers and large trucks (10 wheels or more) registered after January 25, 2016, must install GPS that complies with the Department’s announcement. The system is composed of the GPS itself and a magnetic card reader that connects to the Department’s GPS Transportation Management Center.

For the various forms of public transport and trucks that were registered before January 25, 2016, the Department of Land Transport required that the different types of vehicles comply with the announcement within 2016, so that the owners and vendors would have had time to prepare and fix the

data connection system, and install GPS as specified. For public transport vehicles, trailers, and large trucks (10 wheels or more) the deadline was within 2016, but the use of current GPS models was later extended to 2019. Double-decker buses were also required to have GPS installed within the tax year 2016. For any other forms of public transportation, GPS needs to be installed within the tax year 2017. For all trailers, GPS needs to be installed within the tax year 2018, and for personal trucks (10 wheels or more), the deadline for installation is the tax year 2019.

However, in the wake of an accident during the New Year holiday period involving a van and a pickup truck that caused 25 deaths, the Department of Land Transport announced, on an urgent basis, that all public vans cooperating with the Transport Company departing from Bangkok to any destination

Figure 6: Concept of GPS application usage classification



* Device must be installed.

Abbreviations: DoH = Department of Highways; DRR = Department of Rural Roads; and ISIS = Injury Surveillance Information System.

in Thailand must have a GPS tracking system installed by March 31, 2017. Currently, 139,323 of the target vehicles covered under this announcement have already installed GPS tracking systems; they represent 29 percent of the target. Details are shown in Table 4.

4. ROAD SAFETY CONTROLLED BY GPS TECHNOLOGY

According to a GPS data technology needs assessment survey of various sections in the Ministry of Land Transport, which is overall in charge of Thailand's road safety, those needs could be classified

into three types of uses: passive, active, and reference. Also, the needs could be classified according to three factors: drivers, roads, and vehicles. Figure 6 shows the usage of data from route recorders, classified by application type. There are seven types of applications classified by usage and main factors analysis. Details are shown in Figure 6.

4.1 Passive application

Passive data usage from GPS can be classified into three types: drivers, roads, and vehicles.

For drivers, the Department of Land Transport applies data from its tracking recorder in developing of “**Tracking of driving behavior,**” which monitors:

- Driver’s speed
- Detour route
- Violation by driving into controlled/restricted area
- Driving hours exceed limit
- Latest stop

Data from the vehicle travel record can be used to develop the “**Traffic report system,**” as follows:

- Data on speed from the GPS device installed onboard can be used to analyze traffic flow or route
- Vehicle travel record can be used to analyze and show an accident point along the route

Data from the vehicle travel record can be used to develop the “**Vehicle condition tracking system,**” which is connected to a private inspection center. Its application is as follows:

- The Department of Land Transport uses the application to warn vendors when to check their vehicles or renew their registration
- The system can report data to the Department of Land Transport when the vehicle owner does not follow the warning within the deadline, so that the Department can issue a warning or terminate the legal use of that vehicle

In this type of passive GPS data usage system, after a mistake has occurred, it can be analyzed and action taken. In this context, the action would be a warning or a punishment. This kind of application can be activated soon after a GPS device has been installed and connected to the Department of Land Transport’s GPS Traffic Center.

4.2 Active application

The active data usage report obtained from GPS can be applied to drivers. The Department of Land Transport can use data from the travel record to develop a “**real-time driving inspection system,**” which works as described below:

- Show the real-time travel route of each vehicle from the recorder, and control speeding by sending a warning directly to the driver of that vehicle in real time in order to prevent an accident
- Show the real-time location of each vehicle from the recorder to assess the route of each vehicle. If any vehicle is out of route, a warning would be sent directly to the driver of that vehicle
- Monitor driving hours that exceed the limit established by the Department of Land Transport, display driver’s driving hours from a magnetic reader, and send warning to the driver to switch drivers or get some rest
- Send a warning about an accident ahead by getting road accident information from various sources or from a previous vehicle’s traffic tracking, and inform other vehicles heading toward the accident area
- Check status of devices, such as airbag or seatbelt, by monitoring their real-time functional status, and warn the driver in case that device is not functioning in order to prevent an incident that might occur

To use active GPS device data, it is necessary to install some devices other than a GPS device. Therefore, action cannot be taken right away on the basis of active GPS device data alone.

4.3 Reference application

Reference to GPS device data usage records can be made to three groups: drivers, roads, and vehicles.

For drivers, the Department of Land Transport uses data from its recorder to develop the “**Driver record database.**” The system is connected to the Royal Thai Police for application, as described below.

- Check driver’s traffic violation record. When database is completely connected to the Royal Thai Police, the Department of Land Transport can effectively monitor driving license status and filter out of public transport drivers with a record of past dangerous behavior
- Use data from the vehicle’s GPS device to analyze each driver’s behavior and score driving points. Evaluation includes driving speed, or pattern of braking or acceleration. The score obtained from the system would be considered when the driver attempts to renew his or her driving license
- Use data from the vehicle’s GPS device to analyze total driving distance of each driver to evaluate their personal experience

The Department of Land Transport can apply data obtained from its travel recorder to risky or dangerous points along the route, and connect to an intermediate organization under the Department of Rural Roads in order to:

- Receive data or any matter needed to track and monitor driving, analyze risky or dangerous points along the route, and inform related parties, such as the Department of Highways or the Department of Rural Roads
- Create an accident database based on accident reports from related parties, analyze risky or dangerous points, and use the data as a database to send warnings to drivers

The Department of Land Transport has developed the “**Vehicle record database,**” which provides data to insurance companies or the second-hand market, as follows:

- Vehicle database development enables rapid checking of each vehicle’s accident detailed record
- Vehicle database stores the travel record of all vehicles and analyzes or uses as criteria to define a data-monitoring pattern for each vehicle
- Vehicle database stores detailed check-up history of each vehicle

5. CONCEPT OF THE OVERALL-SYSTEM TRAFFIC CONTROL USING GPS

The design of overall-system traffic control using GPS developed by the Department of Land Transport is divided into two layers: the database layer and the application layer. The application layer itself also has two parts, one for use inside the Department of Land Transport and the other for outside.

5.1 Database layer

For the database layer, data are collected into the GPS system Management Center’s database, which includes the following:

- Driver database — This database stores the driver’s name and surname, sex, age, driving history, type of driving license, accident record, and driving score calculated from GPS data
- Vehicle database — This database stores any data related to vehicles, such as registration plate, brand, model, color, size, load weight, engine number, owner’s name and address, trading record, accident record, mileage, check-up record, any other data calculated from GPS, license, and permitted route
- Operator database — This database stores operator records, scores, and assigned

licenses. The Cargo Transport Office and Passenger Transport Office would consider license renewal based on these data

- Road safety database — This database stores details on unsafe driving on each road that trucks with GPS are using, such as sudden braking or speeding, in order to warn drivers to be more cautious when driving on that road. It is also used as a reference when requesting related parties to improve safety in an unsafe area
- Traffic database — This database is used to evaluate traffic flow based on speed obtained from GPS data, and informs drivers about appropriate routes
- Logistics database — This database stores information on starting and ending points, vehicle kilometers travelled (VKT), and transport routes. Related parties may arrange rest areas or truck terminals, or plan road maps based on such data

5.2 Application layer

5.2.1 Internal usage for the Department of Land Transport

For the application layer, data are collected as follows:

- The Department of Land Transport Inspector and the Transport Provincial Office have web and mobile applications to randomly inspect traffic violations. The Inspector can check a driver's score and license type, check whether the GPS model is the registered one, and check other licenses
- The Cargo Transport Office has a web application to check cargo vendors' traffic violation records in order to issue, suspend, terminate, or renew licenses
- The Passenger Transport Office also has a web application to check passenger vendors' traffic violation records in order to issue, suspend, terminate, or renew licenses

- The Land Transport Safety Office and the Planning Division have a web application to check the records of drivers, vendors, and vehicles
- The Automotive Engineering Office has a web application to check the services of GPS providers in order to certify, suspend, or terminate GPS devices. Moreover, data from application can be used to score providers as well
- The Provincial Transport Office has the same authority as the head office, but the scope of duty is limited to only the province concerned. For example, to inspect speeding, issue passenger/cargo transport licenses, check the records of drivers and vendors, and inspect, install, and connect to GPS data sources

5.2.2 External usage

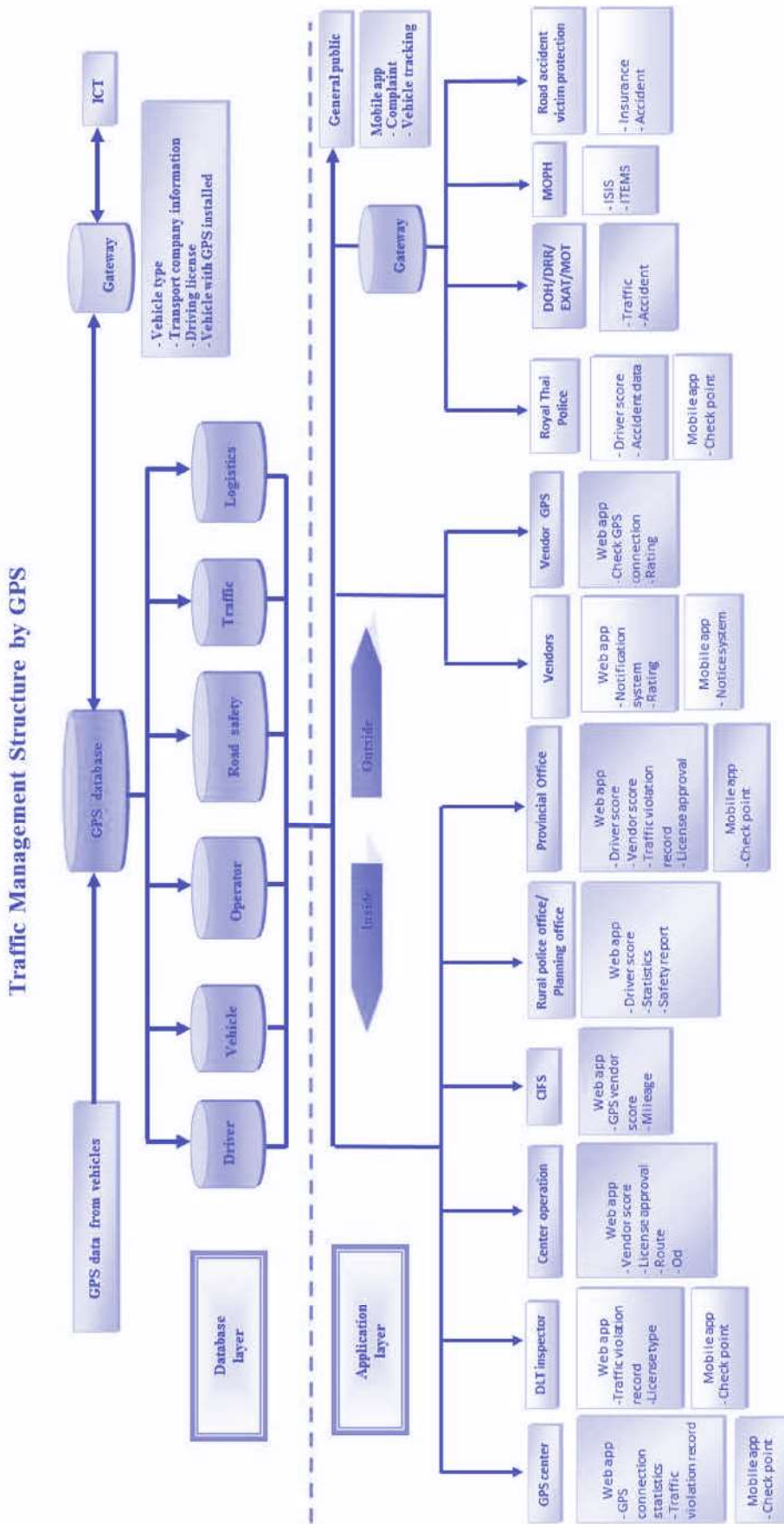
Outsider users, such as the Royal Thai Police, the Department of Highways, the Department of Rural Roads, the Expressway Authority of Thailand, the Ministry of Public Health, and Road Accident Victims Protection Co., Ltd., need to exchange data through a gateway, as shown in Figure 7. Each department is eligible to exchange certain data according to its information system, as follows:

- Royal Thai Police: score system and accident data
- Department of Highways, Department of Rural Roads, Expressway Authority of Thailand, and Ministry of Transport: traffic flow and accident data
- Ministry of Public Health: exchange data from Injury Surveillance Information System (ISIS) and Information Technology for Emergency Medical System (ITEMS) database of the Department of Land Transport

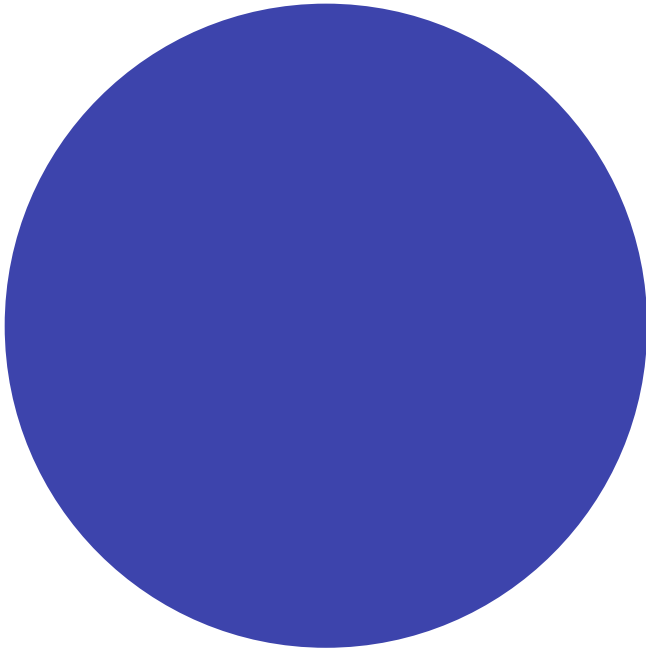
5.3 Traffic control development plan using GPS technology

In order to effectively control traffic using

Figure 7: GPS usage by outside parties



Abbreviations: App = application; DoH = Department of Highways; DRR = Department of Rural Roads; EXAT = Expressway Authority of Thailand; MOT = Ministry of Transport; MOPH = Ministry of Public Health; ISIS = Injury Surveillance Information System; and ITEMS = Information Technology for Emergency Medical System.



GPS technology, continuous development is necessary. In the first stage in 2016, an announcement stated that passenger transport vehicles and cargo transport vehicles would have to install GPS tracking devices and send data back to the GPS Traffic Control Center. These data were used to develop a GPS connection system, traffic violation system to detect such violations as speeding, unidentified drivers, and driving exceeding the time limit, as well as pairing GPS data with the Information Technology Center to inspect the data's reliability. In the second stage, the aim is to develop automatic traffic violation warning (active system) and establish a GPS Traffic Control Center in rural areas to promote road safety. In the third stage, applications should be developed in accordance with the Department's needs. In the fourth step, Business Intelligence (BI) uses data processing to improve the potential and quality development of vendors and drivers. In the last stage, when the GPS Traffic Control System has enough data and the processing system becomes more complicated, it would be necessary to establish a GPS Data Providing Office as a new section in the Department of Land Transport. All stages are expected to be complete within 2019 because by that time all transport vehicles should have GPS devices installed in order to be certified for road safety.



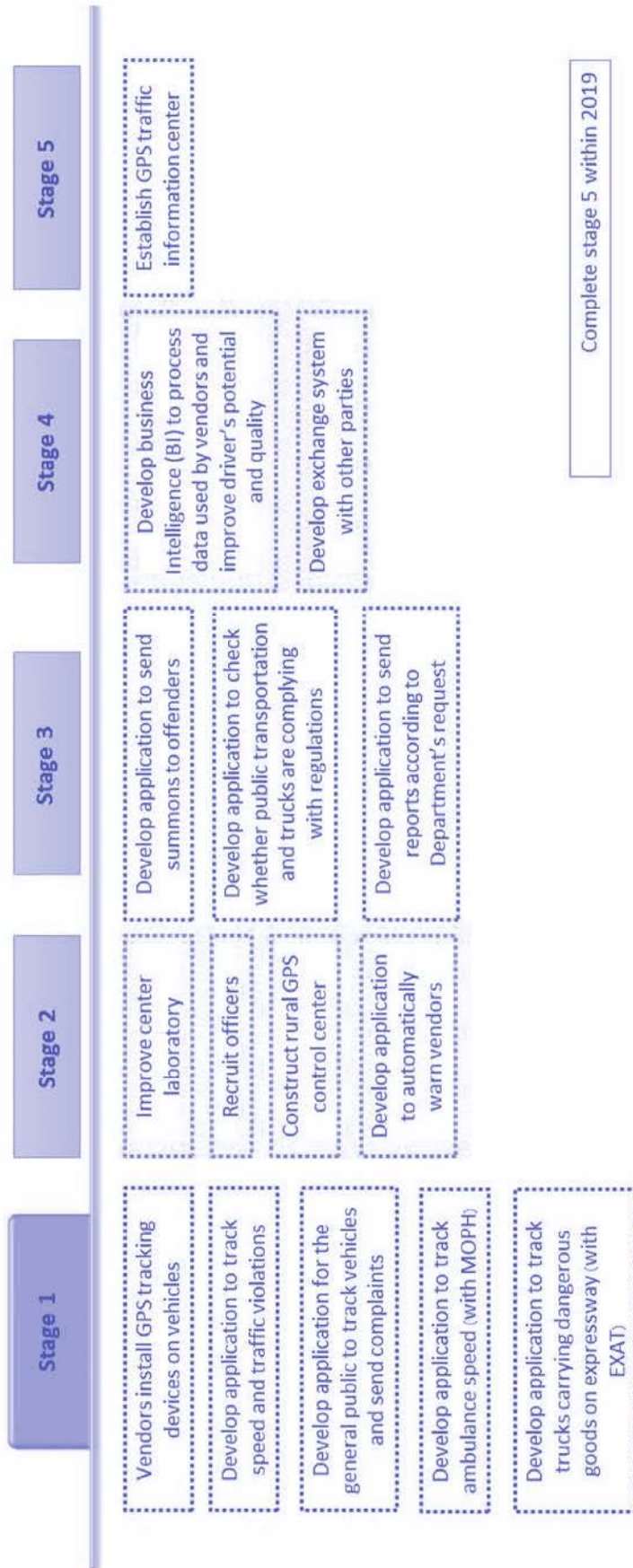
6. APPLICATION OF DATA FROM GPS SYSTEM

6.1 Safety

- **Analysis of speeding**

According to data from the GPS traffic control system, 195,194 vehicles in January 2017 violated speed limits (over 90 km/hr for more than 2 minutes). Most of them were buses with an unfixed route (89,144 cases). However, the percentage of vehicle types shows that 41 percent of the cases regarding this type of transport involved buses with fixed route standard 2. For trucks, the number of speeding vehicles according to the number of trucks in each transport type was only 3 percent. Of these, type-2 personal trucks accounted for the greatest number (7%) of this type of transport vehicle.

Figure 8: GPS Traffic Control Development Plan



Abbreviations: MOPH = Ministry of Public Health; and EXAT = Expressway Authority of Thailand.

Table 5: Top 10 highways with the highest number of speeding vehicles (daytime)

| Rank | Controlled link | Route No. | District | Province | km |
|------|--|-----------|-----------------|--------------|---------|
| 1 | Srinagarindra Road - Bang Pakong | 7 | Bang Pakong | Chachoengsao | 0+000 |
| 2 | Bang Na - Road to Suvarnabhumi Airport | 34 | Bang Phli | Samut Prakan | 13+000 |
| 3 | Khlong 26 - Khlong Rapheephat | 3902 | Wang Noi | Ayutthaya | 1+000 |
| 4 | Pratunam Pra In - Nong Khae | 1 | Wang Noi | Ayutthaya | 62+000 |
| 5 | Dao Khanong - Samae Dam | 35 | Bang Khun Thian | Bangkok | 13+000 |
| 6 | Samrong - Bhumibol Bridge | 3113 | Phra Pradaeng | Samut Prakan | 6+000 |
| 7 | Din Daeng - Ngam Wong Wan | 31 | Phaya Thai | Bangkok | 0+000 |
| 8 | Si Racha – Pattaya | 3 | Si Racha | Chonburi | 128+000 |
| 9 | Samrong - Bang Phli | 3268 | Samut Prakan | Samut Prakan | 8+000 |
| 10 | Khlong Maha Sawat - Khlong Bang Luang | 9 | Bang Bua Thong | Nonthaburi | 49+000 |

Table 6: Top 10 highways with the greatest number of speeding vehicles (night time)

| Rank | Controlled link | Route No. | District | Province | km |
|------|--------------------------------------|-----------|---------------|--------------|--------|
| 1 | Srinagarindra Road - Latkrabang | 7 | Latkrabang | Bangkok | 8+000 |
| 2 | Tandeaw - Sabbon | 2 | Kaeng Khoi | Saraburi | 16+000 |
| 3 | Bang Na - Sanphawut | 3102 | Bang Na | Bangkok | 0+000 |
| 4 | Din Daeng - Ngam Wong Wan | 31 | Chatuchak | Bangkok | 10+000 |
| 5 | Bang Na Road to Suvarnabhumi Airport | 34 | Bang Phli | Samut Prakan | 13+000 |
| 6 | Pratunam Pra In - Nong Khae | 1 | Wang Noi | Ayutthaya | 62+000 |
| 7 | Phra Pradaeng - Bang Khae | 3902 | Phra Pradaeng | Samut Prakan | 1+000 |
| 8 | Udom Suk - Samut Prakan | 3344 | Samut Prakan | Samut Prakan | 18+000 |
| 9 | Samrong - Bhumibol Bridge | 3113 | Phra Pradaeng | Samut Prakan | 6+000 |
| 10 | Samrong - Bang Phli | 3268 | Samut Prakan | Samut Prakan | 8+000 |

Table 7: Points with sudden decreases in speed

| Latitude | Longitude | Controlled link | Route No. | District | Province | km | Brake count (times) |
|-------------|-------------|----------------------------------|-----------|----------------|-------------------|---------|---------------------|
| 14.8400621 | 101.6076211 | Bo Thong - Mo Chabok | 2 | Sikhio | Nakhon Ratchasima | 92+000 | 1,208 |
| 8.096911939 | 98.97789939 | Talat Kao - Khlong Thom | 4 | Nuea Khlong | Krabi | 981+000 | 1,118 |
| 13.72948733 | 100.7423789 | Srinagarindra Road - Bang Pakong | 7 | Latkrabang | Bangkok | 11+000 | 1,106 |
| 13.39128992 | 101.0467656 | Bang Pakong - Khao Kheow | 7 | Chonburi | Chonburi | 67+000 | 1,015 |
| 12.94416428 | 100.9125277 | Ban Pong interchange - Pattaya | 3702 | Bang Lamung | Chonburi | 125+000 | 992 |
| 15.57657177 | 100.1250173 | Hang Nam Nong Khaem - Ban Wa | 1 | Krok Phra | Nakhon Sawan | 327+000 | 889 |
| 15.54799003 | 102.5480106 | Kaeng Sanam Nang - Don Tanin | 2 | Sida | Nakhon Ratchasima | 233+000 | 879 |
| 15.81321012 | 102.6075382 | Nong Waeng Sok Phra - Phon | 2 | Phon | Khon Kaen | 263+000 | 867 |
| 13.38459475 | 101.0448949 | Don Hua Ro - Nong Khang Khok | 3702 | Chonburi | Chonburi | 68+000 | 857 |
| 13.67040362 | 100.8432737 | Latkrabang - Bang Khwai | 7 | Bang Sao Thong | Samut Prakan | 26+000 | 852 |

Furthermore, based on data from the GPS device in each vehicle, it is possible to identify the top 10 highways with the most speeding vehicles both during the day and at night, as shown in Tables 5 and 6 respectively.

• **Analysis of points with sudden speed decrease**

Data on speeding can be used to analyze points with a sudden decrease in speed that helps in understanding driving behavior. Sudden velocity change can be significantly used in in-depth analysis, which provides information on route physical data, such as curved, intersected, or damaged roads. This factor might cause abnormal driving because the driver may lack experience with that route, or highway safety equipment or signs may not be provided.

A sudden brake detected by the GPS system

means decreasing speed from over 80 km/hr to half that speed within a minute, cause red points to become smaller and disappear within 2 minutes. Analysis provides information on where the most sudden speed decrease occurs, as listed in Table 7.

6.2 Transport and logistics

• **Analysis of starting and ending points**

For applications to transport and logistics management, the location of the GPS device can be used to find a vehicle’s location on a road map. The system stores starting and ending points by using GPS applications from various types of vehicles, and transforms the GPS data signals into travel information from starting to ending points. Map data provide information on the behavior of each vehicle type.



- **Rest area analysis**

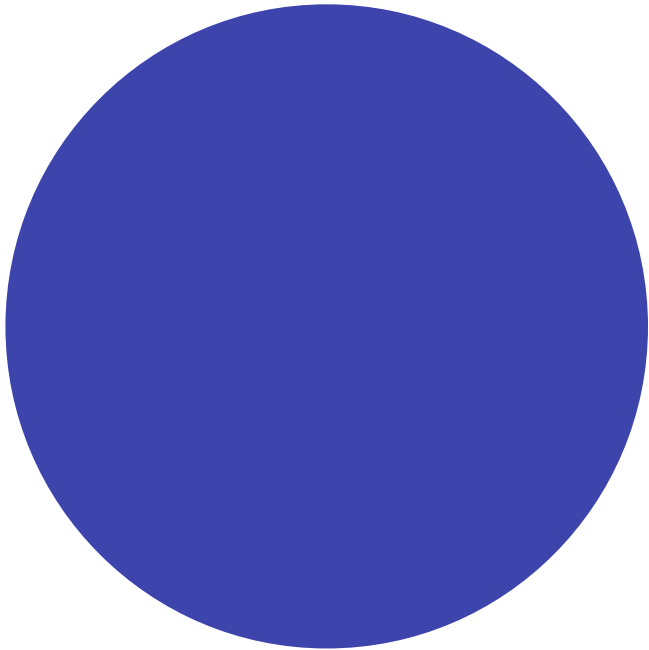
When transport and logistics data application is used to find a rest area, the density of vehicles in each area is also known. Therefore, we know density on a road map as well as the number of trips made by cargo trucks on truck routes, travel needs, and number of trips from points of origin to destinations, which can be used to plan whether to add or remove any rest area.

7. CONCLUSION AND RECOMMENDATIONS

Connecting and exchanging data from a vehicle's GPS device and analysis of large amounts of data to produce understandable information makes it possible to add value to that information. The result of nationwide road map analysis obtained from GPS clearly shows the behavior of drivers of vehicles with GPS installed. Speed analysis can be applied for road safety management. It is not only control of vehicle speeding or traffic flow on a road map that government agencies would know, but also data on highways with vehicles exceeding the speed limit; therefore, it would become possible to manage the process of accident prevention. Sudden brakes in

speed data can be analyzed, and driving behavior can be better understood. A sudden decrease in speed reflects physical characteristics of a route that is curved, intersected, or damaged. These factors might cause abnormal driving if the driver lack experience in driving on that route or no highway safety facility or sign is provided. Speeding data can be used in many applications, or as a guideline for law enforcement, physical improvement of routes, and installation of signs and safety facilities, such as a sign warning drivers to decrease speed ahead. Transportation and logistics management by analyzing starting and ending points enables better understanding of travel patterns, transportation routes and rest areas, and therefore understanding of the distribution and needs along the routes, which can be used to plan whether to add or remove any rest area.

In conclusion, GPS can satisfy the needs of the Department in terms of management and control, which is beneficial to management procedures and promotes road safety, increases transport and logistics efficiency, and encourages research related to transport development.



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