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Vehicle Operation Management System using GPS

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A requirement of the Vehicle Management System is that it be made more effective in order to reduce environmental pollution and offer better service to customers.
We have developed the Advanced Vehicle Operation System with an accurate positioning sensor using GPS (Global Positioning System).
The system will automatically detect each vehicle's position with an accuracy of 100m without manual operation, 24 hours a day, and anywhere in the world.
We have adopted not only the GPS, but also dead reckoning for vehicle location sensing. This allows the system to detect a vehicle's position continuously, even in downtown areas where the GPS signal cannot be received.
In the dispatch center, the operator can easily monitor each vehicle on the screen which shows the vehicle marker indicating the position and the direction overlaid on the map. This system will automatically watch whether the vehicle takes the scheduled route or not, and manage the departure and arrival time of the vehicle.
This paper describes the concept of the Vehicle Operation Management System using the GPS which we have developed.

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Vehicle Management System

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This is a brief description of the Vehicle Operation Management System that we jointly developed and implemented with Fujitsu Ten Limited. We discuss the background of its introduction and considerations for its application development.

We are involved with the mechanized security business, and use a centralized remote monitoring system to guard a large number of offices we have contracted with.

The dispatch centers manage the status of many vehicles, some for rapid security site visits, and other guarded vehicles for collecting or delivering valuable and sensitive consignments. The nature of our service, knowing the location and the mobility information of each vehicle is required not only for efficiency of the vehicle operation, but also for security. This has been done by voice communication via two-way radios. However, voice communication is intermittent and does not give us objective or continuous information of the vehicle status.

In the management of the security vehicles, the operators also have to monitor the travel route and the time of operation for each vehicle. In the case of managing a lot of vehicles, the workload of the monitoring staff will increase, and improvements are thus required.

Several methods of sensing the vehicle location (including receiving RF signals from signposts and dead reckoning using sensors) have been developed.

However, there are many problems in managing the security vehicles. These include poor positioning accuracy, a limited service area, and high costs. The commercial availability of the GPS utilization now makes it possible to sense the vehicle location with higher accuracy, good stability, and at low cost. This vehicle operation management system we have implemented is for monitoring security vehicles operated on a predetermined route. We based development on the following three design concepts;

1. Maximum visual representation of information
2. Maximum automation for higher system reliability
3. Flexible adjustments of system monitoring constants

For the maximum visual representation of information:

The monitoring display should be easy to recognize, the location and the mobility status of each vehicle should be quickly grasped, and the information of all vehicles should shown on one page. The system has a digital map database of large-scale and detailed maps, to allow access to more detailed information on individual vehicles, including their routes. The location of each vehicle is displayed as a vehicle marker with vehicle number overlaid on the map display. Different colors indicate different mobility states such as moving, working, or deviation from a scheduled route.

For maximum automation and higher system reliability:

For managing a vehicle moving along a scheduled route, it is important to monitor the route of each vehicle moving, the travel time between points, and the working time at each stopover. Automated monitoring is possible with entering predetermined routes, travel time, and working time into the database. This allows an operator to concentrate on dealing with unusual events, without watching the monitor display constantly if a vehicle status is normal. The driver simply presses the depart / arrival keys, letting the dispatching center determine the departure or arrival points automatically from the location information. Total system reliability is increased and most functions are automated in this way.

For flexible adjustments of system monitoring constants:

Monitoring constants include the service route, the distance limit for judging route deviation, the closeness for judging vehicles to be at departure or arrival points, travel time between points, working time at each stopover, and time tolerance for judging delays. These parameters have to be modified to reflect route additions or alterations, sensing errors, traffic congestion, road repair, and the workload related with the quantity of consignments. It is thus easy for users to set and alter these parameters.

Implementing the Vehicle Operation Management System has greatly reduced the workload of the monitoring staff, and has also provided better security.

Lastly, we sincerely thank Fujitsu Ten Limited for their cooperation in the development of this system.

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1. Introduction

Many systems which concentrate vehicle location and the other mobility information into a dispatch center to manage vehicles and to optimize dispatching, have been operated in the field. Such systems have been used for higher efficiency and better service to customers. We have developed and delivered a lot of AVM (Automatic Vehicle Monitoring) Systems for the taxi companies, and Security Vehicle Support Systems.

In these conventional systems, each vehicle's location information transferred to a dispatch center was determined by either receiving the RF signal from the Signposts installed in a service area automatically, or pushing the area button manually by a driver. These systems did not go much beyond supplying positioning accuracy, but were still useful in some applications.

Today, more effective vehicle operation is required to offer better service against stiff competition, to work with the limited manpower, and to reduce environmental pollution.

Good vehicle management is required for increasing the efficiency. Conventional systems had limited positioning accuracy, a limited area of coverage, and the inability to determine the direction of a vehicle. It could not satisfy the current user's needs like the most effective vehicle operation and dispatching with the realtime vehicle information. More accurate vehicle position sensing is thus a required.

Many ways for sensing the position of vehicles have been researched and developed. GPS (Global Positioning System) is a recent option of the positioning sensor for the Vehicle Navigation / Location Systems.

GPS provides the absolute location information anywhere in the world using satellite signals and is available 24 hours a day. Position sensing by GPS does have a few errors related to radio propagation and satellite control. It is, however, the most effective way to sense a vehicle location at present because of its high precision and no limitation of service area.

We have developed a GPS based Vehicle Operation Management System for more effective vehicle management.

In this system, dead reckoning is also adopted to cover the GPS dead zones caused by buildings in downtown areas.

The location and travel information of the vehicles will be transmitted to the management center via a transmission channel and the center monitors each vehicle's status.

This system is designed for monitoring scheduled security vehicles and for detecting any deviation from a predetermined route, and the arrival / departure times at stopovers.

In the conventional system, it is difficult to have automatic monitoring along a predetermined route and the driver has to enter the location data manually at each stopover.

Our new system offers easy location monitoring by displaying each vehicle's position overlaid on a map, automatically supervising the driving route using map coordinates, and eliminating manual operation by drivers.

The system is linked with the database (i.e., operation schedule) to automate the performance management and to reduce the supervisor's workload.

The following sections describe the configuration and functions of the new system we developed.

2. System overview

2.1 Functions

This system manages all vehicles' location and mobility information transmitted to the center via a transmission channel at the center side. In this system, we use the MCA (Multi Channel Access) radio as the transmission channel. It is also possible to use a conventional two-way radio, a teleterminal (Packet Data Radio), or a mobile telephone.

The vehicle unit continuously senses its location with the absolute location data from the GPS and interpolates using the relative location data from the sensors (Gyroscope, Terrestrial Geomagnetic Sensor, Vehicle Velocity Sensor). The vehicle unit transmits above location information to the center with adding the mobility information such as arrival or departure .

When the center receives the information from a vehicle, the vehicle location and its direction of travel are displayed on a map display.

If the system detects something unusual during automatic monitoring, the system gives an alarm to the operator.

Any driving routes can be programmed by specifying route points on the map display. The routes can be edited, and the stopover locations can be specified on the map display. The service performance of each vehicle is printed in daily and monthly journals which are used as management information.

2.2 Configuration

Figure-1 and Table-1 describe the configuration of this system.

The mobile station consists of the Antenna / Sensor Unit (which includes a GPS antenna, a Terrestrial Magnetism sensor and a Gyroscope unit), the Signal Processing Unit, the Control Unit and a Two-way Radio.

The equipments at the center are a Workstation (as a main processor), an X-Windows Terminal, a Printer, and a Two-way Radio.

Table 1. System configuration

	Device name	Quantity	Remarks
Mobile station equipment	Radio unit	Up to 100 units	Built-in data transmitter for MCA
	Vehicle processing unit	Up to 100 units	Built-in GPS receiver
	Antenna and sensor unit	Up to 100 units	GPS antenna, geomagnetic sensor, gyroscope
	Vehicle operation unit	Up to 100 units	
	Vehicle velocity sensor	Up to 100 units	Taken from the vehicle speedometer cable
Center equipment	Radio unit	1	Expandable to support up to five stations
	Workstation	1	UNIX workstation with 21-inch monitor
	X-Windows terminal	1	X-Windows terminal with 17-inch monitor
	Printer	1	A4 page printer

3. Mobile station equipment

3.1 Equipment configuration

The mobile station consists of the GPS Antenna / Sensor Unit, the Signal Processing Unit, and the Control Unit.

Figure-2 shows the configuration of the mobile station equipment.

3.1.1 GPS antenna sensor unit

Figure 3 shows the GPS Antenna and Sensor Unit (Model: ANA-003).

This Unit consists of a GPS Antenna, a gyroscope as a dead reckoning sensors and a terrestrial magnetism sensor. These are all housed into one case for easy installation. This unit is designed for installation on the roof of a vehicle. It thus requires good weatherability, heat resistance, watertightness, impact resistance, and easy installation.

1) Weatherability and Heat Resistance
   The case of this unit is made of AAS (Acrylate Acrylonitrile Styrene) resin and a Polycarbonate Alloy material for their exceptional weatherability, heat

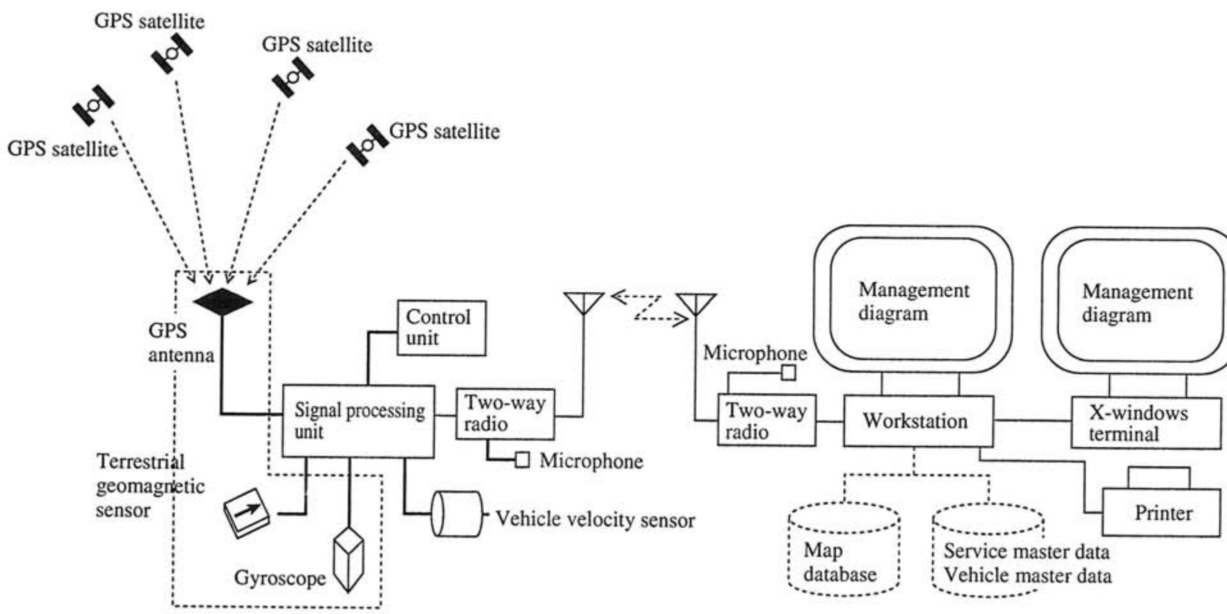


Figure 1 . System configuration

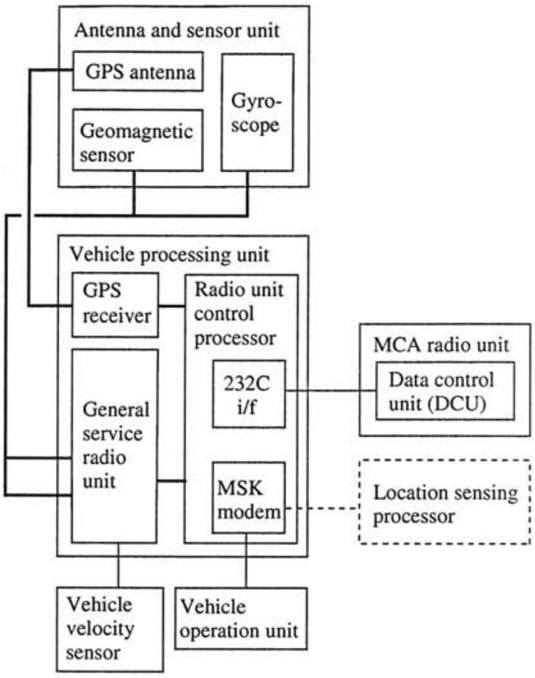


Figure 2 . Vehicle system configuration

resistance, and impact resistance. These materials have provided good performance in radar antenna domes for marine applications.

2) Watertightness

Watertightness (meeting to JIS DO203-S1 or equivalent) is important to the GPS Antenna and Sensor Unit since the unit is installed outdoors.

The sheet metal cover on the bottom of the case is sealed with EPDM (Ethylene Propylene Diene Monomer) form, a special outdoor sealing material, which easily deforms under compression and ensures watertightness without requiring a stiff cover. The same form is put on edges of the case to fill in the gaps between the case and the vehicle roof. This sealing prevents rain water from directly hitting the bottom of the case. A double-sided adhesive is used to clamp the bracket.

The cover has ventilation holes covered with a watertighten sheet to prevent changes of internal air pressure, and to prevent condensation caused by a temperature difference between inside and outside the case.

We selected metal panels and screws made of stainproof and non-magnetic material.

3) Impact Resistance

The gyroscope is vulnerable to impact damage. Wrap it with a rubber sponge spacer during installation to protect it.

This unit is attached to the vehicle with a double-sided adhesive so that the vehicle need not have any holes drilled. The double-sided adhesive we use has proven useful for mounting parts on vehicles, and its taping strength is more than 100 times that of the Antenna / Sensor unit weight.

This unit is mounted by taping a bracket, instead of taping the unit directly, for ease of maintenance. The unit can be removed simply by removing the screw between the unit and the bracket.

Figure 3. GPS antenna and sensor unit

3.1.2 Signal processing unit

Figure 4 shows the Signal Processing Unit (Model: SPU-037A).

The Signal Processing Unit contains a GPS receiver, a location sensing processors and a two-way radio control processor. The two-way radio control processor receives location information from the location sensing processor, and then generates the mobile station data by adding the mobility status from the control unit. The mobile station data is transferred to the DCU (Data Control Unit) inside the MCA radio once every second. The DCU controls the MCA radio for sending and receiving the data.

The Two-way radio Control processor also includes the interface circuit (MSK Modem and its control circuit) for interfacing with not only the MCA radio but also conventional two-way radio (including radios of other manufacturers). This unit connects to the MCA radio(DUC) via an RS-232C interface, so it is possible to interface with a Teleterminal, or a portable telephone with an external modem.

The Location Sensing Processor calculates the present vehicle location by combining the GPS data and the dead reckoning data. This unit is also considered for future systems using only the GPS (no dead reckoning using sensors) for sensing a location. The Location Sensing Logic is described in Section 3.2.

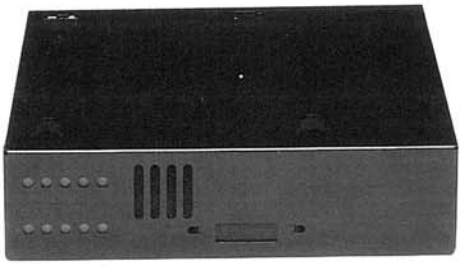


Figure 4. Vehicle processing unit

3.1.3 Control unit

Figure 5 shows the Control Unit (CCA-036A).

The Control Unit consists of key switches for entering departure and arrival status of the vehicle, LEDs for indicating the registration status (i.e., registration completed or executing of registration) and a buzzer which generates key tones and audible alarms.

The registration signal is transmitted to the base station by pressing the buttons on the controller, then the acknowledgment from the base controls LED and audible alarms.

Figure 5. Vehicle operation unit

3.2 Location sensing logic

Figure 6 shows the concept of the Location Sensing Logic.

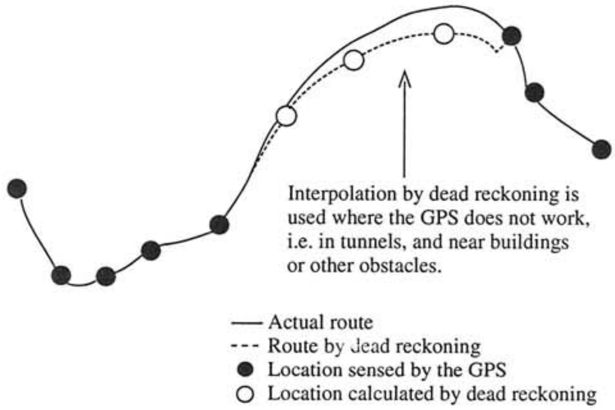


Figure 6. Figure of the positioning process

Location sensing of a moving vehicle is primarily made by the GPS receiver. However, sometimes the GPS does not work or does work with unacceptable error caused by various effects (such as tall buildings or elevated highways). Vehicle location sensing with only the GPS receiver cannot sense continuously for the above reason. To fill in these gaps, this system also has dead reckoning. It continuously calculates the present location from the last valid GPS location as the starting point of dead reckoning by using the sensors.

Figure 7 shows conceptually how dead reckoning works.

For dead reckoning, a relative travel vector is calculated from the direction of the travel and the distance traveled in a unit period of time. This travel vector is added to the starting point coordinates to update the vehicle location, and so it can continuously sense the vehicle location.

The direction of vehicle travel is determined by combining the information from a terrestrial magnetism sensor and a gyroscope. The terrestrial magnetism sensor detects the magnetism surrounding the vehicle and outputs its orthogonal X-Y components. The signal processing program calculates the direction of travel for a vehicle as an absolute azimuth from the output of a gyroscope. The gyroscope detects and outputs angular velocity of rotation. The gyroscope outputs an angle of rotations, which is then added to the the direction of travel to get the absolute azimuth.

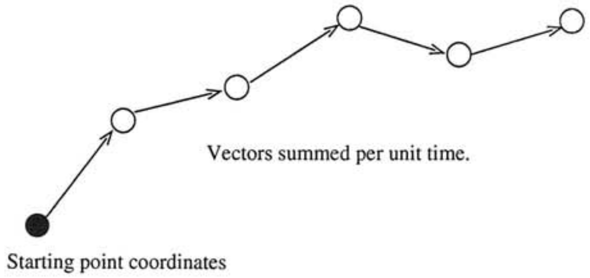


Figure 7. Figure of dead-reckoning

It is possible to calculate the direction of vehicle travel with a terrestrial magnetism sensor alone, but terrestrial magnetism is disturbed by structures like elevated highways or by other vehicles. This sometimes results in errors of over 20° in the calculated directions of vehicle travel. Since directional errors cause the largest errors in dead reckoning, relying on a terrestrial magnetism sensor alone could lead to significant errors. The gyroscope calculates the angle of rotation with high precision over short periods of up to several minutes, but errors become large over a longer period. The terrestrial magnetism sensor and the gyroscope make up for each other's weaknesses; the terrestrial magnetism sensor gives long term accuracy and the gyroscope gives short term high precision. The signal processing algorithm calculates the direction of vehicle travel accurately using the direction given by the gyroscope, and referring to the direction given by the terrestrial magnetism sensor when the terrestrial magnetism is stable. Combining these two sensors can reduces errors in direction, as the result of that, errors of the dead reckoning is minimized as much as possible.

The positioning accuracy of GPS is depends on the radio propagation conditions and the SA (Selective Availability) which is the intentional signal degradation by the DOD (the U.S.Department of Defense). Its average positioning accuracy is about 100m.

The dead reckoning produces position sensing errors of about 10% of the distance of travel which is caused by the tolerance of sensors themselves, the condition of the vehicle (i.e., tire pressure, changing magnetization of the body) and other factors (i.e., disturbances in terrestrial magnetism, tire slip).

The position sensing error of this system is within 100m when using GPS. When using dead reckoning, the position sensing error is the sum of the GPS error at the last valid location and the dead reckoning error in proportion to the travel distance of the vehicle.

4. Center equipment

4.1 Configuration

Figure 8 shows the Center Equipment.

The system consists of a workstation (S-4/2) as the core, an X-Windows terminal, a CMT drive, a printer, an automatic shut-down unit and an MCA radio. The workstation and the X-Windows terminal are operated by the mouse and keyboard of each unit. The MCA radio contains a data control unit (DCU).

Figure 8. Base station

4.2 Major functions

4.2.1 On-map vehicle display

Figure 9 shows an example of a map display.

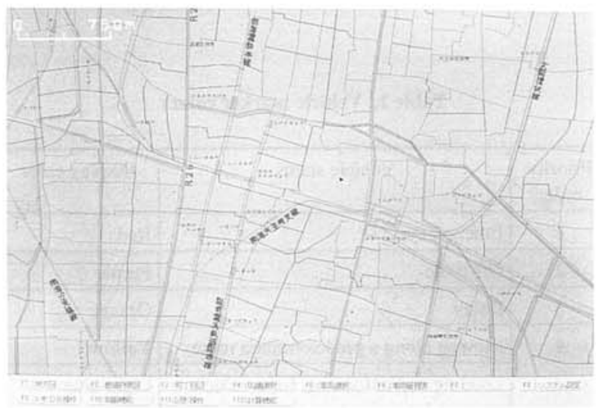


Figure 9. Example of map display

The map display uses the Wide-area Map Database and this system has two levels of map display, a wide-area map display and a detailed map display. The map display is controlled by a menu and a mouse or keyboard.

The following map operations are available;

① Scrolling (variable scrolling amount)
② Scrolling by specifying the center of the map
③ Magnification and Reduction (variable ratio)
④ Specifying an area
⑤ Re-display

When the base station receives the data from a mobile station, it displays a vehicle marker on the map display with the shape shown in Figure 10. The oval shaped vehicle marker has an arrow mark which indicates the direction of vehicle travel and the vehicle number inside. There are eight possible directions: north, northeast, east, southeast, south, southwest, west and northwest. The color of a vehicle marker varies depending on the status of the vehicle. (see Table 2) If some vehicles are close together so that their markers overlap, vehicle numbers and the status of each vehicle are identified by the marker shape shown in Figure 11. There are three possible marker sizes which vary depending on the density of a map. The included small marker on a wide-area map display and a large marker on a detailed map display and the intermediate.

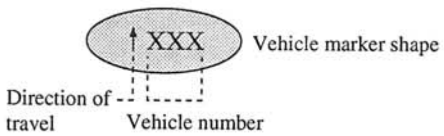


Figure 10. Mark of vehicle

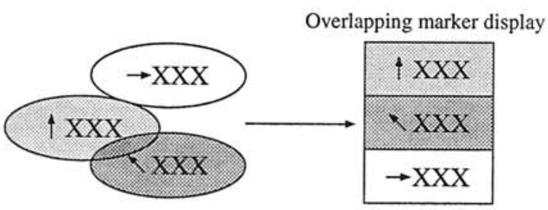


Figure 11. Mark of vehicle (overlap)

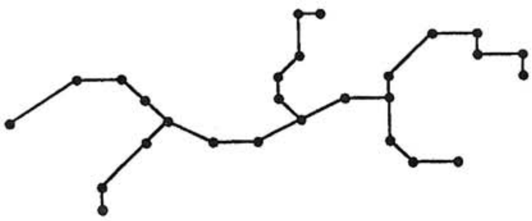
Table 2. Vehicle marker colors

Priority order	Vehicle status	Display color
1	Emergency	Red
2	Off route	Purple
3	Delay	Orange
4	Moving along a predetermined route	Yellow
	Loading and unloading, for a vehicle on a predetermined route	Light blue
5	Vehicle not on a defined route	Green

4.2.2 Deviation monitoring

This system has the deviation monitoring function which constantly watches where vehicles are to make sure they are still on their predetermined route within a reasonable tolerance.

Vehicle routes are defined as sets of points on map coordinates, and are displayed by connecting the points with straight lines. Figure 12 shows the concept of route construction.



• is a coordinate on the route. The coordinates themselves are not shown on the actual map display.

Figure 12. Example of route construction

Vehicle routes are specified by one trunk and multiple branches. The menu lets an operator vary the color and thickness of route displays, and turn the route display on and off.

Figure 13 shows the concept of route deviation monitoring. This system monitor the vehicles to ensure they are within a certain distance from the scheduled route, and if the vehicle is beyond this distance, the system detects a deviation. The deviation distance is variable between 0 and 9999m.

The system calculates the perpendicular distance of a vehicle from the straight line which connects two adjacent points composing the scheduled vehicle route. This calculation is repeated for every pair of adjacent points making up the route. If the perpendicular distance from a straight line is within the deviation limit, the vehicle is assumed to be on route. If not, the vehicle is off the route.

If the route deviation is detected, the system displays the vehicle number and sounds an audible alarm until an operator acknowledges the deviation.

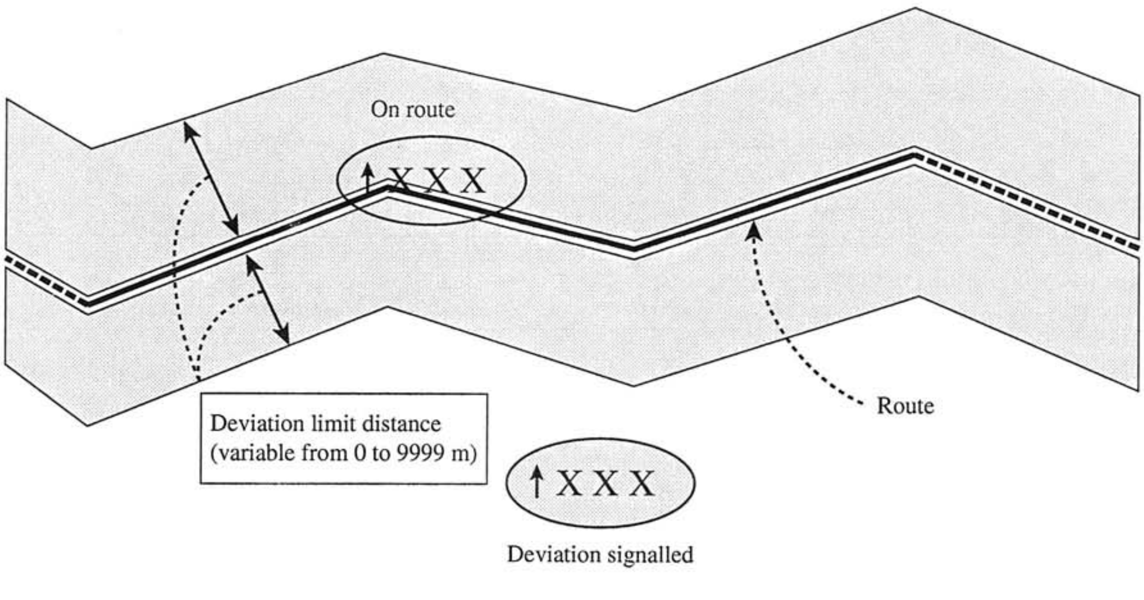


Figure 13. Example of route deviation

If the vehicle which was off route returns to its scheduled route, the system turns off its number display and audible alarm automatically.

4.2.3 Departure / arrival management

When the vehicle arrives at or departs from a stopover (i.e.,store), the driver presses the Depart / Arrival keys. The manual operation for this function is chosen for use in signalling the start and end of work at stopovers.

The mobile unit transmits the current location of the vehicle, and the departure or arrival status to the center when the Departure / Arrival keys are pressed.

The center retains the location of each store as a point on the map coordinates, and location information transmitted from the vehicle is converted into the map coordinates to identify which store the vehicle is at. The distance between the vehicle and the stores is calculated in ascending store number order. The vehicle is considered to be at the store if its distance from the store is within a predefined limit. The vehicle cannot be registered if its distance from each store is more than a predefined limit.

Figure 14 shows the concept of store identification.

On registering the vehicle arrival or departure, a poor radio propagation condition may prevent immediate data transmission to the center. In this case, the location and mobility information transmitted by pressing the Departure / Arrival keys is transmitted later. This makes correct registration of the vehicle arrival or departure possible, even if the vehicle is not at a store when the location information is retransmitted.

4.2.4 Service management diagrams

The X-Windows terminal displays service management diagrams. There are two types of service management diagrams:

① General Service Management Diagram
② Vehicle-specific Service Management Diagram

1) General Service Management Diagram

Figure 15 shows an example display of the General Service Management Diagram.

The General Service Management Diagram shows the latest information for each vehicle. This diagram shows information for up to 30 vehicles on each page.

This diagram indicates whether vehicles are moving or working, and the following informations are displayed according to the status of the vehicle:

Moving: last visited store name and departure time, and destination store name

Working: last visited store name and departure time, and the name of the store the vehicle is at and arrival time

If a predefined travel time (travel delay) or work time (departure delay) is exceeded, the excess time is displayed in the alarm column.

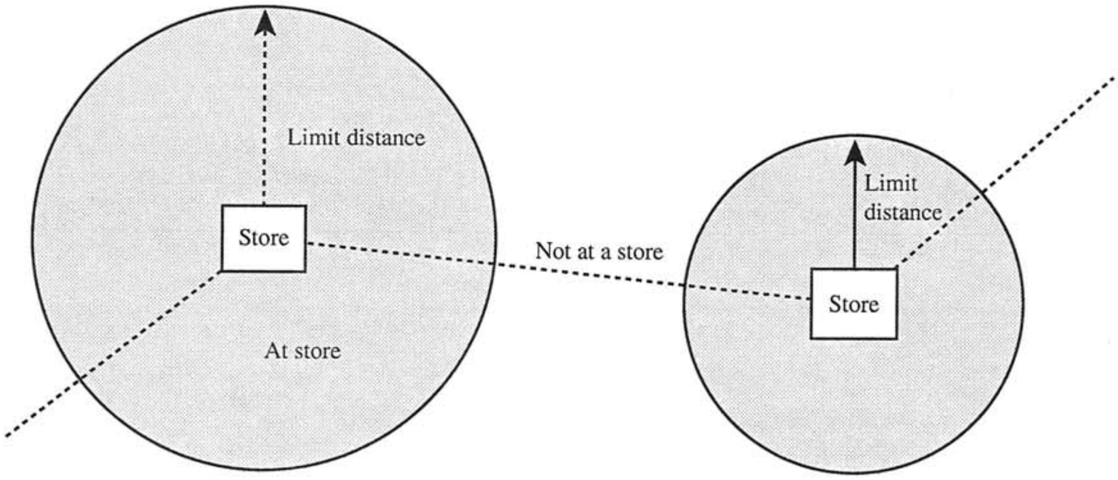


Figure 14. Judgement of store

Table 3. Service management chart mobility display

Priority	Displayed characters	Display color	Vehicle mobility
1	Emergency	Red	Emergency
2	Route deviation	Purple	Off route
3	Delay	Orange	Vehicle with a delay alarm activated
4	On the move	Yellow	Vehicle moving on route
	Loading and unloading	Light blue	Vehicle loading and unloading on route
5	Standby	Pink	Vehicle before it departs from the first store, which is the vehicle center
	Complete	Green	Vehicle arriving at the last store, which is the vehicle center
	Not registered	Gray	Vehicle with no predetermined route

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General vehicle service management diagram

Vehicle	No.	Departed store name	Departure time	Arrived at store name	Arrival time	Alarm	Mobility
001	1	○○○ store	19:00	○○○○ store	19:20	000	Loading and unloading
002	1	○○○○○ store	19:30	○○○○○○ store		000	Moving
003	1	○ store		○○ store		000	Standby
004	1	○○○○○○○ store		○○○○○○○ store		000	Standby

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Figure 15. Management diagram of all vehicles

Each mobility status has a priority as indicated in Table 3, and is indicated in the mobility column with its own color.

2) Vehicle-specific Service Management Diagram
Figure 16 shows an example display of Vehicle-specific Service Management Diagram.
This diagram is for supervising the delay of operation. It compares the service schedule with the actual result. The service schedule and the actual result of each vehicle are displayed on 25 lines per page.
Schedules are displayed in the predetermined store visit sequence. The estimated arrival and departure time of each store are calculated from the start time, the time needed between stores, and the working time at each store.
Before departure: The estimated time at each store calculated from the scheduled departure time is displayed.
After departure: The estimated time of each store calculated from its actual departure time from the center is displayed.
When the center receives the arrival / departure registration data from a vehicle, the actual arrival or departure time is displayed.
The time differences in minutes between the scheduled times and results are displayed in the delay column.

4.2.5 Service route set-up

Service routes are set up by entering a series of points on a map display using a mouse. The points specified are handled as on-map coordinates.

Table 4. Service schedule setup

Item	Description
Course number	Set a course number (1 to 100)
Route number	Number of the corresponding route (route setup done beforehand)
Sequence	Store visit sequence (1 to 100)
Store number	Store number set at store information setup
Time required	Time from the previous store (in minutes: 1 to 999)
Time at store	Time at the store (in minutes: 1 to 999)
Correction required	Marginal correction time necessary to monitor delays in store-to-store transit (in minutes: 1 to 999) The store-to-store transit delay monitoring time is the time required plus the correction.
At-store correction	Marginal correction time necessary to monitor delays at stores (in minutes: 1 to 999) The store delay monitoring time is the time required plus the correction.

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Vehicle-specific service management diagram

September 6 21:27
Vehicle number 001 Course number 001 Route number 001

No.	Store number	Store name	Scheduled arrival time	Arrival time	Scheduled departure time	Departure time	Delay
1	001	Center			16:10	18:10	
2	002	○○○○○○ store	18:30	18:30	18:50	19:04	14
3	003	○○ store	19:00	19:50	20:00	20:20	20
4	004	○○○○ store	20:30	20:33	20:50	21:12	22

(To last window) (Previous) (Next) (End)

Figure 16. Management diagram of selected vehicle

The following information is then added to the sequence of points to produce a service route:

① Route number and route name

② Off route distance limit

4.2.6 Service schedule set-up

Service schedules are predefined as the stores the vehicle will visit, the time from store to store and the work time at each store. These schedules are registered in a predefined store visit sequence.

The items listed in Table 4 are entered and registered as store visit sequence information.

These registered schedules can be assigned to any vehicle individually, along with a service route as described in the preceding paragraph.

4.2.7 Report print-out

The service results of each vehicle can be printed out as daily and monthly reports. To allow for printer failures, the daily reports can be printed out retroactively to one month ago, and the monthly reports can be printed out retroactively to one year ago.

5. Data collection

5.1 Traffic limitations

This Vehicle Operation Management System we developed uses MCA radio for telecommunication channels, but it is also possible to use a conventional two-way radio, a teleterminal, or a portable telephone.

When using the MCA radio as communication channels, communications traffic must be carefully considered. In the MCA radio system, many users communicate with each other using available channels. It is possible that one user may monopolize a channel and degrade the performance of other users if a lot of data is transmitted for collecting the status of vehicles.

This system collects data by automatic polling and by manual operations. Periodic group polling (frequency variable) is used to minimize communications traffic, and is started either automatically or manually when needed.

Table 5 is a theoretical comparison of communication volume for managing vehicles by voice communication with data communication of this system in the following conditions:

① One base station and four land mobile stations

② An average of 20 stores visited per day

③ Working for 10 hours per day

④ All scheduled reporting is made by data communication, with little voice communication

Table 5. Voice communication and data transmission

	Voice communication	Data transmission
Service channel (S-ch) occupation time	31,200 seconds/month Departure/arrival reporting: 24,960 seconds/month Intermediate point reporting: 6240 seconds/month	7296 seconds/month Individual communication: 5904 seconds/month Polling: 1392 seconds/month
	1040 seconds/day	243 seconds/day
	104 seconds/hour	24 hours/hour
Control channel call origination per station	8.6 times/hour Departure/arrival reporting: 6.9 times/hour Intermediate point reporting: 1.7 times/hour	4.5 times/hour Individual communication: 3.6 times/hour Polling: 0.9 time/hour

Both the occupation time of speech channel (S-ch) and the volume of call origination on the control channel (C-ch) are lower than that by voice communication.

5.2 Periodic data collection

Vehicle location and mobility status are collected by periodic polling at the center. In the MCA radio system, the quality of the communication channel is relatively good, and reducing the speech channel occupation time is required. The group polling as shown in Figure 17 is thus used in this system for efficient data collection.

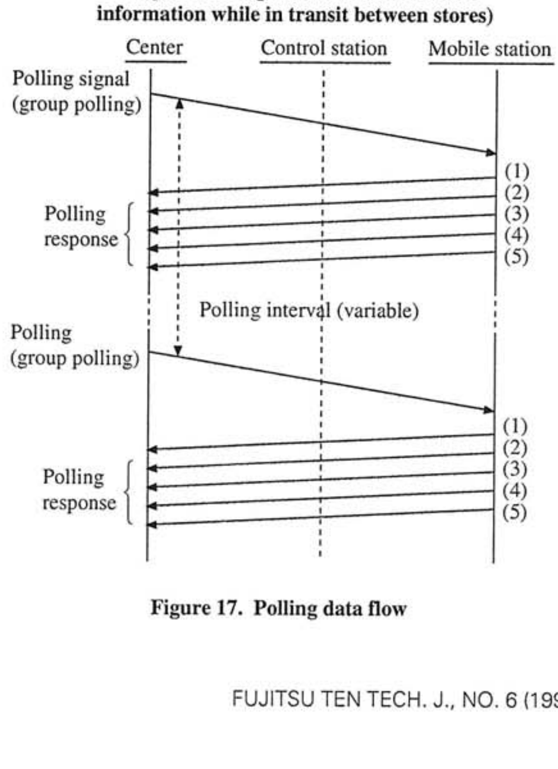

Figure 17. Polling data flow

5.3 Departure / arrival data transmission

Each time the vehicle departs from or arrives at a store, the driver presses the Departure / Arrival Keys on the control unit to transmit data to the center. This data also includes location information, so that the center identifies which store the vehicle is at automatically. Figure 18 shows the data exchanges for vehicle arrival and departure registration.

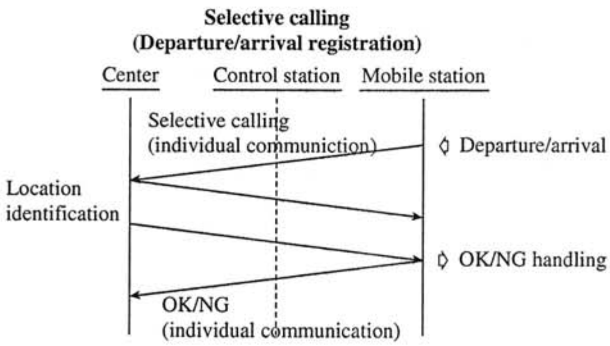

Figure 18. Selective calling data flow

6. Conclusions

This Vehicle Operation Management System gives more precise location and mobility status for vehicle management than other systems. The precise status of each individual vehicle is always available at the control center. Using the map to grasp the status of a vehicle precisely, is also easier to visualize. We would like to utilize the experience of using a map we gained while developing this system in future systems. For example, we want to display and managing the vehicle status and destination graphically.

This system is best suited for managing scheduled vehicles. We are also developing another system which dispatches and manages the scheduled not vehicles such as taxis by utilizing the technology of this system.

Finally, we would like to thank Asahi Security Systems for their cooperation in the development of this system.

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