Automatic Dispatching System with GPS

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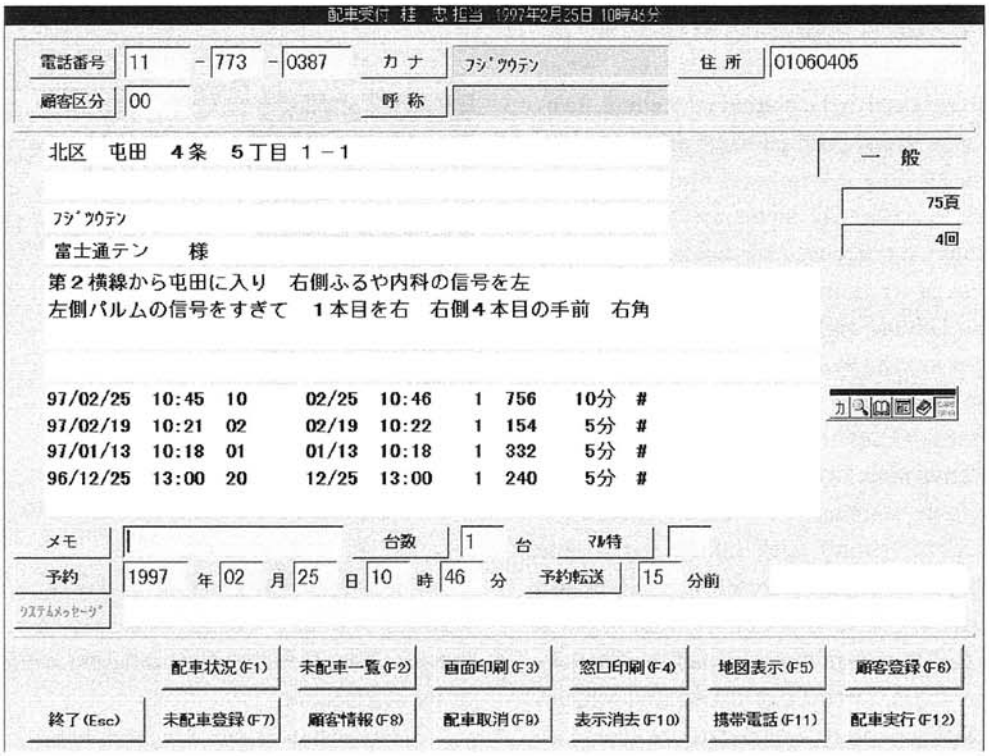


Taxi companies use automatic vehicle monitoring (AVM) systems to obtain information about the location of their taxis. Dispatching the closest taxi to a customer helps improve customer service, cut costs, and reduce driving time.

At present, the global positioning system (GPS) is a popular means of locating mobile objects and is extensively used in car navigation. We developed a GPS-AVM system for taxi companies as a commercial version of the GPS system. This system is currently in operation (Fujitsu TEN Technical Report No. 24). We have developed a new system, which integrates a customer management system relying on a residential map database system and the GPS-AVM system to allow vehicles to be quickly dispatched to customers.

This paper outlines the developed automatic dispatching system and describes its features.

1. Introduction

The dispatching of the closest taxi to a customer helps improve customer service, cut costs, and reduce driving time. Therefore, radio dispatching for taxi service relies on AVM systems installed to collect and manage information regarding the constantly changing status (mainly the position and occupied/unoccupied) of individual taxis.

The keys to more efficient taxi dispatching are: accurate taxi location information; reliable taxi dispatching information to drivers, and short travel time to a customer for a dispatched taxi.

Conventional vehicle dispatching systems are designed to accurately reflect the locations of taxis. When actually dispatching a taxi in the traditional method, dedicated operators give verbal instructions to drivers.

The new dispatching system developed uses data-dedicated waves to accurately report the location of a vehicle. In addition, a residence map database is used to report the address of a customer in degrees latitude and longitude. This latitude and longitude information is combined with location information of vehicles to identify the most suitable vehicle to be dispatched to the customer. This automates the work currently performed by dedicated operators with conventional systems.

In addition to the combination of customer management and GPS-AVM systems, each vehicle is equipped with the capability of displaying dispatch instructions on a screen. Also, listening to voice synthesized messages is possible. This makes transmitting dispatch instructions through data transmission media and dispatching vehicles directly from telephone call reception terminals possible. Thus, the efficiency in which taxis are dispatched is greatly improved.

The configuration and features of the system are described below.

2. System outline

2.1 Outline

Figure 1 outlines automatic dispatching performed by this system. Table 1 lists the components.

The system always collects information about all vehicles and automatically dispatches a vehicle as soon as a customer calls for a taxi.

Once a customer calls for a taxi, the system searches the customer database to identify the customer's location. Then, the system references already collected vehicle information to select the closest vehicle and automatically transmits dispatch instruction data to this vehicle.

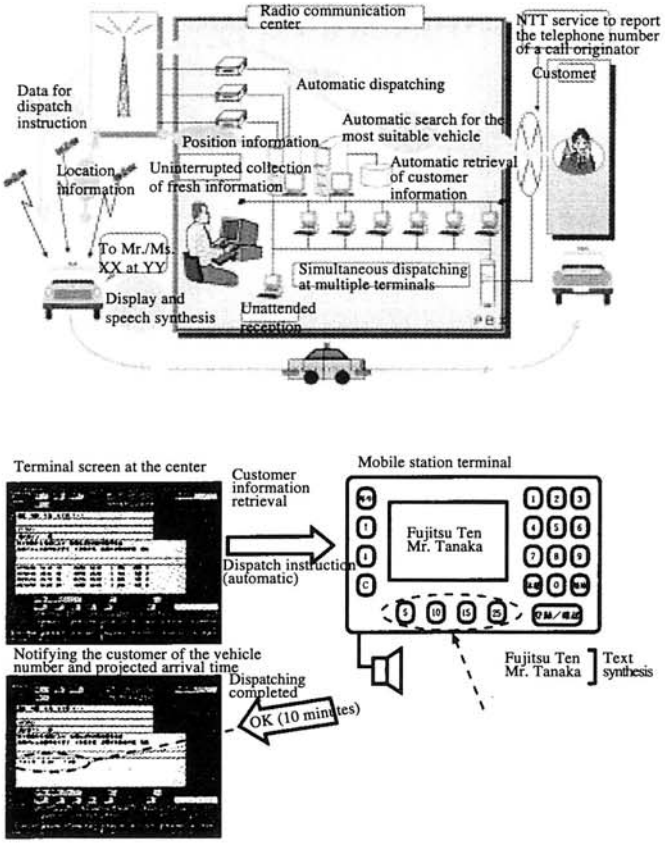


Figure 1. Outline of automatic dispatching system

The dispatch instruction is displayed as text on a terminal in a taxi. At the same time, a voice guidance message is synthesized (text synthesis) to inform the driver of the instructions.

An operation example is given below.

A clerk at a dispatching center can dispatch a taxi only by identifying a customer on the PC screen. The driver can check the customer information display and listen to the synthesized voice message as many times necessary. This helps prevent dispatching errors.

Wireless talking for dispatch instructions is no longer necessary.

2.2 Basic specification

Table 2 lists the basic specifications of this system.

The data collection method used in the system is a combination of the contention method and scheme. The contention method has dynamic control characterizing Fujitsu TEN's GPS-AVM systems. The scheme allows transmission conditions to be specified individually for particular regions (up to five regions). Therefore, collecting detailed vehicle information for critical areas is possible.

Table 1 System configuration (typical size of an initially installed system)

	Device	Number of units	Remarks
Mobile station equipment	Radio unit	2 per vehicle	One unit per vehicle also allows a system to be built.
	Microphone	1 per vehicle	
	Operating unit	1 per vehicle	
	GPS antenna	1 per vehicle	
	GPS receiver	1 per vehicle	
	Speech synthesizer	1 per vehicle	This unit may be omitted if voice guidance is unnecessary.
Dispatching center equipment	Radio communication terminal	12	Up to 16 units can be connected (in contrast to two units in a conventional system)
	Communication server	1	One server can work for both purposes if the number of customers is low.
	Customer management server	1	
	Telephone call reception terminal	12	Up to 25 terminals can be connected (excluding printers).
	Switching hub	1	
	Printer	2	

Operating conditions for each communication method can be freely set on the system setup screen. However, some condition settings could increase traffic. Thus, voice communication could be hindered. Therefore, set operating conditions while considering the traffic and communication modes that are to be used.

2.3 Automatic dispatching

Figure 2 shows the flow of dispatching for taxi service. The half-tone region in this figure represents the portion of the system that has been automated by the new technology.

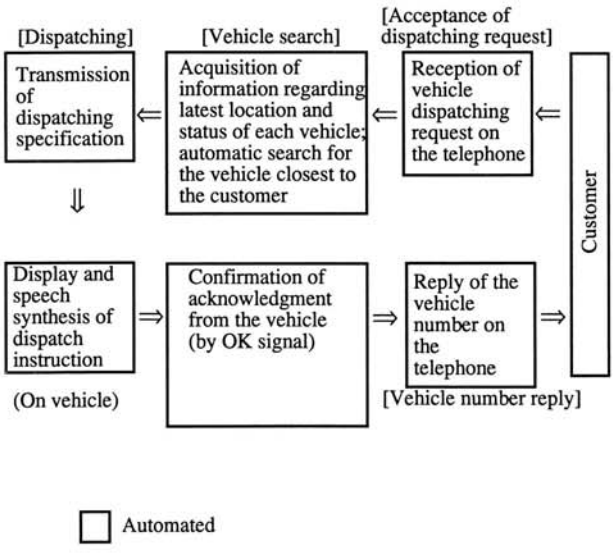


Figure 2. Flow of dispatching

Table 2 Basic specifications

Item	Specification
Communication mode	(1) 1-frequency simplex (2) 2-frequency simplex (3) 2-frequency half duplex (4) 2-frequency half duplex + data-dedicated waves
Base stations	Up to 16 (in contrast to 2 in the previous system)
Mobile stations	Up to 500 (in contrast to 140 in the previous system) (Assuming 3 waves for 2-frequency half duplex and 3 data-dedicated waves)
Positioning method	GPS
Data transmission speed	2400/1200Bps
Data error control	(1) Error detection and correction using BCH code + interleaving (2) Retransmission (contention) (3) Request for instruction retransmission (some dispatch instructions)
Data collection	(1) Contention method (transmission upon busy detection in 1-frequency simplex communication mode) - Combination of status change and traveled distance/ elapsed time - Traveled distance and elapsed time parameters specified individually for five designated regions - With functions for dynamically changing transmission condition parameters
Operation mode selection	(1) ID change (2) Customer management - Customer search and registration - Listing of dispatched taxis - Listing of undispatched taxis - Hard copy of screens - Map display (customer location in the center) (3) Map display - Vehicle status listing - Maintenance mode (speech locking/unlocking, vehicle tracing, among others) (4) Document management - Daily report selection - Monthly report selection - Yearly report selection - Occasional document selection - Master document selection (5) System management - Destination registration - Wait registration - Registration of vehicles confirmed as unoccupied - Transmission condition setup in contention mode (for five regions) - Override registration - System environment setup - Master management - Document management
Types of vehicle statuses	Vehicle, waiting, occupied, dispatched, premium, called, emergency, rest, hired, reserved for dispatching, closed

3. Configuration of a mobile station

3.1 Equipment layout

The mobile station equipment consists of a GPS antenna, a GPS receiver, an operating unit, a radio, a speech synthesizer, and an active speaker. Figure 3 shows the configuration of a mobile station (two-way radio units controlled).

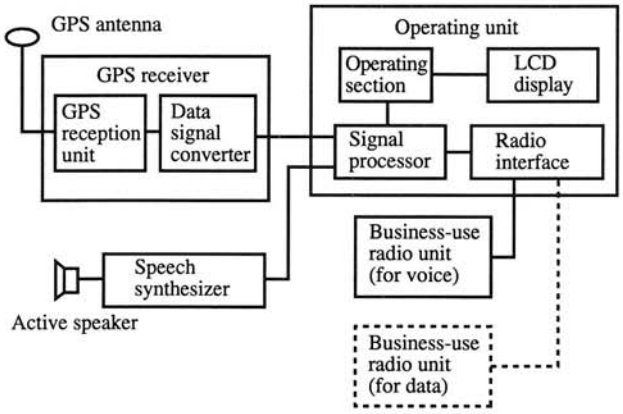


Figure 3. Blockdiagram of mobil station

3.1.1 GPS antenna and receiver

Figure 4 shows the exterior of the GPS antenna and receiver (RCV-025A).

Figure 4. GSP receiver and antenna

The GPS receiver consists of a GPS reception unit and data signal converter. In a taxi AVM system, the dispatching center collects location information from the radios on the mobile stations and uses the information to dispatch the most suitable taxi. For this reason, the system uses the positioning method based on information from the GPS satellite. This receiver is standard equipment, which does not contain a vibratory gyro, geomagnetic, or other dead-reckoning sensors. Requirements for more accurate positioning can be satisfied by designing a system to contain a signal processor or VICS receiver equipped with dead-reckoning sensors between the GPS receiver and the operating unit (SPU-038A).

3.1.2 Operating unit

Figure 5 shows the exterior of the operating unit (SPU-038A).

Figure 5. Operation unit

The components of the operating unit are as follows: an LCD and LED display; the ↑ and ↓ keys to change the mode of the LCD display; a ten key number pad; the Register/Confirm key to make various settings and read information about unoccupied taxis; the 5, 10, 15, 25, and C keys to enter responses to dispatch instructions; the playback key to playback dispatch instructions through the speech synthesizers; and a buzzer. This buzzer is triggered when a key is pressed or an alarm condition occurs. The LCD display (its specifications are listed in Table 3) shows dispatch instructions, notification messages, destinations, the identification of the region where a taxi waits, and reports the messages addressed to the dispatching center. The LED display shows the status of mobile stations.

Table 3 LCD specification

Parameter	Specification
Screen size (mm)	63 wide × 44 high
Displayed characters	8 columns × 4 lines
Dots	128 × 64
Dot size	0.40 × 0.56
Dot spacing	0.44 × 0.60
Color	Yellowish green
LCD type	STN semi-transparent

The operating unit also contains ROM for JIS level-1 and level-2 kanji characters to display special location names.

3.1.3 Speech synthesizer

Figure 6 shows the exterior of the speech synthesizer (SPU-052A) and active speaker (E50ESP).

Figure 6. Speech synthesizer and active speaker

The speech synthesizer consists of a speech synthesis IC, 16 megabytes of dictionary ROM, a section for serial communication with the operating unit, a low-pass filter that accepts D/A conversion outputs, and a status display LED. Outputs of the operating unit are text of kana and shift-JIS kanji characters. The output of text is fed to the speech synthesizer to produce speech. When we built the customer database, we tried to play back customer information in voice and checked whether the voice messages/ statements were easily understandable at the mobile station.

Setting the speech synthesizer to a male or female synthesized voice, one of ten playback speeds, and one of ten sound pitches is possible.

3.2 Method of giving dispatchinstructions

Dispatch instructions sent from a dispatching center to mobile stations include customer information, and directions 1 and 2. Before dispatch instructions are transmitted, they are modulated into MSK codes for analog data transmission. The operating unit (SPU-038A) on the receiving mobile station demodulates the MSK signal and keeps the result in internal memory until dispatching is completed.

After receiving a dispatch instruction, the operating unit (SPU-038A) sends a buzzer sound, the customer information, and directions 1 and 2 to the speech synthesizer in this order. The customer information is displayed on the LCD. The driver checks the voice message and LCD display. Then, the driver presses the [5], [10], [15], or [25] key (the number indicates the time in minutes the vehicle will take to reach the destination) or the [C] key for cancellation. Considering the safety of the vehicle, the LCD does not turn on unless the vehicle speed is 10 km/h or lower (setting may be changed).

A produced voice message can be played back any number of times by pressing the [1] and [Playback] keys for customer information, the [2] and [Playback] keys for directions 1, or [3] and [Playback] keys for directions 2. The customer information, or directions 1 or 2, which are displayed on the LCD, can be scrolled using the [↑] or [↓] key.

3.3 Registration of destinations

The driver of a vehicle dispatched and transporting a passenger can register the passenger's destination with the dispatching center. The vehicle will become eligible to be dispatched (reserved for dispatching) when it enters the vicinity of the destination. If drivers notify the dispatching center of more precise destinations, the center is able to dispatch more efficiently.

This dispatching system assigns 2-digit numbers to areas and allows users to enter this two-digit number followed by another two digits, which indicate a more detailed location, using the ten key number pad. An example is shown below.

Example: Assume that 11 is assigned to Gosho Street, Hyogo Prefecture of Kobe City. To specify 2-chome, 1-ban, Gosho Street, Hyogo Prefecture, enter 110102.

The area identifications are temporarily stored in internal nonvolatile memory (8 kilobytes of space) of the operating unit.

To remind the driver to enter a passenger's destination, a buzzer sounds when the driver does not specify the destination within a specified time.

4. Data collection and dispatch instruction transmission

Data is collected by the contention method, which allows mobile stations to freely send data. This enables base stations to always have the latest location information.

The transmission of dispatching instructions uses the interleave technique (data rearrangement), which was added to the BCH error correction method. This is proven by Fujitsu TEN to be useful in wireless channels. Therefore, the system's measures against burst errors are enhanced.

4.1 Data collection over data-dedicated waves

Information about vehicle locations can be obtained independent of speech and other data communication because data transmitted by the contention method is collected over data-dedicated waves.

The contention method used in this system begins transmission in one of the following conditions:

① The taxi meter changes its reading.
② The taxi travels a certain distance.
③ The time monitor expires.

Figure 7 shows conditions for data transmission and frequency usage.

If the amount of data that can be transmitted over the wireless channel is larger, more detailed information about status changes can be obtained.

Figure 8 shows the transmission capacity of the wireless channel.

Experimental findings on general voice-data shared waves suggest that the loss probability must be kept below 15% to protect the voice. (The loss probability is the percentage of originating calls that are lost because of data contention.)

The use of data-dedicated waves allows the limit of loss probabilities to increase to 25%. This means that a greater number of data items can be transmitted (more detailed conditions for traveled distances can be specified).

control conditions for contention transmission. Thus, the amount of data transmitted is kept within reasonable levels. This function is enhanced in this automatic dispatching system. The conditions for transmission can be specified for five particular regions on a priority basis. These

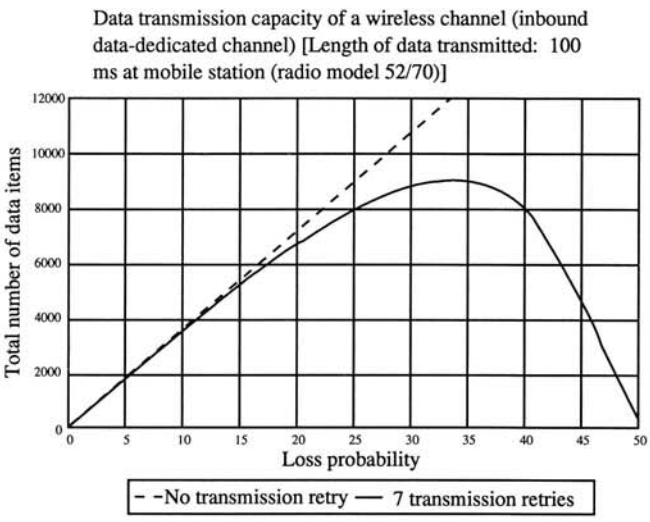


Figure 8. Data transmission capacity of wireless channel

4.2 Data collection parameter setup for individual regions

Fujitsu TEN has continued to develop and use its original function of allowing base stations to dynamically

conditions are separate from the conditions that apply to all regions.

Global and regional conditions are controlled individually to adjust the overall traffic. This allows the system

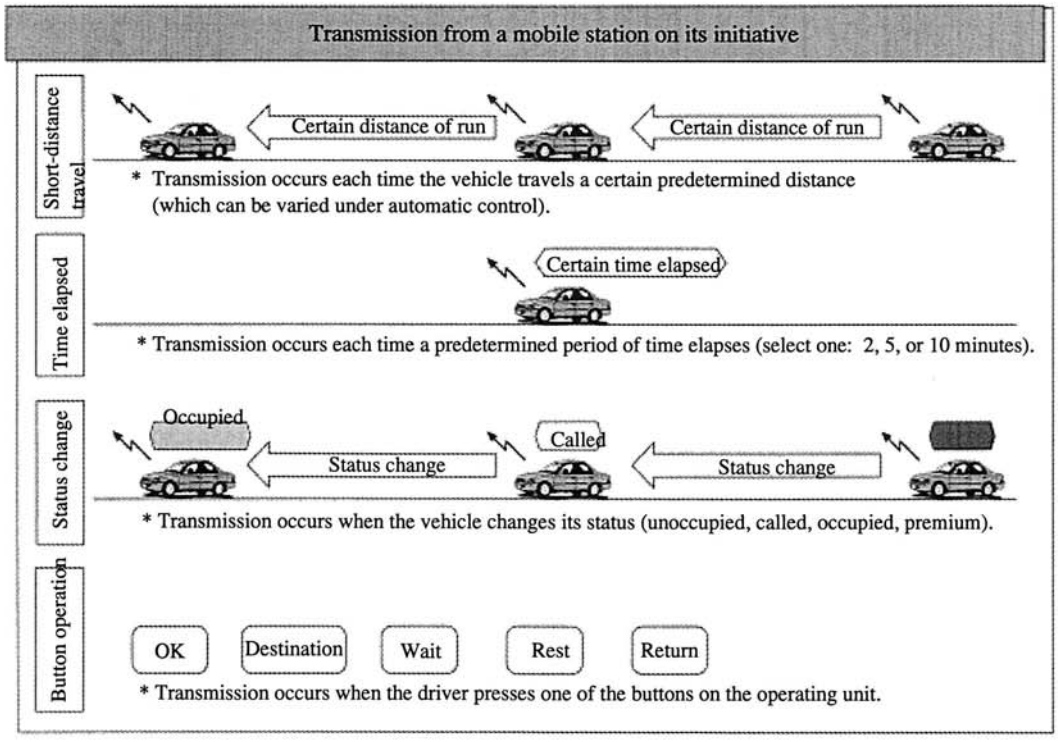


Figure 7. Condition for data transmniting and frequency usage

to collect more detailed location information for particular regions.

This method is useful for a system in which one wave must cover many mobile stations. High efficiency in collecting the necessary information through limited-capacity channels is the most important feature of such a system.

4.3 Transmission of dispatch instruction data

Before a taxi, which is given a dispatch instruction, can reach a designated customer, the driver must receive the customer's name and its pronunciation, address, directions, and a dispatch memo. If the quality of radio transmission is so poor that the sent data cannot be guaranteed, one dispatch instruction is divided into three segments:

① Customer's address, name, pronunciation, and dispatching memorandum
② Directions 1
③ Directions 2

After sending a dispatch instruction, the center judges whether the taxi and driver has received the instruction, as follows:

(1) Received by the taxi: The center receives a reply signal indicating that the taxi has received segment ① of the dispatched instruction.
(2) Driver acknowledgment: The center receives an OK signal sent from the taxi when the driver displays segment ① and hears a synthesized voice message. Then, the driver presses an OK key (5, 10, 15, or 25).

Only if condition (2) holds, the center considers that the dispatch instruction sent to a taxi is received. Otherwise, the center sends the dispatch instruction to another taxi (the next closest taxi). The same dispatch instruction is given to another selected taxi, according to a specific standard, when taxi and driver do not respond. Preventing a dispatch instruction from being given to two or more taxis is important.. If the center sends a dispatch instruction to a taxi, but does not complete the instruction, a dispatch cancel instruction is sent to the taxi. In this case, the number of cancel instruction transmission retries is three times higher than in ordinary transmission. If the center fails to receive a signal confirming the reception of the dispatch cancellation from a taxi, a message stating that no reply has been received is displayed on the screen. This message warns the dispatching operator that the dispatch instruction might have been issued to two or more taxis.

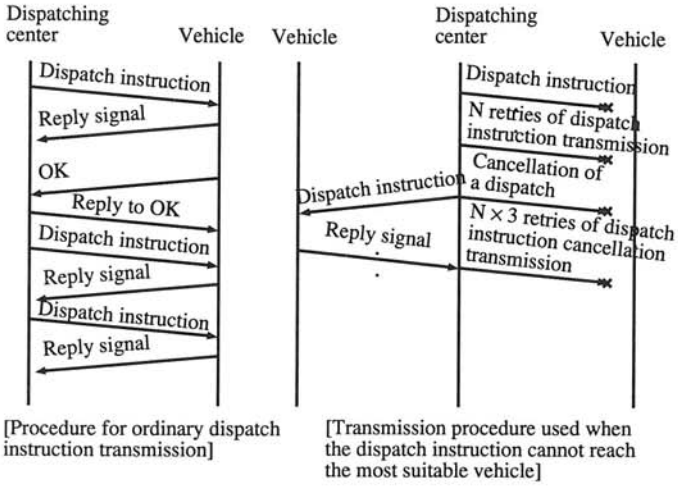


Figure 9. Time chart of dispatching data

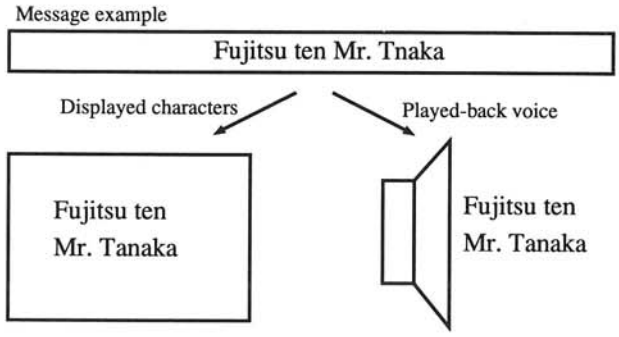


Figure 10. Example of dispatching and action on mobil unit

Figure 9 is a timing chart for dispatch instruction transmission.

Segments ② and ③ are transmitted, following segment ①. To prevent segments ② and ③ from failing to reach a taxi although segment ① is completely received, the center repeats sending segments ② and ③ two times more than segment ① was sent at intervals wider than segment ①. In addition, the taxi's equipment also monitors data reception. If the taxi fails to receive a dispatch instruction, the driver can send a request for retransmission. This method helps avoid unserviced dispatch instructions while preventing data transmission traffic from increasing abnormally.

4.4 Procedure for transmitting dispatch instructions

A problem involved in taxi dispatching in Japan is that some places are pronounced differently; an example is 三田 which is pronounced "sanda" or "mita." To deal with this problem, the dispatching center has a function that returns different pronunciations when such a place is input. Before sending a dispatch instruction to a mobile station,

the dispatching center checks the kanji character name of the place. If the place has more than one pronunciation, the dispatching center sends the appropriate pronunciation together with the dispatch instruction. Figure 10 gives an example of the processing performed by the dispatching center and mobile station when a pronunciation is given together with a dispatch instruction.

In addition, the dispatching center is equipped with a character display terminal and a voice synthesizer which are directly interconnected. This allows an operator attending the dispatching center to check and correct displayed characters and played back in a synthesized voice at mobile stations. Thus, maintainability is improved.

5. Center equipment

5.1 Components of center equipment

The equipment of the dispatching center consists of a communication server, a customer management server, management data, a network hub, telephone call receiving terminals, and printers. The communication server communicates with radio terminal processors and radio terminals. The customer management server controls customer data. The center equipment is laid out in a client/server configuration, which makes this equipment scalable. Also, all terminals share common functions. This allows the center equipment to easily satisfy the requirements for individual tasks. Up to 25 telephone, call-receiving terminals can be easily connected to the system.

The radio communication system is arranged to support simplex, two-frequency half duplex, front-end base station, and data-dedicated wave communication. Up to 16 radio terminals can be connected.

5.2 Principal Functions

The principal functions of the center equipment are for communication with vehicles, customer management, telephone call reception, and document printing.

The function for communication with vehicles includes data collection and dispatch instruction transmission capabilities, as discussed in Chapter 4. In addition, individual vehicles can be called from base stations. Also, drivers and operators can talk between base stations and individual vehicles. Furthermore, information from mobile stations (such as vehicle numbers and registration for a rest, return, or notice) can be transmitted. Data from a mobile station is always supplemented with information about the location of a mobile station. This latest location information replaces the previous location information stored in the base station.

The customer management function is designed to allow information for about 200,000 customers to be retrieved within 0.5 second. For this purpose, a server dedicated to customer management data is provided. This server prevents customer search speed from dropping when traffic increases. Thus, speedy dispatching is possible.

The telephone call receiving function does more than just receive telephone calls. It can also display maps, and manage documents and the system. Thus, the system can easily adapt to customer's requests.

Documents which are output by the document printing function are classified into daily reports, monthly reports, yearly reports, occasional documents, and master documents. It is possible to specify whether to use automatic printing and the number of copies to be printed for daily, monthly, and yearly reports.

5.3 Various screen displays

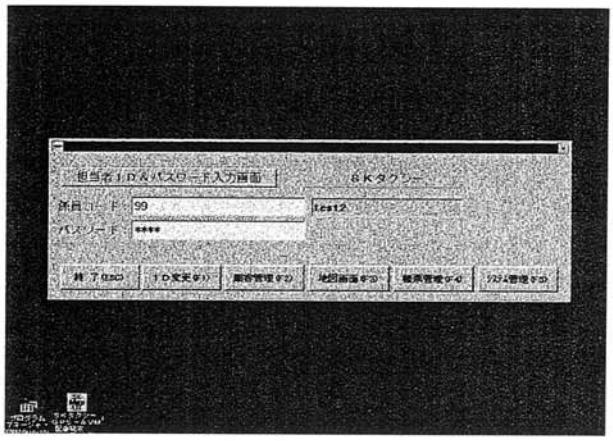
Figure 11 shows a number of screens displayed on the telephone call receiving terminal:

① Operator ID input screen
② Customer management screen
③ Map screen
④ Document management screen
⑤ System management screen

The document management screen is accessible only to users who are granted document access permission. To access the system management screen, users must have the correct password. This secures the system and users are distinguished as regular company staff, part-timers, general users, and system administrators.

One screen may have a number of subordinate screens, including the list of dispatched vehicles. Clicking the mouse or pressing the function keys changes the screens for easy maneuverability.

a) Operator ID input screen



b) Customer management screen

c) Map screen

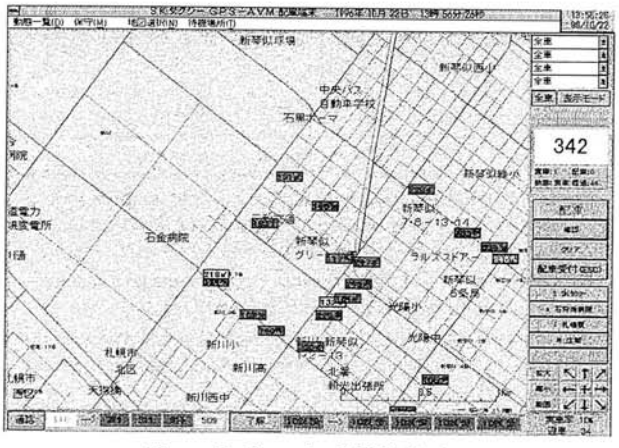


Figure 11. Example of CRT display

5.4 Destination registration

A function to register destinations is provided to allow a driver who is transporting a passenger to register the passenger's destination with the dispatching center. When the vehicle enters the vicinity of the destination, the vehicle is identified as eligible to be dispatched. This helps increase dispatching efficiency.

When a mobile station sends information for destination registration to the base station, the base station obtains the coordinates (latitude and longitude) of the registered destination and understands the difference from this destination and a selected place. To reply to the destination registration signal, the driver returns the coordinates of the destination and a radius of a circle centering this destination to the mobile station.

When the mobile station carried by the vehicle enters the inside of this circle, a signal is transmitted that indicates the driver will soon drop off the passenger. The contention-mode transmission condition for unoccupied vehicles begins to apply to the vehicle instead of the contention-mode transmission condition for occupied vehicles. (The distance traveled of a transmission interval of an occupied vehicle is twice as long as that of an unoccupied vehicle.)

Since mobile stations monitor whether their own taxis are going to be unoccupied, unnecessary data transmission to occupied taxis is eliminated. This helps minimize communication traffic.

Figure 12 shows an example of the setup screen to judge a destination registration.

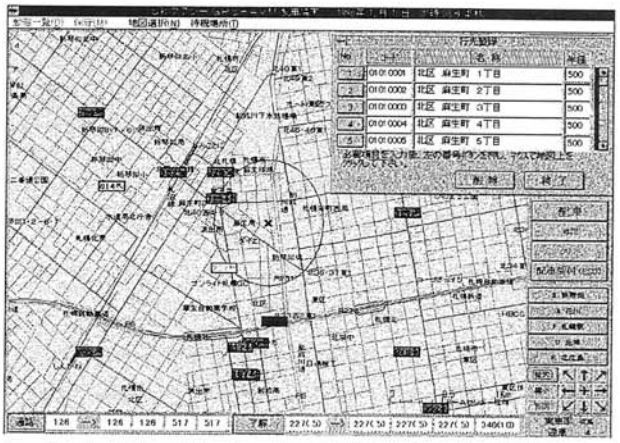


Figure 12. Judging screen for destination registration

5.5 Stand-by registration

A function for stand-by registration is provided to manage vehicles that stay waiting at any location.

Vehicles in wait at stand-by spots longer than others are given higher priority for automatic dispatch assignment.

The base station identifies the coordinates (latitudes and longitudes) of stand-by spots corresponding to stand-by numbers and calculates the distances between stand-by spots and selected locations.

When a mobile station sends a request for stand-by registration, the base station checks whether the location is within the range of one of the waiting drivers in a stand-by spot. If so, the base station begins stand-by registration processing and sends a stand-by acknowledgment signal to the mobile station. If not, the base station sends a stand-by non-acknowledgment signal to the mobile station, notifying the driver that stand-by registration failed.

One of the conditions for releasing a mobile station from stand-by registration is that the mobile station leaves the stand-by spot. Considering possible errors involved in GPS observations, the range of a stand-by spot for this condition is four times wider than the range in which vehicles can wait.

Figure 13 shows the setup screen to judge a stand-by registration.

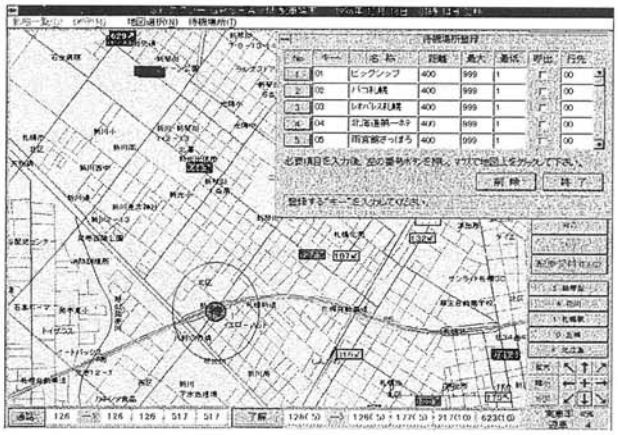


Figure 13. Judging screen for stand-by registration

5.6 Document printing

Documents are created from data based on dispatch instructions and data supplied by mobile stations. In addition, there are master documents for customer management.

Documents are classified into daily reports, monthly reports, yearly reports, occasional documents, and master documents. It is possible to specify whether to use automatic printing and the number of copies to be printed for daily, monthly, and yearly reports.

Daily, monthly, and yearly reports can be printed for the present day (month or year) and optionally the previous day (month or year).

- There are 12 daily and 13 monthly reports, including lists of vehicles dispatched for each company and lists of dispatched vehicles identified by vehicle numbers.
- There are six yearly reports, including a list of vehicles dispatched for each company, with percentages over the previous year.
- There are 13 occasional documents, including a detailed address sheet.
- There are seven master documents, including a direct mailing list.

The system can print the above 51 documents, which are useful to understand the operation of the system, analyze situations for dispatching, and achieve many other purposes.

5.7 Map display

The location and status of each vehicle can be indicated on maps by using markers for the mobile stations.

Maps may be road maps or residential area maps. These two types of maps are switched automatically when the scale is changed. The threshold scales for the switching of displayed map types can be freely specified by users. This helps in making the system easy to handle.

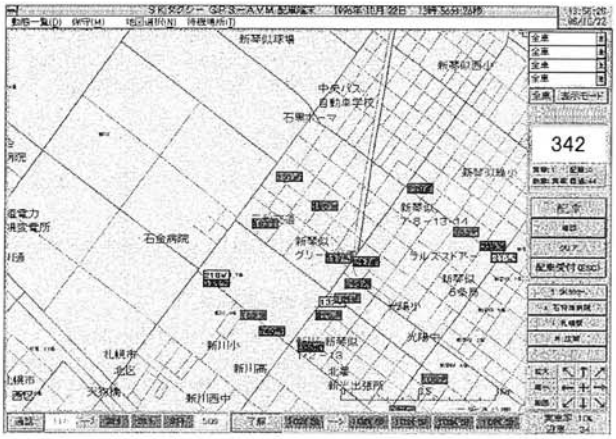
The map screens are designed to display information about a customer on the map screen when a customer is designated on the customer management screen and the screen is switched to the map display. This enables the center operator to flexibly respond to inquiries from vehicle drivers and customers.

Table 4 lists the principal operations on maps. Figure 14 gives examples of an initially opened map display and a map display opened from a customer management screen.

Table 4 Operations on maps

Operations
1) Location information display, identification number of the vehicle in communication, and display of the identification number of the vehicle that has accepted the dispatch request
2) Display mode selection: By company, by frequency, and taxi eligible to be dispatched for all companies
3) Detailed taxi number and identification information display and simplified taxi number and other information display
4) Dispatching operation on map display
5) Checking for individual items
6) Selection of one map from the designated regions and display of a stand-by spot and its surrounding landmarks
7) Scaling up/down
8) Map scrolling
9) Display of one map of the designated regions and its surroundings
10) Display of a range specified on a map
11) List of vehicle statuses
12) Speech locking/unlocking
13) Vehicle tracing
14) Customer information display

a) Map display



b) Map screen opened from the customer management screen

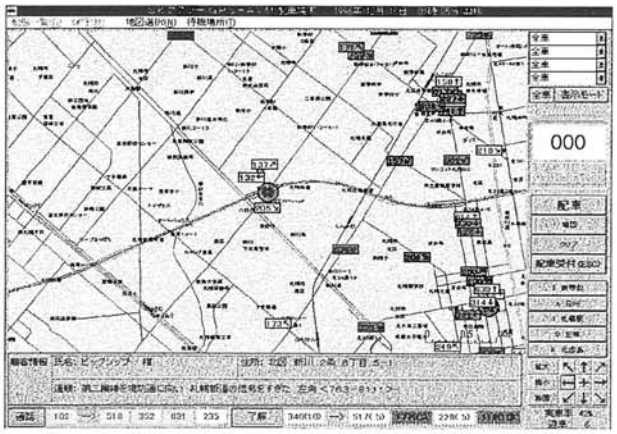


Figure 14. Map display screen and map display window on customer management softfare

Map displays can be scaled up/down and scrolled in units that can be freely specified by the user.

The vehicle marker identifies a vehicle and its status. The color of the outline of the marker indicates the status. The taxi number and arrow indicate the direction in which the taxi is traveling. (One of eight directions is selected.)

The taxi marker colors representing the statuses and taxi vehicle numbers can be freely specified on the system management screen. There are 10 identifiable statuses: unoccupied, stand-by, occupied, premium, dispatched, emergency, rest, closed, hired, and reserved for dispatching.

6. Afterword

This system is an integration of a GPS-AVM for vehicle location management and customer management facilities. It can dispatch the closest taxi to a requesting customer. Dispatching operators who installed this system were able to improve their dispatching performance by at least 10% (over the same month in the previous year). Also, they were able to employ part-timers rather than specialists for dispatching operation. Thus, the system was able to reduce costs as well.

Dispatching request reception has not been automated yet in this system. We plan to develop further automated, labor-saving systems. Such systems will make use of NTT's originator telephone number reporting service, have voice response facilities, and receive dispatching requests through the Internet. In addition, we will develop vehicle equipment containing a navigation unit to provide route guidance and traffic information.

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