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Okazaki et al.

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(54) **TRANSPORTATION SYSTEM, SERVICE MANAGEMENT DEVICE, AND SERVICE MANAGEMENT METHOD**

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(Continued)

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See application file for complete search history.

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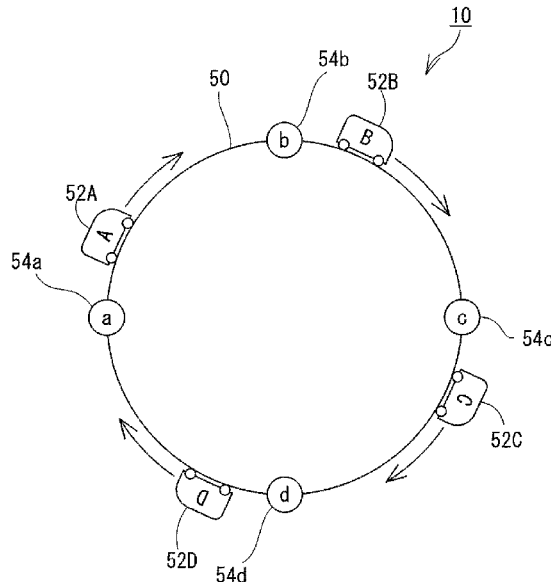
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(57) **ABSTRACT**

A transportation system includes a traveling route, vehicles, and a service management device. The service management device includes a timetable generator that generates a timetable for each of the vehicles, and a communication device that is configured to receive passenger information at least from the vehicles or stops. The timetable generator calculates a boarding and alighting time estimate of the vehicle at the stop based on at least the passenger information such that a higher average speed of the vehicle between the stops and a longer dwell time of the vehicle at the stop are set for a longer boarding and alighting time estimate.

**11 Claims, 12 Drawing Sheets**



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**G07C 5/00** (2006.01)
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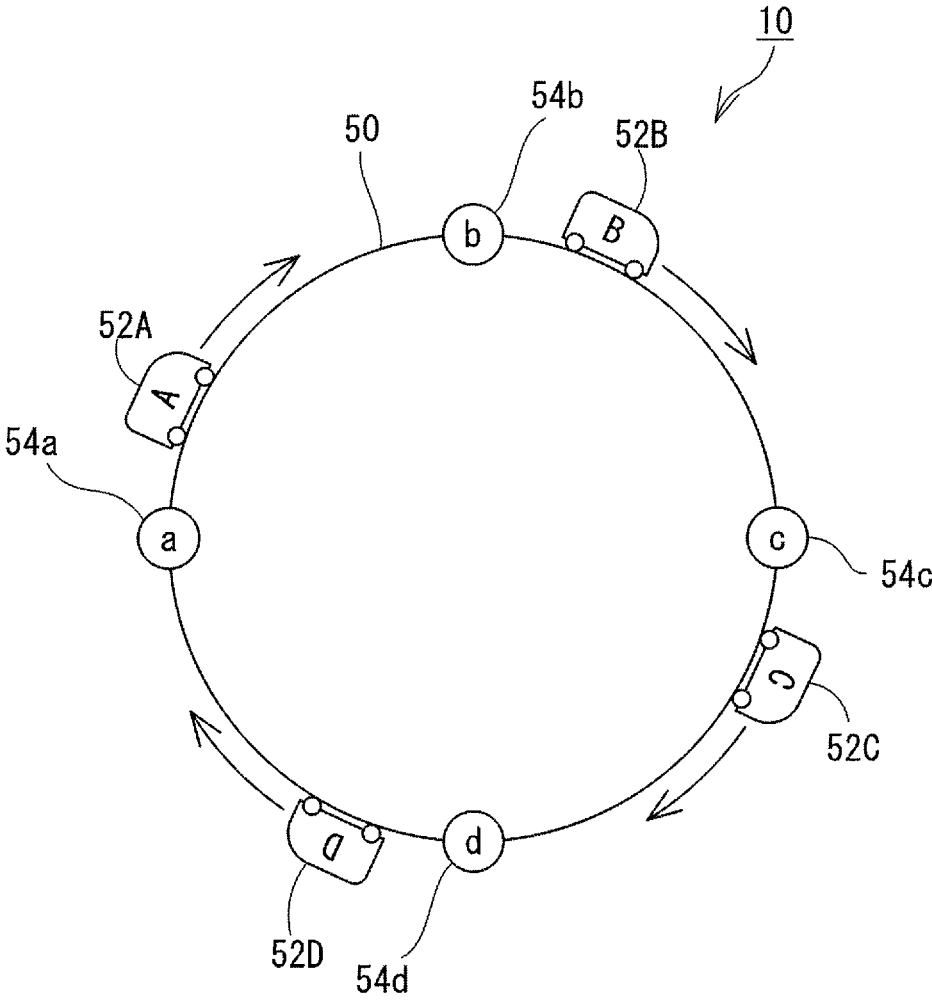


FIG. 1

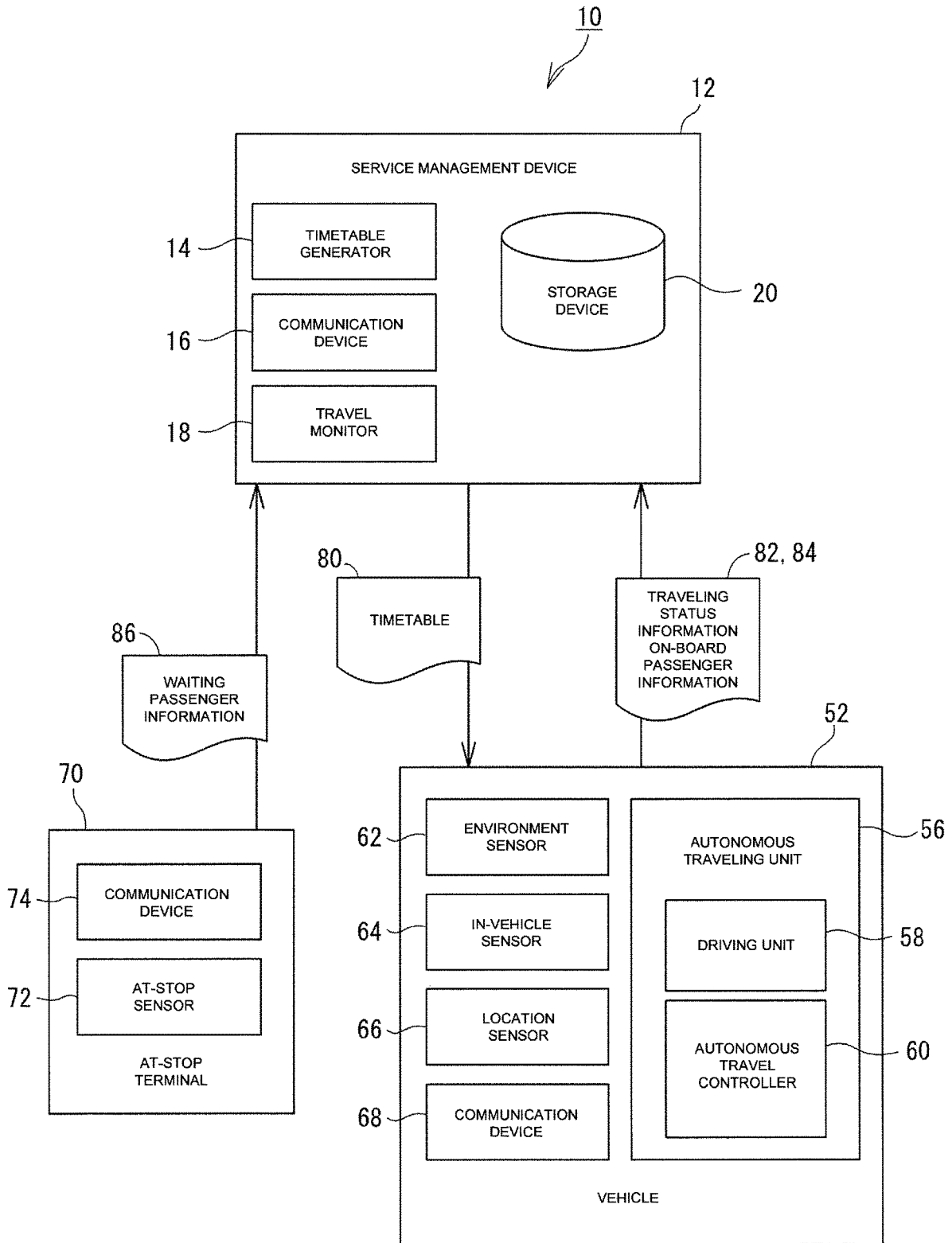


FIG. 2

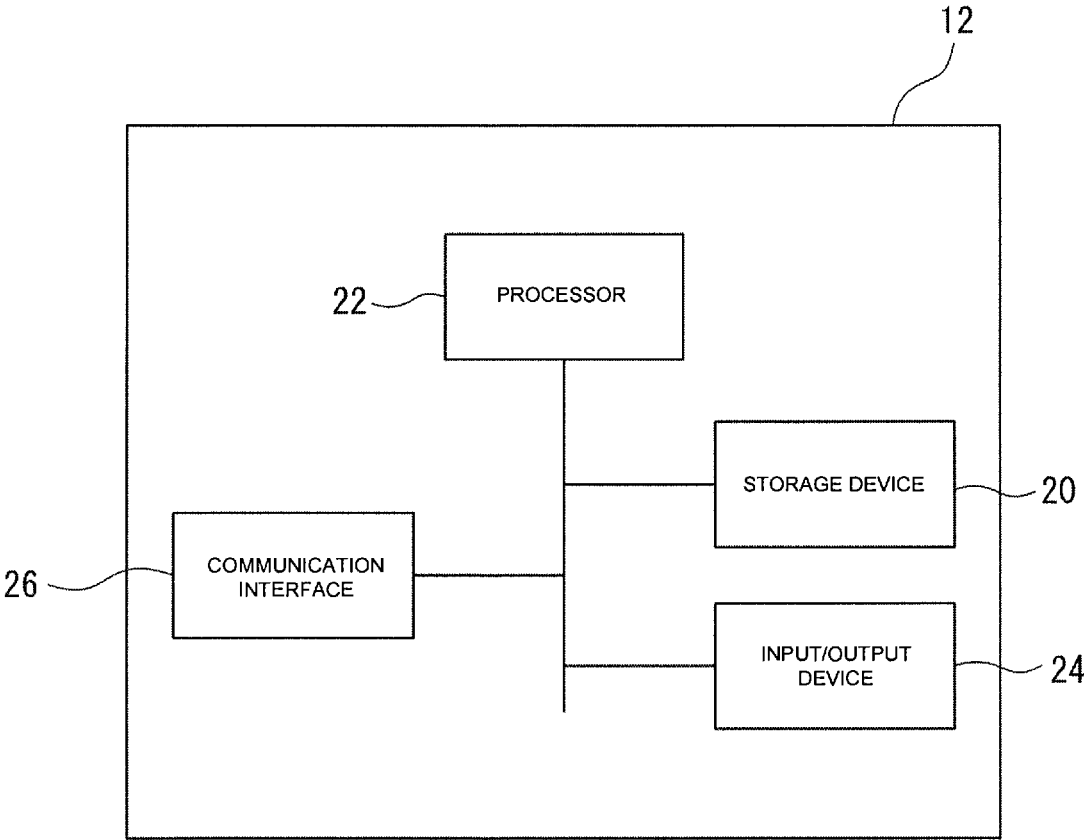


FIG. 3

80

	a		b		c		d	
	ARR.	DEP.	ARR.	DEP.	ARR.	DEP.	ARR.	DEP.
A	7:14	① 7:15	④ 7:19	① 7:20	④ 7:24	7:25	7:29	7:30
B	7:09	7:10	7:14	7:15	7:19	7:20	7:24	7:25
C	7:04	7:05	7:09	7:10	7:14	7:15	7:19	7:20
D	6:59	7:00	7:04	7:05	7:09	7:10	7:14	7:15

80D

FIG. 4

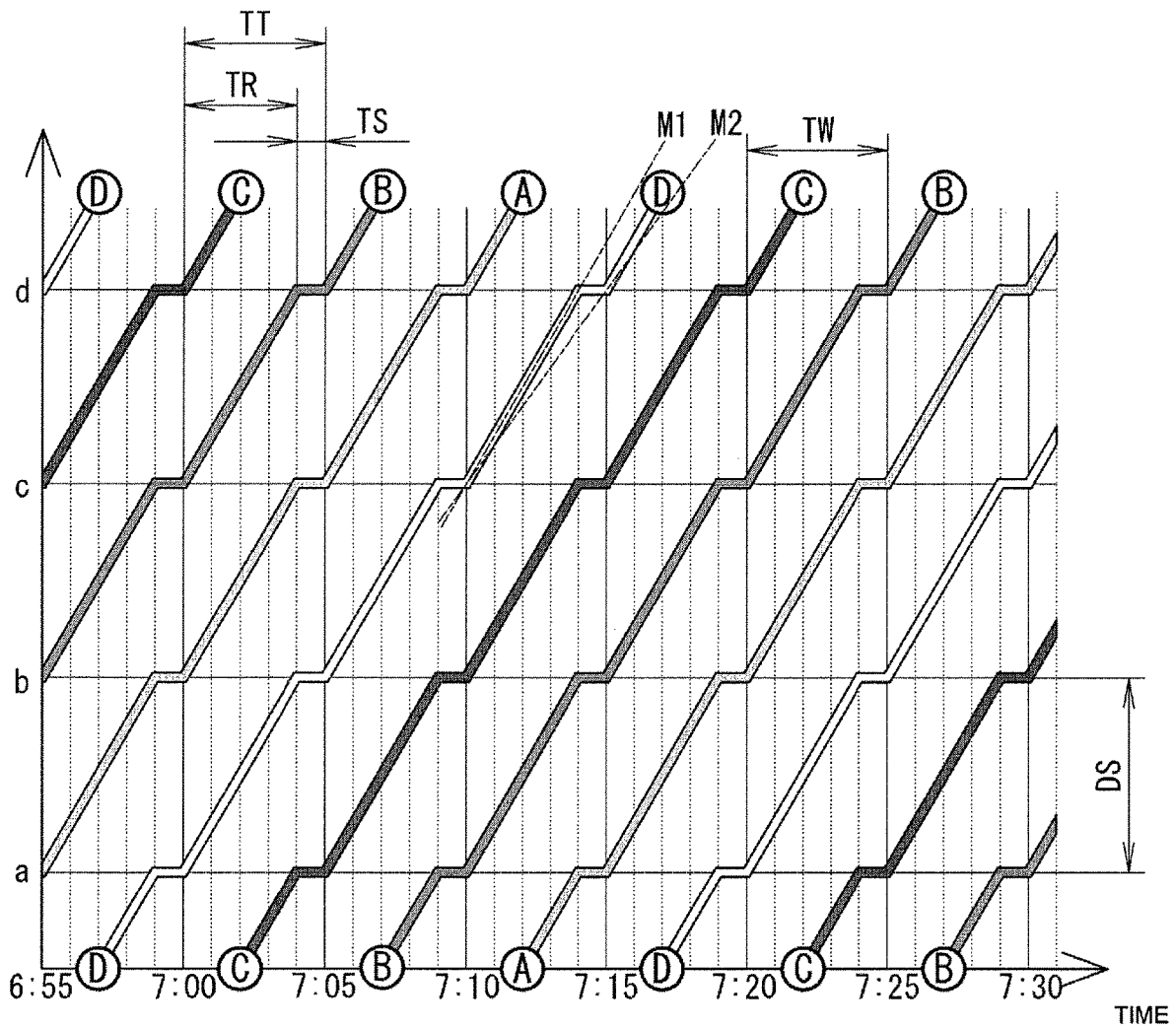


FIG. 5

80

	a		b		c		d	
	ARR.	DEP.	ARR.	DEP.	ARR.	DEP.	ARR.	DEP.
A	7:14	7:15	7:19	7:20	3 7:23	2 7:25	4 7:29	7:30
B	7:09	7:10	7:14	7:15	3 7:18	2 7:20	4 7:24	7:25
C	7:04	7:05	7:09	7:10	3 7:13	2 7:15	4 7:19	7:20
D	6:59	7:00	7:04	7:05	3 7:08	2 7:10	4 7:14	7:15

FIG. 6



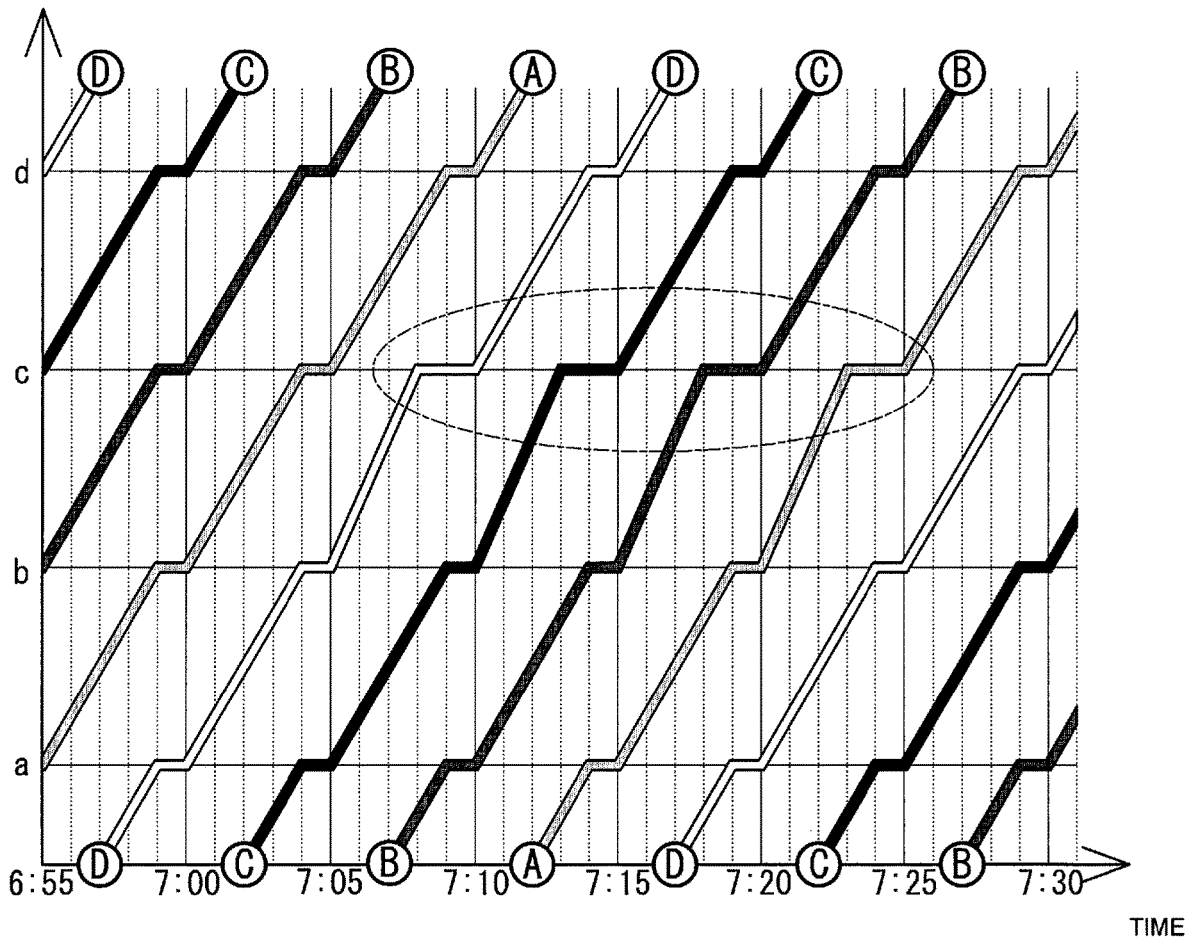
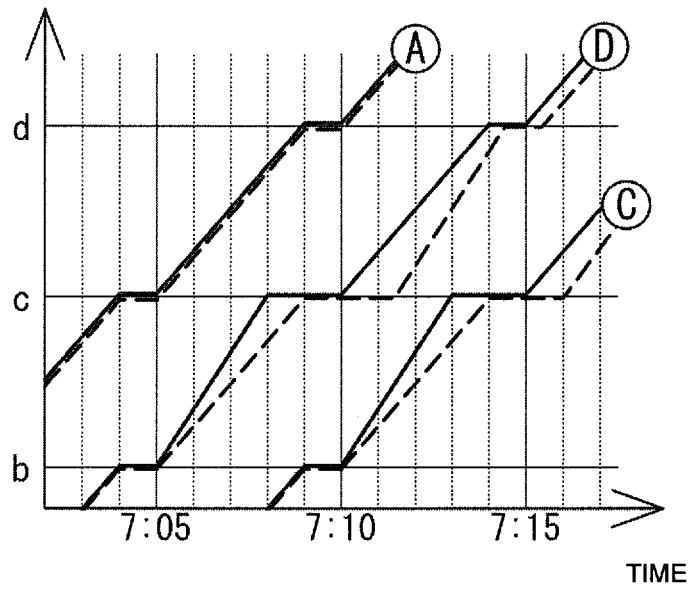


FIG. 7

80

	a		b		c			d			
	ARR.	DEP.	ARR.	DEP.	ARR.	DEP.	ARR.	DEP.			
A	7:14	7:15	7:19	7:20	4	7:24	2	7:26	3	7:29	7:30
B	7:09	7:10	7:14	7:15	4	7:19	2	7:21	3	7:24	7:25
C	7:04	7:05	7:09	7:10	4	7:14	2	7:16	3	7:19	7:20
D	6:59	7:00	7:04	7:05	4	7:09	2	7:11	3	7:14	7:15

FIG. 8



NUMBER OF WAITING PASSENGERS AT STOP C

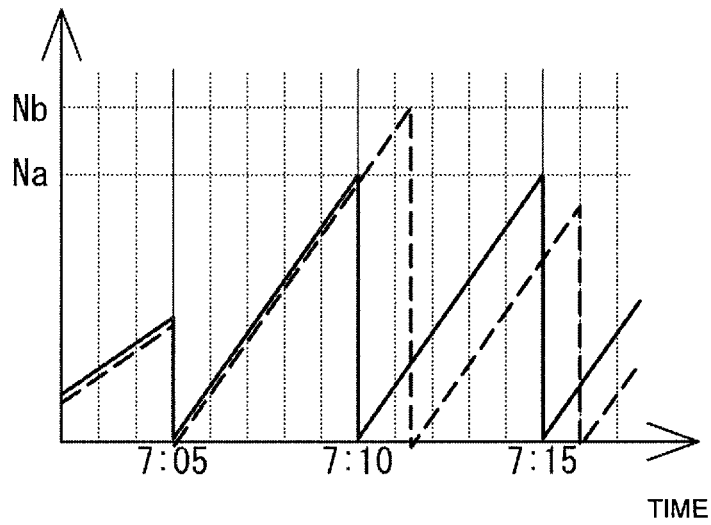


FIG. 9

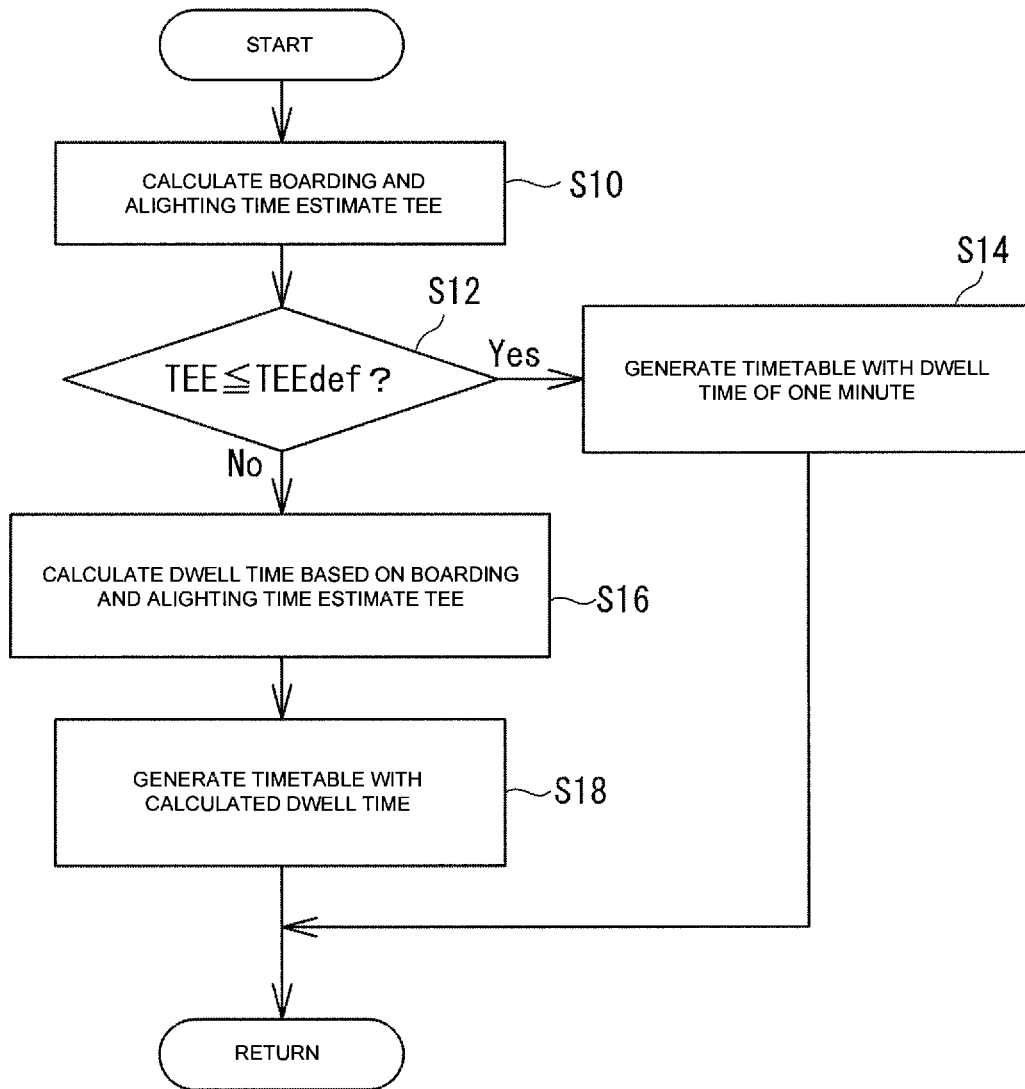


FIG. 10

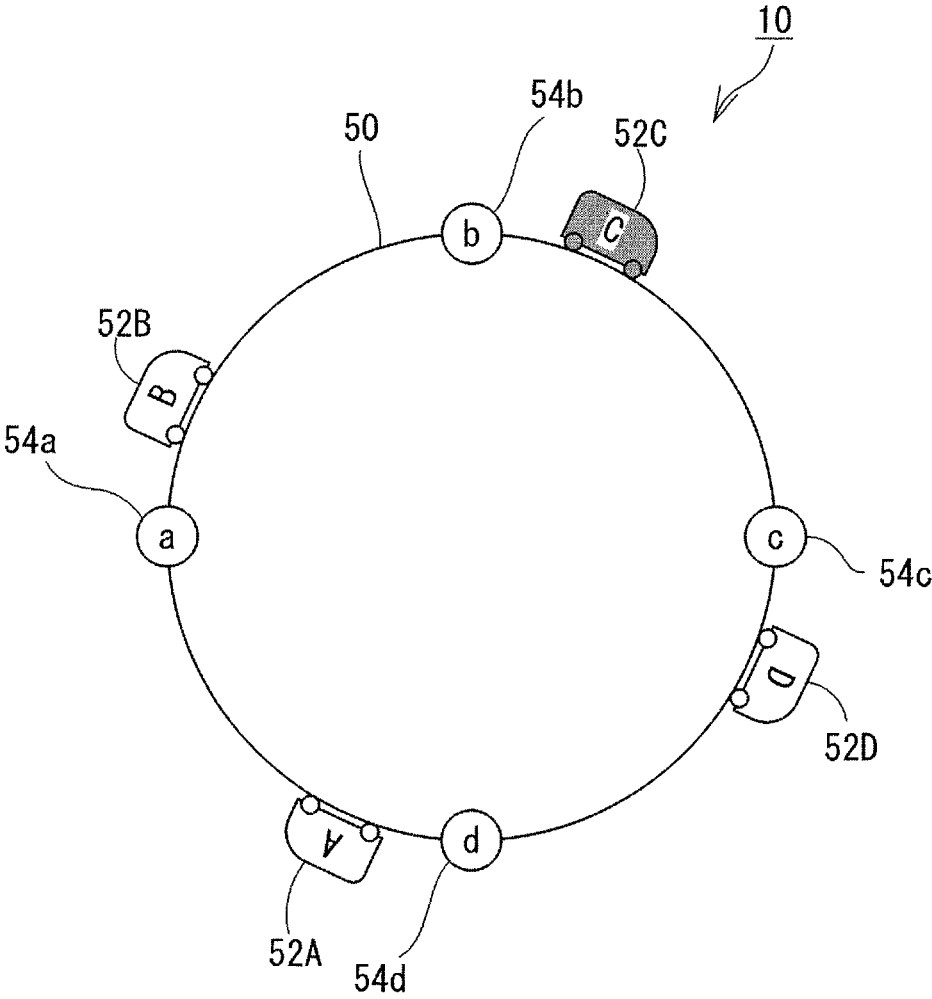


FIG. 11

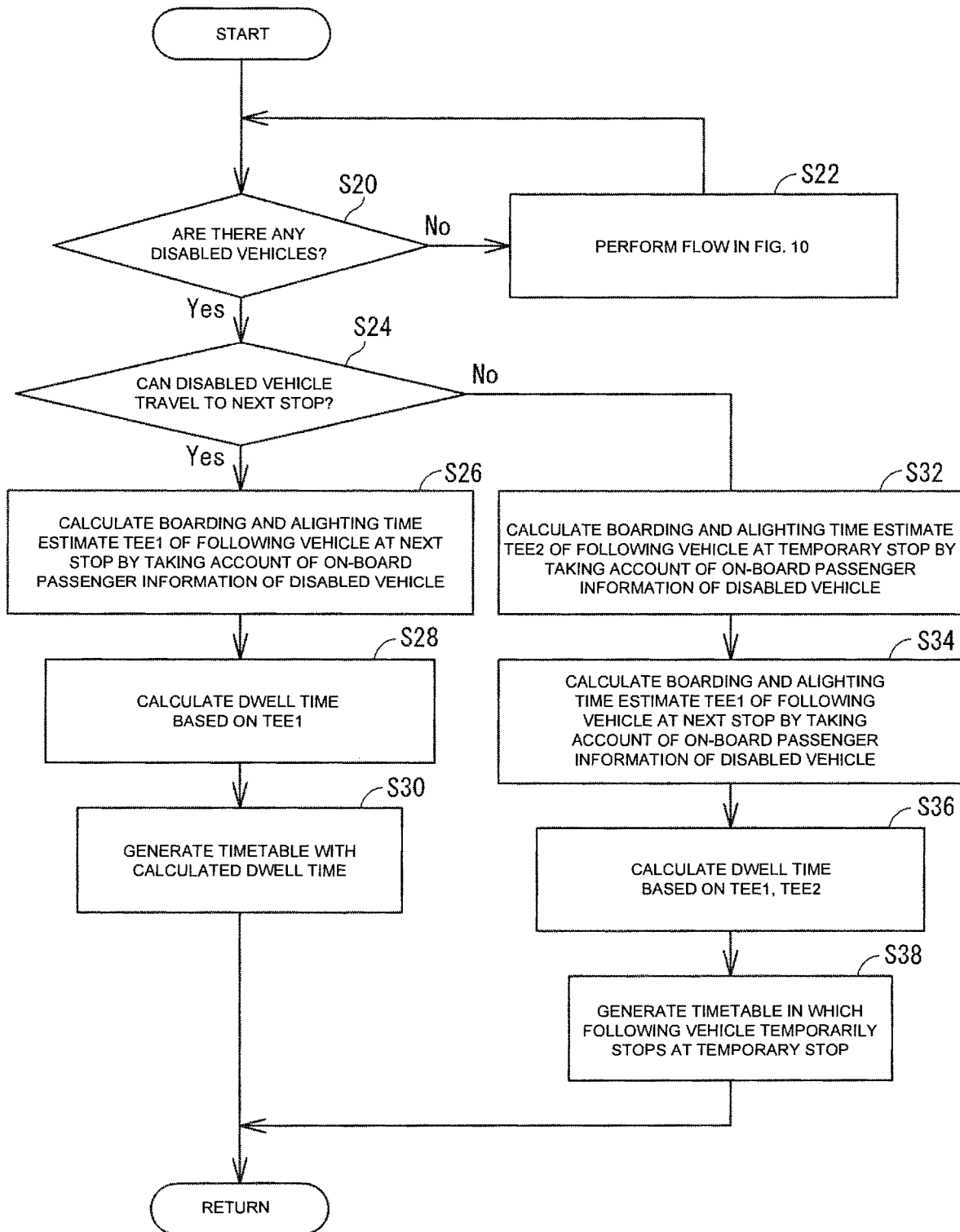


FIG. 12

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## TRANSPORTATION SYSTEM, SERVICE MANAGEMENT DEVICE, AND SERVICE MANAGEMENT METHOD

### CROSS REFERENCE TO RELATED APPLICATION

This application claims priority to Japanese Patent Application No. 2020-066596 filed on Apr. 2, 2020, which is incorporated herein by reference in its entirety including the specification, claims, drawings, and abstract.

### TECHNICAL FIELD

The present disclosure relates to a transportation system which includes multiple vehicles that autonomously travel along predetermined traveling routes, a service management device which controls the multiple vehicles, and a service management method.

### BACKGROUND

Service management devices which control travel of multiple vehicles are already known. For example, JP 2005-222144 A discloses a service information center for managing multiple buses in which each of the busses sends traveling status information, such as the location and occupancy rate of the bus, to the service information center. The service information center determines whether or not to change a service schedule of the busses based on the received traveling status information in order to average the degree of congestion among the busses and optimize intervals between the busses. Possible changes are a skip of a usual bus stop and a change in speed. In JP 2005-222144 A, for example, when one of the busses is crowded or the following bus is too close, the congestion is averaged and the service intervals are optimized by controlling the bus to skip a prescheduled bus stop, and having the following bus pick up the passengers at the skipped bus stop.

Note that the congestion is likely to be high when buses are delayed from a scheduled timetable. Specifically, when a bus is delayed from a scheduled timetable and the interval from the previous bus becomes longer, the delayed bus is likely to become crowded as passengers become concentrated on that bus. As such, in this type of transportation system, it is desirable to be able to control a delay which would otherwise increase congestion.

However, in the techniques disclosed in JP 2005-222144 A, no steps to reduce the congestion or optimize the service intervals are taken until increased congestion is noted. As such, with the techniques disclosed in JP 2005-222144 A, because congestion can be excessively high, albeit temporarily, passengers are more likely to judge the transportation system to be inconvenient.

The present specification discloses a transportation system, a service management device, and a service management method that can improve convenience.

### SUMMARY

A transportation system according to an embodiment of the present disclosure includes a traveling route along which multiple stops are set, a chain of vehicles that are configured to autonomously travel along the traveling route, and a service management device that is configured to manage traveling of the vehicles. The service management device includes a timetable generator that is configured to generate

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a timetable for each of the vehicles, and a communication device configured to send the timetable to the vehicles and receive passenger information about passengers of the transportation system at least from the vehicles or the stops. The timetable generator is configured to generate the timetable by calculating a boarding and alighting time estimate of each of the vehicles at each of the stops based on at least the passenger information such that a higher average speed of the vehicle between the stops and a longer dwell time of the vehicle at the stop are set for a longer boarding and alighting time estimate.

As the dwell time and the average speed are determined based on the boarding and alighting time estimate that has been calculated based on the passenger information, the boarding and alighting of passengers are likely to be completed before the scheduled departure time, reducing vehicle delays and, thus, congestion of passengers in the vehicles. As a result, the convenience of the transportation system can be improved.

The timetable generator may generate the timetable such that when the boarding and alighting time estimate is equal to or less than a preset tolerable boarding and alighting time, the dwell time and the average speed are set to preset values regardless of the calculated boarding and alighting time estimate.

Such a configuration can prevent an excessive slowing of the average speed of the vehicles between the stops.

Each of the vehicles may include an in-vehicle sensor that is configured to obtain on-board passenger information including at least the number of boarded passengers and an attribute about the boarded passengers, and to send the on-board passenger information to the service management device. The passenger information may include the on-board passenger information.

As the passenger information includes information actually obtained inside the vehicle, the accuracy of the boarding and alighting time estimate can be improved.

The timetable generator may calculate overall alighting time of each of the vehicles based on the on-board passenger information and further calculate the alighting time estimate of the vehicle at each of the stops by dividing the calculated overall alighting time of the vehicle by preset ratios for each of the stops.

Such a configuration can improve the accuracy of the boarding and alighting time estimate.

Each of the stops may include an at-stop sensor that is configured to obtain waiting passenger information that includes at least the number of waiting passengers and an attribute about the waiting passengers, and to send the waiting passenger information to the service management device. The passenger information may include the waiting passenger information.

As the passenger information includes the information actually obtained at the stops, the accuracy of the boarding and alighting time estimate can be improved.

Each stop may periodically send the waiting passenger information to the service management device. The timetable generator may calculate increase per unit time of boarding time of the waiting passengers at the stop based on the waiting passenger information, and further calculate a boarding time estimate for each for the vehicles at the stop based on the calculated increase per unit time.

Such a configuration can also improve the accuracy of the boarding and alighting time estimate.

The attribute may include at least one of a presence or absence of a passenger using a wheelchair, a white cane, orthoses, or a stroller, and age groups.

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Such a configuration can further improve the accuracy of the boarding and alighting time estimate.

Each of the vehicles may be configured to send traveling status information that indicate a traveling status of the vehicle to the service management device. When the timetable generator determines, based on the traveling status information, that there is an disabled vehicle that cannot continue service, the timetable generator may calculate the boarding and alighting time estimate of the vehicle following the disabled vehicle at a next scheduled stop of the disabled vehicle based on the on-board passenger information of the following vehicle, waiting passenger information at the next scheduled stop, and the on-board passenger information of the disabled vehicle.

Such a configuration can enable an efficient response to the increase of the boarding and alighting time due to a disabled vehicle, and can thus effectively reduce the delay or other problems of the vehicles.

When the disabled vehicle is capable of traveling to the next scheduled stop, the timetable generator may generate the timetable by assuming that the passengers on the disabled vehicle are to transfer to the following vehicle at the next scheduled stop.

Such a configuration can enable the passengers of the disabled vehicle to efficiently transfer to the following vehicle. As such, even when a vehicle becomes disabled, passengers can be reliably transported to their destinations.

When the disabled vehicle is not capable of traveling to the next scheduled stop, the timetable generator may generate the timetable such that, by assuming that the passengers on the disabled vehicle are to transfer to the following vehicle at a temporary stop where the disabled vehicle stopped, the following vehicle is temporarily stopped at the temporary stop.

Such a configuration can enable the passengers of the disabled vehicle to efficiently transfer to the following vehicle. As such, passengers can be reliably transported to their destinations even when a vehicle becomes disabled.

A service management device according to an embodiment of the present disclosure includes a timetable generator that is configured to generate a timetable for each of the vehicles that are configured to autonomously travel along a preset traveling route. The service management device further includes a communication device that is configured to send the timetable to the vehicles and receive passenger information about passengers of the vehicles from at least the vehicles or the stops along the traveling route. The timetable generator is configured to generate the timetable by calculating a boarding and alighting time estimate of each of the vehicles at each of the stops based on at least the passenger information such that a higher average speed of the vehicle between the stops and a correspondingly longer dwell time of the vehicle at the stop are set when a longer boarding and alighting time is estimated.

A service management method according to an embodiment of the present disclosure includes receiving, at least from vehicles that are configured to autonomously travel along a preset traveling route or stops along the traveling route, passenger information about passengers of the vehicles. The service management method also includes calculating a boarding and alighting time estimate of each of the vehicles at each of the stops based on at least the passenger information, and generating a timetable of each of the vehicles such that a higher average speed of the vehicle between the stops and a longer dwell time of the vehicle at the stop are set for a longer boarding and alighting time

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estimate. The service management method further includes sending the timetable to the vehicles.

The techniques according to disclosure of the present specification can improve convenience of a transportation system.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present disclosure will be described based on the following figures, wherein:

FIG. 1 is an image of a transportation system according to an embodiment of the present disclosure;

FIG. 2 is a block diagram of a transportation system;

FIG. 3 is a block diagram showing a physical configuration of a service management device;

FIG. 4 is an example of a timetable used in the transportation system in FIG. 1;

FIG. 5 is a service timing chart of vehicles that autonomously travel according to the timetable shown in FIG. 4;

FIG. 6 is another example of a timetable used in the transportation system in FIG. 1;

FIG. 7 is a service timing chart of vehicles that autonomously travel according to the timetable shown in FIG. 6;

FIG. 8 is an example of a timetable in which departure times are shifted later;

FIG. 9 is diagrams showing the locations of vehicles and the number of waiting passengers that change over time around 7:10;

FIG. 10 is a flowchart showing steps to generate a timetable performed by a timetable generator;

FIG. 11 is an image with a disabled vehicle; and

FIG. 12 is a flowchart showing steps with the disabled vehicle in consideration performed by the timetable generator.

#### DESCRIPTION OF EMBODIMENTS

The configuration of a transportation system 10 according to an embodiment of the present disclosure is described below with reference to the attached drawings. FIG. 1 is an illustration of the transportation system 10, FIG. 2 is a block diagram of the transportation system 10, and FIG. 3 is a block diagram showing a physical configuration of a service management device 12.

The transportation system 10 is a system used to transport an unspecified number of passengers along a preset traveling route 50. The transportation system 10 includes stops 54a to 54d along the traveling route 50 and multiple vehicles 52A to 52D that can autonomously travel along the traveling route 50. In the description below, when there is no need to distinguish the individual vehicles, the vehicles 52A to 52D are simply referred to as a "vehicle 52" without the letter at the end. Similarly, the stops 54a to 54d are simply referred to as a "stop 54" where appropriate.

The multiple vehicles 52 circulate the traveling route 50 in the same direction to form a chain of vehicles. The vehicles 52 temporarily stop at the respective stops 54. Passengers get on or off the vehicle 52 when the vehicle 52 temporarily stops. In the present embodiment, the vehicles 52 are used as buses that transport an unspecified number of passengers from a stop 54 to another stop 54. The service management device 12 (not shown in FIG. 1; refer to FIGS. 2 and 3) controls travel of the vehicles 52. In the present embodiment, the service management device 12 controls the vehicles 52 to travel at equal intervals, that is, the intervals between the departures of the vehicles 52 at the respective stops 54 are equal to each other. In such an equal interval



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service, for example, when the intervals between departures are five minutes at the stop **54a**, the intervals between departures at the other stops are also five minutes.

Each element of the transportation system **10** is described in more detail below. The vehicles **52** autonomously travel in accordance with a timetable **80** supplied by the service management device **12**. The timetable **80** defines a service schedule of the vehicles **52**. In the present embodiment, as described in more detail below, the timetable **80** shows departure and arrival times at the respective stops **54a** to **54d**. To depart from or arrive at the stops **54a** to **54d** as scheduled by the timetable **80**, the vehicles **52** themselves make decisions, such as the travel speed between the stops, whether or not to stop at signals, and whether or not to overtake other vehicles.

As shown in FIG. 2, each of the vehicles **52** includes an autonomous traveling unit **56** which has two main units, namely, a driving unit **58** and an autonomous travel controller **60**. The driving unit **58** is a basic unit to move the vehicles **52** and includes, for example, a prime mover, a powertrain, a brake, a running gear, a suspension, and a steering device. The autonomous travel controller **60** controls the driving unit **58** to enable autonomous travel of the vehicle **52**. The autonomous travel controller **60** is a computer which includes, for example, a processor and a memory. The term “computer” here includes a microcontroller which is a computer system embedded in a single integrated circuit. The term “processor” refers to a processor in a broad sense, including general-purpose processors (such as a central processing unit (CPU)) and dedicated-purpose processors (such as a graphics processing unit (GPU), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), and a programmable logic device).

To enable autonomous travel, the vehicle **52** further includes an environment sensor **62** and a location sensor **66**. The environment sensor **62** senses the peripheral environment around the vehicle **52**. The environment sensor **62** may include a camera, a Lidar, a millimeter wave radar, a sonar, or a magnetic sensor. Based on the information received from the environment sensor **62**, the autonomous travel controller **60** recognizes types of objects around the vehicle **52**, distances from the objects, road surface markings (for example, white lines) along the traveling route **50**, and traffic signs. The location sensor **66** is, for example, a GPS which senses a current location of the vehicle **52**. The information from location sensor **66** is also sent to the autonomous travel controller **60** that controls the acceleration/deceleration and steering of the vehicle **52** based on the information from the environment sensor **62** and the location sensor **66**. The autonomous travel controller **60** periodically checks the status of the vehicle **52** to determine whether or not to continue service. The control status determined by the autonomous travel controller **60** is sent to the service management device **12** as traveling status information **82**. This traveling status information **82** includes at least the current location of the vehicle **52** and whether or not to continue service.

The vehicles **52** further includes an in-vehicle sensor **64** and a communication device **68**. The in-vehicle sensor **64** is a sensor to obtain on-board passenger information **84** which includes at least the number of boarded passengers. In addition to the number of boarded passengers, the on-board passenger information **84** may include information regarding attributes of boarded passengers that would affect time required for the passengers to get on and off the vehicle **52**.

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The attributes may include at least one of, for example, the presence or absence of a passenger using a wheelchair, a white cane, a stroller, or orthoses, and age groups of passengers. The in-vehicle sensor **64** may be, for example, a camera that captures images inside the vehicle, or a load sensor that senses total weight of the boarded passengers. The information obtained by the in-vehicle sensor **64** is sent to the service management device **12** as the on-board passenger information **84**.

The communication device **68** is a device to wirelessly communicate with the service management device **12**. The communication device **68** can communicate through the Internet via wireless LAN, such as WiFi®, or mobile data communication provided by a mobile phone company or other provider. The communication device **68** receives the timetable **80** from the service management device **12**, and sends the traveling status information **82** and the on-board passenger information **84** to the service management device **12**.

An at-stop terminal **70** is a terminal provided at each stop **54**. The at-stop terminal **70** includes a communication device **74** and an at-stop sensor **72**. The at-stop sensor **72** is a sensor that obtains waiting passenger information **86** that includes at least the number of passengers waiting for the vehicle **52** at the stop **54**. In addition to the number of waiting passengers, the waiting passenger information **86** may include information regarding attributes of waiting passengers that would affect time required for the passengers to get on and off the vehicle **52**. The attributes may include at least one of, for example, the presence or absence of a passenger using a wheelchair, a white cane, a stroller, or other support devices and age groups of passengers. The at-stop sensor **72** may be, for example, a camera that captures images of the stop **54**, or a load sensor or the like that senses a total weight of waiting passengers. The information obtained by the at-stop sensor **72** is sent to the service management device **12** as the waiting passenger information **86**. The communication device **74** is provided to enable the transmission of the waiting passenger information **86**.

The service management device **12** monitors the traveling status of the vehicle **52** and controls the vehicle **52** in accordance with the traveling status. Physically, the service management device **12** is a computer that includes a processor **22**, a storage device **20**, an input/output device **24**, and a communication interface **26**, as shown in FIG. 3. The term “processor” indicates a processor in a broad meaning, including a general-purpose processor (such as a CPU) and a dedicated-purpose processor (such as a GPU, ASIC, FPGA, and a programmable logic device). The storage device **20** may include at least one of a semiconductor memory (for example, a RAM, a ROM, and a solid-state drive) and a magnetic disc (for example, a hard disk drive). Although the service management device **12** is shown as a single computer in FIG. 3, the service management device **12** may be configured with multiple computers which are physically separated.

Functionally, the service management device **12** includes a timetable generator **14**, a communication device **16**, a travel monitor **18**, and the storage device **20**, as shown in FIG. 2. The timetable generator **14** generates the timetable **80** for each of the vehicles **52**. The timetables **80** are generated such that the service intervals between the vehicles **52** are equal to a preset target service intervals.

The communication device **16** is a device to wirelessly communicate with the vehicles **52**. The communication device **16** can communicate through the Internet via WiFi®,

or mobile data communication. The communication device **16** sends the timetables **80** which have been generated or regenerated by the timetable generator **14** to the vehicles **52**, and receives the traveling status information **82** and the on-board passenger information **84** from the vehicles **52** and the waiting passenger information **86** from the at-stop terminal **70**. In the description below, the on-board passenger information **84** and the waiting passenger information **86** are referred to collectively as “passenger information”.

The travel monitor **18** obtains the traveling status of each of the vehicles **52** based on the traveling status information **82** sent from the vehicles **52**. As described above, the traveling status information **82** includes the current location of the vehicle **52**. The travel monitor **18** compares the location of the vehicle **52** and the timetable **80** to obtain information, such as an amount of delay of the vehicle **52** from the timetable **80** and the service intervals between the vehicles **52**.

Generation of the timetable **80** by the service management device **12** is described below. FIG. 4 shows an example of the timetable **80** used in the transportation system **10** in FIG. 1. The embodiment shown in FIG. 1 includes a chain of four vehicles **52A** to **52D** and four stops **54a** to **54d** separated at equal intervals along the traveling route **50**. In the present embodiment, the time required for each of the vehicles **52** to travel once around the traveling route **50**, in other words, a round-trip time **TC**, is assumed to be 20 minutes.

In such a case, the service management device **12** generates the timetable **80** such that the interval between the departures of the vehicles **52** at the stops **54** is five minutes, which is the round-trip time **TC** divided by the number **N** of vehicles **52** ( $20/4=5$ ). The timetable **80** defines departure and arrival times at the stops **54**. For example, the timetable **80D** that is sent to the vehicle **52D** defines target times at which the vehicle **52D** arrives at and departs from the stops **54a** to **54d**.

The timetable **80** may be sent periodically or when a certain event occurs. For example, the timetable **80** may be sent from the service management device **12** to each of the vehicles **52** when the vehicle **52** arrives at a certain stop, for example, the stop **54a**. Alternatively, the timetable **80** may be sent when a certain event occurs, such as when the vehicle **52** has a breakdown or is delayed. In response to receiving a new timetable **80**, the vehicle **52** discards the stored timetable **80** and travels in accordance with the received new timetable **80**. The timetable **80** may include a schedule for one or more stops. For example, the timetable **80** may define a time schedule for the entire one round along the traveling route **50**.

The vehicle **52** autonomously travels in accordance with the received timetable **80**. FIG. 5 shows a service timing chart of the vehicles **52A** to **52D** which autonomously travel in accordance with the timetable **80** in FIG. 4. In FIG. 5, the horizontal axis shows time, while the vertical axis shows the location of the vehicles **52**. Before describing the traveling status of the vehicles **52**, the parameters used in the description below are briefly described.

In the description below, the distance from one of the stops **54** to the next stop **54** is referred to as a “distance between stops **DS**”. The period of time between the departure of the vehicle **52** from the one of the stops **54** and the departure of the vehicle **52** from the next stop **54** is referred to as “time required between stops **TT**”; and the period of time during which the vehicle **52** waits at the stop **54** for passengers to get on and off the vehicle **52**, is referred to as “dwell time **TS**”. The period of time from a departure from one of the stops **54** to an arrival at the next stop **54**, in other

words, the time period obtained by subtracting the dwell time **TS** from the time required between stops **TT**, is referred to as “travel time between stops **TR**”.

The value obtained by dividing a traveling distance by a travel time period including the dwell time **TS** is referred to as a “scheduled speed **VS**”, whereas the value obtained by dividing the traveling distance by a travel time period excluding the dwell time **TS** is referred to as “average speed **VA**”. In FIG. 5, the inclination of line **M1** represents the average speed **VA**, whereas the inclination of line **M2** represents the scheduled speed **VS**. The scheduled speed **VS** is inversely proportional to the time required between stops **TT**.

Traveling of the vehicle **52** is described below with reference to FIG. 5. According to the timetable **80** shown in FIG. 4, the vehicle **52A** departs the stop **54a** at 7:15. Four minutes later, the vehicle **52A** arrives at the stop **54b** at 7:19, stays at the stop **54b** for one minute, and departs from the stop **54b** at 7:20. The vehicle **52A** controls the average speed **VA** to finish traveling from the stop **54a** to the stop **54b** in the four minutes from 7:15 to 7:19.

Normally, the timetable generator **14** generates the timetable **80** such that the dwell time of each vehicle **52** at the stop **54** equals to a preset scheduled dwell time **TSp**. In the embodiment shown in FIG. 5, the scheduled dwell time **TSp** is one minute. The scheduled dwell time **TSp** is set to allow a sufficient boarding and alighting time for passengers.

However, depending on passenger conditions, the passengers may not finish getting on and off the vehicle **52** within the scheduled dwell time **TSp**. For example, when a large number of passengers get on at one of the stops **54**, because extra time may be required, the boarding and alighting time may exceed the scheduled dwell time **TSp**. Even when the number of boarding passengers is not high, the boarding and alighting time may still exceed the scheduled dwell time **TSp** when a passenger requires extra time, such as when a passenger uses a wheelchair or accompanies a child.

When the boarding and alighting time exceeds the scheduled dwell time **TSp**, the departure of the vehicle **52** may be delayed for the exceeded period, resulting in a delay from the timetable **80**. Such a delay causes a longer traveling time for the passengers or crowd in the delayed vehicle **52** due to concentration of passengers. The timetable generator **14** calculates the boarding and alighting time estimate **TEE** based on the on-board passenger information **84** sent from the vehicle **52** and the waiting passenger information **86** sent from the stop **54**. When the boarding and alighting time estimate **TEE** exceeds a preset tolerable boarding and alighting time **TEdef**, the timetable generator **14** generates the timetable **80** in which a higher average speed **VA** between the stops and a longer dwell time **TS** at the stops **54** are set for a longer boarding and alighting time estimate **TEE**. This process is described below.

First, a method to calculate the boarding and alighting time estimate **TEE** is described. The boarding and alighting time estimate **TEE** is calculated for each vehicle **52** at each stop **54**. The calculation method of the boarding and alighting time estimate **TEE** is not limited to any type as long as the boarding and alighting time estimate **TEE** is calculated based on at least one of the on-board passenger information **84** and the waiting passenger information **86**. For example, the overall alighting time of a certain vehicle **52** may be calculated by obtaining the alighting time of each of the passengers on the vehicle **52** based on the passenger's attributes, and calculating the total of the obtained alighting times. The overall alighting time of the vehicle **52** obtained in this manner may be divided for each stop at predeter-

mined ratios and the divided value may be used as the alighting time when the vehicle **52** arrives at the stop **54**. For example, the ratio of the alighting time at the four stops **54a** to **54d** may be assumed to be 1:1:2:1 based on past service records. The alighting time of the vehicle **52A** at the stop **54a** can be calculated from an formula  $Ta \times \frac{1}{5}$  where  $Ta$  is the overall alighting time of the vehicle **52A**.

The waiting passenger information **86** may be periodically sent to the service management device **12** from the at-stop terminal **70**. In such a case, the timetable generator **14** may periodically estimate the boarding time at the stop **54** based on the number and the attributes of passengers at the stop **54**, and obtain a value for the increase in the boarding time per unit time such that the timetable generator **14** can generate, based on the obtained increase value, the time required for boarding of the passengers at the time the vehicle **52** is expected to arrive at the stop **54**. For example, when the number of passengers waiting at the stop **54a** increases by one each minute and the boarding time of each passenger is assumed to be six seconds, the increase of the boarding time per one minute is six seconds. When a vehicle **52** departs from the stop **54a** every five minutes, the number of additional passengers arriving during the period from the departure of the vehicle **52** to the departure of the next vehicle **52** can be estimated to be five. Accordingly, the boarding time required for the next vehicle **52** at the stop **54a** can be estimated by a formula  $6 \times 5 = 30$  (seconds).

According to another embodiment, the timetable generator **14** may include a simulator which virtually simulates boarding and alighting of passengers. In such a case, the timetable generator **14** may input at least one of the on-board passenger information **84** and the waiting passenger information **86** to the simulator to obtain the boarding and alighting time estimate TEE of the designated vehicle **52** at the designated stop **54** based on the simulation.

The boarding and alighting time estimate TEE obtained in a single calculation may be for a single stop or multiple stops. In general, the number of stops for which the boarding and alighting time estimate TEE is obtained may be the same as the number of stops recorded in the timetable **80**. For example, when the timetable **80** of the vehicle **52A** includes the timetables for four stops, the timetable generator **14** obtains the boarding and alighting time estimate TEE of the vehicle **52A** at the respective four stops at a timing to generate the timetable **80**.

After the boarding and alighting time estimate TEE is obtained, the timetable generator **14** compares the obtained boarding and alighting time estimate TEE with the preset tolerable boarding and alighting time TEdef, which can maintain the dwell time TS within the scheduled dwell time TSp. For example, the tolerable boarding and alighting time TEdef may be a time period obtained by subtracting, from the scheduled dwell time TSp, a safety confirmation time required before and after boarding and alighting of passengers.

When the boarding and alighting time estimate TEE is equal to or less than the tolerable boarding and alighting time TEdef, the timetable generator **14** sets the dwell time TS at the stop **54** to the scheduled dwell time TSp regardless of the boarding and alighting time estimate TEE. Such a setting can prevent an excessive slowing of the average speed VA between the stops. Otherwise, with the same departure timing of the vehicle **52**, a lower average speed VA is set for a shorter dwell time TS. As an overly slow average speed VA would disturb traveling of the other vehicles **52**, the timetable generator **14** can prevent the excessive slowing of the average speed VA by setting the dwell time TS to the

scheduled dwell time TSp when the boarding and alighting time estimate TEE is less than a certain value.

In contrast, when the boarding and alighting time estimate TEE exceeds the tolerable boarding and alighting time TEdef, the timetable generator **14** generates the timetable **80** such that a higher average speed VA between the stops and a longer dwell time TS at the stops **54** are set for a longer boarding and alighting time estimate TEE.

For example, a case is described below in which the number of waiting passengers is high, resulting in the boarding and alighting time estimate TEE at the stop **54c** to be one minute longer than the tolerable boarding and alighting time TEdef. In such a case, as shown in FIG. 6, the timetable generator **14** generates a timetable **80** such that every vehicle **52** arrives at the stop **54c** two minutes before the scheduled departure time.

FIG. 7 shows a travel timing chart of the vehicles **52** which travel in accordance with the timetable **80** shown in FIG. 6. When the timetable **80** defines that the vehicles **52** arrive two minutes before the scheduled departure time as shown in FIG. 7, the average speed VA between the stop **54b** and the stop **54c** is set to be higher than the average speed VA between the other stops to depart as scheduled by the timetable **80**. Accordingly, all vehicles **52** arrive at the stop **54c** two minutes before the scheduled departure time and the dwell time TS at the stop **54c** is two minutes. Potential delay of the vehicles **52** from the scheduled departure time can be effectively prevented by making the dwell time TS sufficiently long.

Note that in order to obtain sufficient dwell time TS, it would also be possible to set a delayed departure time instead of an earlier arrival time. For example, as shown in FIG. 8, the timetable **80** could be arranged to delay the departure time at the stop **54c** by one minute and the arrival at the stop **54c** two minutes earlier than in the case shown in FIG. 4.

However, in such a case, passengers could be concentrated at the vehicles **52** which were delayed from the schedule departure time due to a longer time required for boarding and alighting of passengers, in turn increasing the likelihood of a still longer delay from the timetable **80**. This situation is described with reference to FIG. 9, which shows changes over time around 7:10 in the location of the vehicles **52** and the number of waiting passengers at the stop **54c**. In FIG. 9, the upper graph shows the location of the vehicles **52A**, **52D**, and **52C**; and the lower graph shows the number of passengers waiting at the stop **54c**. The solid lines in FIG. 9 show the locations and the number of passengers waiting for the vehicle **52D** when the vehicle **52D** travels in accordance with the timetable **80** in FIG. 6, whereas the broken lines illustrate when the vehicle **52D** travels in accordance with the timetable **80** in FIG. 8.

As shown in the lower graph in FIG. 9, the number of passengers waiting at the stop **54c** is zero immediately after the departure of the vehicle **52**, and then increases over time and becomes zero again when another vehicle **52** departs from the stop **54c**. For the purpose of simplifying description, the number of passengers is assumed to increase directly proportional to time.

The vehicle **52D** is assumed to arrive at the stop **54c** on time at 7:08 in accordance with the timetable **80** in FIG. 6. In such a case, the passengers who arrive at the stop **54c** during the 5-minute interval between the departure of the vehicle **52A** and the departure of the vehicle **52D** will board the vehicle **52D**. As shown by the solid line in FIG. 9, the number of passengers who board the vehicle **52D** at the stop

54c is assumed to be Na and the passengers are assumed to complete boarding and alighting of the vehicle 52D within the dwell time of 2 minutes.

Alternatively, the vehicle 52D is now assumed to arrive at the stop 54c at 7:09 in accordance with the timetable 80 in FIG. 8. Because the time period between the departure of the vehicle 52A and the departure of the vehicle 52D is now 6 minutes, the number of passengers waiting for the vehicle 52D increases corresponding to one minute in comparison with a case as illustrated in the timetable 80 of FIG. 6. As illustrated by broken lines in FIG. 9, because the number of passengers who board the vehicle 52D at the stop 54c is greater than Na, the time period required for the passengers to get on and off the vehicle 52D is longer than in a case in accordance with the timetable 80 in FIG. 6. As a result, the passengers may not finish getting on and off the vehicle 52D within two minutes. In such a case, because the time allowed for the vehicle 52D to reach the next stop 54d becomes shorter, the likelihood of the vehicle 52D delaying from the timetable 80 increases.

As apparent from the above description, by obtaining the dwell time TS, not by shifting the departure time backward but by shifting the arrival time forward as in the present embodiment, concentration of passengers to a single vehicle 52 can be suppressed, and thus the delay from the timetable 80 can be effectively prevented.

With reference to FIG. 10, a flow of generation processes of the timetable 80 performed by the timetable generator 14 is described below. FIG. 10 shows a flow to generate a timetable for one of the vehicles 52 to travel to one of the stops 54. The timetable generator 14 generates the timetable 80 by performing the process shown in FIG. 10 for every vehicles 52 and every stops 54.

The timetable generator 14 calculates the boarding and alighting time estimate TEE of the vehicle 52 at the stop 54 based on the on-board passenger information 84 of the designated vehicle 52 and the waiting passenger information 86 of the designated stop 54 (S10). The timetable generator 14 then compares the obtained boarding and alighting time estimate TEE and the tolerable boarding and alighting time TEdef (S12). When the comparison finds  $TEE \leq TEdef$  (yes in S12), the timetable generator 14 generates the timetable 80 by setting the dwell time TS of the vehicle 52 at the stop 54 to the scheduled dwell time TSp, that is, one minute (S14). In the present embodiment, the vehicle 52 automatically sets the dwell time TS to the scheduled dwell time TSp by designating only the departure time in the timetable 80 as shown in FIG. 4.

In contrast, when  $TEE > TEdef$  (no in S12), the timetable generator 14 calculates a suitable dwell time TS based on the obtained boarding and alighting time estimate TEE (S16). For example, the dwell time TS can be obtained by adding safety confirmation time required before and after the boarding and alighting of the passengers to the boarding and alighting time estimate TEE. Once the dwell time TS is obtained, the timetable generator 14 generates the timetable 80 using the obtained dwell time TS (S18). Specifically, the time obtained by shifting the departure time forward for the dwell time TS is set as the arrival time in the timetable 80.

In the event of vehicle trouble such as vehicle 52 becoming disabled or unable to continue operation, the timetable generator 14 may calculate the boarding and alighting time estimate TEE of the vehicle 52 following the disabled vehicle 52 including consideration of the on-board passenger information 84 of the disabled vehicle 52. This is described in more detail below.

FIG. 11 shows an image in which the vehicle 52C becomes disabled between the stop 54b and the stop 54c. When the vehicle 52C becomes disabled or unable to continue operation, the vehicle 52C sends, as a part of traveling status information 82, alarm information indicating the situation to the service management device 12. This alarm information may include description of the problem that has occurred to the vehicle 52C.

When the timetable generator 14 determines that the vehicle 52C has become disabled based on the traveling status information 82 including the alarm information, the timetable generator 14 calculates the boarding and alighting time estimate TEE of the vehicle 52B following the disabled vehicle 52C by taking account of the on-board passenger information 84 of the disabled vehicle 52C.

Specifically, when the vehicle 52C becomes disabled, the timetable generator 14 first determines based on the alarm information whether the vehicle 52C is capable of traveling to the stop 54c. If so, the timetable generator 14 causes the vehicle 52C to travel to the stop 54c. In such a case, the passengers on the vehicle 52C get off the vehicle 52C at the stop 54c and transfer to the vehicle 52B following the vehicle 52C. When the vehicle 52B arrives at the stop 54c, in addition to the alighting time for the passengers on the vehicle 52B and the boarding time of the passengers waiting at the stop 54c, the boarding time of the passengers who have alighted from the vehicle 52C is also required.

In such a case, the timetable generator 14 calculates the boarding and alighting time estimate TEE1 of the vehicle 52B at the stop 54c based on the on-board passenger information 84 of the vehicle 52B, the waiting passenger information 86 at the stop 54c, and the on-board passenger information 84 of the vehicle 52C. Because of the additional boarding time of the passengers of the vehicle 52C, the boarding and alighting time estimate TEE1, that is, the dwell time TS, of the vehicle 52B at the stop 54c becomes longer than the time estimated before the vehicle 52 becomes disabled. Because of the longer dwell time TS, the travel time between the stops becomes shorter and thus the average speed VA becomes higher than that before the vehicle 52 becomes disabled.

Alternatively, the vehicle 52C may be incapable of traveling to the next stop 54c. In such a case, the passengers of the vehicle 52C must get off the vehicle 52C at the location where the vehicle 52C has stopped (hereinafter referred to as "temporary stop"). To pick up these passengers who have alighted from the vehicle 52C, the timetable generator 14 generates the timetable 80 in which the following vehicle 52B stops at the temporary stop to pick up the passengers who have got off the vehicle 52C. In order to determine the dwell time TS, the timetable generator 14 calculates the boarding and alighting time estimate TEE2 at the temporary stop based on the on-board passenger information 84 of the vehicle 52C. When the passengers of the disabled vehicle 52C get on the following vehicle 52B at the temporary stop, the number of passengers who get off the vehicle 52B at the stop 54c may increase, resulting in a longer boarding and alighting time estimate TEE1. Also in this case, the timetable generator 14 calculates the boarding and alighting time estimate TEE1 of the following vehicle 52B at the stop 54c based on the on-board passenger information 84 of the following vehicle 52B, the waiting passenger information 86 at the stop 54c, and the on-board passenger information 84 of the disabled vehicle 52C. The timetable generator 14 calculates the dwell time TS at the temporary stop and the stop 54c based on the obtained boarding and alighting time

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estimates TEE1 and 2, and generates the timetable 80 in accordance with the obtained dwell time TS.

FIG. 12 is a flowchart which shows a process flow of the timetable generator 14 in consideration of such a disabled vehicle 52. As shown in FIG. 12, the timetable generator 14 periodically checks for existence and absence of any disabled vehicle 52 (S20). When the timetable generator 14 finds no disabled vehicle 52 (no in S20) at a result of the checking, the timetable generator 14 performs the flow shown in FIG. 10 (S22).

In contrast, when a disabled vehicle 52 is found (yes in S20), the timetable generator 14 analyzes the alarm information included in the traveling status information 82 to determine whether the disabled vehicle 52 is capable of traveling to the next stop 54 (S24). When the timetable generator 14 determines that the disabled vehicle 52 is capable of traveling to the next stop 54 (yes in S24), the timetable generator 14 calculates the boarding and alighting time estimate TEE1 of the vehicle 52 following the disabled vehicle 52 at the next stop 54 based on the on-board passenger information 84 of the following vehicle 52, the waiting passenger information 86 at the next stop 54, and the on-board passenger information 84 of the disabled vehicle 52 (S26). The timetable generator 14 then calculates the dwell time TS of the following vehicle 52 at the next stop 54 (S28) based on the obtained boarding and alighting time estimate TEE1, and generates the timetable 80 of the following vehicle 52 using the obtained dwell time TS (S30).

In contrast, when the disabled vehicle 52 is not capable of traveling to the next stop 54 (no in S24), the timetable generator 14 calculates the boarding and alighting time estimate TEE2 of the following vehicle 52 at the temporary stop where the disabled vehicle 52 stopped while considering the on-board passenger information 84 of the disabled vehicle 52 (S32). The timetable generator 14 generates the boarding and alighting time estimate TEE1 of the following vehicle 52 at the next stop 54 based on the on-board passenger information 84 of the following vehicle 52, the waiting passenger information 86 at the next stop 54, and the on-board passenger information 84 of the disabled vehicle 52 (S34). The timetable generator 14 then obtains the dwell time TS of the vehicle 52 at the temporary stop and the next stop 54 based on the obtained boarding and alighting time estimates TEE1 and 2 (S36) to generate the timetable 80 of the following vehicle 52 using the obtained dwell time TS (S38). After completing these steps, the timetable generator 14 returns to step S20 and repeats the steps.

As apparent from the above description, in the present embodiment, when any one of the vehicles 52 becomes disabled, the boarding and alighting time estimate TEE of the following vehicle 52 is calculated while taking into account the on-board passenger information 84 of the disabled vehicle 52. By determining the dwell time TS of the following vehicle 52 based on the obtained boarding and alighting time estimate TEE, sufficient time required for the passengers of the disabled vehicle 52 to transfer to the following vehicle 52 can be allowed.

When the vehicle 52 becomes disabled and is not returned to service, it may not be possible to sufficiently fulfill a transportation demand. Although not shown in flowchart in FIG. 12, the timetable generator 14 may address such circumstances by generating a timetable 80 which excludes the disabled vehicle 52 from the chain of vehicles and adds a new vehicle 52 to the chain of vehicles when available.

The above described configurations are merely examples. The configurations may be changed as required as long as the timetable 80 is generated such that the boarding and

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alighting time estimate TEE of the vehicle 52 at the stop 54 is calculated based on at least one of the on-board passenger information 84 and the waiting passenger information 86 (that is, passenger information), and a higher average speed VA between the stops and a longer dwell time TS are set for a longer boarding and alighting time estimate TEE. For example, in the above embodiments, when the boarding and alighting time estimate TEE is equal to or less than the tolerable boarding and alighting time TDef, the dwell time TS is set to the scheduled dwell time TSp. However, the dwell time TS may be changed in accordance with the boarding and alighting time estimate TEE even when  $TEE \leq TDef$ .

The boarding and alighting time estimate TEE may be calculated while taking account of other information in addition to at least one of the on-board passenger information 84 and the waiting passenger information 86. For example, when reserved travel on the vehicle 52 is available, the status of reservation may be used to calculate the boarding and alighting time estimate TEE. Further, other information such as day of week and time of day, and events around the stops may also be used to calculate the boarding and alighting time estimate TEE. Although the timetable 80 defines the arrival time at the stops 54 in the present embodiment, the average speed VA between the stops may be defined instead of or in addition to the arrival time. Further, the number of and the distances between the vehicles 52 or of the stops 54 may be changed as required. In particular, the intervals set between the vehicles 52 need not be uniform.

The invention claimed is:

1. A transportation system comprising:

a traveling route along which a plurality of stops are set; a chain of a plurality of vehicles configured to autonomously travel along the traveling route; and

a service management device configured to manage traveling of the plurality of vehicles, the service management device including a processor configured to control the traveling of the plurality of vehicles, wherein the processor is configured to:

generate a timetable for each of the plurality of vehicles; and

send the timetable to the plurality of vehicles and receive passenger information about passengers of the transportation system at least from the plurality of vehicles or the plurality of stops, and

generate the timetable by calculating a boarding and alighting time estimate of each of the plurality of vehicles at each of the plurality of stops based on at least the passenger information such that a higher speed of the vehicle between the stops and a longer dwell time of the vehicle at the stop are set for a longer boarding and alighting time estimate, wherein each of the plurality of vehicles is configured to send traveling status information that indicates a traveling status of the vehicle to the processor, and

when the processor determines, based on the traveling status information, that there is a disabled vehicle that cannot continue service, the processor calculates a boarding and alighting time estimate of a vehicle following the disabled vehicle at a next scheduled stop of the disabled vehicle based on on-board passenger information of the following vehicle, waiting passenger information at the next scheduled stop, and on-board passenger information of the disabled vehicle.

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2. The transportation system according to claim 1, wherein

the processor generates the timetable such that when the boarding and alighting time estimate is equal to or less than a preset boarding and alighting time, the dwell time and the speed are set to preset values regardless of the boarding and alighting time estimate.

3. The transportation system according to claim 1, wherein

each of the plurality of vehicles comprises an in-vehicle sensor configured to obtain on-board passenger information comprising at least a number of passengers on board the vehicle and an attribute about the on-board passengers, and to send the on-board passenger information to the processor, and

the passenger information comprises the on-board passenger information.

4. The transportation system according to claim 3, wherein

the processor calculates an overall alighting time of each of the plurality of vehicles based on the on-board passenger information and calculates an alighting time estimate of the vehicle at each of the plurality of stops by dividing the calculated overall alighting time of the vehicle by preset ratios for each of the plurality of stops.

5. The transportation system according to claim 3, wherein

the attribute comprises at least one of age group or presence or absence of a passenger using a wheelchair, a white cane, an orthosis, or a stroller.

6. The transportation system according to claim 1, wherein

each of the plurality of stops comprises an at-stop sensor configured to obtain waiting passenger information comprising at least a number of waiting passengers and an attribute about the waiting passengers, and to send the waiting passenger information to the processor, and the passenger information comprises the waiting passenger information.

7. The transportation system according to claim 6, wherein

each of the plurality of stops periodically sends the waiting passenger information to the processor, and the processor calculates increase per unit time of boarding time of the waiting passengers at the stop based on the waiting passenger information, and further calculates a boarding time estimate for each of the plurality of vehicles at the stop based on the calculated increase per unit time.

8. The transportation system according to claim 1, wherein

when the disabled vehicle is capable of traveling to the next scheduled stop, the processor generates the timetable by assuming that the passengers on the disabled vehicle are to transfer to the following vehicle at the next scheduled stop.

9. The transportation system according to claim 1, wherein

when the disabled vehicle is not capable of traveling to the next scheduled stop, the processor generates the timetable such that, by assuming that the passengers on the disabled vehicle are to transfer to the following vehicle

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at a temporary stop where the disabled vehicle stopped, the following vehicle is temporarily stopped at the temporary stop.

10. A service management device comprising:

a processor configured to control travel of a plurality of vehicles, wherein the processor is configured to:

generate a timetable for each of a plurality of vehicles configured to autonomously travel along a preset traveling route; and

send the timetable to the plurality of vehicles and receive passenger information about passengers of the plurality of vehicles at least from the plurality of vehicles or the plurality of stops along the traveling route, and

generate the timetable by calculating a boarding and alighting time estimate of each of the plurality of vehicles at each of the plurality of stops based on at least the passenger information such that a higher average speed of the vehicle between the stops and a longer dwell time of the vehicle at the stop are set for a longer boarding and alighting time estimate, wherein

each of the plurality of vehicles is configured to send traveling status information that indicates a traveling status of the vehicle to the processor, and

when the processor determines, based on the traveling status information, that there is a disabled vehicle that cannot continue service, the processor calculates a boarding and alighting time estimate of a vehicle following the disabled vehicle at a next scheduled stop of the disabled vehicle based on on-board passenger information of the following vehicle, waiting passenger information at the next scheduled stop, and on-board passenger information of the disabled vehicle.

11. A service management method comprising:

receiving, at least from a plurality of vehicles configured to autonomously travel along a preset traveling route or a plurality of stops along the traveling route, passenger information about passengers of the plurality of vehicles;

calculating a boarding and alighting time estimate of each of the plurality of vehicles at each of the plurality of stops based on at least the passenger information;

generating a timetable of each of the plurality of vehicles such that a higher speed of the vehicle between the stops and a longer dwell time of the vehicle at the stop are set for a longer boarding and alighting time estimate;

sending the timetable to the plurality of vehicles;

controlling travel of the plurality of vehicles;

receiving traveling status information that indicates a traveling status of each vehicle of the plurality of vehicles;

determining whether there is a disabled vehicle that cannot continue service; and

calculating a boarding and alighting time estimate of a vehicle following the disabled vehicle at a next scheduled stop of the disabled vehicle based on on-board passenger information of the following vehicle, waiting passenger information at the next scheduled stop, and on-board passenger information of the disabled vehicle when there is the disabled vehicle that cannot continue service.