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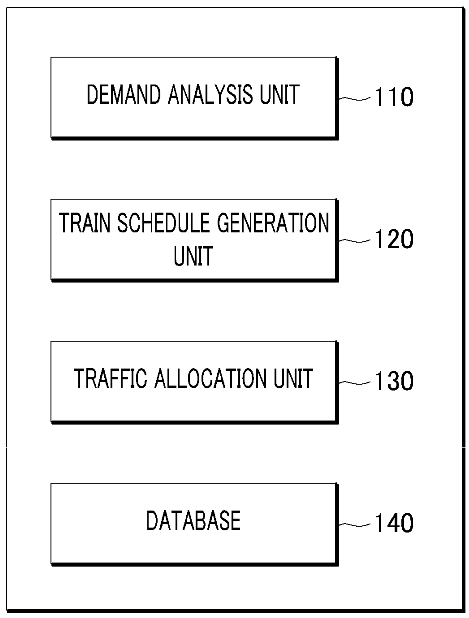
(54) INTELLIGENT TRAIN SCHEDULING METHOD

(57) A train scheduling method of an intelligent train scheduling system included obtaining train schedule information which includes train line information and information about operation time of each train; generating a time extension network which includes stations, as nodes, at which the trains included in the train schedule information stop, lines, as edges, between the stations included in the train schedule information, and operation time information of each train included in the train schedule information; and calculating predictive information about a traffic volume in each section and a traffic volume of each train for the train schedule on the basis of the time extension network.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an intelligent train scheduling method.

BACKGROUND

[0002] Train networks such as railway lines, subway lines, etc. are being developed and bus networks connected thereto are also being developed. Accordingly, methods for efficiently managing a schedule of each transportation are being actively studied. Further, software or hardware products for transportation scheduling have been developed.

[0003] According to a conventional transportation scheduling method, there are separate programs for train scheduling and train operation planning. In the conventional transportation scheduling method, one part is operated to prepare a train schedule on the basis of user's experience. Further, in the conventional transportation scheduling method, another program is operated to prepare a train schedule through an automation algorithm.

[0004] According to the conventional transportation scheduling method, a passenger boarding volume and a congestion rate cannot be predicted. That is, according to the conventional transportation scheduling method, a train schedule cannot provide information about how many passengers will board in each section, in each time zone, or in each train.

[0005] In this regard, Korean Patent Laid-open Publication No. 10-2012-0129344 (entitled "Method and apparatus for establishing an operation schedule of trains") relates to a method and an apparatus for establishing an operation schedule of trains, and discloses a component capable of flexibly increasing and decreasing a turnback allowable range like a schedule planning unit of the subject invention configured to receive data about certain limiting conditions for a train and plan an execution schedule besides a basic schedule of the train.

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0006] The present disclosure provides an intelligent train scheduling method capable of providing predictive information about a traffic volume in each section and a traffic volume of each train for a train schedule and adjusting the train schedule on the basis of the predictive information

MEANS FOR SOLVING THE PROBLEMS

[0007] As a technical means for solving the above-described problem, in accordance with a first exemplary embodiment there is provided a train scheduling method of an intelligent train scheduling system includes: obtaining train schedule information which includes train line information and information about operation time of each train; generating a time extension network which includes stations, as nodes, at which the trains included in the train schedule information stop, lines, as edges, between the stations included in the train schedule information, and operation time information of each train included in the train schedule information; and calculating predictive information about a traffic volume in each section and a traffic volume of each train for the train schedule on the basis of the time extension network.

EFFECTS OF THE INVENTION

[0008] According to the aspect of the present disclosure, it is possible to calculate predictive information about a traffic volume in each section and in each time zone for a previously generated train schedule. Thus, a user in charge of preparing a train schedule can adjust a train schedule considering the result of a prediction about how many passengers will board in which section and which time zone for the train schedule established by the user.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1 illustrates an intelligent train scheduling system in accordance with an exemplary embodiment.
FIG. 2 is a flowchart illustrating a process of calculating predictive information about a traffic volume in accordance with an exemplary embodiment.
FIG. 3 is a diagram illustrating an example of a typical traffic network.
FIG. 4 is a diagram illustrating an example of a time extension network applied to the present disclosure.

FIG. 5 illustrates the concept of classification as a time extension node in accordance with an exemplary embodiment.
FIG. 6 illustrates the concept of classification as a time extension edge in accordance with an exemplary embodiment.
FIG. 7 is a diagram provided to explain the concept of discrete demands in accordance with an exemplary embodiment.
FIG. 8 is a flowchart illustrating a method of calculating predictive information about a traffic volume in accordance with an exemplary embodiment.
FIG. 9 is a diagram provided to explain a method of calculating predictive information about a traffic volume in accordance with an exemplary embodiment.
FIG. 10 is a diagram provide to explain the concept of calculation of a traffic volume considering a priority between paths in accordance with an exemplary embodiment.

MODE FOR CARRYING OUT THE INVENTION

[0010] Hereinafter, embodiments of the present disclosure will be described in detail with reference to the accompanying drawings so that the present disclosure may be readily implemented by those skilled in the art. However, it is to be noted that the present disclosure is not limited to the embodiments but can be embodied in various other ways. In drawings, parts irrelevant to the description are omitted for the simplicity of explanation, and like reference numerals denote like parts through the whole document.

[0011] Through the whole document, the term "connected to" or "coupled to" that is used to designate a connection or coupling of one element to another element includes both a case that an element is "directly connected or coupled to" another element and a case that an element is "electronically connected or coupled to" another element via still another element. Further, the term "comprises or includes" and/or "comprising or including" used in the document means that one or more other components, steps, operation and/or existence or addition of elements are not excluded in addition to the described components, steps, operation and/or elements unless context dictates otherwise.

[0012] **FIG. 1** illustrates an intelligent train scheduling system in accordance with an exemplary embodiment.

[0013] An intelligent train scheduling system 10 includes a demand analysis unit 110, a train schedule generation unit 120, a traffic allocation unit 130, and a database 140.

[0014] The demand analysis unit 110 collects traffic record data of statistically collected users. The demand analysis unit 110 uses the traffic record data to predict a demand for each path including a pair of origin and destination. For example, the demand analysis unit 110 receives information, such as ticket purchase records or the amount of traffic card use of the users, from the database 140. Then, the demand analysis unit 110 performs a prediction of a demand for each path on the basis of the received information. The demand analysis unit 110 calculates a transit traffic volume between lines considering a transit time between the lines and a headway of trains in each line. Then, the demand analysis unit 110 calculates the total traffic volume in each line considering the calculated transit traffic volume. Herein, the demand analysis unit 110 may calculate a traffic volume for transit from the corresponding line to another line and a traffic volume for transit from another line to the corresponding line as a traffic volume of the corresponding line using a shortest path calculation method, and predict a demand for an origin-destination path in the corresponding line considering a headway between trains in the corresponding line and a time required for transit at a transit station.

[0015] The train schedule generation unit 120 generates a basic schedule and an execution schedule of a train. Firstly, a train schedule is a schedule table in which an arrival time and a departure time of each train operating on a train line are set for each station. Further, the basic schedule refers to a train schedule in which a user's experience and subjectivity is reflected and also refers to a train schedule draft in which there may be train conflicts. Further, the execution schedule refers to a conflict-free train schedule without train conflicts which may be present in a train schedule and also refers to a train schedule applicable in reality.

[0016] The train schedule generation unit 120 generates a draft by applying a basic schedule heuristic algorithm in order to generate the basic schedule. Then, the train schedule generation unit 120 may provide the user with a train schedule editing function and thus enables the user to revise the draft depending on an intention of the user. Meanwhile, a specific method of generating a train schedule is out of the scope of the present disclosure. Therefore, a detailed explanation thereof will be omitted.

[0017] The traffic allocation unit 130 calculates predictive information about a traffic volume in each section and a traffic volume in each time zone for a train schedule. In this case, the train schedule may be generated by the train schedule generation unit 120 or may be received from the outside. A process of calculating predictive information about a traffic volume by the traffic allocation unit 130 will be described in detail later.

[0018] The database 140 manages each of basic data for analyzing a demand by the demand analysis unit 110, basic data for generating a train schedule by the train schedule generation unit 120, and basic data for calculating predictive information about a traffic volume by the traffic allocation unit 130. Further, the database 140 receives the data produced by the demand analysis unit 110, the train schedule generation unit 120, and the traffic allocation unit 130 and manages the received data.

[0019] For example, the database 140 collects and manages ticket purchase information or traffic card records. Further, the database 140 manages all information about a line, such as railway sections, stations, gradients of a railway, curves of a railway, speed limit sections, and a base. Further, the database 140 manages information about a train operation, such as prior schedule information, a standard run curve, an operation headway, an operation time, and a stop time. Furthermore, the database 140 manages information about vehicles, such as a type, a formation state and construction of the vehicles. Moreover, the database 140 manages a path including a pair of inter-station origin-destination, information about a demand for a traffic volume in each path, and the like.

[0020] Meanwhile, each of components illustrated in **FIG. 1** in accordance with the embodiment of the present disclosure may imply software or hardware such as a field programmable gate array (FPGA) or an application specific integrated circuit (ASIC), and they carry out a predetermined function.

[0021] However, the components are not limited to the software or the hardware, and each of the components may be stored in an addressable storage medium or may be configured to implement one or more processors.

[0022] Accordingly, the components may include, for example, software, object-oriented software, classes, tasks, processes, functions, attributes, procedures, sub-routines, segments of program codes, drivers, firmware, micro codes, circuits, data, database, data structures, tables, arrays, variables and the like.

[0023] The components and functions thereof can be combined with each other or can be divided up into additional components.

[0024] **FIG. 2** is a flowchart illustrating a process of calculating predictive information about a traffic volume in accordance with an exemplary embodiment.

[0025] Firstly, in the present disclosure, train schedule information previously generated for predictive information about a traffic volume is used (S210). In this case, the train schedule information includes line information of a train and an operation time of each train. The train schedule information may be a basic schedule or an execution schedule.

[0026] Then, a time extension network is generated on the basis of the train schedule information (S220).

[0027] The time extension network includes stations, as nodes, at which the trains included in the train schedule information stop. Further, the time extension network includes lines, as edges, between the stations included in the train schedule information. The time extension network includes operation time information of each train included in the train schedule information. In this case, a repetition number n is set to 0 and the cost for each edge is set to an initial value.

[0028] **FIG. 3** is a diagram illustrating an example of a typical traffic network, and **FIG. 4** is a diagram illustrating an example of a time extension network applied to the present disclosure.

[0029] In case of **FIG. 3**, the typical traffic network includes nodes each of which represents a station and a link which represents a line connecting stations. However, the typical traffic network does not include the concept of time.

[0030] In case of **FIG. 4**, the time extension network extends the typical traffic network by adding a time dimension. Unlike a conventional traffic allocation method based on the number of times of input, the time extension network makes it possible to accurately grasp a waiting time of passengers and a first train to arrive. However, the time extension network needs to differentially express all stations depending on a schedule time. Thus, the network may be greatly increased in size and may become complicated. Therefore, it may be difficult for the time extension network to actually derive a solution in time.

[0031] The time extension network (V X E) includes a time extension node group V and a time extension edge group E.

[0032] **FIG. 5** illustrates the concept of classification as a time extension node in accordance with an exemplary embodiment, and **FIG. 6** illustrates the concept of classification as a time extension edge in accordance with an exemplary embodiment.

[0033] The time extension node group V may include the number of a node, the number of a train, the number of a station, and properties of time information of a node. Further, the nodes included in the time extension node group V are classified into station arrival and departure nodes, a demand generation node, and a demand end node. The time extension edge group E includes the number of an edge, the number of a starting node of an edge, the number of an ending node of an edge, and properties of time information between the end and the start of an edge. Further, the edges included in the time extension edge group are classified into an inter-station movement edge, a stop edge, a transit edge, and demand generation and end edges. Herein, the demand generation node and the demand end node do not represent actual physical stations but correspond to virtual nodes for applying demand values to the respective nodes.

[0034] **FIG. 7** is a diagram provided to explain the concept of discrete demands in accordance with an exemplary embodiment.

[0035] The graph at a lower end of the drawing illustrates demand generation statistics over time for each pair of origin-destination. Such demand generation statistics data are based on the above-described ticket purchase records or amount of traffic card use of the users. It can be seen that as time passes, a demand for each pair of origin-destination is changed. For example, demands are relatively concentrated during the morning rush hour (07:00 to 09:00) and the evening rush hour (18:00 to 20:00). As such, the intelligent train scheduling system considers demand generation nodes in order for continuously changing demand generation to be discrete. That is, the intelligent train scheduling system generates virtual demand generation nodes 300 and 310 for each line referring to demand generation statistics for each pair of origin-destination, and sets the amounts of demand for the nodes for a corresponding time. For example, the intelligent train scheduling system may add up the amounts of demand for pairs of origin-destination during a specific time zone (07:00 to 08:00) and determine the amount of demand for the demand generation node 300. Then, the intelligent train scheduling system 10 sets this value to be considered as a passenger boarding volume of a corresponding line. That is, the intelligent train scheduling system 10 sets a time interval between demand generation nodes and the amount of demand generated on the basis of traffic record data of statistically collected users. Depend on the above-described configuration, a time interval between demand generation nodes is decreased in a time zone in which demands are concentrated and a time interval between demand generation nodes is increased in a time zone in which demands are relatively low.

[0036] The intelligent train scheduling system 10 calculates an optimum solution and an approximated optimum solution of a passenger boarding volume and a congestion rate in each section of each train expressed by the time extension network through a timetable-based transit assignment algorithm suggested below for a timetable-based transit assignment model.

[0037] Then, the intelligent train scheduling system 10 calculates predictive information about a traffic volume in each section and a traffic volume in each time zone for the train schedule on the basis of the time extension network (S230).

[0038] **FIG. 8** is a flowchart illustrating a method of calculating predictive information about a traffic volume in accordance with an exemplary embodiment.

[0039] Firstly, the intelligent train scheduling system 10 performs initial traffic allocation to set the amount of demand for a path defined by a pair of origin-destination as a traffic volume of each path (S231). Herein, the intelligent train scheduling system 10 calculates initial cost for each edge e in the time extension network, and uses Equation 1 for this calculation.

[Equation 1]

$$c_e^n(0),\ \forall e \in E$$

[0040] Further, the intelligent train scheduling system 10 searches a shortest path of each pair of origin-destination and performs the initial traffic allocation to each shortest path. Herein, the intelligent train scheduling system 10 performs the initial traffic allocation to each shortest path by setting the amount of demand as an initial traffic volume as shown in the following Equation 2.

[Equation 2]

$$f_{p_i^*} = d_i,\ \forall i \in I$$

[0041] Herein, d_i represents the amount of demand, p_i* represents a shortest path of a pair of origin-destination, and f_p represents a traffic volume of a path p. Further, I represents a group of all pairs i of origin-destination, and demand generation nodes are aligned in order of time. In this case, the above-described amounts of demand set for demand generation nodes may also be considered.

[0042] Then, edge cost is updated on the basis of a type of each edge constituting a path and a traffic volume (S232).

[0043] Herein, an edge cost function is defined as $c_e = c_e(x_e)$, and edge cost may be differently calculated depending on an edge type as shown in the following Table 1.

[Table 1]

edge type	calculating of edge cost
inter-station movement	$x_e \leq 500$: time X 1.00 $500 \leq x_e \leq 1500$: time X 1.00 $1500 \leq x_e$: time X 1.09
stop	
transit	476
transit (express train -> general train)	194

(continued)

edge type	calculating of edge cost
transit (general train -> express train)	194
demand generated	time X 0.1
demand end	0

[0044] For example, as suggested in Table 1, edge cost varies depending on an edge type. Thus, the intelligent train scheduling system 10 differentially sets edge costs for respective edge types defined in the time extension network. For example, if a traffic volume passing through an edge "e" is equal to or lower than 500 people or 1,500 people, cost corresponding to a passage time for the edge multiplied by a weighted value "1.00" is calculated, and if the traffic volume is higher than 1,500 people, cost corresponding to the passage time multiplied by a weighted value "1.09" is calculated. Further, if a type of the edge "e" is transit, edge cost is calculated by adding a constant value corresponding to the kind of transit. Further, cost corresponding to a time required for a demand generation node multiplied by a weighted value "0.1" is calculated.

[0045] As such, each path may have a different traffic volume and thus may have a different edge cost.

[0046] Then, the intelligent train scheduling system 10 searches a shortest path to substitute for the path defined by a pair of origin-destination on the basis of the updated edge cost (S233), and calculates predictive information about a traffic volume of each path depend on a change in path to the shortest path (S234 to S236).

[0047] FIG. 9 is a diagram provided to explain a method of calculating predictive information about a traffic volume in accordance with an exemplary embodiment.

[0048] Firstly, the intelligent train scheduling system 10 supposes that there are four paths in total satisfying respective pairs of origin-destination. For example, a first path Path 1 satisfying B3->A7, a second path Path 2 satisfying A1->C6, a third path Path 3 satisfying C1->A4, and a fourth path Path 4 satisfying B1->D2 are present. In this case, the intelligent train scheduling system 10 may search a shortest path to substitute for an existing path. For example, the intelligent train scheduling system 10 may search a new shortest path New Path to substitute for the fourth path.

[0049] The intelligent train scheduling system 10 calculates an extendable traffic volume of each edge included in the shortest path in order to calculate predictive information about a traffic volume depend on a change in path to the shortest path (S234). To this end, the intelligent train scheduling system 10 subtracts a traffic volume of a path passing through each edge from a maximum traffic volume of the edge and add a traffic volume of a path passing through the edge with a lower priority than the shortest path. This can be defined by the following Equation 3.

[Equation 3]

$$u_{p_i^{sp}} = \min\left\{u_e - x_e + \sum_{q(e):\, q < p} f_q\right\},\ \forall e \in p_i^{sp}$$

[0050] Herein, u_e represents a maximum traffic volume of each edge, and x_e represents a traffic volume of the edge (the sum of traffic volumes of all paths including the edge e). Herein, q(e) < p means that a path q passing through the edge e has a lower priority than a path p. As such, in the present disclosure, a traffic volume is predicted considering a priority between paths.

[0051] **FIG. 10** is a diagram provide to explain the concept of calculation of a traffic volume considering a priority between paths in accordance with an exemplary embodiment.

[0052] In the present disclosure, if paths passing through different lines pass through one line, a priority is given to a path entering the line first. For example, a path p enters a line Line 2 before a path q, and, thus, the path p has a priority.

[0053] Referring to **FIG. 9** again, a prediction of a traffic volume will be described.

[0054] Extendable traffic volumes of the respective edges constituting the new shortest path New Path are as follows. The maximum traffic volumes of the respective edges are equally 10. Further, traffic volumes of the respective edges are calculated on the basis of traffic volumes shown in the drawing.

$$u_{B1\rightarrow B2} = 10 - 3 + 0 = 7,\quad u_{B2\rightarrow B3} = 10 - 3 + 0 = 7$$

$$u_{B3\rightarrow B4} = 10 - 10 + 7 = 7 \quad u_{C3\rightarrow C4} = 10 - 8 + 0 = 2$$

$$u_{C4\rightarrow C5} = 10 - 8 + 0 = 2 \qquad u_{C5\rightarrow C6} = 10 - 9 + 9 = 10$$

$$u_{D1\rightarrow D2} = 10 - 0 + 0 = 10$$

[0055] For example, an extendable traffic volume of B_3->B_4 is obtained by subtracting a traffic volume (3+7) of the corresponding edge from the maximum traffic volume 10 and adding a traffic volume 7 of the first path Path 1 with a lower priority than a new shortest path. Further, an extendable traffic volume of C_5 -> C_6 is obtained by subtracting a traffic volume 9 of the corresponding edge from the maximum traffic volume 10 and adding a traffic volume 9 of the second path Path 2 with a lower priority than a new shortest path.

[0056] From among extendable traffic volumes of respective edges calculated as such, a minimum value is 2. That is, the intelligent train scheduling system 10 considers a minimum value from among extendable traffic volumes of respective edges constituting a new shortest path to calculate a traffic volume increment caused by addition of the shortest path (S235). For example, it can be calculated by Equation 4.

[Equation 4]

$$f_{p_i^*}(n) \Leftarrow f_{p_i^*}(n-1) + \frac{u_{p_i^*}(n)}{n+1}$$

[0057] Herein, n represents a repetition number. During (n-1) times of repetition, a result obtained by dividing the minimum value from among the extendable traffic volumes by the repetition number is added to a traffic volume of pi*.

[0058] Then, the intelligent train scheduling system 10 adjusts a traffic volume of a path defined by a pair of "origin-destination" by subtracting a traffic volume increment of a path with a highest cost first from among paths defined by a pair of "origin-destination" (S236). For example, the intelligent train scheduling system 10 subtracts a traffic volume of the shortest path New Path from the existing path Path 4 having the same "origin-destination".

[0059] Meanwhile, if a traffic volume of one of all edges included in the shortest path exceeds a maximum traffic volume of the edge, the intelligent train scheduling system 10 may further reduce a traffic volume of a path with a highest cost from among paths passing through the corresponding edge until an excess of traffic volume of the corresponding edge reaches 0. For example, when a traffic volume of the second path Path 2 is 9 and a traffic volume of the new shortest path is 2, a traffic volume of $C_5 \rightarrow C_6$ is 11 and thus exceeds the maximum traffic volume 10. Therefore, the intelligent train scheduling system 10 needs to reduce the traffic volume of the edge $C_5 \rightarrow C_6$ by 1. Therefore, in order to correct this, the intelligent train scheduling system 10 may correct the traffic volume of the second path Path 2 to 8.

[0060] Then, the intelligent train scheduling system 10 repeatedly performs a process of updating edge cost until predictive information about a traffic volume converges on a predetermined level, a process of searching a shortest path, and a process of calculating predictive information about a traffic volume. Herein, n is increased by 1 with each repetition.

[0061] For example, the intelligent train scheduling system 10 may conduct a test on convergence using Equation 5.

[Equation 5]

$$g[n] = \frac{\sum_{e \in E} [c_e(x_e[n]) \cdot x_e[n] - c_e(x_e[n-1]) \cdot x_e[n-1]]}{\sum_{e \in E} c_e(x_e[n-1]) \cdot x_e[n-1]}$$

[0062] Herein, if a calculated value is equal to or lower than a threshold value, the intelligent train scheduling system 10 may stop the repetition of the processes.

[0063] Further, a passenger boarding volume and a congestion rate in each section of each train calculated as a result from the timetable-based transit assignment model may be applied to a train schedule previously established by a train schedule planning unit and traffic volumes may be displayed as being highlighted with colors. For example, a section with a high traffic volume and a high congestion rate is displayed in red and a section with a relatively low congestion rate is displayed in green. Accordingly, a train schedule for the section with a high congestion rate is adjusted.

[0064] The exemplary embodiments can be embodied in a storage medium including instruction codes executable by a computer or processor such as a program module executed by the computer or processor. A data structure in accordance with the exemplary embodiments can be stored in the storage medium executable by the computer or processor. A computer-readable medium can be any usable medium which can be accessed by the computer and includes all volatile/non-volatile and removable/non-removable media. Further, the computer-readable medium may include all computer storage and communication media. The computer storage medium includes all volatile/non-volatile and removable/non-removable media embodied by a certain method or technology for storing information such as a computer-readable instruction code, a data structure, a program module or other data. The communication medium typically includes the computer-readable instruction code, the data structure, the program module, or other data of a modulated data signal such as a carrier wave, or other transmission mechanism, and includes information transmission mediums.

[0065] The system and method of the present disclosure has been explained in relation to a specific embodiment, but its components or a part or all of its operations can be embodied by using a computer system having general-purpose hardware architecture.

[0066] The above description of the present disclosure is provided for the purpose of illustration, and it would be understood by those skilled in the art that various changes and modifications may be made without changing technical conception and essential features of the present disclosure. Thus, it is clear that the above-described embodiments are illustrative in all aspects and do not limit the present disclosure. For example, each component described to be of a single type can be implemented in a distributed manner. Likewise, components described to be distributed can be implemented in a combined manner.

[0067] The scope of the present disclosure is defined by the following claims rather than by the detailed description of the embodiment. It shall be understood that all modifications and embodiments conceived from the meaning and scope of the claims and their equivalents are included in the scope of the present disclosure.

Claims

1. A train scheduling method of an intelligent train scheduling system, comprising:

obtaining train schedule information which includes train line information and information about operation time of each train;
generating a time extension network which includes stations, as nodes, at which the trains included in the train schedule information stop, lines, as edges, between the stations included in the train schedule information, and operation time information of each train included in the train schedule information; and
calculating predictive information about a traffic volume in each section and a traffic volume of each train for the train schedule on the basis of the time extension network.

2. The train scheduling method of Claim 1, further comprising:

displaying the predictive information about a traffic volume on a user interface that displays the train schedule information after the calculating of predictive information about a traffic volume of each train,
wherein a section with a relatively high traffic volume is displayed as being highlighted.

3. The train scheduling method of Claim 1,
wherein the time extension network includes a time extension node group classified into a station arrival node, a station departure node, a demand generation node, or a demand end node and a time extension edge group classified into an inter-station movement edge, a stop edge, a transit edge, a demand generation edge, or a demand end edge.

4. The train scheduling method of Claim 1,
wherein the calculating of predictive information about a traffic volume includes:

initialing traffic allocation to set the amount of demand for a path defined by a pair of origin-destination as a traffic volume of each path;
updating edge cost on the basis of a type of each edge constituting the path and a traffic volume;
searching a shortest path to substitute for the path defined by a pair of origin-destination on the basis of the

updated edge cost; and
calculating predictive information about a traffic volume of each path depend on a change in path to the shortest path.

5. The train scheduling method of Claim 1,
wherein the initialing traffic allocation includes setting demand generation nodes on the basis of traffic record data of statistically collected users and setting a time interval between the demand generation nodes and the amount of demand generated.

6. The train scheduling method of Claim 4,
wherein the calculating of predictive information about a traffic volume of each path depend on a change in path to the shortest path includes:

calculating extendable traffic volumes of respective edges included in the shortest path;
calculating a traffic volume increment caused by the change in path to the shortest path from a minimum value from among the extendable traffic volumes; and
adjusting a traffic volume of the path defined by a pair of origin-destination by subtracting the traffic volume increment of a path with a highest cost first from among the paths defined by a pair of origin-destination.

7. The train scheduling method of Claim 6,
wherein the calculating of extendable traffic volumes includes subtracting a traffic volume of a path passing through each edge from a e traffic volume of the edge and adding a traffic volume of a path passing through the edge with a lower priority than the shortest path.

8. The train scheduling method of Claim 7,
wherein the path with a lower priority is a path entering the path passing through the edge after the shortest path.

9. The train scheduling method of Claim 6, further comprising:

if a traffic volume of one of all edges included in the shortest path exceeds a maximum traffic volume of the edge, reducing a traffic volume of a path with a highest cost from among paths passing through the edge until an excess of traffic volume of the edge reaches 0.

10. The train scheduling method of Claim 4, further comprising:

repeatedly updating the edge cost until the predictive information about a traffic volume converges on a predetermined level, searching the shortest path, and calculating the predictive information about a traffic volume after the calculating of predictive information about a traffic volume of each train.

11. A computer-readable storage medium that records a program for performing each process of a method of any one of Claim 1 to claim 10 on a computer.

FIG. 1

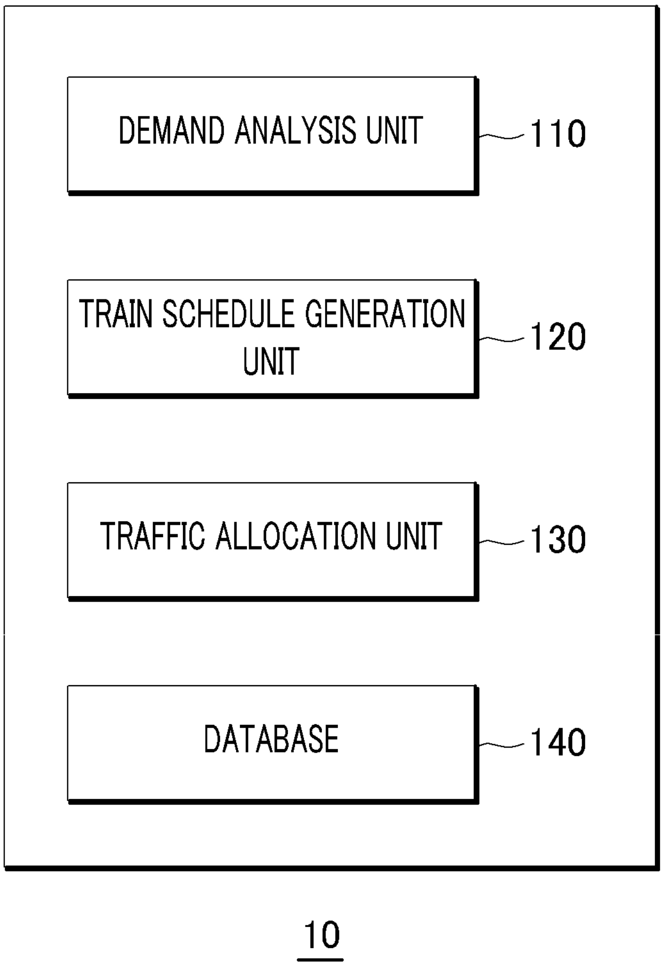

DEMAND ANALYSIS UNIT
110
TRAIN SCHEDULE GENERATION UNIT
120
TRAFFIC ALLOCATION UNIT
130
DATABASE
140
10

FIG. 2

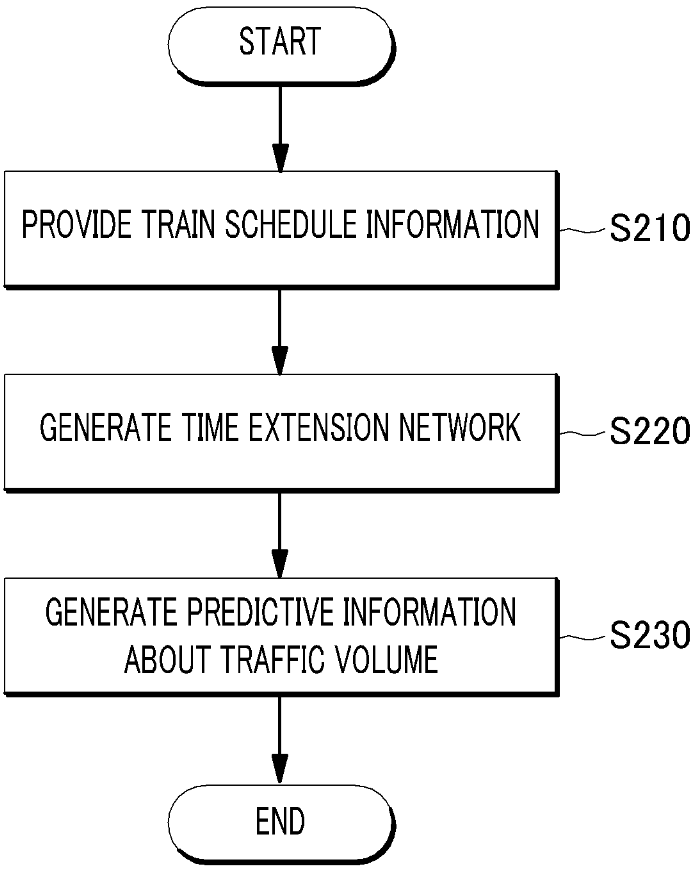

START
PROVIDE TRAIN SCHEDULE INFORMATION
S210
GENERATE TIME EXTENSION NETWORK
S220
GENERATE PREDICTIVE INFORMATION ABOUT TRAFFIC VOLUME
S230
END

FIG. 3

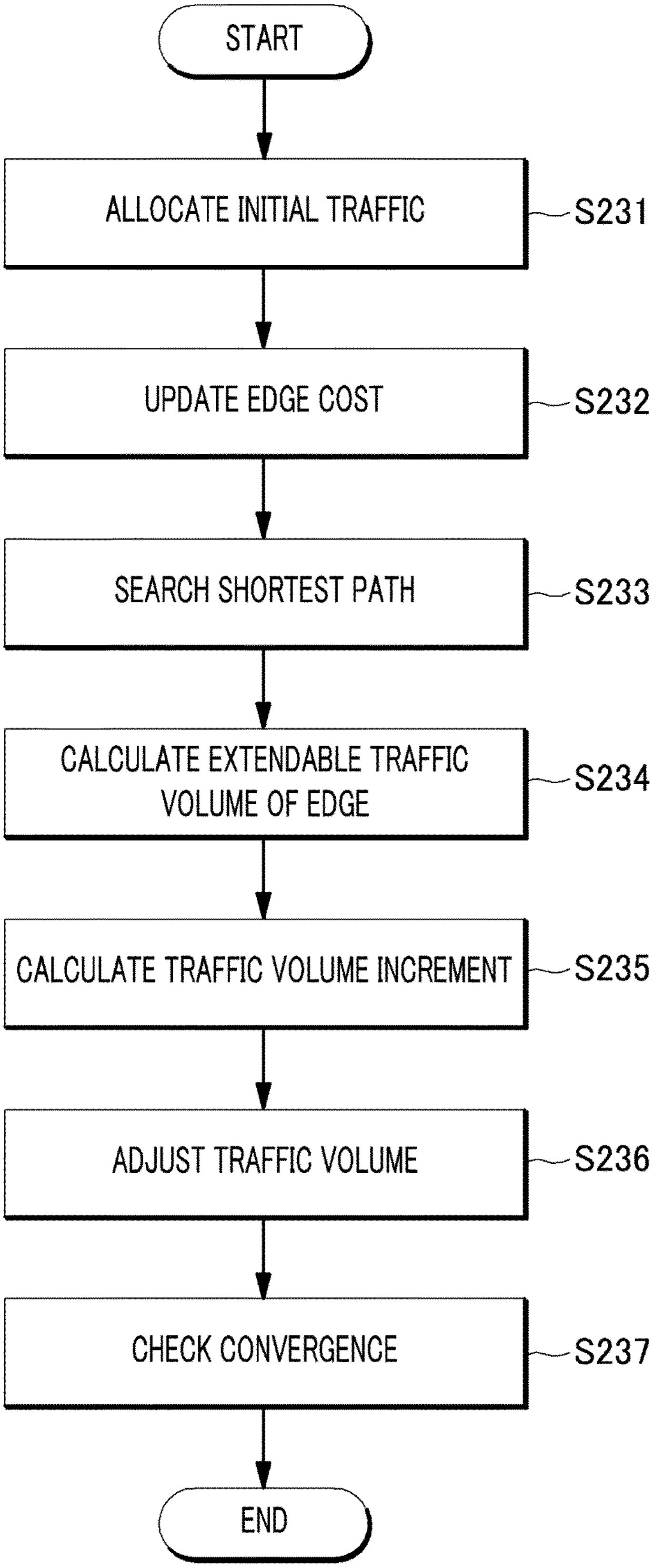
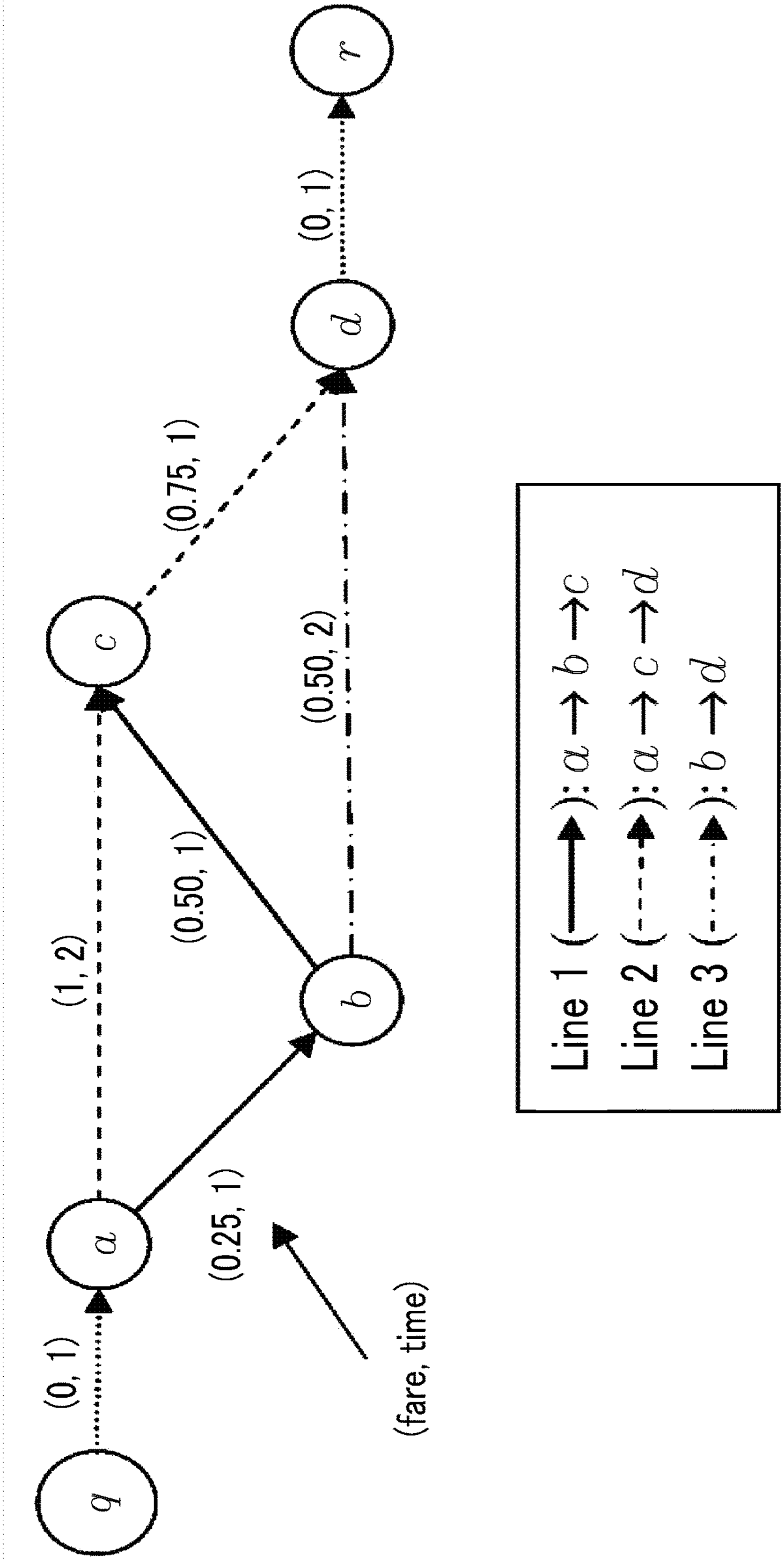
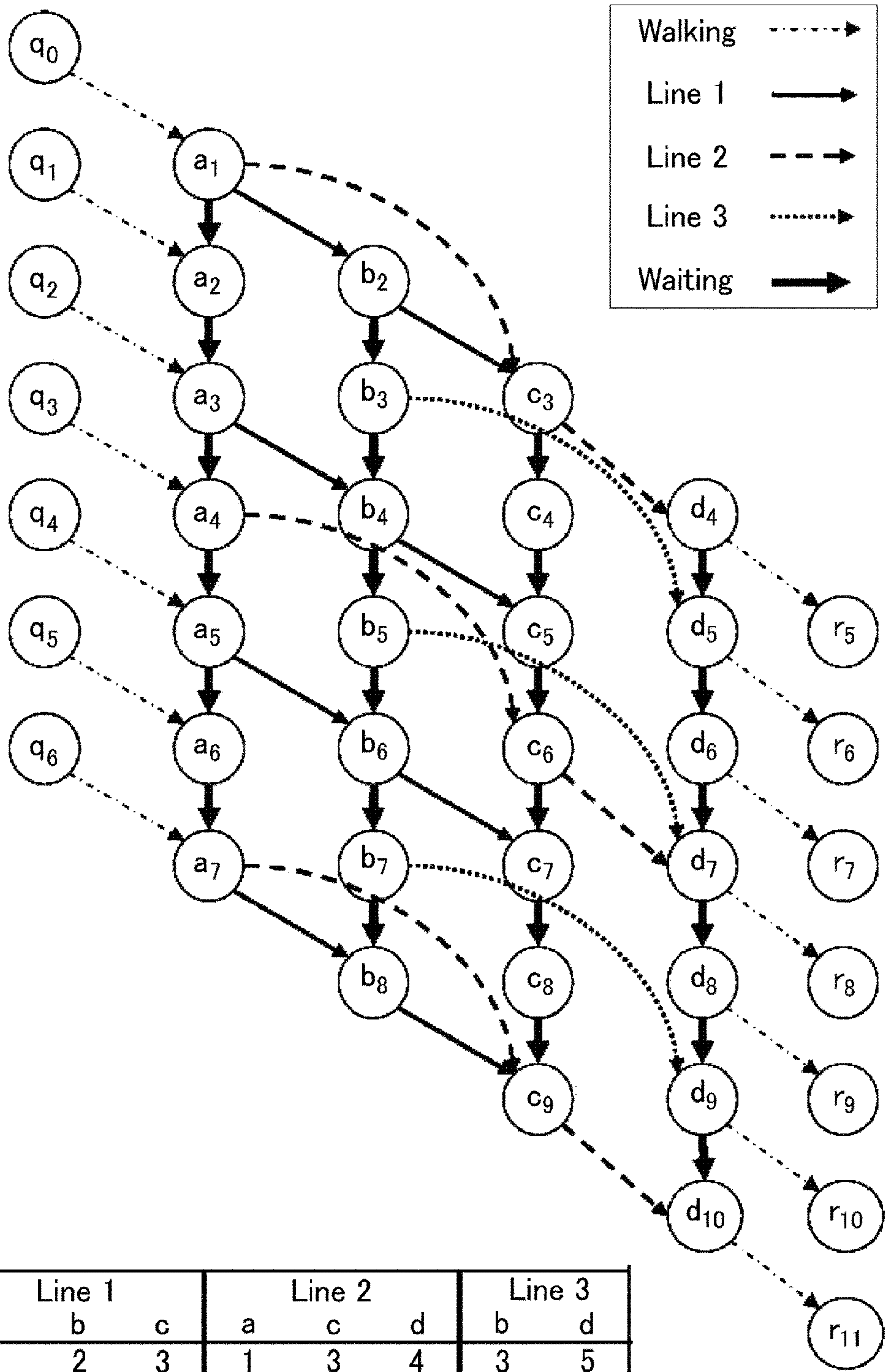

START
ALLOCATE INITIAL TRAFFIC
S231
UPDATE EDGE COST
S232
SEARCH SHORTEST PATH
S233
CALCULATE EXTENDABLE TRAFFIC VOLUME OF EDGE
S234
CALCULATE TRAFFIC VOLUME INCREMENT
S235
ADJUST TRAFFIC VOLUME
S236
CHECK CONVERGENCE
S237
END

FIG. 4



q
a
b
c
d
r
(0, 1)
(1, 2)
(0.25, 1)
(0.50, 1)
(0.50, 2)
(0.75, 1)
(0, 1)
(fare, time)
Line 1 ( ): $a \rightarrow b \rightarrow c$
Line 2 ( ): $a \rightarrow c \rightarrow d$
Line 3 ( ): $b \rightarrow d$

FIG. 5



Line 1			Line 2			Line 3	
a	b	c	a	c	d	b	d
1	2	3	1	3	4	3	5
3	4	5	4	6	7	5	7
5	6	7	7	8	10	7	9
7	8	9					

FIG. 6

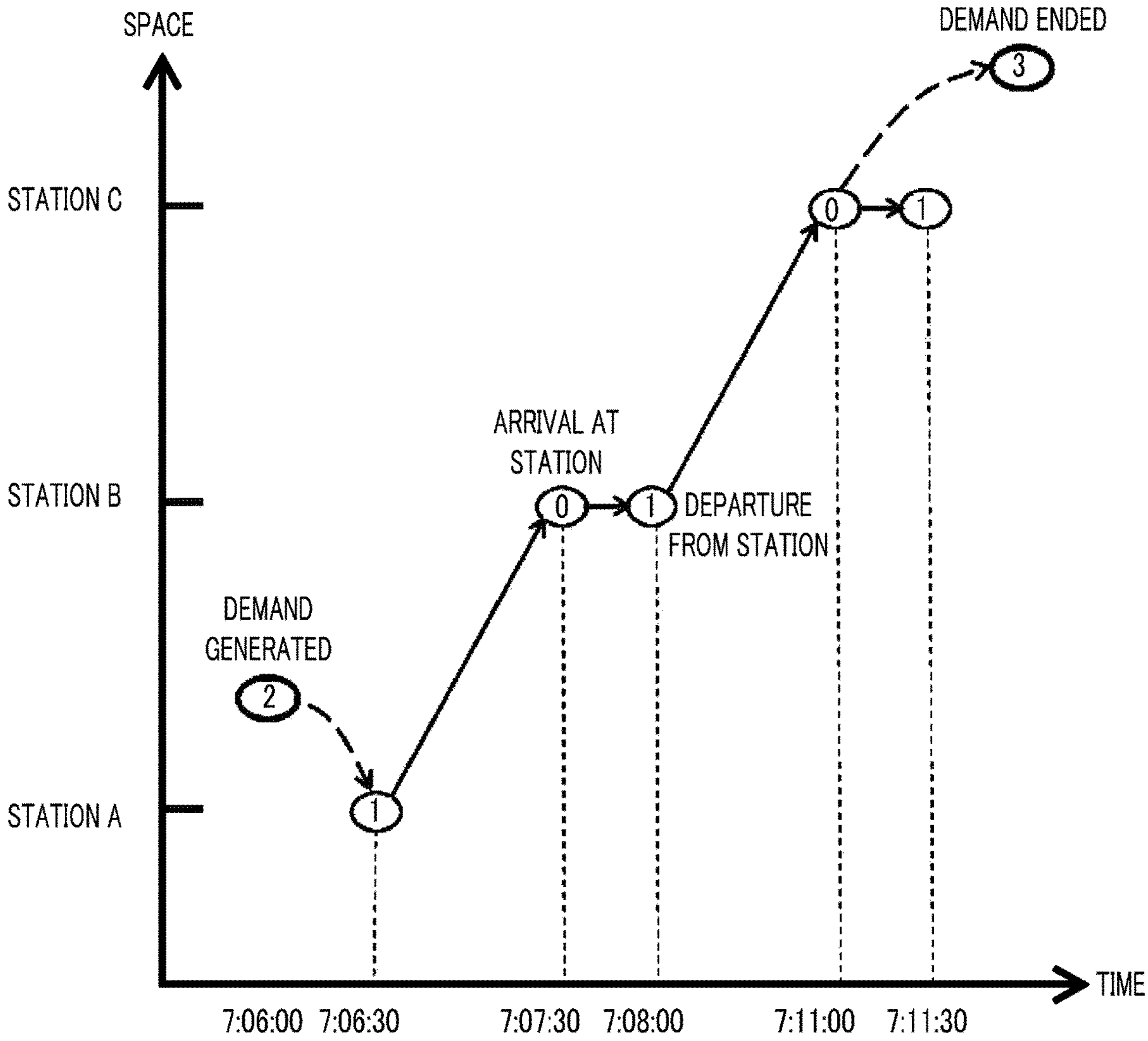

SPACE
DEMAND ENDED
3
STATION C
0
1
ARRIVAL AT STATION
STATION B
0
1
DEPARTURE FROM STATION
DEMAND GENERATED
2
STATION A
1
TIME
7:06:00
7:06:30
7:07:30
7:08:00
7:11:00
7:11:30

FIG. 7

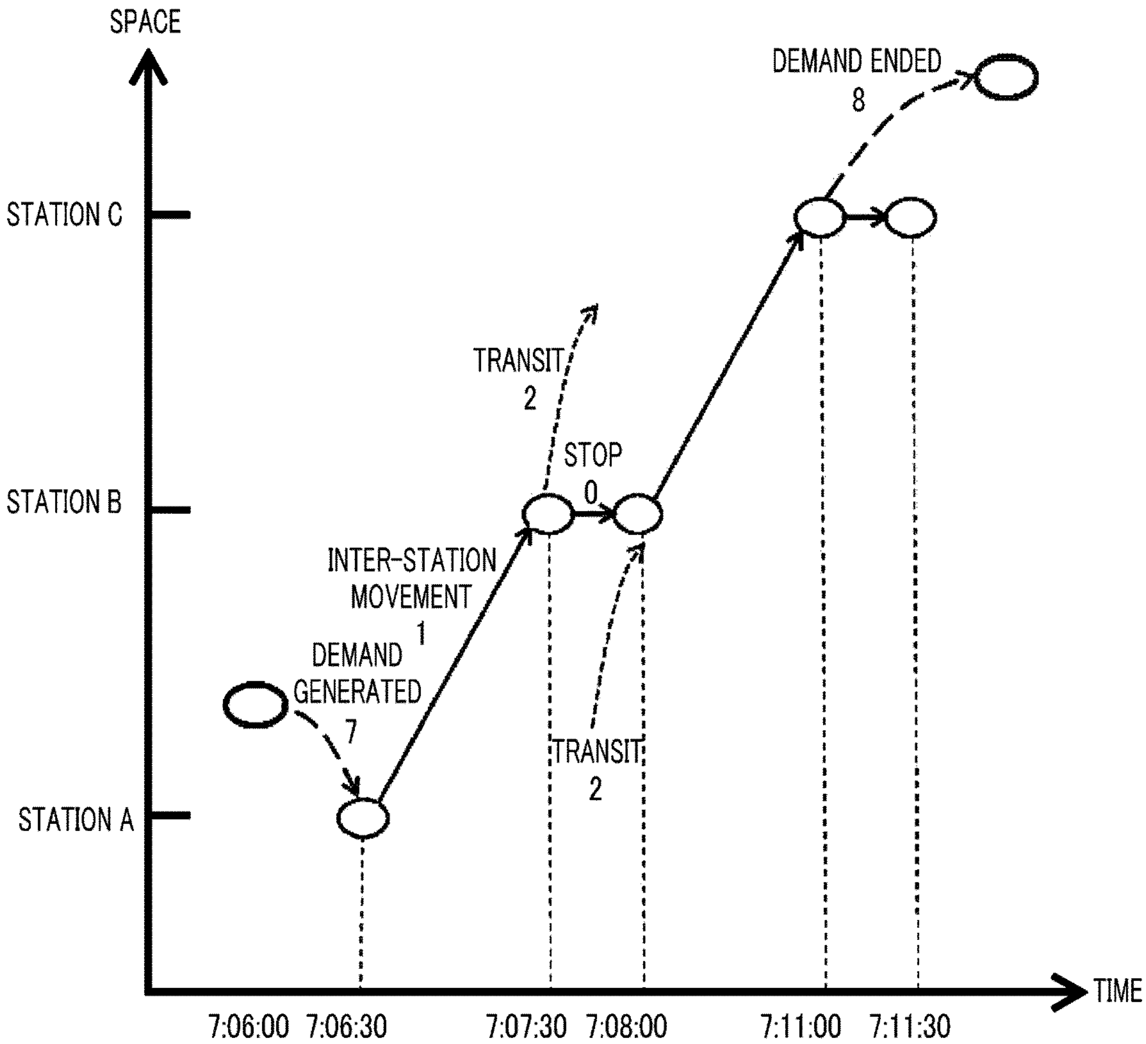

SPACE
STATION C
STATION B
STATION A
DEMAND ENDED
8
TRANSIT
2
STOP
0
INTER-STATION
MOVEMENT
1
DEMAND
GENERATED
7
TRANSIT
2
TIME
7:06:00
7:06:30
7:07:30
7:08:00
7:11:00
7:11:30

FIG. 8

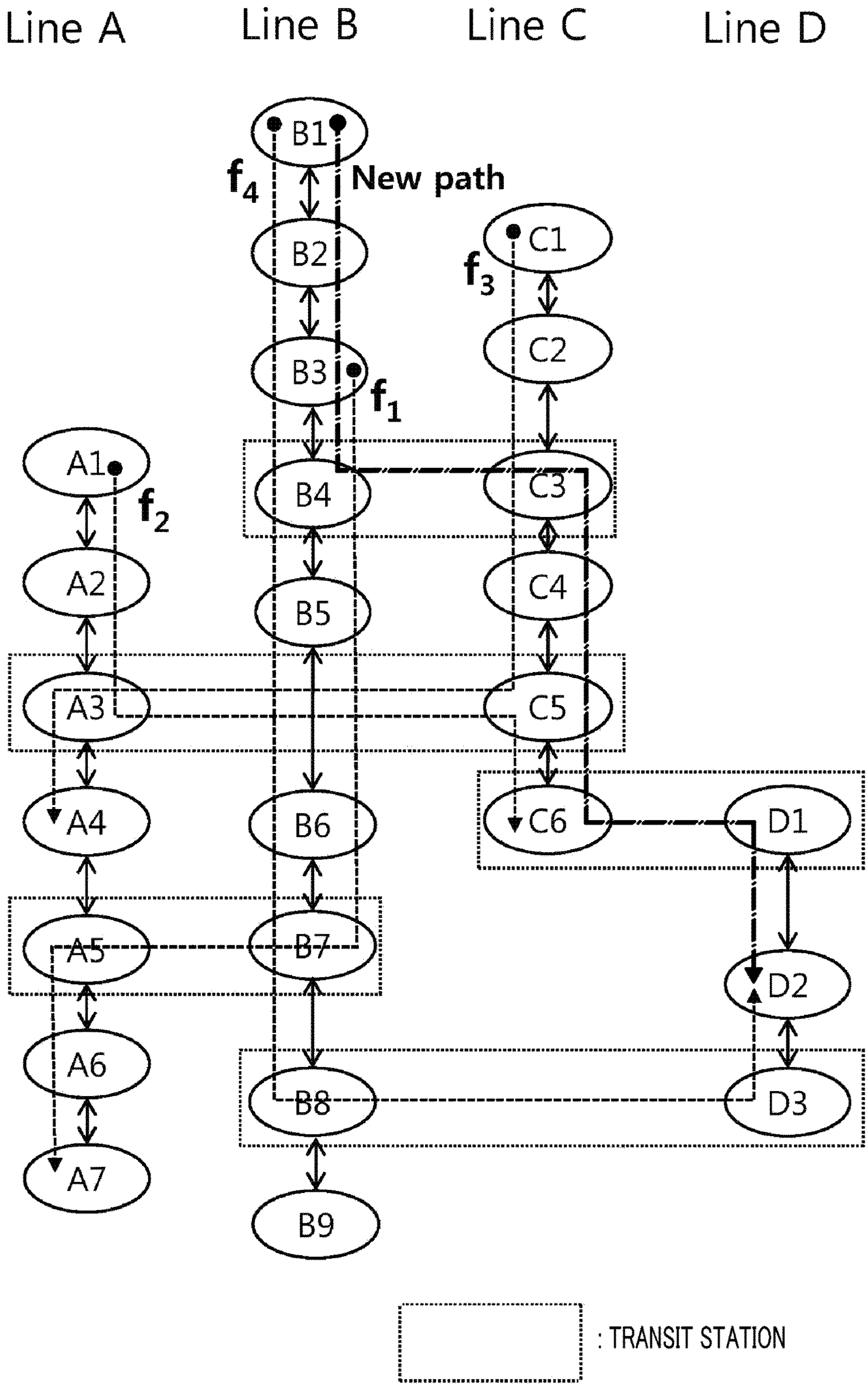

Line A
Line B
Line C
Line D
B1
f4
New path
B2
C1
f3
B3
C2
f1
A1
B4
C3
f2
A2
B5
C4
A3
C5
A4
B6
C6
D1
A5
B7
D2
A6
B8
D3
A7
B9
: TRANSIT STATION

FIG. 9

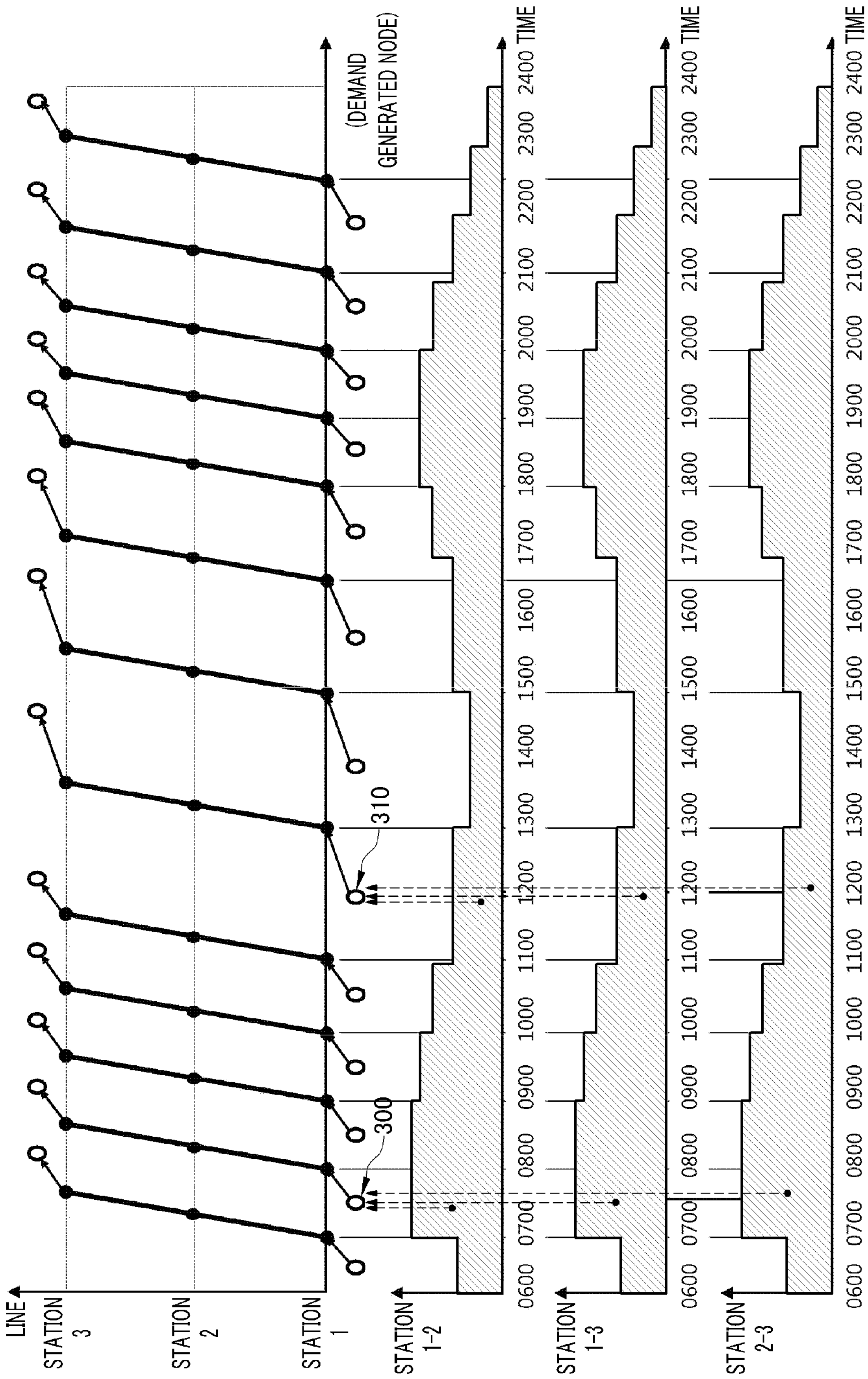
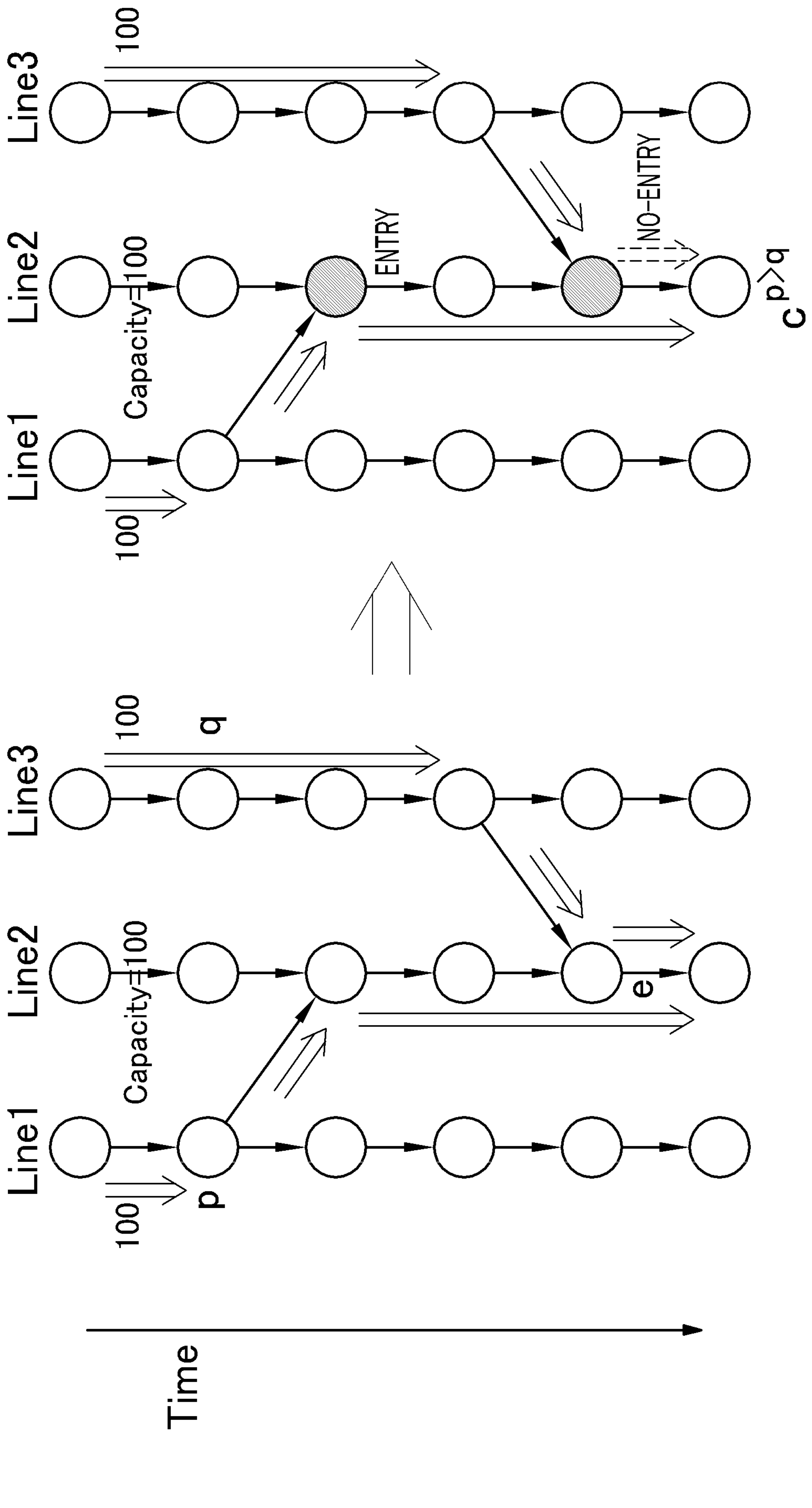

LINE
STATION 3
STATION 2
STATION 1
STATION 1-2
STATION 1-3
STATION 2-3
(DEMAND GENERATED NODE)
300
310
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
TIME

FIG. 10


Line1
Line2
Line3
100
Capacity=100
100
p
q
e
Line1
Line2
Line3
100
Capacity=100
100
ENTRY
NO-ENTRY
c p>q
Time

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2015/001860

A. CLASSIFICATION OF SUBJECT MATTER

B61L 25/00(2006.01)i, G06Q 50/30(2012.01)i, G06F 19/00(2011.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B61L 25/00; B61L 23/18; B61L 25/06; B61L 25/02; G06F 17/60; B61L 27/00; G07B 15/00; B60L 13/06; G06Q 50/30; G06F 19/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models: IPC as above
Japanese Utility models and applications for Utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS (KIPO internal) & Keywords: schedule, SCHEDULE, train pass, route, node, network, station, arrival, departure, stop, transfer, new path, demand occurrence, transfer volume, path.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	KR 10-2012-0021872 A (KRRI) 09 March 2012 Claims 1-4 and figures 3-4	1-3,11 4,6-10
Y A	JP 2005-346324 A (SHARP CORP.) 15 December 2005 The detailed description of the invention paragraphs [0118]-[0119] and figure 6	1-3,11 4,6-10
A	JP 2002-193103 A (NIPPON SIGNAL CO., LTD.:THE) 10 July 2002 Claims 1-3 and figure 1	1-4,6-11
A	KR 10-2010-0127518 A (POSCO) 06 December 2010 Claims 1-3 and figure 3	1-4,6-11

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 MAY 2015 (19.05.2015)	**21 MAY 2015 (21.05.2015)**

Name and mailing address of the ISA/**KR**	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon, 189 Seonsa-ro, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2015/001860

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: **5**
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claim 5 includes the wording "said initial traffic assignment step", which is a constituent element not appearing in the claims prior to claim 5 and claim 1 to which claim 5 refers, and thus it is unclear as to which feature said wording indicates, and it is difficult to clearly specify how the initial traffic assignment step is combined with constituent elements set forth in claim 1.

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2015/001860

Patent document cited in search report	Publication date	Patent family member	Publication date
KR 10-2012-0021872 A	09/03/2012	NONE	
JP 2005-346324 A	15/12/2005	NONE	
JP 2002-193103 A	10/07/2002	NONE	
KR 10-2010-0127518 A	06/12/2010	NONE	

Form PCT/ISA/210 (patent family annex) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- KR 1020120129344 **[0005]**