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(54) Title of the Invention: **Information processing device, information processing method, information processing system, and computer program**
Abstract Title: **Generating a delay time of a departure or arrival event in a train timetable from delays to two preceding events and a scheduled inter-event time**

(57) A plurality of events includes a vehicle departure or arrival at a plurality of stop positions and corresponding times, e.g. events in a railway timetable (Fig.2-3). A second and third event precede a first event in the plurality of events. A delay to an inter-event time between the first and second events is generated based on a delay time of the third event. A delay time of the first event is then generated (Step D, Fig.8) using the inter-event delay time and delay time of the second event. Variation information representing a variation of said inter-event time may be calculated from the second or third event delay time. The variation information may represent a variation in the number of people boarding the vehicle. It may be calculated based on information relating to a connection event or to the first event, e.g. its stop position; weather information or status of a large-scale event at that time; passengers boarding, alighting or doing neither; images captured by a camera on a platform, ticket gate or inside a train.

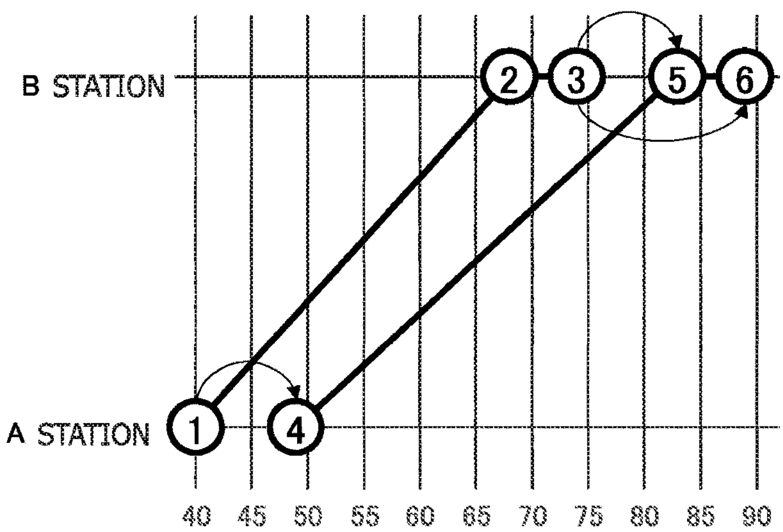


FIG. 11

GB 2615617 A

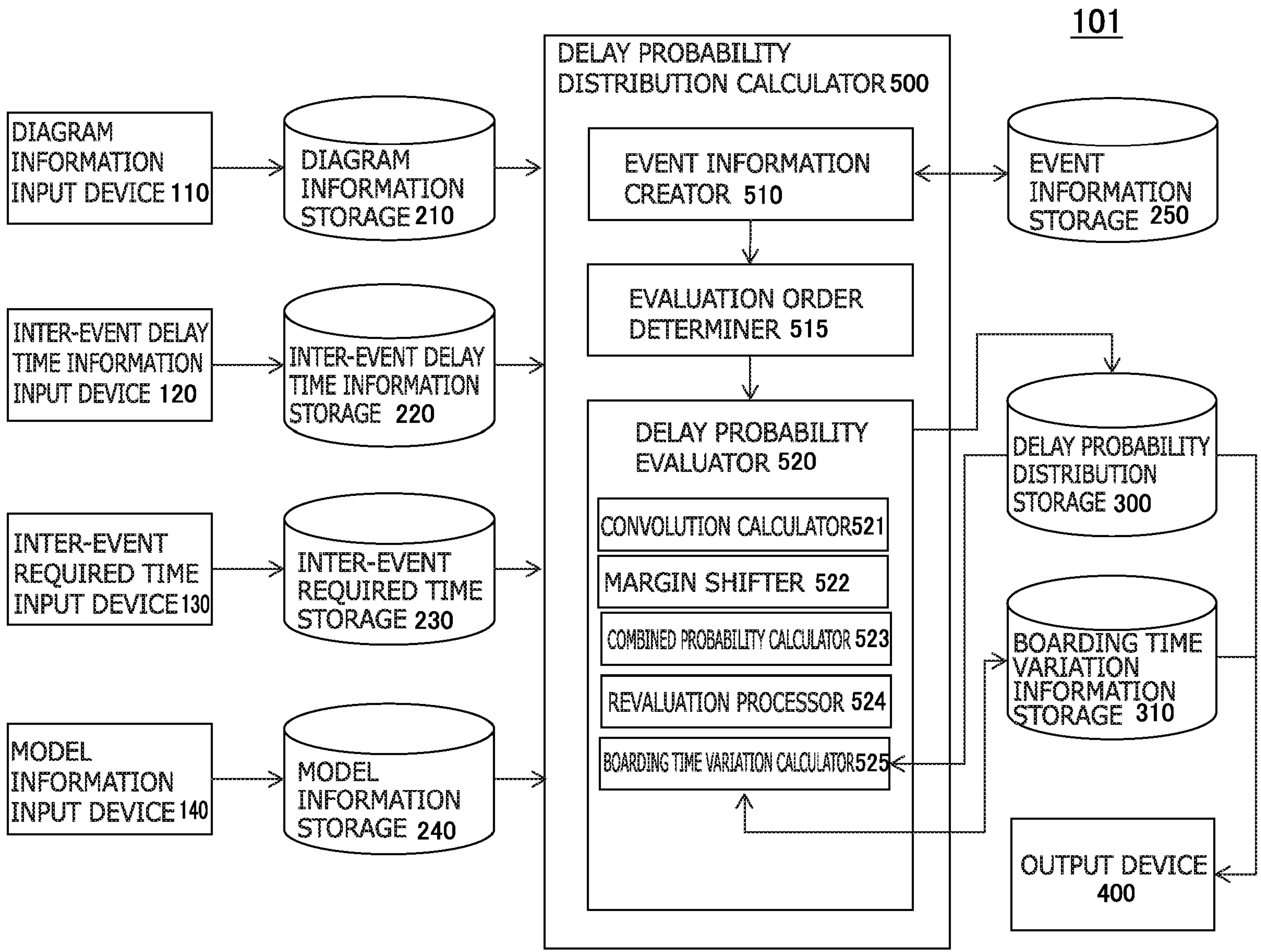

101
DIAGRAM INFORMATION INPUT DEVICE 110
INTER-EVENT DELAY TIME INFORMATION INPUT DEVICE 120
INTER-EVENT REQUIRED TIME INPUT DEVICE 130
MODEL INFORMATION INPUT DEVICE 140
DIAGRAM INFORMATION STORAGE 210
INTER-EVENT DELAY TIME INFORMATION STORAGE 220
INTER-EVENT REQUIRED TIME STORAGE 230
MODEL INFORMATION STORAGE 240
DELAY PROBABILITY DISTRIBUTION CALCULATOR 500
EVENT INFORMATION CREATOR 510
EVALUATION ORDER DETERMINER 515
DELAY PROBABILITY EVALUATOR 520
CONVOLUTION CALCULATOR521
MARGIN SHIFTER 522
COMBINED PROBABILITY CALCULATOR 523
REVALUATION PROCESSOR 524
BOARDING TIME VARIATION CALCULATOR525
EVENT INFORMATION STORAGE 250
DELAY PROBABILITY DISTRIBUTION STORAGE 300
BOARDING TIME VARIATION INFORMATION STORAGE 310
OUTPUT DEVICE 400

FIG. 1

EVENT IDENTIFIER	TRIP IDENTIFIER	FIXED TIME	LOCATION	TYPE
1	1	40	A STATION	DEPARTURE
2	1	68	B STATION	ARRIVAL
3	1	74	B STATION	DEPARTURE
4	2	50	A STATION	DEPARTURE
5	2	83	B STATION	ARRIVAL
6	2	89	B STATION	ARRIVAL

FIG. 2A

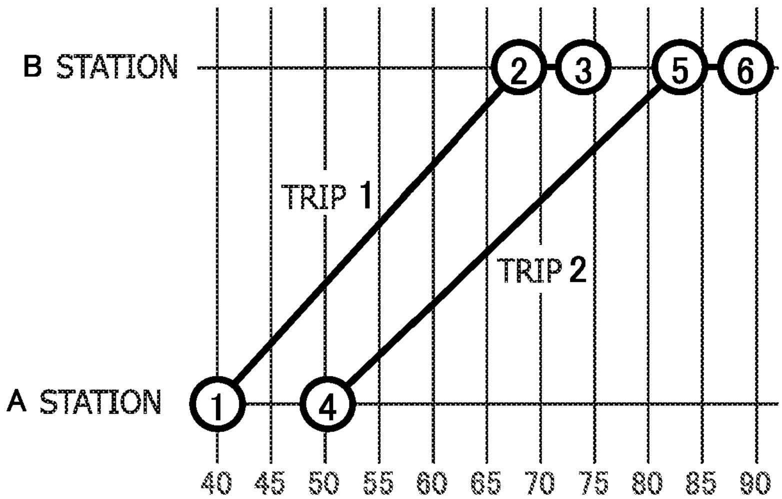


FIG. 2B

IDENTIFIER OF TARGET EVENT	IDENTIFIER OF PRECEDING EVENT	EXPECTED VALUE OF DELAY TIME
1	–	0
2	1	0
3	2	1
4	1	0
5	3	0
5	4	30
6	3	0
6	5	1

FIG. 3

IDENTIFIER OF TARGET EVENT	IDENTIFIER OF PRECEDING EVENT	INTER-EVENT REQUIRED TIME
1	–	–
2	1	27
3	2	6
4	1	0
5	3	9
5	4	32
6	3	5
6	5	5

FIG. 4

IDENTIFIER OF TARGET EVENT	IDENTIFIER OF PRECEDING EVENT	REQUIRED TIME	EXTRA TIME	DIFFERENCE BETWEEN FIXED TIMES
1	–	–	–	–
2	1	27	1	28
3	2	6	0	6
4	1	0	10	10
5	3	9	0	9
5	4	32	1	33
6	3	5	10	15
6	5	5	1	6

FIG. 5

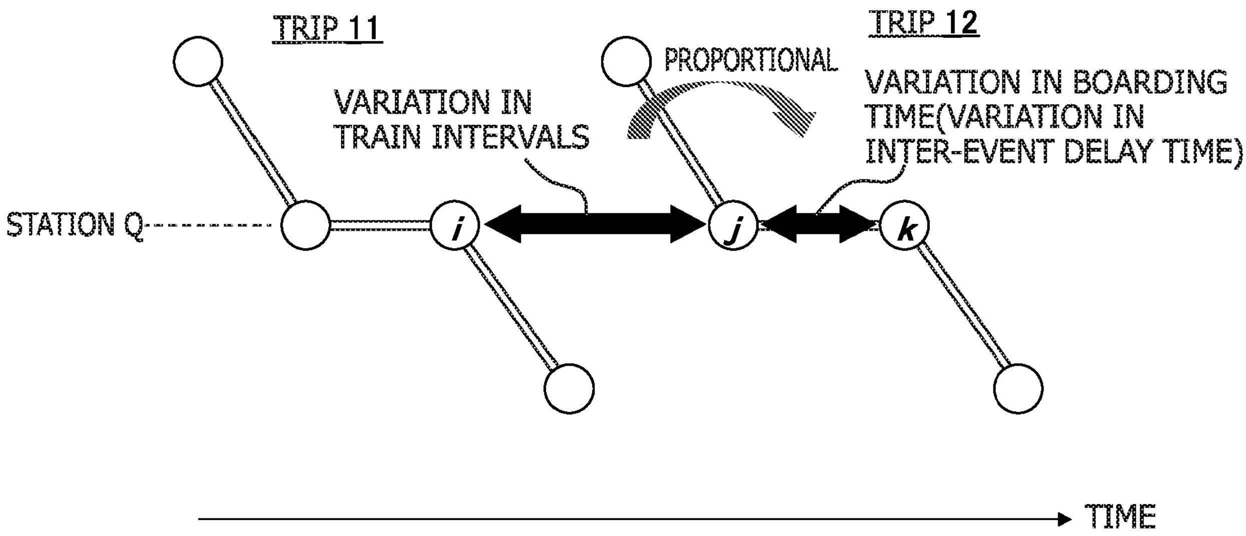

TRIP 11
TRIP 12
PROPORTIONAL
VARIATION IN TRAIN INTERVALS
VARIATION IN BOARDING TIME(VARIATION IN INTER-EVENT DELAY TIME)
STATION Q
i
j
k
TIME

FIG. 6

IDENTIFIER OF TARGET DEPARTURE EVENT	IDENTIFIER OF PRECEDING ARRIVAL EVENT	BOARDING TIME PROPORTIONALITY COEFFICIENT
1	–	–
2	–	–
3	2	–
4	–	–
5	–	–
6	5	0.5

FIG. 7

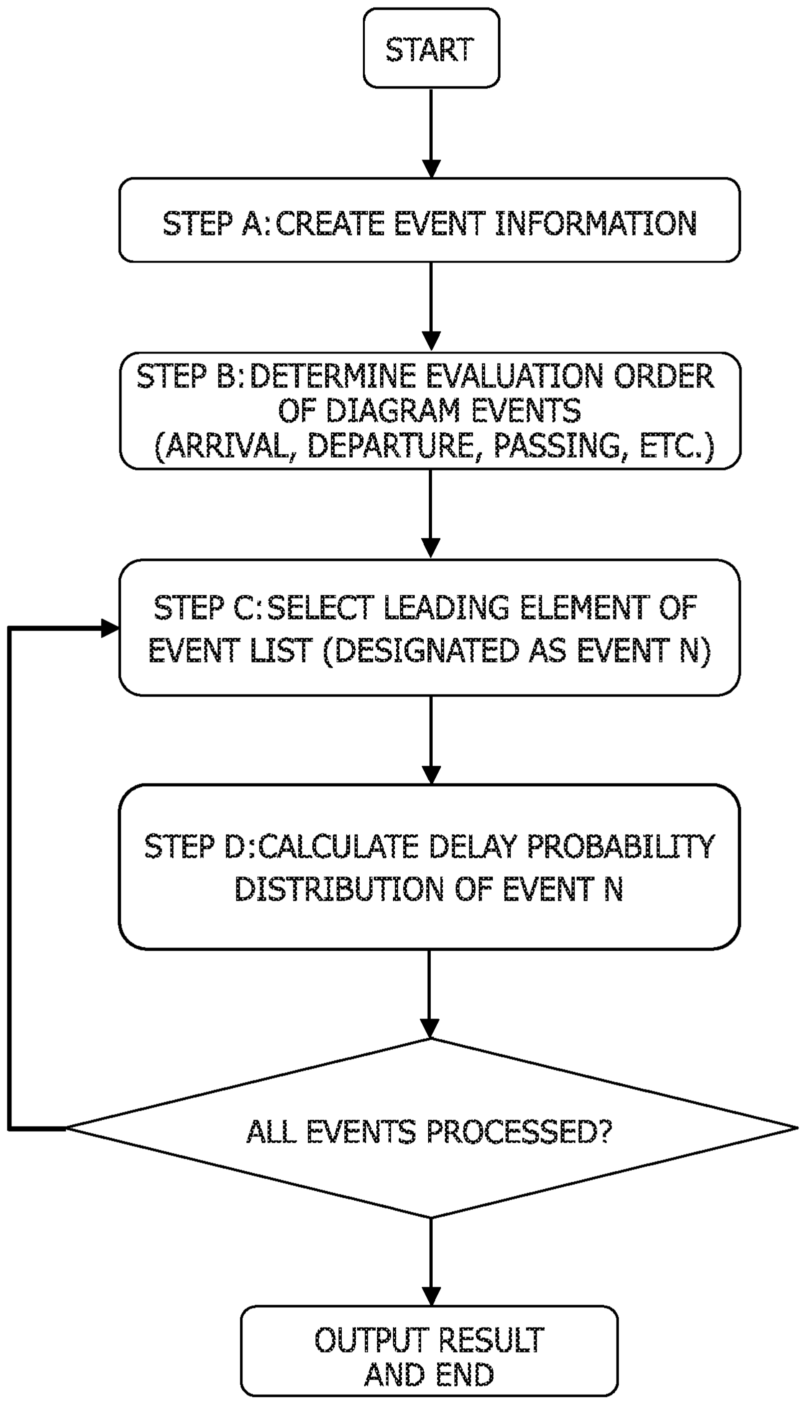

START
STEP A: CREATE EVENT INFORMATION
STEP B: DETERMINE EVALUATION ORDER OF DIAGRAM EVENTS (ARRIVAL, DEPARTURE, PASSING, ETC.)
STEP C: SELECT LEADING ELEMENT OF EVENT LIST (DESIGNATED AS EVENT N)
STEP D: CALCULATE DELAY PROBABILITY DISTRIBUTION OF EVENT N
ALL EVENTS PROCESSED?
OUTPUT RESULT AND END

FIG. 8

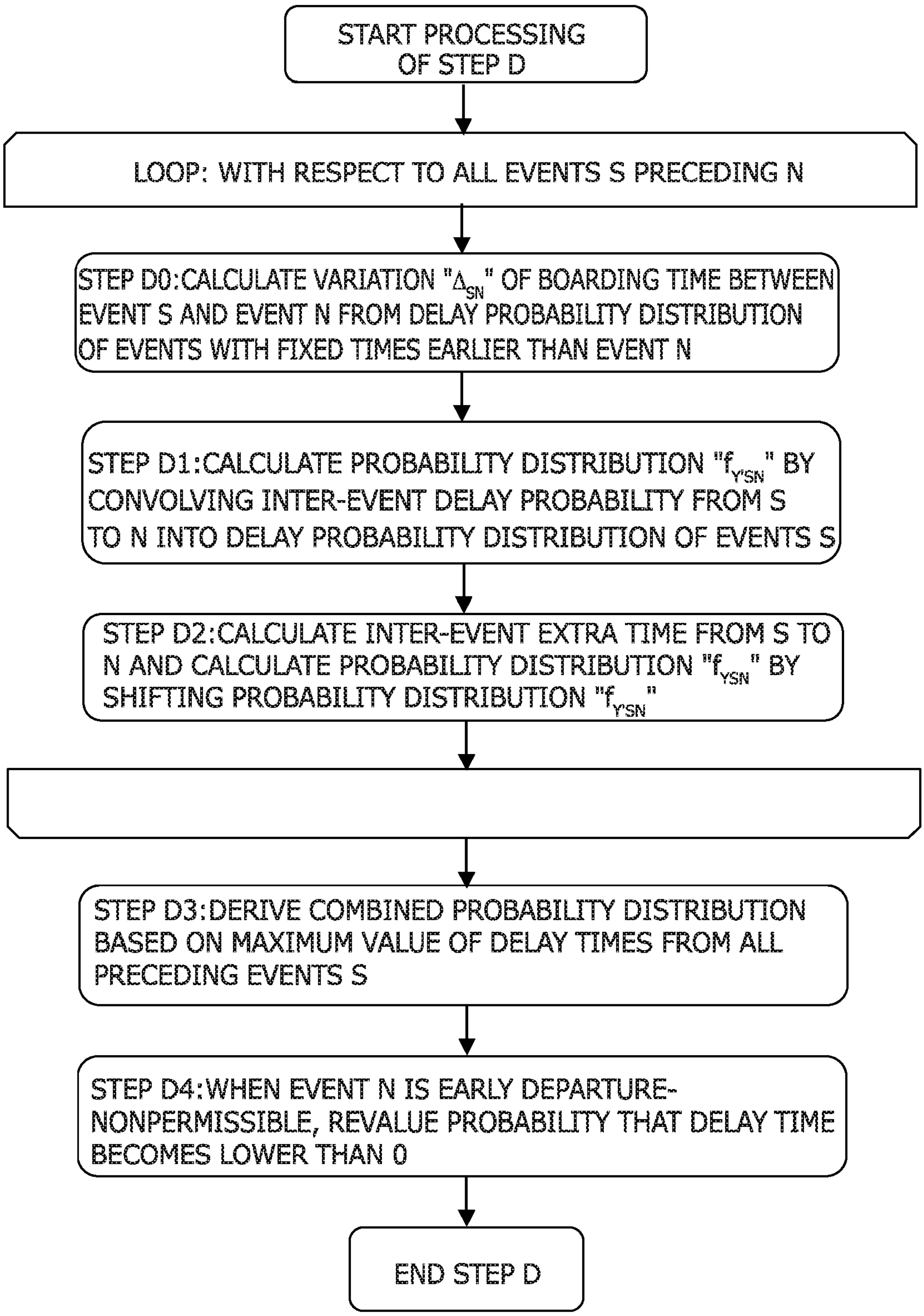

START PROCESSING OF STEP D
LOOP: WITH RESPECT TO ALL EVENTS S PRECEDING N
STEP D0:CALCULATE VARIATION "Δ_{SN}" OF BOARDING TIME BETWEEN EVENT S AND EVENT N FROM DELAY PROBABILITY DISTRIBUTION OF EVENTS WITH FIXED TIMES EARLIER THAN EVENT N
STEP D1:CALCULATE PROBABILITY DISTRIBUTION "$f_{Y'SN}$" BY CONVOLVING INTER-EVENT DELAY PROBABILITY FROM S TO N INTO DELAY PROBABILITY DISTRIBUTION OF EVENTS S
STEP D2:CALCULATE INTER-EVENT EXTRA TIME FROM S TO N AND CALCULATE PROBABILITY DISTRIBUTION "f_{YSN}" BY SHIFTING PROBABILITY DISTRIBUTION "$f_{Y'SN}$"
STEP D3:DERIVE COMBINED PROBABILITY DISTRIBUTION BASED ON MAXIMUM VALUE OF DELAY TIMES FROM ALL PRECEDING EVENTS S
STEP D4:WHEN EVENT N IS EARLY DEPARTURE-NONPERMISSIBLE, REVALUE PROBABILITY THAT DELAY TIME BECOMES LOWER THAN 0
END STEP D

FIG. 9

IDENTIFIER	EARLY DEPARTURE	IDENTIFIER OF PRECEDING EVENT 1	DELAY TIME EXPECTED VALUE 1	EXTRA TIME 1	BOARDING TIME PROPORTIONALITY COEFFICIENT 1	IDENTIFIER OF PRECEDING EVENT 2	DELAY TIME EXPECTED VALUE 2	EXTRA TIME 2	BOARDING TIME PROPORTIONALITY COEFFICIENT 2
1	NONPERMISSIBLE	–	–	–	–	–	–	–	–
2	PERMISSIBLE	1	0	1	–	–	–	–	–
3	NONPERMISSIBLE	2	1	0	–	–	–	–	–
4	NONPERMISSIBLE	1	0	10	–	–	–	–	–
5	PERMISSIBLE	3	0	0	–	4	30	1	–
6	NONPERMISSIBLE	3	0	10	–	5	1	1	0.5

FIG. 10

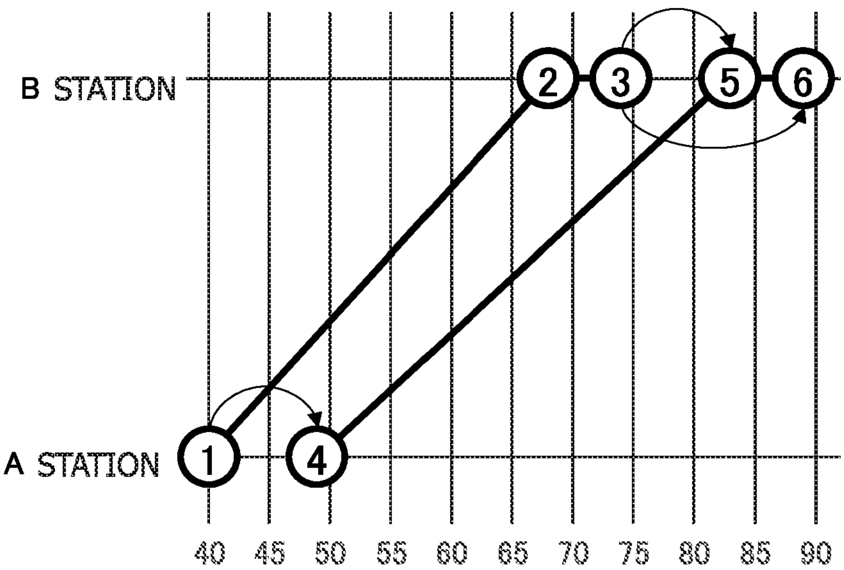


FIG. 11

(A)

	-1 MINUTE	0 MINUTE	1 MINUTE	2 MINUTE
DELAY PROBABILITY DISTRIBUTION THROUGH PRECEDING EVENT 1 (E.G., DELAY FROM PRECEDING TRIP)	40%	30%	20%	10%
DELAY PROBABILITY DISTRIBUTION THROUGH PRECEDING EVENT 2 (E.G., DELAY FROM PRECEDING STATION OF OWN TRIP)	50%	40%	10%	0%

(B)

UPPER PART: DELAY TIME (MINUTES) LOWER PART: DELAY PROBABILITY		PRECEDING EVENT 1			
		−1 40%	0 30%	1 20%	2 10%
PRECEDING EVENT 2	−1 50%	−1 20%	0 15%	1 10%	2 5%
	0 40%	0 16%	0 12%	1 8%	2 4%
	1 10%	1 4%	1 3%	1 2%	2 1%
	2 0%	2 0%	2 0%	2 0%	2 0%

(C)

	-1 MINUTE	0 MINUTE	1 MINUTE	2 MINUTE
COMBINED PROBABILITY DISTRIBUTION	20%	43%	27%	10%

FIG. 12

IDENTIFIER OF TARGET EVENT	IDENTIFIER OF PRECEDING ARRIVAL EVENT	EXPECTED VALUE OF VARIATION IN BOARDING TIME
1	–	–
2	–	–
3	2	–
4	–	–
5	–	–
6	5	14.18904

FIG. 13

DELAY TIME/ IDENTIFIER OF EVENT	⋯	−1	0	1	2	3	4	5	⋯
1	⋯	0	1	0	0	0	0	0	⋯
2	⋯	0.296	0.148	0.066	0.027	0.011	0.004	0.002	⋯
3	⋯	0	0.680	0.146	0.085	0.046	0.023	0.011	⋯
4	⋯	0	1	0	0	0	0	0	⋯
5	⋯	0	0.014	0.013	0.016	0.018	0.019	0.020	⋯
6	⋯	0	0	0.001	0.001	0.002	0.002	0.003	⋯

FIG. 14

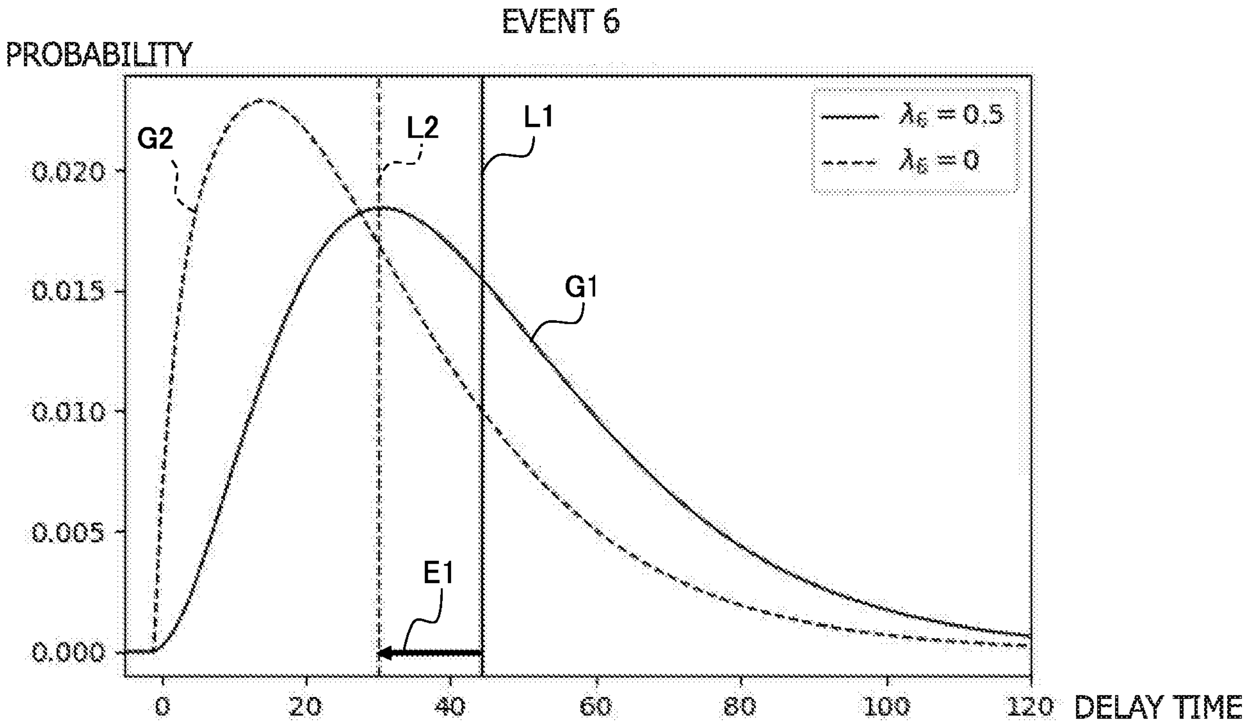

EVENT 6
PROBABILITY
G2
L2
L1
G1
E1
$\lambda_6 = 0.5$
$\lambda_6 = 0$
0.020
0.015
0.010
0.005
0.000
0
20
40
60
80
100
120
DELAY TIME

FIG. 15

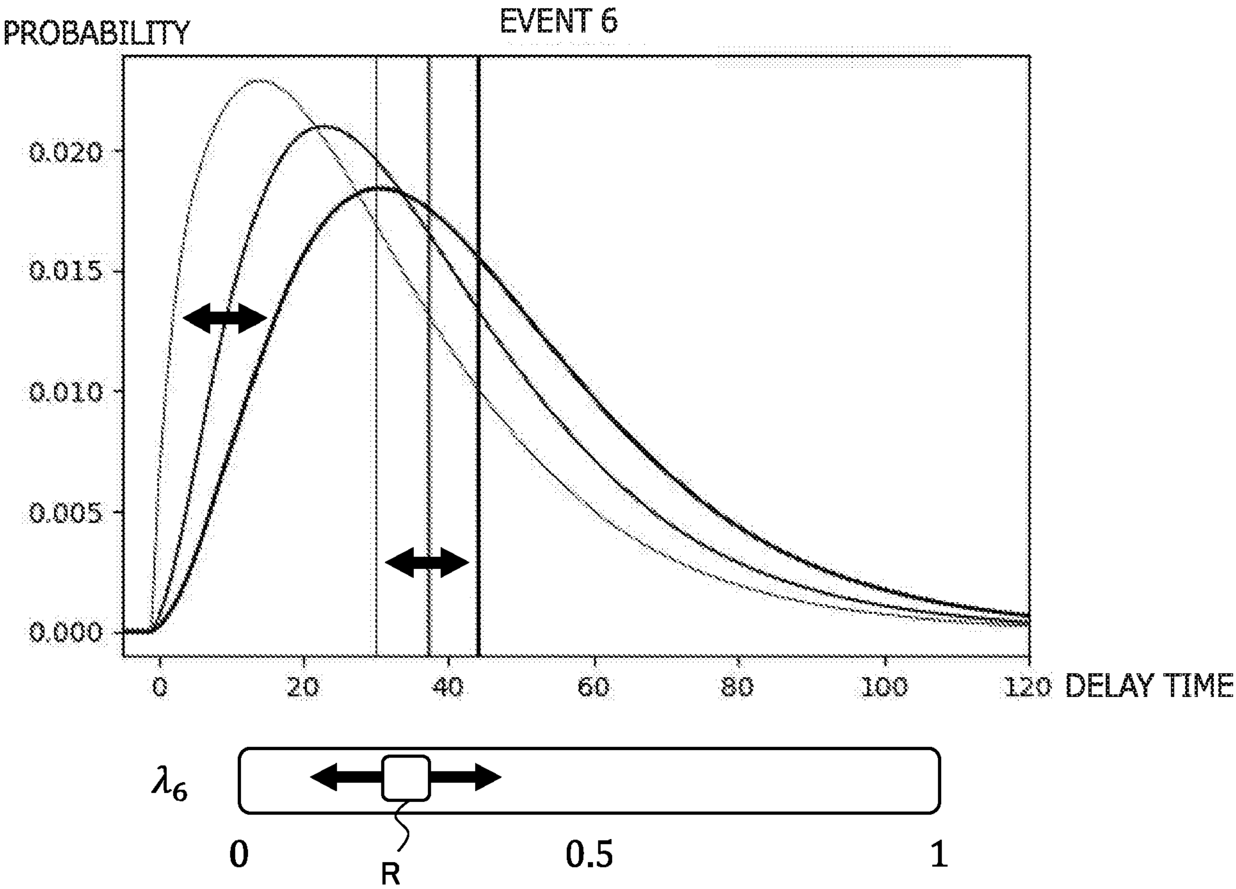
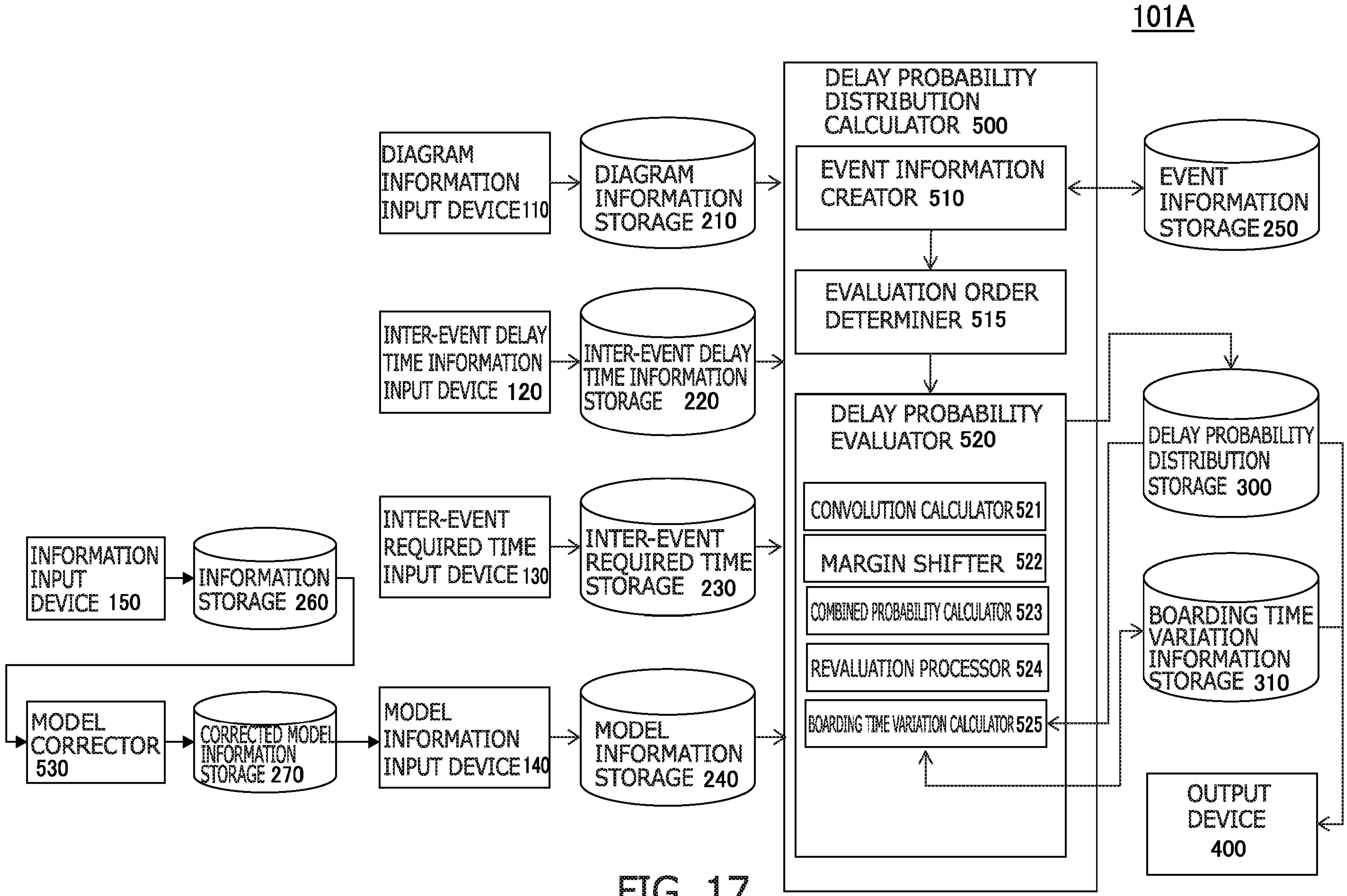

PROBABILITY
EVENT 6
0.020
0.015
0.010
0.005
0.000
0
20
40
60
80
100
120
DELAY TIME
λ_6
0
0.5
1
R

FIG. 16



101A
DIAGRAM INFORMATION INPUT DEVICE 110
DIAGRAM INFORMATION STORAGE 210
INTER-EVENT DELAY TIME INFORMATION INPUT DEVICE 120
INTER-EVENT DELAY TIME INFORMATION STORAGE 220
INTER-EVENT REQUIRED TIME INPUT DEVICE 130
INTER-EVENT REQUIRED TIME STORAGE 230
INFORMATION INPUT DEVICE 150
INFORMATION STORAGE 260
MODEL CORRECTOR 530
CORRECTED MODEL INFORMATION STORAGE 270
MODEL INFORMATION INPUT DEVICE 140
MODEL INFORMATION STORAGE 240
DELAY PROBABILITY DISTRIBUTION CALCULATOR 500
EVENT INFORMATION CREATOR 510
EVALUATION ORDER DETERMINER 515
DELAY PROBABILITY EVALUATOR 520
CONVOLUTION CALCULATOR 521
MARGIN SHIFTER 522
COMBINED PROBABILITY CALCULATOR 523
REVALUATION PROCESSOR 524
BOARDING TIME VARIATION CALCULATOR 525
EVENT INFORMATION STORAGE 250
DELAY PROBABILITY DISTRIBUTION STORAGE 300
BOARDING TIME VARIATION INFORMATION STORAGE 310
OUTPUT DEVICE 400

FIG. 17

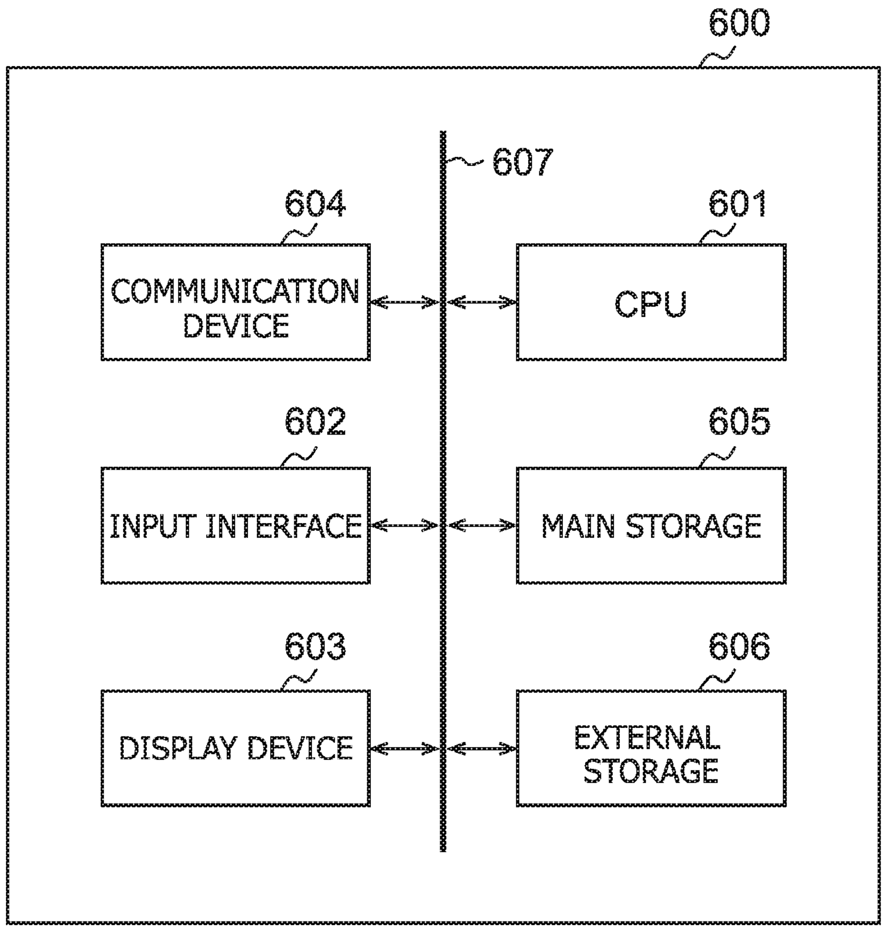

600
607
604
COMMUNICATION DEVICE
601
CPU
602
INPUT INTERFACE
605
MAIN STORAGE
603
DISPLAY DEVICE
606
EXTERNAL STORAGE

FIG. 18

INFORMATION PROCESSING DEVICE, INFORMATION PROCESSING METHOD, INFORMATION PROCESSING SYSTEM, AND COMPUTER PROGRAM

FIELD

[0001]

Approaches relate to an information processing device, an information processing method, an information processing system, and a computer program.

BACKGROUND

[0002]

To a railway company and the like, a delay in a diagram (timetable) that represents an operation schedule of the railway is a serious issue that brings about decreasing sales and increasing cost such as payment of fines. Therefore, a robust diagram as tolerant of delay as possible is desirably created. If a diagram can be evaluated while minimizing the use of historic data of operations, such a diagram evaluation method is highly valuable.

[0003]

Examples of a diagram evaluation method include methods of calculating a delay probability of each station. For example, there is a method of outputting a delay probability of each station using a Bayesian network method. In addition, there is a method which assumes that arrival, departure, and passing of a station are events and which calculates a delay probability distribution of a given event by using, as inputs, a delay probability distribution (for example, an expected value or the like of a delay time) between an event preceding the given event and the given event and a required time between events.

[0004]

However, the delay probability distribution between the events may vary in accordance with a delay situation of other events. Large-scale historic data is required in order to consider a variation in a delay probability distribution between events by the method described above. Therefore, it is difficult to evaluate a variation in a delay time of the departure event that is attributable to a variation in a delay probability distribution between events.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005]

FIG. 1 shows a diagram evaluator that is an information processing device according to a first approach;

FIG. 2A and 2B show an example of diagram information;

FIG. 3 shows an example of inter-event delay time information;

FIG. 4 shows an example of inter-event required time information;

FIG. 5 shows an example of acquiring an inter-event required time based on extra time;

FIG. 6 shows an overview of a boarding time varying model;

FIG. 7 shows an example of a boarding time proportionality coefficient;

FIG. 8 is a flow chart of an example of processing by a delay probability distribution calculator;

FIG. 9 is a flow chart of an example of processing by a delay probability evaluator;

FIG. 10 shows an example of event information;

FIG. 11 shows the event information in a graph format;

FIG. 12 shows a specific example of processing for generating a combined probability distribution;

FIG. 13 shows an example of boarding time variation information;

FIG. 14 shows an example of delay probability distribution information;

FIG. 15 shows a display example of evaluation information;

FIG. 16 shows another display example of evaluation information;

FIG. 17 shows a diagram evaluator that is an information processing device according to a second approach; and

FIG. 18 shows a hardware configuration of an information processing device according to each approach.

DETAILED DESCRIPTION

[0006]

According to one embodiment, an information processing device, includes: a processor configured to generate first inter-event delay time information representing a delay time between a first event and a second event that precedes the first event among a plurality of events based on delay time information representing a delay time of a third event that precedes the first event, the plurality events including a departure or an arrival at a plurality of stop positions and a time of the departure or the arrival with respect to at least one vehicle; and generate delay time information representing a delay time of the first event based on the first inter-event delay time information and delay time information representing a delay time of the second event.

[0007]

Hereinafter, approaches will be described with reference to the drawings. While a train including a plurality of vehicles will be described in each of the approaches to be presented below, for example, the present invention can be similarly implemented with respect to any vehicle such as a train including a single vehicle, a bus, or a taxi.

[0008]

FIG. 1 shows a diagram evaluator 101 (hereinafter, a present device 101) that is an information processing device according to a first approach. The present device 101 includes a diagram information input device 110, an inter-event delay time information input device 120, an inter-event required time input device 130, a model information input device 140, a delay probability distribution calculator (processor) 500, and an output device 400.

[0009]

As a plurality of storages, the present device 101 includes a diagram information storage 210, an inter-event delay time information storage 220, an inter-event required time storage 230, a model information storage 240, an event information storage 250, a delay probability distribution storage (delay time information storage) 300, and a boarding time variation information storage 310.

[0010]

[Diagram information]

The diagram information input device 110 accepts an input operation of diagram information from a user who is an operator of the present device 101, and acquires diagram information. The diagram information defines an operation diagram of a railway including a plurality of operations. The operation diagram is called a diagram, a train operation schedule, a timetable, or the like.

[0011]

The diagram information storage 210 stores the diagram information acquired by the diagram information input device 110.

[0012]

Each operation determined in diagram information includes a plurality of events of which a stop position (a location or a station), a time, and the like are determined such as a departure, an arrival, or passing. A time of an event determined in a diagram is referred to as a "fixed time".

[0013]

A single operation can be defined in various units such as from departing from a depot until returning to the depot or traveling from a first station to a last station. While a single operation is basically assigned to a single train, there may be cases where a single operation is assigned to a plurality of trains. Hereinafter, a case where a single train is assigned to a single operation will be assumed. A set of events belonging to a same train (in other words, operation(s) assigned to a same train) is referred to as a trip. Instead of the trip, “a train line” or “a service” is called.

[0014]

FIGS. 2A and 2B show an example of diagram information. FIG. 2A shows an example of diagram information in a tabular format. FIG. 2B shows the diagram information in FIG. 2A in a graph format.

[0015]

As shown in FIG. 2A, the diagram information includes information on a plurality of events. Information on each event includes an identifier of the event (an event identifier or an event ID), a time (fixed time) of the event, an identifier of a trip to which the event belongs, a location at which the event takes place (occurs), and a type of the event.

[0016]

While a location where events occur is limited to a station in the illustrated example, there may be locations other than a station such as a block section or a depot.

[0017]

In addition, while the type of event is either a departure or an arrival in the illustrated example, there may be other examples such as passing, overtaking, and rendezvous. An event of a departure will be described as a departure event, an event of an arrival will be described as an arrival event, an event of passing will be described as a passing event, and the like.

[0018]

In the graph shown in FIG. 2B, an axis of ordinate represents a location and an axis of abscissa represents time. An event is depicted by a circle and events belonging to a same trip are connected by a line. A numeral inside a circle is an identifier of an event (an event ID). A trip may include a turn or a way station may be used as a starting station.

[0019]

Examples of information on an event included in diagram information are not limited to those shown in FIG. 2A and FIG. 2B. For example, information on permissibility of early departure or information indicating one or more events (preceding events) that precede an event may be included. A given event preceding another event means that the time (fixed time) of the given event is earlier than the time (fixed time) of the other event. For example, when a second event precedes a first event, this means that the time (fixed time) of the second event is earlier than the time (fixed time) of the first event. Early departure means that a departure event is to be executed before a fixed time. The preceding event indicates an event of which a fixed time is earlier than that of the given event on a same trip or a different trip. A range of a preceding event may be defined in advance. For example, a preceding event may be limited to a latest event that takes place on a same trip with respect to a given event. Alternatively, a preceding event may be an event in a predetermined relationship with a given event on a different trip. As an example, in the case of a departure event at a given station, a latest arrival event on a same trip and at a same station or a departure event on a different trip that takes place before a latest event at the same station may be considered preceding events. In the case of this example, a preceding event with respect to event 6 is event 5 that belongs to the same trip and event 3 that belongs to a different trip.

[0020]

[Inter-event delay time information]

The inter-event delay time information input device 120 accepts an input operation of inter-event delay time information that is information representing a delay time between events from the user and acquires the inter-event delay time information.

The inter-event delay time information storage 220 stores the inter-event delay time information acquired by the inter-event delay time information input device 120.

[0021]

A delay time between events is a time of delay with respect to a difference between a fixed time of an event to be a target (a target event) and a fixed time of an event (a preceding event) that precedes the target event. The preceding event in this case is assumed to be an event which may directly influence a delay time of the target event (which may be a delay propagation route) among events of which a fixed time is earlier than the target event. Typically, events which may have an influence include events belonging to the same trip as the target event (for example, an event that takes place immediately before the target event) and events at a same station but belonging to a different trip as that of the target event (for example, an event that takes place immediately before the target event at the same station).

[0022]

Inter-event delay time information may come in various forms. For example, a probability distribution of a delay time between events (a delay probability distribution) may be used, statistics such as an average value or a dispersion of a delay time between events may be used, or a parameter that defines a delay probability distribution may be used. The form of inter-event delay time information may differ from one event pair to the next. In the present approach, a negative binomial distribution is assumed as the delay probability distribution between events and an expected value is given as a parameter of the negative binomial distribution. In other words, as inter-event delay time information, an expected value of the delay time between events is acquired by the inter-event delay time information input device 120. The negative binomial distribution obtained by providing the acquired expected value as a parameter corresponds to the delay probability distribution between events.

[0023]

FIG. 3 shows an example of inter-event delay time information. In the present example, an expected value of a delay time is stored for each pair made up by an event to be a target (a target event) and a preceding event that precedes the target event. A delay time expected value between event 4 and the event 5 is 30 and is large as compared to other event pairs. Therefore, the delay time of the event 5 is expected to increase.

[0024]

[Inter-event required time information]

The inter-event required time input device 130 accepts an input operation of information (inter-event required time information) related to a required time between two events (for example, a minimum time required between the two events) from the user and acquires inter-event required time information. The inter-event required time storage 230 stores the inter-event required time information acquired by the inter-event required time input device 130.

[0025]

For example, there are a time required by travel between stations (travel required time), a time required at a station (stoppage required time), and the like. There are also a time required for alighting (alighting required time), a time required for boarding (boarding required time), a time required for a safety confirmation (confirmation required time), and the like. A safety confirmation is an operation performed by a station employee after a train arrives at a station and before the train departs the station in order to check for safety. In addition, there may be a time required between a departure event and an arrival event which consecutively occur at a same station and which each belong to a different trip (hereinafter, a required train interval time). A value of the required train interval time may differ from one trip to the next or differ from one station to the next. Furthermore, other examples of a time required between events belonging to different trips include an interval between an arrival event and an arrival event and an interval between a departure event and a departure event.

[0026]

FIG. 4 shows an example of inter-event required time information. Information indicating an inter-event required time is stored for each pair made up by an event to be a target (a target event) and a preceding event that precedes the target event.

[0027]

The present device 101 may acquire information on an extra time (margin time) that is permitted between events instead of inter-event required time information. An extra time is a time of delay that is permitted with respect to an inter-event required time (for example, a maximum permitted time of delay). Specifically, an extra time is a value obtained by subtracting, from a difference between fixed times of two events, an inter-event required time between the two events. In other words, a time between fixed times (a fixed time interval) of two events determined on a diagram corresponds to a time obtained by adding an extra time between the two events to the required time between the two events. Therefore, when the present device 101 acquires extra time information, an inter-event required time can be obtained by subtracting, from a difference between fixed times of events as determined on a diagram, an extra time between the events.

[0028]

FIG. 5 shows an example of acquiring an inter-event required time for each event pair when the present device 101 acquires information on an extra time. The inter-event required times are obtained by subtracting extra times from fixed time intervals.

[0029]

In addition, instead of acquiring inter-event delay time information, the present device 101 may acquire distribution information of a travel time between events (for example, a probability distribution, an expected value, or the like of travel times) and distribution information (for example, a probability distribution, an expected value, or the like) of a stoppage time. Alternatively, the present device 101 may acquire distribution information of an alighting time (for example, a probability distribution, an expected value, or the like), distribution information of a boarding time (for example, a probability distribution, an expected value, or the like), and distribution information of a confirmation time (for example, a probability distribution, an expected value, or the like). Based on the acquired information and the inter-event required time described above, the present device 101 can obtain inter-event delay time information. For example, by subtracting a required time (a travel required time) between events from an expected value of a travel time between the events, an expected value of a delay time of travel can be obtained.

[0030]

[Event delay time]

A delay time of an event is defined based on the inter-event delay time and the inter-event required time described above. An event delay time is obtained by subtracting a difference between the fixed times of a target event and a preceding event from a sum of a delay time of the preceding event, a delay time between the target event and the preceding event (an inter-event delay time), and a required time between the target event and the preceding event. As described earlier, a value obtained by subtracting a required time between events from a difference between fixed times of the events is referred to as an extra time. When a sum of a delay time of a preceding event and a delay time between a target event and the preceding event is larger than the extra time, the delay time takes a positive value and a delay occurs. Examples of information representing a delay time of an event (delay time information of an event) include statistics such as a probability distribution of the delay time of the event (a delay probability distribution of the event) and an expected value of the delay time of the event. Information on the delay time of an event (delay time information of the event) is calculated by the delay probability distribution calculator 500 to be described later.

[0031]

The model information input device 140 accepts an input operation of information including a boarding time varying model (boarding time varying model information) and acquires the boarding time varying model information. The model information storage 240 stores the boarding time varying model information acquired by the model information input device 140.

[0032]

A boarding time varying model is a model that calculates or estimates a variation in a boarding time (a time required by passengers in order to board a train from a station) between a departure event to be a target at a station and an immediately-preceding arrival event at the same station. A boarding time varying model corresponds to an example of a model that calculates variation information representing a variation in a delay time between an event to be a target and a preceding event. The variation in the boarding time between a departure event to be a target and an immediately-preceding arrival event at a same station corresponds to an example of a variation in a delay time between the departure event to be a target and the immediately-preceding arrival event at the same station.

[0033]

FIG. 6 shows an overview of a boarding time varying model. Two trips (operations) 11 and 12 are shown. A circle represents an event. A varying model (function) of a boarding time between an arrival event j and a departure event k at a station Q of the trip 12 will be considered. In the varying model, distribution information of a delay time of an immediately-preceding departure event i at the same station Q on the other trip 11 (delay time information of the departure event i: for example, an expected value, a probability distribution, or the like of the delay time of the departure event i) and distribution information of a delay time of the arrival event j (delay time information of the arrival event j: for example, an expected value, a probability distribution, or the like of the delay time of the arrival event j) are used as arguments. Specifically, for example, a difference between the delay time information of the departure event i on the other trip 11 and the delay time information of the immediately-preceding arrival event j on the same trip 12 (in other words, delay time information between the event i and the event j or headway) is used as an argument. When an interval between the time of the departure event i and the time of the arrival event j is considered a train interval, the difference corresponds to a difference from a fixed time interval of train intervals on a same route.

[0034]

This difference affects a variation in the boarding time between the arrival event j and the departure event k. A variation in the number of passengers who board at the station Q affects a variation in the boarding time between the arrival event j and the departure event k.

[0035]

Let us assume that a variation in the boarding time is proportional to a variation in an interval (a train interval) between the departure event i and the arrival event j. A flow rate (number of people/second) of passengers boarding a train is considered constant. The flow rate may be called a boarding rate. As a proportionality coefficient, a proportionality coefficient (hereinafter, a boarding time proportionality coefficient) "λ_k" (≥ 0) that corresponds a variation per unit time in the number of passengers who board at the station Q multiplied by the flow rate is given. It is assumed that the inter-event delay time between the departure event k and the arrival event j increases in correspondence to an increase (a variation) in the boarding time and that the increase is proportional to the variation in the train interval described above by the proportionality coefficient "λ_k". A feature of the present approach is that a distribution of the delay time of the departure event k (the delay time information of the departure event k) is calculated by reflecting the increase (the variation) in the boarding time onto the inter-event delay time. A specific example of the boarding time varying model will be described later (for example, refer to Expression (1) to Expression (3) and the like to be described later).

[0036]

FIG. 7 shows an example of a boarding time proportionality coefficient. In this example, pairs of a departure event to be a target and an arrival event are a pair of the events 3 and 2 and a pair of the events 6 and 5. A value (= 0.5) of the boarding time proportionality coefficient is determined with respect to the pair of the events 6 and 5. Since there is no event on a different trip with an earlier fixed time than the event 3 in this example, the boarding time proportionality coefficient has not been defined with respect to the pair of the events 3 and 2. The value of the boarding time proportionality coefficient may be determined by any method such as performing a simulation and adopting a value with high accuracy or by rule of thumb based on actual operation data. A specific example of a method of determining the value of the boarding time proportionality coefficient will be described later.

[0037]

In the example of FIGS. 2A and 2B described above, since there is a departure event (the event 3) at the same station on a different trip and an immediately-preceding arrival event (the event 5) on the same trip with respect to the departure event 6, 0.5 is determined as a boarding time proportionality coefficient "λ_6" with respect to the pair of the events 5 and 6. Since the delay time of the event 5 is expected to be larger than other events as mentioned in the description of FIG. 3, it is expected that the difference between the delay time of the event 3 and the delay time of the event 5 or, in other words, an inter-event delay time between the event 3 and the event 5 is a positive value. Therefore, it is expected that a variation in the boarding time between the event 5 and the event 6 as calculated by the boarding time varying model will take a positive value.

[0038]

The delay probability distribution calculator 500 calculates delay time information (for example, a delay probability distribution, an expected value, or the like of an event) representing a delay time of an event based on information stored in the storages 210 to 240. The delay probability distribution calculator 500 corresponds to a processor that calculates delay time information representing a delay time of an event. The delay probability distribution calculator 500 includes an event information creator 510, an evaluation order determiner 515, and a delay probability evaluator 520. Hereinafter, processing by the delay probability distribution calculator 500 will be described with reference to FIGS. 8 and 9.

[0039]

FIG. 8 is a flow chart of an example of processing by the delay probability distribution calculator 500.

The event information creator 510 creates event information using each event included in each trip in diagram information as a target event (a first event) (Step_A). The event information storage 250 stores the created event information of each event.

[0040]

FIG. 10 shows an example of event information. Event information includes an identifier of an event, early departure permissibility information, and information on a preceding event. FIG. 11 shows the event information shown in FIG. 10 in a graph format. On the graph shown in FIG. 11, a given event and a preceding event of the given event are connected by a solid line or an arrowed arc. The given event is connected by a solid line to a preceding event on the same trip but connected by an arrowed arc to a preceding event on a different trip.

[0041]

Early departure permissibility information is information indicating permissibility of an early departure. An early departure is a delay time of a departure event taking a negative value or, in other words, departing earlier than a fixed time of the departure event. In the example shown in FIG. 10, all departure events 1, 3, 4, and 6 are early departure-nonpermissible. The arrival events 2 and 5 are not departure events and are therefore early departure-permissible. Although an arrival earlier than a fixed time is permitted with respect to arrival events, permissibility of an early arrival may also be defined per event for arrival events. Permissibility of early passing may also be defined per event for passing events. Early departure permissibility information may be included in diagram information or stored in advance in the event information storage 250 as data of a different file. Alternatively, the user may input event information at the start of the present processing. Alternatively, all departure events may be uniformly determined in advance as early departure-nonpermissible. In the present approach, a case where early departure permissibility information is included in diagram information is assumed.

[0042]

Information on a preceding event is only stored when at least any of the preceding events of types 1 to 3 described below is present with respect to a target event. However, the types of preceding events are not limited to these types and can be optionally determined in accordance with a purpose of evaluation of the diagram information.

Type 1: a latter event among a pair of consecutive events (connected by a solid line on the graph shown in FIG. 2B) belonging to the same trip. In other words, an event that is connected by a solid line to the target event and that is performed last.

Type 2: when the target event is an arrival event, an immediately-preceding departure event at the same station (the event is referred to as a departure-arrival event). The departure-arrival event belongs to a different trip to the target event.

Type 3: when the target event is a departure event, a preceding departure event at the same station as the departure event (the event is referred to as a departure-departure event). The departure-departure event belongs to a different trip to the target event.

[0043]

When there are a plurality of tracks that a train can arrive on at a station and the target event is an arrival event, an example other than the types 1 to 3 may be the departure-arrival event described above on a same track as the arrival event. In addition, when the target event is a departure event, another example may be the departure-departure event described above on a same track as the departure event.

In addition, when there are two directions of travel (for example, upbound and downbound), a departure-arrival event or a departure-departure event may be individually adopted as a preceding event for each of a same direction and an opposite direction.

When a shuttle operation is performed, an arrival event and a departure event before and after the shuttle may be considered in a similar manner to an arrival event and a departure event in a same direction.

Furthermore, when the target event is a passing event, in a similar manner to an arrival event, an immediately-preceding departure event (referred to as a departure-passing event) at the same station (when there are a plurality of tracks, a same track) may be adopted as a preceding event. There may be an immediately-preceding departure event either in the same direction as the passing event or in the opposite direction to the passing event.

[0044]

Information on a preceding event includes an expected value of an inter-event delay time between a target event and the preceding event and an extra time between the target event and the preceding event. In addition, when the target event is a departure event and there are an arrival event at the same station on the same trip and a departure-departure event (an event of type 3 described above) as preceding events, information on the preceding event includes a boarding time proportionality coefficient.

[0045]

The evaluation order determiner 515 creates an event list on which identifiers (event IDs) of events are arranged in an evaluation order (Step_B). A topological sort of the event IDs is performed and an order after the sort is adopted as an evaluation order. In the present example, as an example of a topological sort, the event IDs are sorted in a descending order of fixed times of the events and the order after the sort is adopted as the evaluation order of the events. Performing subsequent processing according to the evaluation order guarantees that, when processing the event information of each event, the event information of all preceding events have already been processed.

[0046]

The delay probability evaluator 520 receives a leading element (designate as event N) of the event list (Step_C) and, based on the event information of the event, calculates delay time information (in the present example, a delay probability distribution) representing a delay time of the event (Step_D).

[0047]

The delay probability evaluator 520 includes a convolution calculator 521, a margin shifter 522, a combined probability calculator 523, a revaluation processor (or a rounding up processor) 524, and a boarding time variation calculator 525.

[0048]

FIG. 9 is a flow chart of an example of processing by the delay probability evaluator 520.

First, in steps D0 to D2, an inter-event delay probability distribution is calculated between the event N and all preceding events {S}. Hereinafter, an example of a case where the event N is a departure event and the event S is an arrival event being an immediately-preceding event on a same trip will be mainly described.

[0049]

The boarding time variation calculator 525 determines whether or not the event N is a departure event. The boarding time variation calculator 525 does not perform any processing when the event N is not a departure event. When the event N is a departure event, the boarding time variation calculator 525 determines whether or not an immediately-preceding arrival event is present at the same station and that the departure-departure event described earlier is present. When either one is absent, no processing is performed. When both events are present, based on the boarding time varying model, a variation "Δ_{SN}" in a boarding time (a time required by passengers in order to board a train at a station) between the event S and the event N is calculated. As an example of the variation "Δ_{SN}", an expected value "ΔE_{SN}" of the variation is calculated. An example of the boarding time varying model when calculating the expected value "ΔE_{SN}" is represented by Expression (1).

$$\Delta E_{SN} = \lambda_N(E[X_S] - E[X_M]) \quad (1)$$

[0050]

In Expression (1), an immediately-preceding arrival event on the same trip as the target event (event N) is represented by S and an immediately-preceding departure event at the same station (same route) (a departure-departure event) is represented by M. "Xi" represents a probability variable of a delay time of an event i. "E[•]" represents an expected value according to a probability distribution which a probability variable "•" follows. Therefore, "$E[X_S]$" represents an expected value of a time delay of the departure event M and "$E[X_M]$" represents an expected value of a time delay of the arrival event S.

[0051]

The model represented by Expression (1) is a function having a difference between "$E[X_S]$" and "$E[X_M]$" ($E[X_S] - E[X_M]$) as an argument and "λ_N" as a proportionality coefficient. The difference is an expected value of a difference (a variation) in a delay time between the arrival event S and the departure event M. The difference may take either a positive or a negative value. The model represented by Expression (1) assumes that the expected value "ΔE_{SN}" of the variation in a boarding time between the event S and the event N is proportional to the difference ($E[X_S] - E[X_M]$).

[0052]

An expected value of Expression (2) that is a function having probability variables ("X_S", "X_M") as an argument may be calculated instead of Expression (1).

$$\lambda_N(X_S - X_M) \quad (2)$$

In other words, the expected value "ΔE_{SN}" of the variation in the boarding time may be calculated based on Expression (3) below.

$$\Delta E_{SN} = E[\lambda_N(X_S - X_M)] \quad (3)$$

[0053]

In the present example, the boarding time variation calculator 525 substitutes an expected value of a delay probability distribution of each of the preceding events S and M of which fixed times are earlier than the event N into "$E[X_S]$" and "$E[X_M]$" in the function represented by Expression (1) and calculates the expected value ΔE_{SN} of the variation in the boarding time (Step_D0). As an example, the preceding event S corresponds to a second event with an earlier fixed time than the event N and the preceding event M corresponds to a third event with an earlier fixed time than the event N.

[0054]

The expected value "ΔE_{SN}" of the variation in the boarding time calculated by the boarding time variation calculator 525 is stored in the boarding time variation information storage 310 as boarding time variation information in association with an identifier of each of the event N and the preceding event S (refer to FIG. 13 to be described later).

[0055]

The convolution calculator 521 generates a probability distribution ("$f_{Y'SN}$") having a sum of a delay time of the event S that precedes the event N and a delay time between the event S and the event N (an inter-event delay time) as a probability variable (Step_D1). In other words, the convolution calculator 521 calculates a delay probability distribution of the event N when going through the event S as the probability distribution ("$f_{Y'SN}$"). "SN" may be a subscript of "Y'".

[0056]

The present probability distribution "$f_{Y'SN}$" is a convolution of a delay probability distribution "f_{XS}" that is a probability distribution of the delay time of the event S and an inter-event delay probability distribution (denoted as "f_{DSN}") that is a probability distribution of the delay time between the event S and the event N. "SN" may be a subscript of "D'". "Y'_{SN}" is a probability variable that represents a delay time of the event N. "f_{DSN}" is a distribution that represents the delay time between the events S and N which is generated based on a distribution that represents the delay time between events given by the inter-event delay time information and a variation "Δ_{SN}" of a boarding time (a variation in the inter-event delay time).

"f_{DSN}" corresponds to first inter-event delay time information representing the delay time between the events S and N in which the variation "Δ_{SN}" of the boarding time is reflected onto the delay time between the events S and N. The distribution that represents the delay time between events given by the inter-event delay time information corresponds to second inter-event delay time information representing the delay time between the events S and N in which the variation "Δ_{SN}" of the boarding time is not reflected on the delay time between the events S and N.

[0057]

In the present approach, a negative binomial distribution is assumed as the inter-event delay probability distribution and an expected value of an inter-event delay time is given as a parameter that defines the distribution. In doing so, in the present example, a variation in a boarding time is taken into consideration. Therefore, an expected value of an inter-event delay time between the event N (in the present example, a departure event) and an immediately-preceding arrival event (the event S) on the same trip is calculated based on a sum of an expected value of an inter-event delay time given by inter-event delay time information and the expected value "ΔE_{SN}" of the variation in the boarding time. The inter-event delay time information (the inter-event delay time given by the inter-event delay time information) is varied according to the variation in the boarding time and the inter-event delay time information after the variation is given as a parameter of the negative binomial distribution. Accordingly, an inter-event delay probability distribution is obtained in which the variation "Δ_{SN}" of the boarding time is reflected on the delay time between the events S and N.

[0058]

The margin shifter 522 shifts the delay probability distribution of the event N (the probability distribution "$f_{Y'SN}$") when going through the event S by the extra time between events (Step_D2). By shifting "$f_{Y'SN}$" by the extra time "m_{SN}", a delay probability distribution "f_{YSN}" of the event N when going through the event S in consideration of the extra time is obtained. "SN" may be a subscript of "Y'". In this case, $Y_{SN}: = Y'_{SN} - m_{SN}$ is satisfied. In other words, "Y_{SN}" is defined as a subtraction of "m_{SN}" from "Y'_{SN}".

[0059]

Next, a delay probability distribution of the event N is obtained by steps D3 and D4. Details are as follows.

[0060]

When the number of events preceding the event N (the number of the events S having become a target of calculating "f_{YSN}") is one, the combined probability calculator 523 adopts the delay probability distribution "f_{YSN}" of a case where the event N goes through a single event S in consideration of the extra time as a delay probability distribution "W" of the event N. The delay probability distribution may be represented by "W(k)" using a probability variable "k" of the delay time (the same applies hereafter).

[0061]

When the number of events preceding the event N (the number of the events S having become a target of calculating "f_{YSN}") is zero, the combined probability calculator 523 adopts an initial delay distribution determined in advance as the delay probability distribution "W" of the event N. For example, since an initially selected event does not have a preceding event, the initial delay distribution becomes the delay probability distribution with respect to the initially selected event.

[0062]

When there are a plurality of events preceding the event N (when the number of the events S having become a target of calculating "f_{YSN}" is a plurality), the combined probability calculator 523 combines a delay distribution "f_{YSN}" calculated with respect to each of all preceding events S of the event N. Accordingly, the delay probability distribution "W" of the event N is obtained. Specifically, the following processing is performed.

[0063]

The combined probability calculator 523 calculates a probability distribution (a combined probability distribution) having a maximum value of delay times when going through each of all preceding events S of the event N as a probability variable and adopts the calculated probability distribution as the delay probability distribution "W" of the event N (Step_D3).

[0064]

For example, when events S1 to Sh (where h is an integer of 2 or more) are present as the preceding events S, combinations of values of "k" (probability variable) are generated among the preceding events S1 to Sh. When there are g-number of possible values of "k", h×g-number of combinations are obtained. For each combination, a product of "$f_{YSN}(k)$" is calculated and a maximum value of "k" is selected. "$f_{YSN}(k)$" is a value of "f_{YSN}" in the case of the probability variable "k". Accordingly, for each combination, a pair of a value of "k" and a product is obtained. The obtained pairs are classified according to the values of "k" to obtain a plurality of groups. A sum of products is calculated for each group and the sum is adopted as a delay probability (a combined probability) that corresponds to the group. Accordingly, a delay probability (a combined probability) of each value of "k" is obtained and a set of the delay probability (the combined probability) of each value of "k" is obtained as a combined probability distribution (the delay probability distribution "W" of the event N).

[0065]

FIG. 12 shows a specific example of processing for generating the combined probability distribution in Step_D3. For the sake of simplicity, it is assumed that "k" takes discrete values at 1-minute intervals within a range of -1 or more and 2 or less. The number "h" of preceding events S is assumed to be two. The preceding events S will be respectively referred to as preceding event 1 and preceding event 2.

[0066]

The probability distribution "f_{YSN} (k)" when going through the preceding event 1 and the probability distribution "f_{YSN} (k)" when going through the preceding event 2 are respectively shown in FIG. 12(A).

[0067]

FIG. 12(B) shows a table in which values of "k" of the preceding event 1 are adopted as horizontal items and values of "k" of the preceding event 2 are adopted as vertical items. A maximum value among a corresponding value of "k" of the preceding event 1 and a corresponding value of "k" of the preceding event 2 (when the values are the same, any one value) is stored in an upper part of each cell in the table. In addition, a product of "f_{YSN} (k)" in the case of a corresponding value of "k" of the preceding event 1 and "f_{YSN} (k)" in the case of a corresponding value of "k" of the preceding event 2 is stored in a lower part of each cell. This is comparable to an occurrence probability when the preceding event 1 and the preceding event 2 are assumed to be independent.

[0068]

For example, in the case of a top-right cell in the table, the corresponding value of "k" of the preceding event 1 is 2 and the corresponding value of "k" of the preceding event 2 is -1. Therefore, 2, which is the larger of 2 and -1, is stored. In addition, the delay probability "f_{YSN} (2)" in the case where the value of "k" of the preceding event 1 is 2 is 10% and the delay probability "f_{YSN} (-1)" in the case where the value of "k" of the preceding event 2 is -1 is 50%. Therefore, a product of the delay probabilities is 10% $\times$ 50% = 5%. Therefore, 5% is stored in this cell. Other cells similarly store a maximum value of "k" and a product.

[0069]

The cells of the table in FIG. 12(B) are classified into groups of same values (maximum values) of "k" and products included in the cells are added up for each group. Accordingly, a delay probability is obtained for each value of "k".

[0070]

FIG. 12(C) shows a table obtained by calculating the sum for each group. An example of calculating a sum with respect to a group where "k" is 2 will be described. First, all cells including 2 are specified from the table in FIG. 12(B). In other words, a group of cells in which "k" is 2 is specified. Eight cells in a rightmost column and a bottom row of the table are specified. A sum of products (the values in lower parts) in the cells is calculated as 5 + 4 + 1 + 0 + 0 + 0 + 0 + 0 = 10%. In a similar manner, 20% is calculated as the sum in the case where "k" is -1, 43% is calculated as the sum in the case where "k" is 0, and 27% is calculated as the sum in the case where "k" is 1. In this manner, a sum (delay probability) is obtained for each value of "k". A set of these sums corresponds to a combined probability distribution.

[0071]

A combination of the preceding event S and the event N that maximizes the delay time may be referred to as a delay propagation route. In the following description, a delay probability distribution of the event N is assumed to be the delay probability distribution "W" calculated in Step_D3 and a delay time of the event N is assumed to be a delay time (for example, an expected value) based on the delay probability distribution "W" calculated in Step_D3.

[0072]

The revaluation processor 524 determines whether or not the event N is early departure-nonpermissible, and in the case of early departure-nonpermissible, performs processing of revaluing a probability that the delay time of the event N becomes negative in the delay probability distribution "W" of the event N (Step_D4). A probability that the delay time of the event becomes lower than 0 is added to a probability that the delay time becomes 0 and, instead, the probability that the delay time becomes lower than 0 is revalued to 0.

[0073]

The calculated delay probability distribution "W" of the event N (including both a case where revaluation processing is performed and a case where revaluation processing is not performed) is stored in the delay probability distribution storage 300 as delay probability distribution information.

[0074]

All the events are sequentially selected as the event N and the processing of steps (D0 to D4) described above with respect to the event N are repetitively executed.

[0075]

FIG. 13 shows an example of boarding time variation information that is stored in the boarding time variation information storage 310 as a result of processing by the delay probability evaluator 520. When the event N is the event 6 and a preceding arrival event is the arrival event 5, 14.18904 is stored as the expected value "ΔE_{SN}" of the variation in the boarding time (note that a departure-departure event with respect to the event N is the event 3). When the event N is the event 3, since there is no departure-departure event with respect to the event 3 even though the event 2 is a preceding arrival event, the expected value "ΔE_{SN}" of the variation in the boarding time is not calculated with respect to the event 3. However, it is also possible to not make the presence of a departure-departure event a requirement when calculating the expected value "ΔE_{SN}" of the variation in the boarding time. In this case, the expected value "ΔE_{SN}" of the variation in the boarding time may be calculated with respect to the event 3.

[0076]

FIG. 14 shows an example of delay probability distribution information that is stored in the delay probability distribution storage 300 as a result of processing by the delay probability evaluator 520. Horizontal columns represent delay times and vertical rows represent identifiers of events (event N). For example, in the case of the event 6, probabilities that the delay time is 0, 1, 2, 3, 4, and 5 are, respectively, 0, 0.001, 0.001, 0.002, 0.002, and 0.003. Since the event 6 is early departure-nonpermissible, the value of the delay time does not become negative (the same applies to the events 1, 3, and 4). On the other hand, since the events 2 and 5 are arrival events and are early arrival-permissible, the value of the delay time may become negative. In the example in FIG. 14, in the case of the event 2, the probability that the delay time is -1 is 0.296.

[0077]

As the processing by the delay probability evaluator 520 described above, a method of attempting a simulation such as the Monte Carlo method many times may be used (for example, performing processing by selecting a delay time by using a random number with respect to an inter-event delay probability distribution and a delay probability distribution of events). In such a case, processing of Step_C and thereafter is to be repetitively performed many times and a delay probability distribution of the event N is to be obtained from a histogram thereof. Observed values of the delay time and the variation in boarding time in each attempt may be stored in the delay probability distribution storage 300 and the boarding time variation information storage 310. In addition, information on a propagation route in each attempt may be stored in the delay probability distribution storage 300. According to the present method, since processing of each part of the delay probability evaluator 520 is simplified, a single attempt can be executed at high speed.

[0078]

The output device 400 reads information from at least one of the delay probability distribution storage 300 and the boarding time variation information storage 310, generates evaluation information of the operation diagram, and displays the evaluation information on a screen. In addition to at least one of the delay probability distribution information and the boarding time variation information, evaluation information may be generated using information obtained by processing performed by the delay probability distribution calculator 500, information acquired by the input devices 110 to 140, and the like.

[0079]

FIG. 15 shows a display example of evaluation information. Graphs G1 and G2 showing a delay probability distribution of the event 6 are displayed. The solid-line graph G1 represents a delay probability distribution of the event 6 when a boarding time proportionality coefficient "λ_6" between the event 5 and the event 6 is set to 0.5. The dashed-line graph G2 represents a delay probability distribution of the event 6 when the boarding time proportionality coefficient "λ_6" is set to 0 or, in other words, when a variation in a boarding time is not taken into consideration (when the variation in the boarding time is set to zero).

[0080]

Due to an increase in the boarding time between the event 5 and the event 6 caused by a major delay of the event 5, it is expected that the delay time of the event 6 is to increase. The solid-line graph G1 in FIG. 15 shows that, by taking a variation in the boarding time into consideration, a mode of the delay probability distribution (the value of the delay time is approximately 30) becomes larger than a mode of the dashed-line graph G2 (the value of the delay time is approximately 15) and a spread of a base of the graph G1 is also wider than that of the dashed-line graph G2.

[0081]

In addition, a solid perpendicular line L1 in FIG. 15 represents an expected value of a delay time of the event 6 when "λ_6" is set to 0.5. A dashed perpendicular line L2 represents an expected value of a delay time of the event 6 when "λ_6" is set to 0. A length of a horizontal line E1 that extends in a negative direction from the solid perpendicular line L1 represents an expected value of the variation in the boarding time. An end point of the solid horizontal line E1 coincides with an expected value (the dashed perpendicular line L2) in a case where the variation in the boarding time is not taken into consideration. Therefore, the variation in the expected value of the delay time of the event 6 due to taking a variation in the boarding time into consideration coincides with the expected value of the variation of the boarding time.

[0082]

FIG. 16 shows another display example of evaluation information. The user sets a value of a parameter ("λ_6" in the present approach) of the boarding time varying model by moving a slider R being an input interface leftward or rightward in the screen. In the illustrated example, the user can set the value of "λ_6" within a range of 0 or more and 1 or less. A delay probability distribution of the event 6 corresponding to a parameter value set by the user is generated by the delay probability distribution calculator 500 (processor). The output device 400 displays the generated graph of the delay probability distribution and a vertical line representing the expected value of the delay time of the event 6 on the screen. Accordingly, the user can readily do trial and error on various scenarios with respect to the value of "λ".

[0083]

Variations of the evaluation information to be displayed on the output device 400 are described in (1) to (5) below.

(1) Each event may display a probability of a delay equal to a threshold time or longer or shorter. Statistics such as an expected value, a dispersion, or a quartile of the delay time of each event may be displayed.

[0084]

(2) Statistics such as an expected value of the delay time of a specific section (between a start point and an end point of a sequence of consecutive events) may be displayed.

[0085]

(3) Statistics such as a covariance or a correlation coefficient of a delay time between an event preceding a target event and the target event may be displayed. In addition, a delay propagation route that is estimated based on the statistics may be displayed.

[0086]

(4) When information regarding an event (a connecting event) of connecting to the target event is given, statistics such as a probability that the connection from the connecting event to the target event cannot be made may be displayed. For example, there may be cases where the target event is a departure event at a given station, the connecting event is an arrival event at a time earlier than the departure event at the same station, and a connection is to be made from a train of the connecting event to a train of the departure event. In this case, when a delay by the extra time or more occurs with respect to the time determined as a time required by passengers to make a connection in the connecting event, the connection cannot be made. Therefore, as a probability that a connection cannot be made, statistics such as a probability of occurrence of a delay equal to or longer than the extra time is displayed. Information regarding the connecting event may be acquired by a configuration presented in a second approach to be described later or may be stored in diagram information in advance.

[0087]

(5) Statistics such as a ratio, a covariance, or the like of the expected value of the delay time and the expected value of the boarding time may be displayed. Based on the statistics, a result of estimating

an influence of a variation in the boarding time with respect to the delay time may be displayed.

[0088]

[Method of determining a parameter of boarding time varying model]

Two methods of determining a parameter (boarding time proportionality coefficient) "λi" of the boarding time varying model will be described as method 1 and method 2. As described above, the boarding time proportionality coefficient "λi" is a proportionality coefficient when assuming that a variation in a boarding time is proportional to an interval (a train interval or a headway) between an immediately-preceding arrival event at a same station (a same route) as a departure event i and an immediately-preceding departure event on a different trip at the same station. However, the parameter of the boarding time varying model is not limited to the boarding time proportionality coefficient. For example, there may be a coefficient that is a constant term (a correction term) as shown in the second approach to be described later.

[0089]

(Method 1) Obtain "λi" by linear regression with respect to the variation in train intervals of actual operation data with respect to the event i. For example, based on actual operation data, "λi" can be obtained by subjecting the variation in the delay time of the event i to regression by the variation in the train interval (as described earlier, a time interval between the time of an immediately-preceding arrival event on a same trip as the event i and the time of an immediately-preceding departure event on a different trip).

[0090]

(Method 2) Assume that a variation in the number of passengers who board in the event i is proportional to a variation in the train interval. According to the present assumption, a variation per unit time of the number of passengers who board (the number of boarding passengers) becomes constant. In addition, assume that a boarding passenger flow rate (the number of people who board a train per unit time) is approximately constant.

Therefore, "λi" is calculated by modifying an expression as represented by Expression (3) below.

[0091]

λi = (variation per unit time of number of boarding passengers) × (boarding time per unit passenger)
= [(number of boarding passengers during scheduled operation]/(train interval during scheduled operation)] × [(required time for boarding during scheduled operation)/ (number of boarding passengers during scheduled operation)]
= [(required time for boarding during scheduled operation)/ (train interval during scheduled operation)]   (3)

[0092]

During scheduled operation means during a period in which operations are performed on-time.

The train interval during scheduled operation is an interval determined by the operation diagram and is obtained from diagram information.

When the required time for boarding during scheduled operation is being actually measured, historic data may be used as the required time for boarding during scheduled operation. Alternatively, assuming that the required time for boarding during scheduled operation approximates a product of a stoppage time during an occurrence of a delay and a ratio of the boarding time to the stoppage time, the stoppage time during an occurrence of a delay may be specified from actual operation data and the ratio of the boarding time may be specified from historic data.

[0093]

[Variation of boarding time varying model]

The boarding time varying model is a function having an argument that is dependent on delay time information of a preceding event of which a fixed time is earlier than a departure event to be a target. While the preceding events to be a target of the boarding time varying model according to the first approach are an immediately-preceding departure event of another trip at a same station and an immediately-preceding arrival event on a same trip, these events are not restrictive. For example, only one of these events may be adopted as a preceding event. For example, when delay time information representing a delay time between a second event that precedes an event (a first event) to be a target and the first event is generated based on delay time information representing a delay time of a third event that precedes the first event, the third event may or may not be the same as the second event.

[0094]

In addition, an event that differs from the two preceding events described above may be adopted as a preceding event. For example, a first departure event on a same trip or second from last (or third or further from last) immediately-preceding consecutive departure events at the same station may be adopted as preceding events. The number of preceding events is not limited to one or two and may be three or more. Another example of a preceding event when a station has a plurality of tracks is an immediately-preceding departure event on a same track. Yet another example of a preceding event when there are two travel directions is an immediately-preceding departure event in each of a same direction and an opposite direction.

[0095]

In addition, the boarding time varying model may not be formed so that a difference in delay time information (such as an expected value) between two events is proportional to a proportionality coefficient as represented by Expression (1) to Expression (3). For example, the boarding time varying model may be a non-linear function instead of a linear function. Furthermore, the boarding time varying model may be a regression model of another form such as a neural network.

[0096]

Examples of delay time information to be used as an argument include a delay time, an expected value of the delay time, a probability distribution of the delay time, and a function representing the probability distribution. In addition, examples of the argument include a variation in a train interval (a time interval between an immediately-preceding departure event on a different trip at the same station and an immediately-preceding arrival event on the same trip).

[0097]

[Variation of processing in Step_D0]

A variation of processing in Step_D0 that is performed by the boarding time variation calculator 525 will be described.

In the first approach described above, a variation in a boarding time is represented by a function of an expected value of a difference in a delay time (train interval) between preceding events or the like. As another method, the variation in a boarding time may be calculated by a function of an observed value in one attempt of a simulation such as the Monte Carlo method in which a large number of attempts are made as described above. In this case, for example, probability variables "X_S" and "X_M" are generated (in other words, probability variables "X_S" and "X_M" are observed) using random numbers or the like and a value of a variation in the boarding time is calculated by substituting values of the probability variables "X_S" and "X_M" into Expression (2).

[0098]

In addition, while an expected value of a variation in a boarding time is calculated as variation information that represents the variation in the boarding time in the first approach, a probability distribution of the variation in the boarding time may be calculated. In this case, since the variation in the boarding time is a function dependent on delay time information (delay time) of one or more preceding events of which a fixed time is earlier than a target event, the present probability distribution of the variation in the boarding time is a convolution of a delay probability distribution of the one or more preceding events. In the present approach, a probability distribution of each of the probability variables "X_S" and "X_M" is convolved in accordance with Expression (2). Specifically, by multiplying a probability variable of a probability distribution obtained as a result of performing convolution by "λ_N", a probability distribution of the variation in the boarding time can be obtained.

[0099]

Specifically, for example, denoting the probability variables by "X" and "Y" and respective probability distributions thereof by "pX(x)" and "pY(y)", convolution is performed by calculating a probability distribution "pZ(z)" of a function Z = f(X, Y) as represented by Expression (4) below.

$$pZ(z) = \int \Delta(z - f(x, y))pX(x)pY(y)dxdy \quad (4)$$

[0100]

[Variation of processing in Step_D1]

A variation of processing in Step_D1 that is performed by the convolution calculator 521 will be described.

In the first approach, a negative binomial distribution is assumed and a delay probability distribution of a target event (an event N) is considered a distribution with an expected value that is shifted by a variation of a boarding time from an expected value of a distribution (hereinafter, an original distribution) that is determined according to inter-event delay time information. The original distribution corresponds to a delay probability distribution that is calculated when the variation in the boarding time is not taken into consideration. As another method, instead of shifting the expected value, a distribution obtained by shifting the original distribution itself by the variation in the boarding time may be adopted as the delay probability distribution of the target event. Shift processing may be processing similar to that performed by the margin shifter 522.

[0101]

Alternatively, instead of a distribution obtained by shifting the original distribution, a probability distribution having, as a new probability variable, a sum of the probability variable of the original distribution and the probability variable of the variation in the boarding time may be adopted as the delay probability distribution of the target event. In this case, in a similar manner to the processing by the convolution calculator 521, the delay probability distribution of the target event can be obtained by a convolution of the original distribution and the probability distribution of the variation in the boarding time.

[0102]

As described above, according to the first approach, the following effects can be obtained. The number of people who board a train at a station between the train arriving at the station and the train departing the station varies depending on a delay time of a preceding event of another train, a delay time of the arrival of the train to be boarded at the station, and the like. In the present approach, the varying affects an inter-event delay time between an event in which the train departs and an event in which the train arrives and affects a delay time of the event in which the train departs. In the present approach, by arranging the variation in the number of people boarding onto a delay time between events, the delay time of the departing event can be correctly evaluated. Accordingly, an operation diagram can be correctly reflected onto the evaluation. In other words, the number of people who board a train between the train arriving at the station and the train departing the station varies depending on a delay time of a departure of another train which precedes the train to be boarded at the station, a delay time of the arrival of the train to be boarded at the station, and the like. For example, when the preceding departure of the other train is delayed but the arrival of the train to be boarded is on-time, the inter-event delay time becomes shorter than an expected value and the number of people who board the train conceivably decreases. In addition, when the preceding departure of the other train is delayed and the arrival of the train to be boarded is significantly delayed, the inter-event delay time becomes longer than the expected value and the number of people who board the train conceivably increases. Such variations in the number of people boarding affect a delay time between an event in which the train departs and an event in which the train arrives and affects a delay time of the event in which the train departs. In the present approach, by arranging such variations in the number of people boarding onto a delay time between events, the delay time of the departing event can be correctly evaluated.

[0103]

While a case where a variation in a delay time between an arrival and a departure at a station is affected by a variation in the number of people boarding has been described as an example in the present approach, a target that affects the variation in the delay time is not limited to the variation in the number of people boarding. For example, there may be cases where the variation in the delay time is affected by a variation in a confirmation time by a station employee or a variation in the number of people alighting from a train having arrived at the station. In both cases, the variation in the confirmation time by a station employee or the like can be handled in a similar manner to the variation in the people boarding and a probability distribution of a delay time of a departure event can be created which reflects the variation in the confirmation time by a station employee or the like.

[0104]

The user may correct diagram information based on a delay time of an event having been evaluated according to the present approach. A correction of the diagram information is performed by, for example, an input operation using an input interface. When the diagram information is corrected, operation of trains may be controlled using a train controller based on the corrected diagram information. An information processing system including the present information processing device and trains (one or more vehicles) may be constructed. Alternatively, an information processing system including the present information processing device, trains (one or more vehicles), and a train controller may be constructed.

[0105]

FIG. 17 shows a diagram evaluator 101A (hereinafter, a present device 101A) that is an information processing device according to a second approach. A configuration that performs correction processing of a boarding time varying model has been added. Specifically, in addition to the device 101 shown in FIG. 1, the present device 101A includes an information input device 150, an information storage 260, a model corrector 530, and a corrected model information storage 270.

[0106]

The information input device 150 acquires information for correcting a boarding time varying model. The information input device 150 may acquire the information via an input operation by the user or acquire information from a sensor or a computer such as a server. An example of the sensor is a camera installed on a platform or inside a vehicle. From an image taken by the camera, a computer or the information input device 150 may acquire information such as the number of people on the platform, the number of people alighting from a train, or the number of people boarding a train as historic data.

[0107]

The information storage 260 stores information acquired by the information input device 150.

[0108]

The model corrector 530 corrects the boarding time varying model based on the information stored in the information storage 260. For example, the model corrector 530 performs processing such as correcting a parameter value of the boarding time varying model, adding a correction term to the boarding time varying model, or modifying a function form of the boarding time varying model itself. The correction has an effect of enhancing accuracy of the boarding time varying model.

[0109]

The corrected model information storage 270 stores information of the boarding time varying model after the correction.

[0110]

Information stored in the corrected model information storage 270 is read by the model information input device 140 and stored in the model information storage 240. The information stored in the model information storage 240 is read by the delay probability distribution calculator 500 and the corrected boarding time varying model indicated in the information is used in processing by the delay probability distribution calculator 500. In the processing in Step_D0, the delay probability distribution calculator 500 calculates a variation in a boarding time (a variation in an inter-event delay time) using the corrected boarding time varying model. In other words, the delay probability distribution calculator 500 calculates the variation in the boarding time (the variation in the inter-event delay time) based on the information acquired by the information input device 150.

[0111]

Hereinafter, a variation of information acquired by the information input device 150 will be described together with an example of correction processing performed by the model corrector 530. Two or more types of correction processing based on information of each variation described below may be combined. In addition, acquired information and correction processing may vary for each event.

[0112]

[Event attribute information]

The information input device 150 acquires attribute information of an event (event attribute information). For example, event attribute information includes attributes of an event such as a station, a route, a direction of travel, a type of operation such as local service or express, and a time of the event. A part of event attribute information may be included in diagram information. For example, the time of an event is included in diagram information.

[0113]

The model corrector 530 corrects the boarding time varying model based on the present information. For example, when the type of operation of a target event is an express, assuming that the number of passengers that increases per unit time due to a delay is larger than in a case of local service, a proportionality coefficient may be multiplied by a weight that is larger than 1. Alternatively, other types of correction may be performed such as adding a correction term that is a predetermined positive value to the boarding time varying model. In the processing in

Step_D0, the delay probability distribution calculator 500 calculates a variation in a boarding time (a variation in an inter-event delay time) using the corrected boarding time varying model. In other words, the delay probability distribution calculator 500 calculates the variation in the boarding time (the variation in the inter-event delay time) based on the event attribute information acquired by the information input device 150.

[0114]

[Connection information]

The information input device 150 acquires connection information. For example, connection information includes information related to the connecting event (an arrival event that becomes a source of connection to a target event) described earlier and a trip including the connecting event (a train to which the trip is assigned is referred to as a "connecting train").

[0115]

Specific examples include crowdedness (or a congestion degree) on a platform of a connecting event, the number of alighting passengers (the number of passengers alighting from a train in the connecting event), a ratio of the number of alighting passengers to the number of passengers on the train, and a time required by a connection to the target event (required connection time). In addition, the connection information may include information related to an event other than an event to be a target of a connection from the connecting event (the target event described above) and a trip including the event.

[0116]

The model corrector 530 corrects the boarding time varying model based on the connection information. For example, assuming that the boarding time increases when the crowdedness of a platform is high, a proportionality coefficient may be multiplied by a weight in accordance with the crowdedness. Alternatively, other types of correction may be performed such as adding a correction term in accordance with the crowdedness to the boarding time varying model. For example, the crowdedness may be calculated by dividing the number of people present on a platform including the number of alighting passengers with the allowable number of people on the platform or by other methods. A platform on which the connecting event takes place may be the same as or different from a platform on which the target event takes place.

[0117]

In addition, the model corrector 530 may determine whether or not, due to a delay of a connecting event, a time interval between a time of a target event and a time (delayed time) of the connecting event becomes equal to or shorter than a required connection time (whether or not connection becomes infeasible). When connection becomes infeasible, the model corrector 530 corrects the boarding time varying model so that a variation in a boarding time of the target event becomes smaller due to a decrease in the number of connecting passengers. A proportionality coefficient may be multiplied by a weight that is smaller than 1. Alternatively, other types of correction may be performed such as adding a correction term that has a predetermined negative value to the boarding time varying model. Furthermore, the model corrector 530 corrects a boarding time varying model with respect to a departure event on a different trip immediately following the target event on a same track (a same route) so that a variation in a boarding time of the departure event becomes larger due to an increase in the number of connecting passengers. A proportionality coefficient may be multiplied by a weight that is larger than 1. Alternatively, other types of correction may be performed such as adding a correction term that has a predetermined positive value to the boarding time varying model.

[0118]

In the processing in Step_D0, the delay probability distribution calculator 500 calculates a variation in a boarding time (a variation in an inter-event delay time) using the corrected boarding time varying model. In other words, the delay probability distribution calculator 500 calculates the variation in the boarding time (the variation in the inter-event delay time) based on the connection information acquired by the information input device 150.

[0119]

[Weather information]

The information input device 150 acquires weather information. For example, the weather information includes forecast values at the time of occurrence of the target event such as outside temperature, the presence or absence of precipitation, and an amount of precipitation. When there is a rainfall forecast for the time of occurrence of the target event, assuming that the number of boarding passengers decreases, the model corrector 530 corrects the boarding time varying model so that a variation in a boarding time becomes smaller in accordance with the amount of precipitation. For example, a correction term that reduces the variation in the boarding time in accordance with the amount of precipitation is added to the boarding time varying model. Alternatively, a proportionality coefficient may be multiplied by a weight in accordance with the amount of precipitation. In the processing in Step_D0, the delay probability distribution calculator 500 calculates a variation in a boarding time (a variation in an inter-event delay time) using the corrected boarding time varying model. In other words, the delay probability distribution calculator 500 calculates the variation in the boarding time (the variation in the inter-event delay time) based on the weather information acquired by the information input device 150.

[0120]

[Facility information]

The information input device 150 acquires facility information. An example of facility information is facility information of a location related to a stop position (track) of a target event. As a specific example, facility information includes the number of at least one of stairs and elevators present on a path from a platform to a ticket gate or to a route being a connection destination (a platform being a connection destination). Positions of at least one of stairs and elevators may be included in addition to the number thereof.

[0121]

It is assumed that passengers converge around a door of a vehicle to be positioned near stairs in a train that is a target event and that a boarding time at such a door becomes dominant in a variation of a boarding time of the target event. The model corrector 530 predicts a proportion of the number of passengers at a door with a maximum number of boarding passengers relative to all doors (a convergence of boarding passengers). The prediction may be performed based on past historic data, based on captured image data of inside of the train, or the numbers of boarding and alighting passengers for each door in passenger information to be described later. The model corrector 530 corrects the boarding time varying model based on a result of the prediction. A proportionality coefficient may be multiplied by a weight in accordance with the convergence. Alternatively, other types of correction may be performed such as adding a correction term in accordance with the convergence to the boarding time varying model. In the processing in Step_D0, the delay probability distribution calculator 500 calculates a variation in a boarding time (a variation in an inter-event delay time) using the corrected boarding time varying model. In other words, the delay probability distribution calculator 500 calculates the variation in the boarding time (the variation in the inter-event delay time) based on the facility information acquired by the information input device 150.

[0122]

[Information on large-scale events]

The information input device 150 acquires information on a large-scale event such a special event or a festival (please be noted that "a large-scale event" is different from a target event with respect to a train as described before in each approach). For example, the information on a large-scale event includes information on whether or not a large-scale event near a station of a target event for a train is to be held, a date and time of the large-scale event, and the number of people to participate in the large-scale event.

[0123]

The model corrector 530 determines whether or not the target event is included within a certain period of time with respect to at least one of a start time and an end time of the large-scale event near the station of the target event (whether or not a target event is near to at least one of the start time and the end time of the large-scale event). When included within the certain period of time (when near), a correction term that increases a variation of a boarding time of the target event in accordance with the number of people participating in the large-scale event is added to the boarding time varying model. Alternatively, a proportionality coefficient may be multiplied by a weight in accordance with the number of participants. In the processing in Step_D0, the delay probability distribution calculator 500 calculates a variation in a boarding time (a variation in an inter-event delay time) using the corrected boarding time varying model. In other words, the delay probability distribution calculator 500 calculates the variation in the boarding time (the variation in the inter-event delay time) based on the information on a large-scale event acquired by the information input device 150.

[0124]

[Vehicle attribute information]

The information input device 150 acquires vehicle attribute information. For example, the vehicle attribute information includes the number of units included a train that operates in a target event and a vehicle type of each vehicle such as a moderately air-conditioned unit.

[0125]

When the target event is operated on a same track (a same route) by trains of which the numbers of vehicles differ from each other, it is assumed that a train with a smaller number of vehicles requires a longer boarding time as compared to a train with a larger number of vehicles. The model corrector 530 corrects a boarding time varying model so that a variation in a boarding time of the target event varies in accordance with the numbers of vehicles in a train of the target event. For example, a correction term in accordance with the number of vehicles is added to the boarding time varying model or a proportionality coefficient is multiplied by a weight in accordance with the number of vehicles. In the processing in Step_D0, the delay probability distribution calculator 500 calculates a variation in a boarding time (a variation in an inter-event delay time) using the corrected boarding time varying model. In other words, the delay probability distribution calculator 500 calculates the variation in the boarding time (the variation in the inter-event delay time) based on the vehicle attribute information acquired by the information input device 150.

[0126]

[Passenger information]

The information input device 150 acquires passenger information. For example, the passenger information includes the number of boarding passengers and a ratio thereof, and the number of alighting passengers and a ratio thereof. In addition, the passenger information may include these numbers and ratios of passengers for each vehicle or each vehicle door.

[0127]

With a departure event after an immediately-preceding arrival event with a high ratio of the number of alighting passengers to the number of passengers on a train, since the number of passengers on the train decreases, it is assumed that a boarding time has a small effect on a stoppage time (a time interval between the departure event and the immediately-preceding arrival event). The model corrector 530 corrects a boarding time varying model so that a variation in a boarding time of the departure event (the target event) decreases in accordance with a ratio of the number of alighting passengers in the immediately-preceding arrival event. For example, a correction term in accordance with the ratio is added to the boarding time varying model or a proportionality coefficient is multiplied by a weight in accordance with the ratio. In the processing in Step_D0, the delay probability distribution calculator 500 calculates a variation in a boarding time (a variation in an inter-event delay time) using the corrected boarding time varying model. In other words, the delay probability distribution calculator 500 calculates the variation in the boarding time (the variation in the inter-event delay time) based on the passenger information acquired by the information input device 150.

[0128]

[Information on other passengers]

The information input device 150 acquires information on other passengers. Other passengers refer to passengers other than boarding passengers and alighting passengers of a target event. Examples of other passengers include passengers on a train who do not alight therefrom and passengers on a platform who do not board the train. For example, information on other passengers include the number of other passengers in vehicles or a ratio (crowdedness) thereof. These values may be included for each vehicle of a train or for each vehicle door. The information on other passengers may include the number of other passengers on a platform or a ratio (crowdedness) thereof.

[0129]

It is assumed that, when crowdedness inside a vehicle is high, a boarding time increases (the time required to board the vehicle increases). The model corrector 530 corrects a boarding time varying model so that a variation in a boarding time of the target event increases in accordance with the crowdedness. For example, a correction term in accordance with the crowdedness is added to the boarding time varying model or a proportionality coefficient is multiplied by a weight in accordance with the crowdedness. In the processing in Step_D0, the delay probability distribution calculator 500 calculates a variation in a boarding time (a variation in an inter-event delay time) using the corrected boarding time varying model. In other words, the delay probability distribution calculator 500 calculates the variation in the boarding time (the variation in the inter-event delay time) based on the information on other passengers acquired by the information input device 150.

[0130]

[Camera image information]

The information input device 150 acquires camera image information. For example, camera image information includes images taken by a camera installed at a ticket gate or a platform of a station or inside a vehicle and information extracted from the images.

[0131]

The model corrector 530 estimates the number of boarding passengers from the camera images and corrects the boarding time varying model in accordance with an estimated value. For example, a correction term in accordance with the number of boarding passengers is added to the boarding time varying model or a proportionality coefficient is multiplied by a weight in accordance with the number of boarding passengers. In the processing in Step_D0, the delay probability distribution calculator 500 calculates a variation in a boarding time (a variation in an inter-event delay time) using the corrected boarding time varying model. In other words, the delay probability distribution calculator 500 calculates the variation in the boarding time (the variation in the inter-event delay time) based on the camera image information acquired by the information input device 150.

[0132]

(Hardware configuration)

FIG. 18 illustrates a hardware configuration of the information processing device according to each approach. The information processing device is configured as a computer device 600. The computer device 600 includes a CPU 601, an input interface 602, a display device 603, a communication device 604, a main storage device 605, and an external storage device 606, and these components are mutually connected through a bus 607.

[0133]

The CPU (central processing unit) 601 executes an information processing program as a computer program on the main storage device 605. The information processing program is a computer program configured to achieve each above-described functional component of the present device. The information processing program may be achieved by a combination of a plurality of computer programs and scripts instead of one computer program. Each functional component is achieved as the CPU 601 executes the information processing program.

[0134]

The input interface 602 is a circuit for inputting, to the present device, an operation signal from an input device such as a keyboard, a mouse, or a touch panel. The input interface 602 corresponds to the input device in each approach.

[0135]

The display device 603 displays data output from the present device. The display device 603 is, for example, a liquid crystal display (LCD), an organic electroluminescence display, a cathode-ray tube (CRT), or a plasma display (PDP) but is not limited thereto. Data output from the computer device 600 can be displayed on the display device 603. The display device 603 corresponds to the output device in each approach.

[0136]

The communication device 604 is a circuit for the present device to communicate with an external device in a wireless or wired manner. Data can be input from the external device through the communication device 604. The data input from the external device can be stored in the main storage device 605 or the external storage device 606. The communication device 604 corresponds to the input device in each approach.

[0137]

The main storage device 605 stores, for example, the information processing program, data necessary for execution of the information processing program, and data generated through execution of the information processing program. The information processing program is loaded and executed on the main storage device 605. The main storage device 605 is, for example, a RAM, a DRAM, or an SRAM but is not limited thereto. Each storage or database in the information processing device in each approach may be implemented on the main storage device

605.

[0138]

The external storage device 606 stores, for example, the information processing program, data necessary for execution of the information processing program, and data generated through execution of the information processing program. The information processing program and the data are read onto the main storage device 605 at execution of the information processing program. The external storage device 606 is, for example, a hard disk, an optical disk, a flash memory, or a magnetic tape but is not limited thereto. Each storage or database in the information processing device in each approach may be implemented on the external storage device 606.

[0139]

The information processing program may be installed on the computer device 600 in advance or may be stored in a storage medium such as a CD-ROM. Moreover, the information processing program in each approach may be uploaded on the Internet.

[0140]

The present device may be configured as a single computer device 600 or may be configured as a system including a plurality of mutually connected computer devices 600.

[0141]

While certain approaches have been described, these approaches have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel approaches described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the approaches described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

[0142]

The approaches as described before may be configured as below.

(Clauses)

Clause 1. An information processing device, comprising:

a processor configured to:

generate first inter-event delay time information representing a delay time between a first event and a second event that precedes the first event among a plurality of events based on delay time information representing a delay time of a third event that precedes the first event, the plurality events including a departure or an arrival at a plurality of stop positions and a time of the departure or the arrival with respect to at least one vehicle; and

generate delay time information representing a delay time of the first event based on the first inter-event delay time information and delay time information representing a delay time of the second event.

Clause 2. The information processing device according to clause 1, wherein

the processor is configured to:

calculate variation information representing a variation of the delay time between the first event and the second event based on the delay time information of at least one of the third event and the second event; and

generate the first inter-event delay time information based on the variation information and second inter-event delay time information representing a delay time between the first event and the second event.

Clause 3. The information processing device according to clause 2, wherein

the first event is an event including the departure of a first vehicle at a first stop position, and

the variation information represents a variation in the number of people boarding the first vehicle at the first stop position.

Clause 4. The information processing device according to clause 3, wherein

the second event includes an event which precedes the first event and which includes the arrival of the first vehicle at the first stop position.

Clause 5. The information processing device according to clause 3 or 4, wherein

the third event includes an event which precedes the second event and in which a second vehicle departs the first stop position.

Clause 6. The information processing device according to any one of clauses 2 to 5, wherein

the processor is configured to calculate the variation information in accordance with a difference between an expected value of the delay time of the second event and an expected value of the delay time of the third event.

Clause 7. The information processing device according to clause 6, wherein

the processor is configured to calculate the variation information by multiplying the difference by a proportionality coefficient corresponding to a variation in the delay time between the first event and the second event.

Clause 8. The information processing device according to any one of clauses 2 to 7, wherein

the second inter-event delay time information is an expected value of a delay time between the first event and the second event, and

the first inter-event delay time information is generated by changing the expected value in accordance with the variation information and providing the varied expected value as an input parameter of a negative binomial distribution.

Clause 9. The information processing device according to clause 8, wherein

the processor is configured to generate the delay time information of the first event by convolving the first inter-event delay time information and the delay time information of the second event.

Clause 10. The information processing device according to any one of clauses 2 to 6, wherein

the delay time information of the second event includes a probability distribution of a delay time of the second event,

the delay time information of the third event includes a probability distribution of a delay time of the third event, and the processor is configured to calculate a probability distribution of the variation by performing a convolution of the probability distribution of the delay time of the second event and the probability distribution of the delay time of the third event and by multiplying a probability variable of a probability distribution obtained due to the convolution by a proportionality coefficient corresponding to a variation in the delay time between the first event and the second event.

Clause 11. The information processing device according to any one of clauses 2 to 10, wherein

the processor is configured to calculate the variation information based on attribute information of the first event.

Clause 12. The information processing device according to any one of clauses 2 to 11, wherein

the first event is an event including the departure of a first vehicle at a first stop position, and

the processor is configured to calculate the variation information based on information related to a connecting event that is an event of an arrival of a second vehicle to be a connection source to the first vehicle in the first event.

Clause 13. The information processing device according to any one of clauses 2 to 12, wherein

the processor is configured to calculate the variation information based on weather information corresponding to the time of the first event.

Clause 14. The information processing device according to any one of clauses 2 to 13, wherein

the processor is configured to calculate the variation information based on facility information of a location related to a stop position of the first event.

Clause 15. The information processing device according to any one of clauses 2 to 14, wherein

the processor is configured to calculate the variation information based on an implementation status of a large-scale event near a stop position of the first event at a time of the first event.

Clause 16. The information processing device according to any one of clauses 2 to 15, wherein

the processor is configured to calculate the variation information based on attribute information of a vehicle to operate the first event.

Clause 17. The information processing device according to any one of clauses 2 to 16, wherein

the processor is configured to calculate the variation information based on information related to passengers boarding or alighting from a vehicle to operate the first event.

Clause 18. The information processing device according to any one of clauses 2 to 17, wherein

the processor is configured to calculate the variation information based on information related to, among passengers near a vehicle to operate the first event or near a stop position of the first event, passengers who neither board the vehicle nor alight from the vehicle.

Clause 19. The information processing device according to any one of clauses 2 to 18, wherein

the processor is configured to calculate the variation information based on an image captured by a camera installed on at least one of a platform including a stop position of the first event, a ticket gate of a station including the stop position, and inside a vehicle to operate the first event.

Clause 20. The information processing device according to clause 7 to 10, further comprising an output device configured to

display an input interface to which a user can input a value of the proportionality coefficient on a screen and display, on the screen, the delay time information of the first event having been generated by the processor based on the value of the proportionality coefficient input via the input interface.

Clause 21. The information processing device according to any one of clauses 1 to 19, wherein

the vehicle is a train including a plurality of vehicles.

Clause 22. An information processing system, comprising:

at least one vehicle;

a processor configured to:

generate first inter-event delay time information representing a delay time between a first event and a second event that precedes the first event among a plurality of events based on delay time information representing a delay time of a third event that precedes the first event, the plurality events including a departure or an arrival at a plurality of stop positions and a time of the departure or the arrival with respect to the at least one vehicle; and

generate delay time information representing a delay time of the first event based on the first inter-event delay time information and delay time information representing a delay time of the second event.

Clause 23. An information processing method, comprising:

generating first inter-event delay time information representing a delay time between a first event and a second event that precedes the first event among a plurality of events based on delay time information representing a delay time of a third event that precedes the first event, the plurality events including a departure or an arrival at a plurality of stop positions and a time of the departure or the arrival with respect to at least one vehicle; and

generating delay time information representing a delay time of the first event based on the first inter-event delay time information and delay time information representing a delay time of the second event.

Clause 24. A computer program which when executed by a computer, causes the computer to perform processes, comprising:

generating first inter-event delay time information representing a delay time between a first event and a second event that precedes the first event among a plurality of events based on delay time information representing a delay time of a third event that precedes the first event, the plurality events including a departure or an arrival at a plurality of stop positions and a time of the departure or the arrival with respect to at least one vehicle; and

generating delay time information representing a delay time of the first event based on the first inter-event delay time information and delay time information representing a delay time of the second event.

CLAIMS

1. An information processing device, comprising:

a processor configured to:

generate first inter-event delay time information representing a delay time between a first event and a second event that precedes the first event among a plurality of events based on delay time information representing a delay time of a third event that precedes the first event, the plurality events including a departure or an arrival at a plurality of stop positions and a time of the departure or the arrival with respect to at least one vehicle; and

generate delay time information representing a delay time of the first event based on the first inter-event delay time information and delay time information representing a delay time of the second event.

2. The information processing device according to claim 1, wherein

the processor is configured to:

calculate variation information representing a variation of the delay time between the first event and the second event based on the delay time information of at least one of the third event and the second event; and

generate the first inter-event delay time information based on the variation information and second inter-event delay time information representing a delay time between the first event and the second event.

3. The information processing device according to claim 2, wherein

the first event is an event including the departure of a first vehicle at a first stop position, and

the variation information represents a variation in the number of people boarding the first vehicle at the first stop position.

4. The information processing device according to claim 3, wherein

the second event includes an event which precedes the first event and which includes the arrival of the first vehicle at the first stop position.

5. The information processing device according to claim 3 or 4,

wherein

the third event includes an event which precedes the second event and in which a second vehicle departs the first stop position.

6. The information processing device according to any one of claims 2 to 5, wherein

the processor is configured to calculate the variation information in accordance with a difference between an expected value of the delay time of the second event and an expected value of the delay time of the third event.

7. The information processing device according to claim 6, wherein

the processor is configured to calculate the variation information by multiplying the difference by a proportionality coefficient corresponding to a variation in the delay time between the first event and the second event.

8. The information processing device according to any one of claims 2 to 7, wherein

the second inter-event delay time information is an expected value of a delay time between the first event and the second event, and

the first inter-event delay time information is generated by changing the expected value in accordance with the variation information and providing the varied expected value as an input parameter of a negative binomial distribution.

9. The information processing device according to claim 8, wherein

the processor is configured to generate the delay time information of the first event by convolving the first inter-event delay time information and the delay time information of the second event.

10. The information processing device according to any one of claims 2 to 6, wherein

the delay time information of the second event includes a probability distribution of a delay time of the second event,

the delay time information of the third event includes a probability distribution of a delay time of the third event, and the processor is configured to calculate a probability distribution of the variation by performing a convolution of the probability distribution of the delay time of the second event and the probability distribution of the delay time of the third event and by multiplying a probability variable of a probability distribution obtained due to the convolution by a proportionality coefficient corresponding to a variation in the delay time between the first event and the second event.

11. The information processing device according to any one of claims 2 to 10, wherein

the processor is configured to calculate the variation information based on attribute information of the first event.

12. The information processing device according to any one of claims 2 to 11, wherein

the first event is an event including the departure of a first vehicle at a first stop position, and

the processor is configured to calculate the variation information based on information related to a connecting event that is an event of an arrival of a second vehicle to be a connection source to the first vehicle in the first event.

13. The information processing device according to any one of claims 2 to 12, wherein

the processor is configured to calculate the variation information based on weather information corresponding to the time of the first event.

14. The information processing device according to any one of claims 2 to 13, wherein

the processor is configured to calculate the variation information based on facility information of a location related to a stop position of the first event.

15. The information processing device according to any one of claims 2 to 14, wherein

the processor is configured to calculate the variation information based on an implementation status of a large-scale event near a stop position of the first event at a time of the first event.

16. The information processing device according to any one of claims 2 to 15, wherein

the processor is configured to calculate the variation information based on attribute information of a vehicle to operate the first event.

17. The information processing device according to any one of claims 2 to 16, wherein

the processor is configured to calculate the variation information based on information related to passengers boarding or alighting from a vehicle to operate the first event.

18. The information processing device according to any one of claims 2 to 17, wherein

the processor is configured to calculate the variation information based on information related to, among passengers near a vehicle to operate the first event or near a stop position of the first event, passengers who neither board the vehicle nor alight from the vehicle.

19. The information processing device according to any one of claims 2 to 18, wherein

the processor is configured to calculate the variation information based on an image captured by a camera installed on at least one of a platform including a stop position of the first event, a ticket gate of a station including the stop position, and inside a vehicle to operate the first event.

20. The information processing device according to claim 7 or 10, further comprising an output device configured to

display an input interface to which a user can input a value of the proportionality coefficient on a screen and display, on the screen, the delay time information of the first event having been generated by the processor based on the value of the proportionality coefficient input via the input interface.

21. The information processing device according to any one of claims 1 to 19, wherein

the vehicle is a train including a plurality of vehicles.

22. An information processing system, comprising:

at least one vehicle;

a processor configured to:

generate first inter-event delay time information representing a delay time between a first event and a second event that precedes the first event among a plurality of events based on delay time information representing a delay time of a third event that precedes the first event, the plurality events including a departure or an arrival at a plurality of stop positions and a time of the departure or the arrival with respect to the at least one vehicle; and

generate delay time information representing a delay time of the first event based on the first inter-event delay time information and delay time information representing a delay time of the second event.

23. An information processing method, comprising:

generating first inter-event delay time information representing a delay time between a first event and a second event that precedes the first event among a plurality of events based on delay time information representing a delay time of a third event that precedes the first event, the plurality events including a departure or an arrival at a plurality of stop positions and a time of the departure or the arrival with respect to at least one vehicle; and

generating delay time information representing a delay time of the first event based on the first inter-event delay time information and delay time information representing a delay time of the second event.

24. A computer program which when executed by a computer, causes the computer to perform processes, comprising:

generating first inter-event delay time information representing a delay time between a first event and a second event that precedes the first event among a plurality of events based on delay time information representing a delay time of a third event that precedes the first event, the plurality events including a departure or an arrival at a plurality of stop positions and a time of the departure or the arrival with respect to at least one vehicle; and

generating delay time information representing a delay time of the first event based on the first inter-event delay time information and delay time information representing a delay time of the second event.