(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 212 406 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
19.07.2023 Bulletin 2023/29

(21) Application number: **22194351.7**

(22) Date of filing: **07.09.2022**

(51) International Patent Classification (IPC):
B61L 27/12 *(2022.01)* ***B61L 27/16*** *(2022.01)*

(52) Cooperative Patent Classification (CPC):
B61L 27/12; B61L 27/16

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **07.01.2022 JP 2022001827**

(71) Applicant: **KABUSHIKI KAISHA TOSHIBA**
Minato-ku
Tokyo
105-0023 (JP)

(72) Inventors:
- **Hatakeyama, Ryoko**
  Tokyo, 105-0023 (JP)
- **Otsuki, Tomoshi**
  Tokyo, 105-0023 (JP)
- **Hideki, Kubo**
  Tokyo, 105-0023 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) **INFORMATION PROCESSING DEVICE, INFORMATION PROCESSING METHOD, AND COMPUTER PROGRAM**

(57) According to one approach, an information processing device includes a processor. The processor acquires time information related to arrival times of a plurality of moving objects at a target zone including a plurality of storage sections in which one or more moving objects can be stored and departure times at which the plurality of moving objects depart from the target zone. The processor acquires direction information related to directions in which the plurality of storage sections can be arrived and directions from which the plurality of storage sections can be departed. The processor determines a storage section in which the plurality of the moving objects is to be stored among the plurality of storage sections, based on the time information and the direction information.

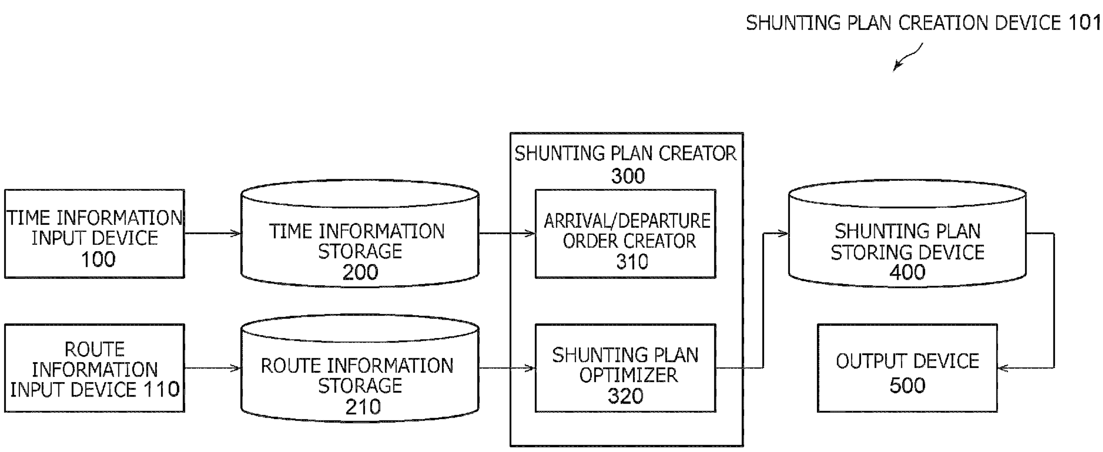

FIG. 1

Processed by Luminess, 75001 PARIS (FR)

Description

FIELD

[0001] Approaches described herein relate to an information processing device, an information processing method, and a computer program.

BACKGROUND

[0002] A railway operator creates a rolling stock operation plan (operation plan) in order to realize a given train timetable and also creates a shunting plan for storing the train at a railway yard or a station after the end of service. There are many constraints that must be taken into consideration when creating a shunting plan or an operation plan. For example, while a shunting plan is desirably created to satisfy as many constraints as possible, manually creating a shunting plan is time-consuming.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003]

FIG. 1 is a block diagram showing a shunting plan creation device that is an information processing device according to a first configuration example of a first approach;
FIG. 2 is a schematic view showing an example of a track structure from which a train having arrived first departs last;
FIG. 3 is a schematic view showing an example of a track structure from which a train having arrived first departs first;
FIG. 4 is a schematic view showing another example of a track structure from which a train having arrived first departs last;
FIG. 5 is a schematic view showing another example of a track structure from which a train having arrived first depart first;
FIG. 6 is a diagram representing an example of time information indicating an arrival time and a next-day departure time of each train;
FIG. 7 is a diagram representing an example of arrival/departure order information indicating an order of arrival and next-day departure of each train;
FIG. 8 is a diagram showing an example of information on tracks at a target railway yard;
FIG. 9 is a diagram showing an example of a shunting plan created by a shunting plan optimizer;
FIG. 10 is a diagram showing an example of an output format of a shunting plan;
FIG. 11 is a diagram showing an example of an output format of a shunting plan;
FIG. 12 is a flow chart of an example of operations of the shunting plan creation device that is an information processing device according to the first configuration example of the first approach;
FIG. 13 is a block diagram of a shunting plan creation device that is an information processing device according to a second configuration example of the first approach;
FIG. 14 is a diagram representing an example of train unit count information indicating the number of vehicles in each train;
FIG. 15 is a diagram showing an example of information on tracks at a target railway yard when train unit count information is provided;
FIG. 16 is a diagram showing an example of an output format of a shunting plan when train unit count information is provided;
FIG. 17 is a block diagram of a shunting plan creation device that is an information processing device according to a third configuration example of the first approach;
FIG. 18 is a diagram showing an example of a track structure represented by route connection information;
FIG. 19 is a block diagram of a shunting plan creation device that is an information processing device according to a fourth configuration example of the first approach;
FIG. 20 is a diagram describing an example of storage condition information;
FIG. 21 is a block diagram of a shunting plan creation device that is an information processing device according to a fifth configuration example of the first approach;
FIG. 22 is a block diagram of an operation plan creation device that is an information processing device according to a first configuration example of a second approach;
FIG. 23 is a diagram showing an example of creating a vehicle operation plan using a rolling stock circulation;
FIG. 24 is a diagram showing information (correspondence table) that associates a duty of a weekday timetable and a duty of a holiday timetable to each other on a one-to-one basis;

FIG. 25 is a diagram showing an example of train timetable information;
FIG. 26 is a diagram showing an example of work information stored in a work information storage;
FIG. 27 is a diagram showing an example of periodic information stored in a periodic information storage;
FIG. 28 is a diagram showing a plurality of duties created for each of a weekday timetable and a holiday timetable;
FIG. 29 is a diagram showing an example of a duty table for each of a weekday timetable and a holiday timetable;
FIGS. 30A and 30B show a diagram showing an example of collectively outputting a rolling stock circulation and a correspondence table in a tabular format as an optimization result table to an output device;
FIG. 31 is a diagram showing another display example of a rolling stock circulation and a correspondence table;
FIG. 32 is a flow chart of an example of operation plan creation processing executed by an operation plan creation device;
FIG. 33 is a block diagram of an operation plan creation device that is an information processing device according to a second configuration example of the second approach;
FIG. 34 is a block diagram of an operation plan creation device that is an information processing device according to a first configuration example of a third approach;
FIG. 35 is a diagram showing an example of track information as route information;
FIGS. 36A and 36B show a diagram showing a display example of an operation plan (including a shunting plan, a rolling stock circulation, and a correspondence table);
FIG. 37 is a flow chart of an example of operation plan creation processing executed by an operation plan creation device;
FIG. 38 is a block diagram of an operation plan creation device that is an information processing device according to a second configuration example of the third approach;
FIG. 39 is a block diagram of an operation plan creation device that is an information processing device according to a third configuration example of the third approach;
FIG. 40 is a diagram showing an output example of a shunting plan; and
FIG. 41 is a diagram showing a hardware configuration of an information processing device according to each approach.

DETAILED DESCRIPTION

[0004] According to one approach, an information processing device includes a processor. The processor acquires time information related to arrival times of a plurality of moving objects at a target zone including a plurality of storage sections in which one or more moving objects can be stored and departure times at which the plurality of moving objects depart from the target zone. The processor acquires direction information related to directions in which the plurality of storage sections can be arrived and directions from which the plurality of storage sections can be departed. The processor determines a storage section in which the plurality of the moving objects is to be stored among the plurality of storage sections, based on the time information and the direction information.

[0005] Hereinafter, approaches of the present invention will be described with reference to the drawings. While a train will be described in each of the approaches to be presented below, the present invention can be implemented on any moving object such as a bus, a vessel, a robot, an AGV (Automatic Guided Vehicle), a transporter, or the like in a similar manner to a train.

(First approach)

[First configuration example]

[0006] FIG. 1 is a block diagram of a shunting plan creation device 101 that is an information processing device according to a first configuration example of a first approach. The shunting plan creation device 101 creates a shunting plan for storing a train of vehicles in a target zone (storage zone) such as a railway station or a railway yard. Storing a train in a target zone is called storage. The target zone is provided with one or a plurality of storage sections where the train is stored. The storage section is also referred to as a track or a route. One or a plurality of trains can be stored (detained) in tandem on one track (one storage section), depending on a length of the track.

[0007] In the present approach, a shunting plan is created so as to eliminate the need to shunt a train on a track, to minimize, or to reduce as much as possible, sets of trains that need to be shunted. The shunting plan creation device 101 determines a track (storage section) where each train is to be stored based on time information including an arrival time at which a train arrives at a target zone and a departure time at which the train departs the target zone and route information (section length information) including a length of a track. A time at which the train arrives the target zone is referred to as an arrival time and a time at which the train departs from the target zone is referred to as a departure time. The shunting plan creation device 101 creates a shunting plan including a track determined for each train.

[0008] The shunting plan creation device 101 includes a time information input device 100, a route information input device 110, a time information storage 200, a route information storage 210, a shunting plan creator 300, a shunting plan storing device 400, and an output device 500. The shunting plan creator 300 is processing circuitry or a processor including an arrival/departure order creator 310 and a shunting plan optimizer 320.

[0009] The time information input device 100 accepts an input operation of time information including at least times at which each train arrives and departs a railway yard or the like from a user who is an operator of the shunting plan creation device 101 and acquires the time information.

[0010] The route information input device 110 accepts an input operation of route information including at least a length of a track and a type of the track in a railway yard of a railway or the like from the user of the shunting plan creation device 101 and acquires the route information. A direction in which a track can be arrived and a direction in which the track can be departed are determined according to the type of the track. While types of tracks include a LIFO (Last In First Out) scheme, a FIFO (First In First Out) scheme, and a FREE scheme, details will be given later. A track is an example of a storage section in which a train is to be stored at a railway yard or the like and is not limited to being referred to as such.

[0011] The time information storage 200 stores time information input to the time information input device 100. As an example, the time information storage 200 is made of a storage medium such as a memory or a hard disk.

[0012] The route information storage 210 stores route information input to the route information input device 110. As an example, the route information storage 210 is made of a storage medium such as a memory or a hard disk.

[0013] The output device 500 is a device that outputs information (shunting plan output information) based on a shunting plan created by the shunting plan creation device 101. As an example, the output device 500 is a display device capable of displaying data such as a liquid crystal display, an organic electroluminescence display, an LED (Light Emitting Diode) display, or a display using another scheme. The output device 500 may be a printer that prints data on a sheet of paper or a transmitter which transmits data in a wireless or wired manner. In the following description, a case where the output device 500 is a display device will be assumed.

[0014] A shunting plan is data in which one or a plurality of target trains is assigned to tracks in a railway yard or the like. A shunting plan is created by assigning one or a plurality of target trains to tracks in a railway yard or the like. Tracks in a railway yard or the like include a track capable of storing a plurality of trains in tandem, a track with a branch, or a complex track structure combining such tracks. A maximum value of the number of vehicles that can be stored in tandem on a given track will be referred to as the number of units storable in tandem (capacity) of the track. When the number of vehicles included in one train (hereinafter, referred to as the number of units in train) is equal in all trains, a maximum number of storable trains may be used as the number of units storable in tandem. In other words, a unit of the number of units storable in tandem may be a train. In the first configuration example, it is assumed that all of the numbers of units in train are equal and the number of units storable in tandem (capacity) is a maximum value of the number of trains storable in tandem on a given track.

[0015] An overnight stay means storing a train having arrived at a track after one day's operation until the following day's operation. During overnight stay, since all arrived trains basically cannot be shunted with other trains until the start of business operation on the following day, a limit is imposed on next-day departs depending on a track structure of the railway yard, a type of each track, or tracks on which other trains are stored.

[0016] FIG. 2 shows an example of a track structure of a typical type. A long thin line indicates a track and short bold lines indicate trains. Four trains L1 to L4 are stored on a track R1. The track R1 can only be arrived and departed on one side and an opposite side is an end. Therefore, "Last In First Out" in which a train having arrived last departs first is implemented. Accordingly, a limit is imposed in that an order of arrival and a reverse order of an order of departure coincide with each other on a same track. A type of such a track will be referred to as a LIFO scheme. In other words, a LIFO scheme is a scheme in which a track (storage section) can be arrived from a first direction, can be departed from the first direction, cannot be departed from a second direction that is opposite to the first direction, and cannot be arrived from the second direction.

[0017] FIG. 3 shows another example of a track structure of a typical type. In this track structure, one side of the track R1 enables a train to only arrive and the other side enables a train to only depart. In this track structure, "First In First Out" in which a train having arrived first departs first is implemented. A limit is imposed in that an order of arrival and an order of departure coincide with each other on a same track. A type of such a track will be referred to as a FIFO scheme. In other words, a FIFO scheme is a scheme in which a track (storage section) can be arrived from a first direction, cannot be departed from the first direction, can be departed from a second direction that is opposite to the first direction, and cannot be arrived from the second direction.

[0018] In addition to the LIFO scheme and the FIFO scheme, there is a track structure of a type that enables a train to arrive and depart from both ends of a track (not illustrated). A type of such a track will be referred to as a FREE scheme. In other words, a FREE scheme is a scheme in which a track (storage section) can be arrived from a first direction, can be departed from the first direction, can be departed from a second direction that is opposite to the first direction, and can be arrived from the second direction.

[0019] The railway yard mentioned in the following description is assumed to have a track structure adopting the LIFO scheme shown in FIG. 2.

[0020] While a simplified track structure only including one track has been demonstrated above for the sake of describing a track structure, a railway yard or the like may include a plurality of tracks.

[0021] FIG. 4 shows an example of a railway yard including a plurality of tracks having a track structure adopting the LIFO scheme. FIG. 5 shows an example of a railway yard including a plurality of tracks having a track structure adopting the FIFO scheme.

[0022] FIG. 6 shows an example of time information in the time information storage 200. The trains L1 to L5 are shown to be targets of creating a shunting plan. Time information includes an arrival time and a next-day departure time of each train at a railway yard and the like (a railway yard and a station where a train or a plurality of trains is to be stored overnight). When there are a plurality of railway yards and the like, the time information may include information on a departure location and an arrival location of each train.

[0023] Based on the time information in the time information storage 200 and the route information in the route information storage 210, the shunting plan creator 300 (processing circuitry or a processor) shown in FIG. 1 creates a shunting plan in which a train is assigned to a track in a railway yard and the like as a storage section for storing each train. The arrival/departure order creator 310 in the shunting plan creator 300 calculates an order of arrival (an order of arrival) and an order of depart (an order of departure) of trains based on the arrival time and the departure time (also referred to as a next-day departure time) of each train included in the time information. The order of departure is also referred to as an order of next-day departure. Trains of which an arrival time and a next-day departure time have been determined are sorted in the order of arrival times and the order of next-day departure times and an order of arrival and an order of departure are respectively determined.

[0024] FIG. 7 shows information on an order of arrival and an order of departure of each train (arrival/departure order information) obtained as a result of sorting.

[0025] Handling of a train that neither departs nor shunts (move to another track) on the following day and of which a next-day departure time has not been determined will now be described. Such a train is referred to as a reserve train. When there are one reserve train and n-number of arbitrary trains of which a next-day departure time has been determined, an order of departure of the reserve train is determined to be n+1. When there is a plurality of reserve trains, a suitable order of departure that does not change the orders of departure of the reserve trains is set. For example, when there are two trains to be reserve trains on the next day and assigned to business operation on the day after the next, an order of departure is set to n+1 and n+2 in an order of early business operation start times on the day after the next.

[0026] FIG. 8 shows an example of route information (track information) in the route information storage 210. Track information includes information on a length of a track and a type of the track. Information on the length of a track corresponds to information on a length of a storage section. Information on a type of a track corresponds to information on a direction in which the track (storage section) can be arrived and a direction from which the track (storage section) can be departed.

[0027] The example in FIG. 8 shows that there are two tracks R1 and R2 in a railway yard to be a target (a target railway yard). Route lengths or, in other words, the numbers of units stored in tandem of the tracks R1 and R2 are, respectively, 4 and 2. As types, both tracks R1 and R2 adopt the LIFO scheme. Since there are five trains (target trains) to be a target of creating a shunting plan (refer to FIG. 6), the target railway yard has an available storage position (space) for one train.

[0028] Information indicating an arrival/departure order (arrival/departure order information) calculated by the arrival/departure order creator 310 is input to the shunting plan optimizer 320 (processing circuitry or a processor). The shunting plan optimizer 320 constructs a mathematical model with decision variables, which determine a track on which each train is to be stored and the like. Based on the arrival/departure order information and the route information (track information), the shunting plan optimizer 320 calculates a solution to the mathematical model and creates a shunting plan based on the calculated solution.

[0029] First, symbols for describing a mathematical model when the number of units in train of each train is the same will be defined below.

P=6: number of trains

$\mathcal{P}$: set of trains {1, 2, ···, 6}

$\mathcal{T}$: set of tracks {1, 2}

t_p^{arv} : arrival time of train p $(p \in \mathcal{P})$

t_p^{dep} : departure time of train p $(p \in \mathcal{P})$

c_t: number of units stored in tandem on track t $(t \in \mathcal{T})$

variable y_{pt}: a variable that takes a value of 0 or 1 depending on whether or not train p is to be stored on track t $(p \in \mathcal{P}, t \in \mathcal{T})$

variable s_{pt}: a variable that takes a value of 0 or 1 depending on whether or not trains p and q need to be shunted $(p < q \in \mathcal{P})$

[0030] An example of a constraint for creating a shunting plan is represented by Expression 1 below. Expression 1 is a constraint that all trains p are to be stored on any of the tracks t.

[Expression 1]

$$\sum_{t \in \mathcal{T}} y_{pt} = 1 \quad \forall p \in \mathcal{P} \qquad (1)$$

[0031] An example of a constraint that the number of stored trains p does not exceed the number of units that in tandem on the track t is represented by Expression 2 below.

[Expression 2]

$$\sum_{p \in \mathcal{P}} y_{pt} \leq' C_t \quad \forall t \in \mathcal{T} \qquad (2)$$

[0032] As described above, a limit is imposed on orders of arrival and departure depending on a type of each track. Let us suppose that a set of trains p and q of which magnitude relationships of arrival and departure times are equal or, in other words, $t_p^{arv} < t_q^{arv}$ and $t_p^{dep} < t_q^{dep} \left(t_q^{arv} < t_p^{dep}\right)$ are satisfied are to be stored in tandem on a track adopting the LIFO scheme. In this case, since arriving according to arrival times results in storage in tandem in the order of trains p and q from a distal end and the train p is unable to depart according to the departure times because the train q is in the way, the trains p and q must be shunted upon arrival of the train q or until the departure of the train p. Therefore, tracks t adopting the LIFO scheme require a constraint that a set of trains p and q which need to be shunted are not stored on a same track (only one of the trains can be stored). An example of this constraint is represented by Expression 3 below.

[Expression 3]

$$y_{pt} + y_{qt} \leq' 1 \ \forall t \in \mathcal{T}, p \neq q \in \mathcal{P} \ \text{ s.t. } t_p^{arv} < t_q^{arv} < t_p^{dep} < t_q^{dep} \qquad (3)$$

[0033] Tracks t adopting the FIFO scheme require a constraint that a set of trains p and q of which magnitude relationships of arrival and departure times are reversed are not stored on a same track (only one of the trains can be stored). An example of this constraint is represented by Expression 4 below.

[Expression 4]

$$y_{pt} + y_{qt} \leq' 1 \ \forall t \in \mathcal{T}, \forall p \neq q \in \mathcal{P} \ \text{ s.t. } t_p^{arv} < t_q^{arv} < t_q^{dep} < t_p^{dep} \qquad (4)$$

[0034] With a track t adopting the FREE scheme which can be arrived and departed from both ends, a direction of arriving (also referred to as a direction of arrival) or a direction of departing (also referred to as a direction of departure) must also be designated. To this end, a variable y_{ptio} is used as a decision variable in place of the variable y_{pt}. The variable y_{ptio} takes a value of 1 when the train p arrives the track t from a direction i to be stored on the track t and departs

from a direction o. Assuming that a first direction is 0 and a second direction opposite to the first direction is 1, the direction i and the direction o each take a value of 0 or 1. An example of the constraint on the track t adopting the FREE scheme is represented by Expression 5 below.
[Expression 5]

$$\begin{aligned}
&\sum_{i,o\in\{0,1\}} y_{ptio} + y_{qt01} + y_{qt10} \leq' 1 \ \ \forall p \neq q \in \mathcal{P} \ \text{s.t.}\ t_p^{arv} < t_q^{arv} < t_q^{dep} < t_p^{dep}, \\
&\sum_{o\in\{0,1\}} y_{pti0} + \sum_{i\in\{0,1\}} y_{pt0o} \leq' 1 \ \ \forall p \neq q \in \mathcal{P} \ \text{s.t.}\ t_p^{arv} < t_q^{arv} < t_q^{dep} < t_p^{dep}, \qquad (5) \\
&\sum_{o\in\{0,1\}} y_{pti1} + \sum_{i\in\{0,1\}} y_{pt1o} \leq' 1 \ \ \forall p \neq q \in \mathcal{P} \ \text{s.t.}\ t_p^{arv} < t_q^{arv} < t_q^{dep} < t_p^{dep}
\end{aligned}$$

[0035] Since Expression 3, Expression 4, and Expression 5 are described for each track, a plurality of track types may be present in a mixed manner. In addition, when there is a track adopting the FREE scheme, the variable y_{pt} in Expression 1 and Expression 2 is changed to the variable y_{ptio}.

[0036] The shunting plan optimizer 320 generates a constraint condition representing the constraints described above and, by solving expressions of the mathematical model based on the constraint condition, obtains an optimal solution or a quasi-optimal solution of the variable y_{pt} (y_{ptio}) that satisfies the constraint condition. In other words, the shunting plan optimizer 320 determines a track to store a train based on a constraint that prohibits shunting of trains on a same track (storage section). As a solution method, a mathematical programming solver such as Gurobi Optimizer or CPLEX may be used or a meta-heuristic solution method such as a gradient method, simulated annealing, or a genetic algorithm may be used. Accordingly, for example, a solution such as $y_{1,1} = 1$, $y_{1,t} = 0 \ \forall t \in \mathcal{T}$; $t \neq 1$, ···is obtained. A shunting plan is obtained based on the obtained solution.

[0037] FIG. 9 shows an example of a shunting plan. A "train" column and a "track" column in FIG. 9 indicate an assignment of each train to a track. In an example of the train L1, a track assigned to the train L1 is the track R1 (t = R1) which satisfies $y_{1,t} = 1$. A stack indicates each storage position included in one track and identifiers Sx (where x = 1, 2, 3, ···) are given in an ascending order from a departure side. A stack of each train is to be determined in accordance with the number of trains to be stored on a track and an order of arrival to the track. For example, when the number of locations where a train can be stored on the track is larger than the number of trains, the trains can be arranged on the departure side with no stack therebetween. In the example shown in FIG. 9, on the same track, a train closest to the departure side is S1, a next closest train is S2, and so on. When there is no need to shunt trains, the stack of each train after business operation and the stack of each train prior to next-day business operation coincide with each other. FIG. 9 shows that an order of arrival of each train assigned to the same track and a reverse order of an order of next-day departure of the train coincide with each other. Therefore, a constraint on orders of arrival and departure with respect to a track adopting the LIFO scheme is satisfied. Specifically, in an example of the track R1, since trains arrive the track R1 in an order of L1, L2, and L4, the trains are stored in tandem in an order of L4, L2, and L1 from the departure side. Since the order of next-day departure is L4, L2, and L1, each train departs in order from a near side of the track R1. Therefore, a shunting plan without shunting has been obtained.

[0038] Based on the created shunting plan (refer to FIG. 9) and the time information (refer to FIG. 6), the shunting plan optimizer 320 generates shunting plan output information for displaying contents of the shunting plan to the user. The shunting plan storing device 400 stores the shunting plan output information generated by the shunting plan optimizer 320.

[0039] The output device 500 is an output GUI for presenting information to the user. The shunting plan output information is read from the shunting plan storing device 400 and the read information is displayed on a screen. The output device 500 may be a communicator. In such a case, the output device 500 may transmit the shunting plan output information to a terminal of the user.

[0040] FIG. 10 and FIG. 11 respectively show an example of shunting plan output information. The shunting plan output information in FIG. 10 and FIG. 11 shows objects L1 to L5 of the respective trains (train objects) and objects R1 and R2 of the respective tracks (track objects). Each train object is arranged at a position of a corresponding stack in a track object of a track to which each train is assigned. In FIG. 10, a business operation end time is associated with an object representing each train. In FIG. 11, a next-day business operation start time is associated with an object representing each train. Referring to FIG. 10 and FIG. 11, for example, it is shown that the train L2 arrives the track R1 at 22:30, stored at a position of a stack S2, and departs the track R1 at 5:45 on the following day. Note that FIG. 10 and FIG. 11 merely represent an example of an output format of a shunting plan and display formats are not limited thereto. For example, a business operation end time and a next-day business operation start time may be collectively displayed. In addition, a bar for designating time may be displayed and a shunting plan to be displayed may be changed by moving slides E1 and E2 to change the time. For example, the shunting plans shown in FIG. 10 and FIG. 11 may be displayed by respectively designating a business operation end time and a next-day business operation start time.

[0041] Hereinafter, handling of a case will be described where a solution of the mathematical model described above (a solution satisfying a constraint condition) does not exist or, in other words, a case where a shunting plan that does not require shunting cannot be obtained. In this case, a symbol will be newly defined in addition to the mathematical model described above. When there is a plurality of types of train timetables, a symbol may be defined for each train timetable. For example, when there is a train timetable for weekdays (a weekday timetable) and a train timetable for holidays (a holiday timetable), a symbol is defined for each of the timetables. Hereinafter, an example of such a case will be described. An apostrophized symbol is a symbol corresponding to the holiday timetable.

[0042] s_{pq}, s'_{pq}: a variable that takes a value of 0 or 1 depending on whether or not trains p and q need to be shunted in the weekday timetable/holiday timetable ($p < q \in P$) For example, in the case of the weekday timetable, when both of a set of trains p and q satisfying $t_p^{arv} < t_q^{arv}$ and $t_p^{dep} < t_q^{dep}$ are stored on the track t adopting the LIFO scheme, $s_{pq} = 1$ is satisfied ($s'_{pq} = 1$ in the case of the holiday timetable). While the following description assumes a case of the weekday timetable, symbols need only be appropriately changed in a case of the holiday timetable.

[0043] A constraint for determining whether or not a set of trains that requires shunting on a track adopting the LIFO scheme is to be stored on a same track is represented by Expression 6 below. In other words, this constraint allows shunting of trains on a track adopting the LIFO scheme.

[Expression 6]

$$y_{pt} + y_{qt} \leq' 1 + s_{pq} \ \forall t \in \mathcal{T}, p \neq q \in \mathcal{P} \ \text{ s.t. } \ t_p^{arv} < t_q^{arv} < t_p^{dep} < t_q^{dep} \qquad (6)$$

[0044] A constraint for determining whether or not a set of trains that requires shunting on a track adopting the FIFO scheme is to be stored on a same track is represented by Expression 7 below. In other words, this constraint allows shunting of trains on a track adopting the FIFO scheme.

[Expression 7]

$$y_{pt} + y_{qt} \leq' 1 + s_{pq} \ \forall p \neq q \in \mathcal{P} \ \text{ s.t. } \ t_p^{arv} < t_q^{arv} < t_q^{dep} < t_p^{dep} \qquad (7)$$

[0045] A constraint for determining whether or not a set of trains that requires shunting on a track adopting the FREE scheme is to be stored on a same track is represented by Expression 8 below. In other words, this constraint allows shunting of trains on a track adopting the FREE scheme.

[Expression 8]

$$\begin{aligned}
&\sum_{i,o \in \{0,1\}} y_{ptio} + y_{qt01} + y_{qt10} \leq' 1 + s_{pq} \ \forall p \neq q \in \mathcal{P} \ \text{ s.t. } \ t_p^{arv} < t_q^{arv} < t_q^{dep} < t_p^{dep}, \\
&\sum_{o \in \{0,1\}} y_{pti0} + \sum_{i \in \{0,1\}} y_{pt0o} \leq' 1 \ \forall p \neq q \in \mathcal{P} \ \text{ s.t. } \ t_p^{arv} < t_q^{arv} < t_q^{dep} < t_p^{dep}, \qquad (8) \\
&\sum_{o \in \{0,1\}} y_{pti1} + \sum_{i \in \{0,1\}} y_{pt1o} \leq' 1 \ \forall p \neq q \in \mathcal{P} \ \text{ s.t. } \ t_p^{arv} < t_q^{arv} < t_q^{dep} < t_p^{dep},
\end{aligned}$$

[0046] A calculation formula of a penalty with respect to the number of sets of trains that require shunting is represented by Expression 9 below. Since a shunting plan with a small number of shunted sets is desirable, Expression 9 will be adopted as an objective function in the present mathematical model. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 9 and one or more other terms expressed as an objective function in the present approach or other approaches to be described later and then adding up the terms may be adopted as an objective function. The objective function is minimized or quasi-minimized based on the constraints described above. Accordingly, an optimal solution or a quasi-optimal solution of the variable y_{pt} (y_{ptio}) is obtained. As a solution method, a mathematical programming solver such as Gurobi Optimizer or CPLEX may be used or a meta-heuristic solution method such as a gradient method, simulated annealing, or a genetic algorithm may be used. In this manner, by determining a track on which a train is to be stored based on the number of sets of trains which must be shunted on a same track, the number of sets of trains which must be shunted can be minimized or quasi-minimized. A shunting plan in which a cost required by shunting is low can be obtained.

[Expression 9]

$$\sum_{p<q\in\mathcal{P}} s_{pq} \qquad (9)$$

[0047] When there is a set of trains that need to be shunted, the output device 500 may display information to the effect that shunting of the set of trains must be performed. For example, when a solution expressed by $s_{pq} = 1$ is obtained, the output device 500 may display information to the effect that shunting of the set of trains p and q must be performed. This information may be displayed by applying hatching to the objects representing the trains p and q. Since there is a possibility that a shunting plan without shunting can be created by changing an arrival time and/or a next-day departure time of the trains p and q, the output device 500 may display information that encourages changing an arrival time and/or a next-day departure time of the trains p and q.

[0048] An operation of the shunting plan creation device 101 shown in FIG. 1 will be described.

[0049] FIG. 12 is a flow chart of an example of shunting plan creation processing executed by the shunting plan creation device 101.

[0050] First, the time information input device 100 receives time information (refer to FIG. 6) including arrival and departure times of each train with respect to a railway yard and the like via user input or the like (step S101). The route information input device 110 receives route information (refer to FIG. 8) including a length of a track and a type of the track with respect to a railway yard and the like via user input or the like (same step S101). The time information input device 100 and the route information input device 110 respectively store the time information and the route information in the time information storage 200 and the route information storage 210.

[0051] Next, the arrival/departure order creator 310 calculates orders of arrival and departure of a train based on the arrival time and the departure time of each train included in the time information stored in the time information storage 200 (step S102). Information indicating the calculated orders of arrival and depart (arrival/departure order information) is input to the shunting plan optimizer 320.

[0052] Next, based on the arrival/departure order information and the route information in the route information storage 210, the shunting plan optimizer 320 creates a shunting plan so as to prohibit shunting or to minimize or reduce, as much as possible, the number of times shunting is to be performed (step S103). Specifically, a solution of a variable that satisfies a constraint condition based on various constraints for realizing this objective (a variable indicating whether or not each train is to be assigned to each track) is obtained. Alternatively, a solution of the variable is obtained so as to minimize or quasi-minimize the objective function while satisfying the constraint condition. The shunting plan optimizer 320 stores the created shunting plan in the shunting plan storing device 400. In addition, the shunting plan optimizer 320 may generate shunting plan output information for displaying contents of the shunting plan to the user and store the shunting plan output information in the shunting plan storing device 400.

[0053] The output device 500 reads the shunting plan output information or the shunting plan stored in the shunting plan storing device 400 and displays the same on a screen (step S104). The user can readily understand contents of the shunting plan by checking the shunting plan output information. Accordingly, the shunting plan creation processing is completed.

[0054] As described above, according to the first configuration example of the first approach, a shunting plan that prevents an occurrence of shunting trains on a track or a shunting plan that minimizes or quasi-minimizes the number of trains to be shunted can be created.

[Second configuration example]

[0055] FIG. 13 is a block diagram of a shunting plan creation device 101A that is an information processing device according to a second configuration example of the first approach. Elements with a same name or a same function as the elements according to the first configuration example shown in FIG. 1 and described above will be denoted by same reference symbols. While it was assumed that the number of units (the number of vehicles) in all trains is the same in the first configuration example, a case where the number of units in each train differs will be described in the second configuration example. To this end, information regarding the number of units in train of each train is added. In addition to the shunting plan creation device 101 according to the first configuration example, the shunting plan creation device 101A according to the second configuration example further includes a moving object length information input device 120 and a moving object length information storage 220. Hereinafter, descriptions will be omitted with the exception of changed or added items.

[0056] The moving object length information input device 120 accepts an input operation of moving object length information including the number of units in train of each train as length information of each train (moving object) from the user of the shunting plan creation device 101A and acquires moving object length information. The moving object length information includes information related to the length of the moving object (train).

[0057] The moving object length information storage 220 stores the moving object length information input to the moving object length information input device 120. As an example, the moving object length information storage 220 is made of a storage medium such as a memory or a hard disk.

[0058] Hereinafter, processing by the shunting plan optimizer 320 shown in FIG. 13 will be described with a focus on a difference from the first configuration example.

[0059] FIG. 14 shows an example of train unit count information as moving object length information. The number of vehicles is included as information related to a train length for each train.

[0060] FIG. 15 is a diagram showing an example of track information as route information. The number of units storable in tandem is represented by the number of vehicles.

[0061] Hereinafter, a mathematical model also capable of accommodating a case where the number of units in train of each train differs will be described. Symbols will be newly defined in addition to the mathematical model used when the number of units in train of each train is the same.

l_p: number of units in train of train p

[0062] A constraint that a sum of the numbers of units in trains of the stored trains does not exceed the number of units storable in tandem is represented by Expression 10 below.

[Expression 10]

$$\sum_{p\in\mathcal{P}} l_p y_{pt} \leq' C_t \quad \forall t\in\mathcal{T} \qquad (10)$$

[0063] The shunting plan optimizer 320 replaces Expression 2 in the mathematical model according to the first configuration example in a case where the number of units in train of each train is the same, with Expression 10 and solves the mathematical model. Accordingly, the shunting plan optimizer 320 obtains a shunting plan when track information using a vehicle as a unit of the number of units storable in tandem and train unit count information are provided. Based on the shunting plan, the shunting plan optimizer 320 generates shunting plan output information for presenting contents of the shunting plan to the user. The output device 500 displays the shunting plan output information.

[0064] FIG. 16 shows an output example of the output device 500. FIG. 16 represents a shunting plan prior to next-day business operation. A total of five vehicles made up of trains L1 and L2, each of which the number of units in train is two, and the train L4 of which the number of units in train is one, are stored on the track R1 of which the number of units storable in tandem is five. In addition, a total of two vehicles made up of trains L3 and L5, each of which the number of units in train is one, are stored on the track R2 of which the number of units storable in tandem is three. The track R2 has an empty space corresponding to just one vehicle.

[0065] As described above, according to the second configuration example of the first approach, even when the number of units in train of each train differs, a shunting plan that prevents the number of units storable in tandem of a track from being exceeded can be created.

[Third configuration example]

[0066] FIG. 17 is a block diagram of a shunting plan creation device 101B that is an information processing device according to a third configuration example of the first approach. In addition to the shunting plan creation device 101A according to the second configuration example, the shunting plan creation device 101B according to the third configuration example further includes a route connection information input device 130, a route connection information storage 230, and an arrival/departure constraint creator 330.

[0067] The route connection information input device 130 accepts an input operation of route connection information including at least a connection relationship of tracks (track structure) in a railway yard of a railway or the like from the user of the shunting plan creation device 101B and acquires the route connection information.

[0068] The route connection information storage 230 stores route connection information input to the route connection information input device 130. As an example, the route connection information storage 230 is made of a storage medium such as a memory or a hard disk.

[0069] Hereinafter, processing of the arrival/departure constraint creator 330 shown in FIG. 17 will be described in detail.

[0070] FIG. 18 is a diagram showing an example of a track structure represented by route connection information. A track structure with a branched tree structure is shown. The track structure enables other routes which a train passes when arriving and departing a route to be specified. In the present example, a track R1 branches into tracks R2 and R3. The tracks R1 to R3 adopt the LIFO scheme and a train must inevitably pass through the track R1 when arriving and departing the tracks R2 and R3. Specifically, since the tracks R2 and R1 are connected in series, a train must inevitably pass through the track R1 when arriving and departing the track R2. In a similar manner, specifically, since the tracks R3 and R1 are connected in series, a train must inevitably pass through the track R1 when arriving and departing the track R3.

[0071] The arrival/departure constraint creator 330 shown in FIG. 17 creates an arrival/departure constraint based on the route connection information. Hereinafter, a mathematical model when a track has a tree structure or the like will be described using the example of the track structure shown in FIG. 18.

[0072] Constraints of not storing, on a plurality of tracks in series, a set of trains for which the need for shunting arises are represented by Expression 11 and Expression 12 below. Expression 11 and Expression 12 are equivalent to Expression 3 in a case where the track R2 and the track R1 which a train passes through when arriving and departing the track R2 are interpreted as a single track. Expression 12 represents a constraint for not simultaneously storing the train p with an early arrival time on the track R1 and the train q with a late arrival time on the track R2.

[Expression 11]

$$y_{p2} + y_{q1} \leq' 1 \ \ \forall\, p \neq q \in \mathcal{P} \ \text{ s.t. } t_p^{arv} < t_q^{arv} < t_p^{dep} < t_q^{dep} \qquad (11)$$

[Expression 12]

$$y_{p1} + y_{q2} \leq' 1 \ \ \forall\, p \neq q \in \mathcal{P} \ \text{ s.t. } t_p^{arv} < t_q^{arv} \qquad (12)$$

[0073] Expression 12 can be resolved into Expression 13 and Expression 14 which represent an assignment of a track on which shunting must be performed once upon arrival and an assignment of a track on which shunting must be performed twice upon arrival and depart respectively.

[Expression 13]

$$y_{p1} + y_{q2} \leq' 1 \ \ \forall\, p \neq q \in \mathcal{P} \ \text{ s.t. } t_p^{arv} < t_q^{arv} < t_p^{dep} < t_q^{dep} \qquad (13)$$

[Expression 14]

$$y_{p1} + y_{q2} \leq' 1 \ \ \forall\, p \neq q \in \mathcal{P} \ \text{ s.t. } t_p^{arv} < t_q^{arv} < t_q^{dep} < t_p^{dep} \qquad (14)$$

[0074] While the constraints represented by Expression 11 and Expression 12 are constraints related to the track R2 and the track R1, constraints related to the track R3 and the track R1 are also described in a similar manner. In addition, when the track type is the FIFO scheme or the FREE scheme, Expression 11 and Expression 12 may be appropriately modified.

[0075] The shunting plan optimizer 320 solves the mathematical model with the constraints of Expression 11 and Expression 12 in addition to the mathematical model described above. The shunting plan optimizer 320 determines a track (a storage section) to store a train based on a constraint for prohibiting shunting of trains between a plurality of tracks (a first storage section and a second storage section) in series. Accordingly, the shunting plan optimizer 320 can create a shunting plan that does not necessitate shunting when the track has a branched structure.

[0076] When allowing shunting of trains, S_{pq} (a variable that takes a value of 1 when shunting occurs) may be added to right sides of Expressions 11 to 14. The shunting plan optimizer 320 calculates the number of sets in which shunting of trains occur between the plurality of tracks (the first storage section and the second storage section) in series and, based on the number of sets (by minimizing or quasi-minimizing the number of sets), determines a track (a storage section) to store a train. Accordingly, a shunting plan which minimizes or quasi-minimizes the number of shunts can be obtained.

[0077] As described above, according to the third configuration example of the first approach, a shunting plan that prevents an occurrence of shunting or a shunting plan that minimizes or quasi-minimizes the number of times shunting is performed can be created even when a track has a branched structure.

[Fourth configuration example]

[0078] FIG. 19 is a block diagram of a shunting plan creation device 101C that is an information processing device according to a fourth configuration example of the first approach. In addition to the shunting plan creation device 101B according to the third configuration example, the shunting plan creation device 101C according to the fourth configuration example further includes a storage condition information input device 140, a storage condition information storage 240, and a storage constraint creator 340.

[0079] The storage condition information input device 140 accepts an input operation of storage condition information from the user of the shunting plan creation device 101C and acquires the storage condition information. The storage condition information includes a storage condition of storing a train on each track or a storage condition of storing a train at a storage position (stack) in each track. The storage condition information includes a penalty value that is assigned when the storage condition is not satisfied. Examples of the penalty value include a penalty value at each storage position on the track and/or a penalty value related to arrival/departure times of each track.

[0080] The storage condition information storage 240 stores storage condition information input to the storage condition information input device 140. As an example, the storage condition information storage 240 is made of a storage medium such as a memory or a hard disk.

[0081] Hereinafter, processing of the storage constraint creator 340 shown in FIG. 19 will be described in detail.

[0082] FIG. 20 is a diagram describing an example of storage condition information. The storage condition information includes a penalty value at each storage position and a penalty value related to arrival/departure times of each route. Let us assume that each train has the same number of vehicles for the sake of simplicity. In addition, track information as route information is assumed to be as shown in FIG. 8.

[0083] As shown in FIG. 20, the track R1 of which the number of units storable in tandem is four trains can be interpreted as including four stacks S1 to S4 and, in a similar manner, the track R2 of which the number of units storable in tandem is two trains can be interpreted as including two stacks S1 and S2. A stack represents a storage position. The penalty related to a storage position is added to the objective function when a train is stored at a position corresponding to a specific stack.

[0084] As shown in FIG. 20, a penalty value due to the storage position corresponding to the stack S2 in the track R2 is 1 and a penalty value with respect to stacks other than the stack S2 in the track R2 is 0. Therefore, when four trains and one train are respectively assigned to the tracks R1 and R2, an increase in an objective function value is 0. When three trains and two trains are respectively assigned to the tracks R1 and R2, an increase in the objective function value is 1.

[0085] In addition to a penalty related to a specific storage position as described above, penalties due to a storage position may include a penalty related to a combination of a specific train and a storage position which specifies a storage position of the train.

[0086] A penalty related to arrival and departure times of each track is a penalty related to the arrival and departure times of a train stored on each track. For example, a condition related to an arrival time (an arrival time condition) and a condition related to a departure time (a departure time condition) are provided for each stack or each track. A penalty value is added in accordance with whether or not each condition is satisfied. For example, by providing an allowable range of the arrival time, an arrival time condition may be considered satisfied when the arrival time is included in the range but a penalty value may be added on the understanding that the arrival time condition is not satisfied when the arrival time is outside of the range. When neither condition is satisfied, penalty values corresponding to both conditions may be added. By introducing a penalty related to an arrival time and a penalty related to a departure time, a need to preferentially store, on the track, a train with an early departure time or the like can be satisfied. Such a need may arise in order to also use, for yard work, a track previously used for overnight stay. Penalties related to arrival and departure times reflect such preferences of the user.

[0087] The storage constraint creator 340 shown in FIG. 19 creates a constraint (a storage constraint) based on the storage condition information. A symbol will be newly defined in addition to the mathematical model described above.

P_{ti}: a penalty value of storing train at stack i of track t

[0088] Variable ω_{ti}: a variable which takes value of 0 or 1 depending on whether or not train is to be stored at stack i of track t

[0089] A constraint for storing trains on a near side of a track (a side where trains arrive and depart the track (a side that enables arrival and depart)) with no gaps between the trains is represented by Expression 15 below. The variable ω_{ti} is a variable introduced in order to count the number of trains to be stored on the track t. It should be noted that, in reality, there is no need to store the trains assigned to the track with no gaps therebetween on a near side of the track.
[Expression 15]

$$\omega_{ti} \geq \omega_{t,i+1} \quad \forall t \in \mathcal{T}, 1 \leq' i \leq' C_t \qquad (15)$$

[0090] A constraint related to a capacity of the track is represented by Expression 16 below. This constraint is similar to Expression 2 of the mathematical model in the case where the number of units in train of each train is the same.
[Expression 16]

$$\sum_{p \in \mathcal{P}} y_{pt} \leq' \sum_{i=1}^{C_t} \omega_{ti} \quad \forall t \in \mathcal{T} \qquad (16)$$

[0091] A calculation formula of a penalty due to a storage position is represented by Expression 17 below. The shunting plan optimizer 320 generates Expression 17 as an objective function. The shunting plan optimizer 320 generates a constraint condition representing the constraints of Expression 15, Expression 16, and the like described above and minimizes or quasi-minimizes the objective function of Expression 17 so as to satisfy the constraint condition. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 17 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function.
[Expression 17]

$$\sum_{t \in \mathcal{T}} \sum_{i=1}^{C_t} P_{ti} \omega_{ti} \qquad (17)$$

[0092] As described above, the shunting plan optimizer 320 determines a track on which each train is to be stored based on a sum of at least one penalty value among a penalty value related to a storage position, a penalty value related to an arrival time, and a penalty value related to a departure time. Accordingly, a shunting plan in which the number of trains to be shunted and the like are minimized can be created while suppressing the number of trains to be stored at positions where trains are preferably not stored.

[0093] As described above, according to the fourth configuration example of the first approach, a shunting plan can be created in which the number of trains to be shunted and the like are minimized while suppressing the number of trains to be stored at positions where trains are preferably not stored per the user's request.

[Fifth configuration example]

[0094] FIG. 21 is a block diagram of a shunting plan creation device 101D that is an information processing device according to a fifth configuration example of the first approach. In addition to the shunting plan creation device 101C according to the fourth configuration example, the shunting plan creation device 101D according to the fifth configuration example further includes an original shunting plan information input device 150, an original shunting plan storing device 250, and a difference constraint creator 350.

[0095] The original shunting plan information input device 150 accepts an input operation of original shunting plan information from the user of the shunting plan creation device 101D and acquires the original shunting plan information. As an example, the original shunting plan information includes a shunting plan of the previous day, a shunting plan prior to revision of a train timetable, or a shunting plan before or after change due to a disruption in the train timetable.

[0096] The original shunting plan storing device 250 stores the original shunting plan information input to the original shunting plan information input device 150. As an example, the original shunting plan storing device 250 is made of a storage medium such as a memory or a hard disk.

[0097] Hereinafter, processing of the difference constraint creator 350 shown in FIG. 21 will be described in detail. The difference constraint creator 350 creates a constraint (a difference constraint) for evaluating a difference between original shunting plan information and a shunting plan to be created. In the present fifth configuration example, a shunting plan with a small difference from an original shunting plan is created by using the difference constraint. Therefore, a symbol will be newly defined in addition to the mathematical model described above.

$\hat{y}_{pt}$: a value of variable y_{pt} in original shunting plan
variable z_p: a variable which takes a value of 0 or 1 depending on whether or not a track on which train p is to be stored differs from the original shunting plan

When the track of the shunting plan to be created differs from that of the original shunting plan (when the track does not match), $z_p = 1$ is satisfied, but when the track of the shunting plan to be created matches that of the original shunting plan, $z_p = 0$ is satisfied.

[0098] A constraint for matching the track on which the train p is to be stored with that of the original shunting plan is represented by Expression 18 below. In other words, when the track of the shunting plan to be created does not coincide with that of the original shunting plan, since the left side is 1, the right side satisfies $z_p = 1$ accordingly. When the track of the shunting plan to be created coincides with that of the original shunting plan, since the left side is 0, the right side satisfies $z_p = 0$ accordingly. The difference constraint creator 350 generates the constraint of Expression 18 as a difference constraint.

[Expression 18]

$$\left|y_{pt} - \hat{y}_{pt}\right| \leq' z_p \quad \forall p \in \mathcal{P}, t \in \mathcal{T} \qquad (18)$$

[0099] A penalty for a non-coincidence with the original shunting plan is represented by Expression 19 below. The shunting plan optimizer 320 generates Expression 19 as an objective function. The shunting plan optimizer 320 generates a constraint condition representing the constraints of Expression 18, and the like described above and minimizes or quasi-minimizes the objective function so as to satisfy the constraint condition. Alternatively, a function obtained by weighting a term expressed as an objective function in Expression 19 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function. Accordingly, a shunting plan that minimizes or quasi-minimizes the number of trains stored on tracks that differ from an original shunting plan is obtained.

[Expression 19]

$$\sum_{p \in \mathcal{P}} z_p \qquad (19)$$

[0100] When $z_p = 1$ is obtained as a solution, this means that the track on which the train p is to be stored differs from the original shunting plan. The shunting plan optimizer 320 may generate information indicating that the track on which the train p is to be stored differs from the original shunting plan and the generated information may be displayed by the output device 500. The shunting plan optimizer 320 may generate information indicating a track t (in the original shunting plan) which satisfies $y_{pt} = 1$ and the generated information may be displayed by the output device 500. The shunting plan optimizer 320 may apply hatching to the train p and the track t that satisfies $y_{pt} = 1$ (in other words, on which the train p is to be stored) in the shunting plan output information.

[0101] It should be noted that the mathematical models described above are merely examples and other objective functions and constraint expressions may be used.

[0102] As described above, according to the fifth configuration example of the first approach, a shunting plan that minimizes or quasi-minimizes the number of trains stored on tracks that differ from an original shunting plan can be created.

(Second approach)

[0103] Hereinafter, a second approach of the present invention will be described using a case of creating a vehicle operation plan of a railway as an example.

[0104] The vehicle operation plan is a plan that specifies an assignment of trains with respect to a train timetable in which a departure time, an arrival time, and the like with respect to a target zone such as each station and railway yard are specified. A target zone from which a train departs is referred to as a departure location or a departure zone and a target zone which a train arrives is referred to as an arrival location or an arrival zone. For example, when a train departs a railway yard and arrives a station for storage (a station), the departure zone is the railway yard and the arrival zone is the station.

[0105] A train operation schedule to which a same train is assigned is referred to as a "trip". A trip is assumed to be a schedule from departing a target zone such as a railway yard, a station, or the like to arriving a target zone such as a railway yard, a station, or the like. An example of a trip is, for example, a series of operations from departing a railway yard to arriving a railway yard such as "leaving yard at 05:10 ... Station A arriving at 06:00 ... Station A leaving at 06:10 ... Station B arriving at 06:20 ... Station B leaving at 06:25 ... Railway yard arriving at 23:50". While the trip in this example takes a long time from early in the morning to late at night, there may be trips with a short time from early morning to late morning. Therefore, one train per day may be assigned one trip in some cases but may be assigned a plurality of trips in other cases.

[0106] A combination of a series of trips to which a same train is assigned per day is referred to as a "duty" (a train operation schedule bundle). Therefore, a duty may only include one trip in some cases but may include a plurality of trips in other cases. For example, there may be cases where a train is assigned a single trip from early morning to late at night or assigned two trips including a trip of a part of hours in the morning and a trip of a part of hours in the afternoon. When a duty only includes a single trip, the duty coincides with the single trip.

[0107] Based on a train timetable, a plurality of duties to which any train is to be assigned in one day are obtained. The number of duties coincides with the number of trains to be operated.

[0108] When a plurality of duties is arranged in sequence and, among consecutive duties, an arrival location (an arrival zone) of a former duty and a departure location (a departure zone) of a latter duty coincide with each other, the string of duties are referred to as a rolling stock circulation. In other words, when a duty string is cyclically assigned to each train by shifting the duties by one duty (or a plurality of duties) and an arrival location on the previous day (previous business day) and a departure location on the following day (following business day) coincide with each other, the duty string is referred to as a rolling stock circulation.

[0109] For example, let us consider a case where there are six duties (tentatively denoted as L1 to L6). When (L4, L5, L2, L1, L6, and L3) is a rolling stock circulation, the departure location of the duty L3 coincides with the arrival location of the duty L6, the departure location of the duty L6 coincides with the arrival location of the duty L1, ..., and the departure location of the duty L4 coincides with the arrival location of the duty L3.

[0110] The arrival location (arrival zone) of a duty refers to an arrival location (arrival zone) of a last trip among the one or more trips included in the duty. The departure location (departure zone) of the duty refers to a departure location (departure zone) of a first trip among the one or more trips included in the duty. Therefore, when the duty only includes one trip, the arrival location of the duty is the arrival location of the one trip and the departure location of the duty is the departure location of the one trip.

[0111] The arrival location (arrival zone) and the departure location (departure zone) mean a target zone such as a railway yard, a station, or the like. When a plurality of trains is to depart from a same target zone, the tracks from which the trains depart or, in other words, the tracks on which the trains had been stored may differ from each other or may be the same as long as the plurality of trains depart from the same target zone. In a similar manner, when a plurality of trains is to arrive a same target zone, the tracks which the trains arrive or, in other words, the tracks on which the trains are to be stored may differ from each other or may be the same as long as the plurality of trains arrive the same target zone.

[0112] When assigning a duty to each of a plurality of trains, assigning the duties included in a rolling stock circulation by shifting the duties by one duty per one business day (so that a last duty moves to the top or, in other words, duties cyclically move within the rolling stock circulation), duties can be efficiently or readily assigned to the plurality of trains. A specific example of the rolling stock circulation will be described later.

[0113] Many railway operators have a plurality of train timetables such as weekday timetables and holiday timetables in order to accommodate changes in demand among the days of a week. In this case, as many rolling stock circulations as the number of train timetables are created and a rolling stock circulation is shunted to another when a train timetable is shunted to another. For example, when there are train timetables for weekdays and holidays, a rolling stock circulation for weekdays is assigned to regular Mondays to Fridays and a rolling stock circulation for holidays is assigned to Saturdays, Sundays, non-periodic public holidays, and the like.

[First configuration example]

[0114] FIG. 22 is a block diagram of an operation plan creation device 102 that is an information processing device according to a first configuration example of the second approach. Based on a plurality of pieces of train timetable information respectively indicating a different train timetable, the operation plan creation device 102 creates a rolling stock circulation in which duties are arranged per train timetable and a correspondence table in which duties are associated with each other between train timetables. Duties associated with each other in the correspondence table have a same departure location and a same arrival location. In the present example, a rolling stock circulation for each train timetable is generated so that duties at a same location in the rolling stock circulation for each train timetable are associated with each other in the correspondence table. This situation is called "rolling stock circulations being synchronized with each other" (details will be provided later).

[0115] The operation plan creation device 102 includes a train timetable information input device 160, a train timetable information storage 260, a work information input device 170, a work information storage 270, a periodic information input device 180, a periodic information storage 280, an operation plan creator 302 (processing circuitry or a processor), a rolling stock circulation storage 410, a correspondence table storage 420, and an output device 500.

[0116] The operation plan creator 302 is processing circuitry including a duty creator 361, an arrival/departure order creator 362, an operation plan optimizer 360, a work label creator 370, and a periodic constraint creator 380.

[0117] The train timetable information input device 160 accepts an input operation of train timetable information including train timetables of at least one or two or more trips from the user of the operation plan creation device 102 and acquires the train timetable information. For example, train timetable information for weekdays and train timetable information for holidays are acquired.

[0118] The train timetable information storage 260 stores train timetable information acquired by the train timetable information input device 160. As an example, the train timetable information storage 260 is made of a storage medium such as a memory or a hard disk.

[0119] The duty creator 361 creates one or more duties by combining trips included in a train timetable based on the train timetable information in the train timetable information storage 260.

[0120] The arrival/departure order creator 362 creates an order of arrival and an order of departure of one or more duties created by the duty creator 361.

[0121] FIG. 23 shows an example of creating a vehicle operation plan for weekdays using a single rolling stock circulation and then, along the way, creating a vehicle operation plan for holidays by shunting to another single rolling stock circulation. (L3, L6, L1, L2, L5, L4) is shown in an upper diagram of FIG. 23 as an example of a rolling stock circulation (in the present example, a rolling stock circulation for weekdays). A black triangle indicates that work is to be performed. For example, at least one of an inspection and cleaning is able to be performed as work on the duty L1.

[0122] A lower diagram in FIG. 23 shows an example of obtaining a periodic vehicle operation plan by repetitively assigning the rolling stock circulation for weekdays to trains 1 to 6 by cyclically shifting the rolling stock circulation by one duty per day for a period from January 1st to January 5th. A period of the vehicle operation plan created in this manner equals a length (number of elements) of the rolling stock circulation or, in other words, the number of trains.

[0123] Since January 6th and January 7th are holidays, the rolling stock circulation must be shunted between January 5th and January 6th in accordance with the shunting of the train timetable. A method of shunting among a plurality of rolling stock circulations in accordance with train timetables will be described using a different example from FIG. 23.

[0124] It is assumed that a first train timetable (hereinafter, a timetable 1) is used on a first day and a shunt is made to a second train timetable (hereinafter, a timetable 2) on a second day and the second train timetable is to be used thereafter. It is assumed that a rolling stock circulation 1 corresponds to the timetable 1 and a rolling stock circulation 2 corresponds to the timetable 2. It is also assumed that an assignment of a plurality of duties to each train based on the timetable 1 on the first day has already been provided. It is assumed that a duty in a rolling stock circulation of the timetable 1 and a duty in a rolling stock circulation of the timetable 2 have a one-to-one correspondence. In other words, it is assumed that a departure location and an arrival location of mutually-corresponding (same-day) duties coincide with each other. In such a case, the rolling stock circulation of the timetable 1 and the rolling stock circulation of the timetable 2 can be described as being synchronized with each other.

[0125] When in synchronization with each other, a duty to be assigned to each train on the second day on which a shunt to the timetable 2 is made is a duty (hereinafter, a next-day duty) in the rolling stock circulation 2 which corresponds to a duty on a following day (next position) of the duty assigned to each train on the first day in the rolling stock circulation 1. In a similar manner, a duty on a third day is a duty (next-day duty) on a following day of the duty assigned in the rolling stock circulation 2. For example, when a first duty of the rolling stock circulation 1 is assigned to a given train, a second duty of the rolling stock circulation 2 is assigned to the train on the second day and a third duty of the rolling stock circulation 2 is assigned to the train on the third day. In this manner, from the second day on, the rolling stock circulation 2 is assigned by shifting by one duty with respect to the rolling stock circulation 1. In consecutive duties in the rolling stock circulation (1 or 2), an arrival location and a departure location are the same (the arrival location of a former duty coincides with the departure location of a latter duty). In this manner, by assigning the rolling stock circulation 2 by shifting by one duty with respect to the rolling stock circulation 1 when shunting the timetable 1 to the timetable 2, an operation plan after the shunt can be readily created.

[0126] While the timetable 1 and the timetable 2 have been described above as an example, a further description will be given using a weekday timetable and a holiday timetable as an example.

[0127] FIG. 24 shows information (correspondence table) that associates a duty of a weekday timetable and a duty of a holiday timetable to each other on a one-to-one basis. A departure location and an arrival location of mutually-corresponding duties coincide with each other (illustration of the departure location is omitted). In other words, a departure location and an arrival location of mutually-corresponding duties of different timetables coincide with each other. In addition, a rolling stock circulation (L4 -> L5 -> L2 -> L3 -> L1) based on the weekday timetable and a rolling stock circulation (L'2 -> L'5 -> L'3 -> L'4 -> L'1) based on the holiday timetable are shown. Duties in a same row of the rolling stock circulations for weekdays and holidays are in a correspondence relationship on the correspondence table. L1 and L'1 correspond to each other, L3 and L'4 correspond to each other, L2 and L'3 correspond to each other, L5 and L'5 correspond to each other, and L4 and L'2 correspond to each other. Therefore, duties at mutually same positions (same day) in the rolling stock circulations for weekdays and holidays are in a correspondence relationship on the correspondence table (departure locations and arrival locations coincide with each other). Therefore, the rolling stock circulations for weekdays and holidays are synchronized with each other.

[0128] When the rolling stock circulations for weekdays and holidays are synchronized with each other, shunting of rolling stock circulations accompanying a shunt of timetables may be performed by assigning the rolling stock circulation for holidays by shifting the rolling stock circulation by one duty in a similar manner to shifting the rolling stock circulation for weekdays by one duty for a following day.

[0129] As shown in the lower diagram in FIG. 24 described earlier, when shunting rolling stock circulations from January 5th to January 6th, the rolling stock circulation for holidays may be assigned by shifting the rolling stock circulation by one duty. Accordingly, even when timetables are to be shunted, an operation plan after the shunt can be more readily created.

[0130] The present approach realizes the creation of rolling stock circulations that are synchronized with each other between a plurality of train timetables.

[0131] Hereinafter, a case where a vehicle operation plan is to be created for a given line (target line) will be described. On the target line, two train timetables for weekdays and holidays are provided. Each train timetable includes IDs of a plurality of trips, a departure location and an arrival location of each trip, and a departure time and an arrival time of each trip. There are two arrival and departure locations, namely, a railway yard and a station (in other words, there are only one railway yard and only one station that has storage track in the present example). The number of the trains is six. Let us assume that each train has the same number of vehicles for the sake of simplicity.

[0132] FIG. 25 shows an example of train timetable information. The train timetable for weekdays (weekday timetable) includes eight trips: L1, L2, L3, ..., L8. The train timetable for holidays (holiday timetable) includes seven trips: L'1, L'2, L'3, ..., L'7.

[0133] The weekday timetable includes the trip L1 which arrives the station and the trip L5 which departs the station, and all other trips use the railway yard as arrival and departure locations. In a similar manner, the holiday timetable includes the trip L'1 which arrives the station and the trip L'5 which departs the station, and all other trips use the railway yard as arrival and departure locations.

[0134] The trip L'6 is not a trip to be exact and indicates that a train is to be stored at the railway yard without being used for business operation. When a train is to be stored at the railway yard all day, such a train operation is to be assigned to the train as a trip (reserve trip). Since a case where a train is to be stored at the railway yard all day must also be taken into consideration, such a train operation is to be also handled as a trip (reserve trip). A reserve trip is not provided with an arrival time and a departure time (arrival and departure times).

[0135] On trip L5, trip L6, and trip L'5, an arrival and a departure are performed in the morning. Such a trip will be referred to as a "morning trip". On trip L7, trip L8, and trip L'7, an arrival and a departure are performed in the afternoon. Such a trip will be referred to as an "afternoon trip".

[0136] A train is stored on a track of a railway yard or a track of a station after the end of business operation until business operation of the following day. Such storage will be referred to as overnight stay. Among overnight stay, overnight stay at a station will be particularly referred to as "stored at a station". A trip (duty) determined to arrive a track of the station for stored at a station at the end of business operation will be referred to as a "trip (duty) stored at a station". In the present example, trips stored at a station in the weekday timetable and the holiday timetable are, respectively, trips L1 and L'1.

[0137] FIG. 26 shows an example of work information stored in the work information storage 270. Predetermined work must be performed on trains. An example of work is at least one of daily inspection (for example, an inspection of brake equipment, a beacon light, and the like) and cleaning. Being able to perform work with respect to a given duty (trip) means that work can be assigned to a train to which the duty (trip) has been assigned. A time slot, a location (mainly a railway yard), and the like at which work can be performed are predetermined. Whether or not work can be performed can be determined based on whether or not a train to which a duty has been assigned satisfies a condition related to time and place. For example, whether or not the condition is satisfied can be determined based on whether or not a train is stored at the determined location and in the determined time slot. The condition will be referred to as a "work condition" and the time slot, location, and the like described above related to the condition will be referred to as "work information". In the example in FIG. 26, the work location where the work can be performed is the railway yard and the time slot is 11:00 to 15:00. In the example of the weekday timetable shown in FIG. 25, the trips L5, L6, L7, and L8 satisfy the work condition.

[0138] FIG. 27 is a diagram showing an example of periodic information stored in the periodic information storage 280. Periodic information includes a condition (a periodic condition) related to intervals at which work is to be performed. For example, daily inspection is provided with a statutory period. Work such as cleaning is also desirably performed regularly. In addition, a train assigned a duty stored at a station does not arrive a railway yard for a certain period of time and, during such time, work such as a daily inspection and cleaning cannot be performed. Therefore, for security reasons, a same train is preferably not assigned consecutively or at short time intervals to a duty stored at a station. In an operation plan created using a single rolling stock circulation (for example, a rolling stock circulation for weekdays or for holidays), a time interval at which a workable duty is assigned and a time interval at which a duty stored at a station is assigned become equal to an interval in the rolling stock circulation. Therefore, in the rolling stock circulation, the duties (the workable duty and the duty stored at a station) are desirably arranged according to the periodic condition or, in other words, arranged with impartiality.

[0139] The periodic condition shown in the example of FIG. 27 includes, as the number of days representing an interval (referred to as a work interval) at which workable duties are arranged in the rolling stock circulation, a maximum work interval (in the present example, 4 days) and a minimum work interval (in the present example, two days). As another example of the periodic condition, one of a maximum value or a minimum value, both of a maximum value or a minimum value, or the like of an outside storage interval being an interval at which outside storages (when present in plurality) are arranged may be included. By appropriately setting the periodic condition such as at least one of a work interval and an outside storage interval, workable duties and duties stored at a station can be arranged at appropriate intervals.

[0140] Hereinafter, processing in which the operation plan creator 302 shown in FIG. 22 creates a rolling stock circulation for each of a plurality of train timetables will be described in detail.

[0141] The duty creator 361 shown in FIG. 22 creates, for each train timetable, one or more duties by combining trips included in the train timetable. A duty is created according to the following rules. As an ID of a duty, an ID of a first trip among trips included in the duty is adopted. When a duty includes one trip, the ID of the trip is adopted as the ID of the duty.

Rule A: With a trip on which business operation is performed for a whole day, create a duty only including the trip.
Rule B: With respect to a plurality of trips such as morning trips and afternoon trips, when arrival and departure locations coincide with each other (for example, when an arrival location (arrival location) of a morning trip coincides with a departure location (departure location) of an afternoon trip) and time slots do not overlap with each other, create a single duty by combining the plurality of trips.
Rule C: With respect to a reserve trip, create a duty only including the reserve trip.

[0142] From each of a weekday timetable and a holiday timetable, six duties, equal to the number of trains, are created. When creating a single duty by combining one each of a morning trip and an afternoon trip, the duty is to be described as (ID of morning trip, ID of afternoon trip). Specifically, two duties of (L5, L7) and (L6, L8) or two duties of (L5, L8) and (L6, L7) can be created from the weekday timetable. Here, the former will be adopted to create the two duties of (L5, L7) and (L6, L8). Any of two duties each including only one of the trip L'5 and the trip L'7 or a single duty of (L'5, L'7) can be created from the holiday timetable. In the present example, in order to make one train among the six trains a reserve train (a reserve vehicle) and enable a reserve trip to be assigned to the reserve train, the latter is adopted to create a single duty of (L'5, L'7).

[0143] FIG. 28 shows duties L1 to L6 and duties L'1 to L'6 respectively created from the weekday timetable and the holiday timetable shown in FIG. 25 according to the rules A to C. With both the weekday timetable and the holiday timetable, the number of duties coincide with the number of trains.

[0144] The arrival/departure order creator 362 shown in FIG. 22 calculates an order of arrival and an order of departure of a plurality of duties for each of the weekday timetable and the holiday timetable according to the following procedures.

Procedure 1: With a duty including a plurality of trips created according to rule B, respectively adopt the departure time of the first trip included in the duty and the arrival time of the last trip included in the duty as the departure time and the arrival time of the duty.
Procedure 2: Respectively sort the duties created according to rule A and rule B in an order of arrival times and an order of departure times to obtain an order of arrival and an order of depart.
Procedure 3: Assign numbers in ascending order from 1 to duties created according to rule C. A numeral obtained by adding the number to the number of duties created according to rule A and rule B and a numeral obtained by subtracting the number from a sum of the total number of duties and 1 are respectively adopted as the orders of departs and arrivals. For example, when the total number of duties is denoted by N and the sum of the numbers of

duties created according to rule A and rule B is denoted by M (the number of duties created according to rule C is N - M), the order of departure of the first duty created according to rule C is M + 1 and the order of arrival thereof is N. In a similar manner, orders of departure and arrival of the second duty created according to rule C are respectively M + 2 and N - 1, and orders of departure and arrival of a (N - M)-th duty are respectively M + (N - M) = N and N + 1 - (N - M) = M + 1.

[0145] On a target line, as is apparent from FIG. 28, the order of departure of the weekday timetable is L2, L3, L5, L1, L6, and L4 and an order of arrival thereof is L2, L3, L5, L6, L1, and L4. In a similar manner, the order of departure of the holiday timetable is L'2, L'3, L'5, L'1, L'4, and L'6 and an order of arrival thereof is L'6, L'2, L'3, L'5, L'1, and L'4.

[0146] The work label creator 370 shown in FIG. 22 sets a work label of a duty satisfying a work condition (refer to FIG. 26) to "1" and a work label of a duty not satisfying the work condition to "0". On the target line, work labels of the duties L5, L6, L'5, and L'6 including storage from 11:00 to 15:00 at the railway yard are set to "1" and the work labels of other duties are set to "0".

[0147] As a result of the processing described above, the operation plan creator 302 creates a duty table representing attributes of duties for each of the weekday timetable and the holiday timetable.

[0148] FIG. 29 shows an example of a duty table for each of a weekday timetable and a holiday timetable. The duty table includes an ID, an order of departure, an order of arrival, a departure location, an arrival location, and a work label of each duty.

[0149] The operation plan optimizer 360 shown in FIG. 22 creates a rolling stock circulation and a correspondence table by constructing a mathematical model and calculating a solution thereof.

[0150] A mathematical model will be defined as a traveling salesman problem (or a Hamilton cycle problem) on a graph having duties as vertices and connections between the duties as edges. Free formulation (ff) that is a formulation will be used in which a salesman receives an item every time he/she virtually visits a city (vertex) and transports the item by traveling along sides between cities. In ff, a city (vertex) to serve as an origin where the number of items is reset to zero must be determined. This corresponds to determining a duty to serve as an origin of a rolling stock circulation. In the present example, duties to serve as an origin of rolling stock circulations respectively corresponding to the weekday timetable and the holiday timetable are to be the duties L1 and L'1 which both stored at a station.

[0151] Symbols for describing the mathematical model will be defined below.

$P = 6$: number of duties (number of trains)

$\mathcal{P}$: set of duties {1, 2, ···, 6}

$\{1, 2, \cdots, 6\} \in \mathcal{P}$ indicates L1, L2, ···, L6 in the case of the weekday timetable and L'1, L'2, ···, L'6 in the case of the holiday timetable.

p: duty $(p \in \mathcal{P})$

$\mathcal{B}$: set of locations {1 (railway yard), 2 (station)}

B: location $(B \in \mathcal{B})$

B_p^{arv}, B'^{arv}_p : arrival location of duty p in weekday timetable/holiday timetable $(B \in \mathcal{B},\ p \in \mathcal{P})$

B_p^{dep}, B'^{dep}_p : departure location of duty p in weekday timetable/holiday timetable $(B \in \mathcal{B},\ p \in \mathcal{P})$

k_p, k'_p: work label of duty p in weekday timetable/holiday timetable $(p \in \mathcal{P})$

d_{max}, d_{min}: maximum work interval, minimum work interval $p^{railway\ yard}$ $p'^{railway\ yard}$: city to serve as origin ($p^{railway}$ = $p'^{railway\ yard}$ = 1) (corresponds to duties L1 and L'1)

Variable x_{pq}, x'_{pq}: a variable that takes a value of 0 or 1 depending on whether or not a next-day duty of the duty p in the weekday timetable/holiday timetable is duty q $(p \neq q \in \mathcal{P})$. The variable takes a value of 1 when the next-day duty is the duty q but takes a value of 0 when the next-day duty is not the duty q.

Variable u_{pq}, u'_{pq}: auxiliary discrete variable that takes an integer value [0, P - 1] representing the number of items transported by a salesman between cities p and q in the weekday timetable/holiday timetable $(p \neq q \in P)$

Variable d_p, d'_p: discrete variable that represents number of days elapsed from workable duty in the weekday timetable/holiday timetable $(p \in P)$

Variable h_{pq}: a variable that takes a value of 0 or 1 depending on whether or not the respective duties p and q in the weekday timetable/holiday timetable are to be associated with each other $(p, q \in P)$. The variable takes a value of 1 when the duties are to be associated with each other but takes a value of 0 if not.

<Constraint condition of rolling stock circulation>

[0152] Hereinafter, a constraint condition of a rolling stock circulation will be shown.

[0153] First, a constraint for correspondence between an arrival location of a duty and a departure location of a next-day duty (a next-day departure location) will be shown.

[0154] Since the present constraint is common to the weekday timetable and the holiday timetable, only the weekday timetable will be described. A constraint of the holiday timetable is obtained by replacing variables of the weekday timetable with variables of the holiday timetable. Expression 20 and Expression 21 below represent a constraint to determine one next-day duty so that the arrival location of a duty and a departure location of the next-day duty coincide with each other. In other words, this constraint uniquely determines a duty q (or p) that comes next to the duty p (or q).

[Expression 20]

$$\sum_{q\in\mathcal{P}:q\neq p\ \&\ \mathcal{B}_q^{dep}=\mathcal{B}_p^{arv}} x_{pq} = 1\ \forall p\in\mathcal{P} \quad (20)$$

[Expression 21]

$$\sum_{q\in\mathcal{P}:q\neq p\ \&\ \mathcal{B}_q^{arv}=\mathcal{B}_p^{dep}} x_{qp} = 1\ \forall p\in\mathcal{P} \quad (21)$$

[0155] A constraint that makes, when the salesman does not virtually pass between a city p and a city q (between cities p and q), the number of items that pass between the cities p and q zero is represented by Expression 22 below.

[Expression 22]

$$\mathrm{u_{pq}} \leq' (P-1)x_{pq}\ \forall p\neq q\in\mathcal{P} \quad (22)$$

[0156] The number of items transported by the salesman when the salesman virtually departs the city p is represented by Expression 23 below. The number of items coincide with an order of the city p as counted from a city $p^{railway\ yard}$ that serves as an origin or, in other words, an order of the duty p as counted from a duty that serves as an origin. In this case, an order represents at what order the salesman had visited the city p assuming that the order at which the salesman had visited the city $p^{railway\ yard}$ that serves an origin is 0. With respect to the city q not passed next after the city p, u_{qp} is calculated as zero using Expression 22.

[Expression 23]

$$\sum_{q\in\mathcal{P}\setminus\{p\}} u_{pq} \quad (23)$$

$\mathcal{P}\setminus\{\mathrm{p}\}$ represents a set obtained by removing p from P.

[0157] A constraint that the number of items possessed by the salesman when the salesman virtually departs the city p ($\neq p^{railway\ yard}$) that is not a city serving as an origin increases by one item from the time of arrival is represented by Expression 24 below.

[Expression 24]

$$\sum_{q\in\mathcal{P}\setminus\{p\}} u_{pq} = \sum_{q\in\mathcal{P}\setminus\{p\}} u_{qp} + 1\ \forall p\in\mathcal{P}\setminus\{p^{depot}\} \quad (24)$$

[0158] A constraint that the number of items possessed by the salesman when the salesman virtually departs the city $p^{railway\ yard}$ that serves as an origin decreases by (P - 1)-number of items from the time of arrival is represented by Expression 25 below.
[Expression 25]

$$\sum_{q\in\mathcal{P}\setminus\{p^{depot}\}} u_{p^{depot}q} = \sum_{q\in\mathcal{P}\setminus\{p^{depot}\}} u_{qp^{depot}} - (P-1) \quad (25)$$

<Periodic condition>

[0159] Next, a periodic constraint will be described.
[0160] The periodic constraint creator 380 shown in FIG. 22 creates a constraint (a periodic constraint) related to a periodic condition based on periodic information. First, a periodic constraint related to a single rolling stock circulation will be shown. Expression 26 to Expression 30 below represent a periodic constraint related to work.
[0161] More specifically, Expression 26 to Expression 28 represent a constraint for counting the number of days elapsed from a workable duty. A constraint for making the number of elapsed days d_p with respect to a workable duty p (k_p = 1) is represented by Expression 26. d_p is made zero if k_p = 1.
[Expression 26]

$$d_p = 0 \quad \forall p \in \mathcal{P}: k_p = 1 \quad (26)$$

[0162] A constraint for making the number of elapsed days with respect to the duty q being a next-day duty of the duty p larger than the number of elapsed days of the duty p by one is represented by Expression 27 and Expression 28 below.
[Expression 27]

$$d_q \leq' d_p + 1 + P(1 - x_{pq}) \quad \forall p \neq q \in \mathcal{P} \quad (27)$$

[Expression 28]

$$d_q \geq d_p + 1 - P(1 - x_{pq}) \quad \forall p \neq q \in \mathcal{P}: k_q = 0 \quad (28)$$

[0163] A constraint for setting a work interval to or shorter than a maximum work interval is represented by Expression 29 below.
[Expression 29]

$$d_p \leq' d_{max} - 1 \quad \forall p \in \mathcal{P} \quad (29)$$

[0164] A constraint for setting a work interval to or longer than a minimum work interval is represented by Expression 30 below.
[Expression 30]

$$d_p \geq (d_{min} - 1)\ x_{pq} \forall p \neq q \in \mathcal{P}: k_q = 1 \quad (30)$$

[Constraint for creating a correspondence table between duties of weekday timetable/holiday timetable]

[0165] Next, a constraint for creating a correspondence table between duties of a weekday timetable and a holiday timetable will be shown.
[0166] A constraint for associating duties in the weekday timetable and the holiday timetable to each other on a one-to-one basis is represented by Expression 31 and Expression 32. In other words, this constraint is a constraint for

avoiding a situation where a duty corresponding to a duty in the weekday timetable is not present in the holiday timetable or a situation where a duty corresponding to a duty in the weekday timetable is present in plurality in the holiday timetable.
[Expression 31]

$$\sum_{q \in \mathcal{P}} h_{pq} = 1 \quad \forall p \in \mathcal{P} \qquad (31)$$

[Expression 32]

$$\sum_{q \in \mathcal{P}} h_{qp} = 1 \quad \forall p \in \mathcal{P} \qquad (32)$$

[Constraint for synchronizing rolling stock circulations]

[0167] A constraint for synchronizing rolling stock circulations will be shown.

[0168] In duties that correspond to each other in a correspondence table, a departure location and an arrival location must coincide with each other. On a target line, there is one duty stored at a station each in the weekday timetable and the holiday timetable, namely the duties L1 and L'1, and the duties correspond to each other. Since the duties L1 and L'1 are respectively made origins of the rolling stock circulations of the weekday timetable and the holiday timetable, duties at an equal order as counted from the origins of the respective rolling stock circulations may be made to correspond to each other (a departure location and an arrival location thereof may be made to coincide with each other) in order to obtain rolling stock circulations that are synchronized with each other. A constraint for associating duties p and q at an equal order as counted from the respective origins of the weekday timetable and the holiday timetable is represented by Expression 33 below.
[Expression 33]

$$\left| \sum_{r \in \mathcal{P} \setminus \{p\}} u_{pr} - \sum_{r \in \mathcal{P} \setminus \{q\}} u'_{qr} \right| \leq' P\left(1 - h_{p,q}\right) \qquad (33)$$

[Periodic constraint of rolling stock circulation around train timetables shunting]

[0169] A periodic constraint of a rolling stock circulation that spans train timetables will be shown.

[0170] Since shunting of train timetables occurs aperiodically due to holidays and the like, a rolling stock circulation that satisfies a periodic condition with respect to shunting of arbitrary time intervals (intervals in number of days) is desirably created. It is assumed that, in each of the rolling stock circulations (rolling stock circulations for weekdays and holidays), the periodic condition related to a single rolling stock circulation described above is satisfied. In this case, a constraint for associating, between the rolling stock circulations, duties with equal or similar number of elapsed days from a workable duty with each other is provided. Accordingly, the periodic condition related to work can be satisfied with respect to shunting of arbitrary intervals in number of days. Since the constraint for creating rolling stock circulations that are synchronized with each other is satisfied and the periodic constraint of a single rolling stock circulation is also satisfied, associating workable duties to each other naturally satisfies the constraint for associating duties with equal or similar number of elapsed days from a workable duty with each other. A constraint for associating respective workable duties p, q ($k_p = k'_q = 1$) in the weekday timetable and the holiday timetable on a one-to-one basis is represented by Expression 34 and Expression 35 below.
[Expression 34]

$$\sum_{q \in \mathcal{P}: k'_q = 1} h_{pq} = 1 \quad \forall p \in \mathcal{P}: k_p = 1 \qquad (34)$$

[Expression 35]

$$\sum_{q\in\mathcal{P}:k_q=1} h_{qp} = 1 \quad \forall p\in\mathcal{P}: k'_p = 1 \qquad (35)$$

[0171] When the operation plan optimizer 360 finds a solution that satisfies the various constraints described above, the solution is obtained as follows.

$$x_{1,5} = 1$$
$$x_{1,p} = 0 \quad \forall p \in \mathcal{P};\ p \neq 5$$
$$\ldots$$

[0172] Based on the obtained solution, the operation plan optimizer 360 obtains a rolling stock circulation for each train timetable and a correspondence table of duties between a plurality of train timetables. The rolling stock circulations and the correspondence table are respectively stored in the rolling stock circulation storage 410 and the correspondence table storage 420.

[0173] The output device 500 is a GUI (Graphical User Interface) that reads the rolling stock circulation and the correspondence table stored in the rolling stock circulation storage 410 and the correspondence table storage 420 and displays the same on a screen.

[0174] FIG. 30A shows an example in which a rolling stock circulation and a correspondence table are collectively output in a tabular format as an optimization result table to the output device 500. "Weekday timetable duty" and "Holiday timetable duty" which represent first and second columns of the table are columns of duties and respectively correspond to rolling stock circulations of a weekday timetable and a holiday timetable. The rolling stock circulation of the weekday timetable is (L1, L5, L4, L3, L6, L2) and the rolling stock circulation of the holiday timetable is (L'1, L'5, L'2, L'3, L'6, L'4).

[0175] A first row of the optimization result table shows the duties L1 and L'1 to serve as origins of the weekday timetable and the holiday timetable, and second and subsequent rows show a next-day duty of the duty shown in the row immediately above. In an example of the duty L1 that serves as the origin of the weekday timetable (an origin of a weekday rolling stock circulation), the next-day duty is the duty L5 that satisfies $x_{1,p} = 1$.

[0176] The remaining columns represent information on each duty obtained from the duty table shown in FIG. 29. It is shown that the arrival location of each duty and a next-day departure location coincide with each other. It is also shown that the intervals between workable duties is three (three days) and that the periodic condition shown in FIG. 27 is satisfied. Therefore, when a vehicle operation plan (refer to FIG. 23) is created using only one of the obtained rolling stock circulations of the weekday and holiday timetables, since the arrival location of a duty and a departure location of a next-day duty coincide with each other, work can be assigned at three-day intervals and empty run need not be performed.

[0177] Data including the first and second columns of the optimization result table shown in FIG. 30A doubles as a correspondence table. The rolling stock circulations for weekdays and holidays are synchronized with each other. In other words, respective duties of the weekday timetable and the holiday timetable described on a same row correspond to each other. In this case, departure locations and arrival locations of the corresponding duties of the weekday timetable and the holiday timetable coincide with each other and, in addition, values of work labels also coincide with each other.

[0178] Therefore, when creating a vehicle operation plan that spans weekdays and holidays by shunting the obtained rolling stock circulations for weekdays and holidays according to the shunting of timetables as described above, a vehicle operation plan that also satisfies the constraint of work intervals can be similarly obtained without having to perform empty run (train empty run).

[0179] FIG. 30B shows another display example of the optimization result table. "Arrival location" and "Next-day departure location" in FIG. 30A have been changed to "Departure location" and "Arrival location".

[0180] FIG. 31 shows another display example of a rolling stock circulation and a correspondence table. The rolling stock circulation is shown across two sections. An upper section represents a rolling stock circulation corresponding to a holiday timetable and a lower section represents a rolling stock circulation corresponding to a weekday timetable. One block represents information on one duty. Top left in a block shows a departure location of the duty and bottom right in the block shows an arrival location. A center shows a duty ID. In the case of a duty including a plurality of trips, IDs of the plurality of trips and a departure location and an arrival location of each trip are shown. A set of duties indicated by blocks at a same position (same position in a lateral direction) in both rolling stock circulations show a relationship of duties that correspond to each other.

<Handling of cases with no solution>

[0181] Handling of cases where a solution satisfying the various constraints cannot be found or, in other words, cases where there is no solution will be described.

• When the number of workable duties are not equal between the weekday timetable and the holiday timetable

[0182] When the number of workable duties are not equal between the weekday timetable and the holiday timetable, one of Expression 34 and Expression 35 is not satisfied. In this case, a constraint may be provided which allows a duty in a given row (at a given position) in one of the rolling stock circulation to be unworkable and a duty in the same row (at the same position) in the other rolling stock circulation to be workable. Hereinafter, a specific example of the constraint will be described using an example of a case where, among the rolling stock circulation corresponding to the weekday timetable and the rolling stock circulation corresponding to the holiday timetable, the number of workable duties in the rolling stock circulation corresponding to the weekday timetable is smaller than the number of workable duties in the rolling stock circulation corresponding to the holiday timetable. A symbol will be newly defined in addition to the mathematical model described above. Hereinafter, for simplicity of expression, "the timetable" may be read as "the rolling stock circulation corresponding to the timetable" as appropriate. For example, "a workable duty in the weekday timetable" may be read as "a workable duty in the rolling stock circulation corresponding to the weekday timetable."

[0183] Variable ω_p: a variable that takes a value of 0 or 1 depending on whether or not a workable duty p in the holiday timetable does not correspond to a workable duty in the weekday timetable.

[0184] The variable takes a value of 1 when there is no correspondence but takes a value of 0 when there is correspondence. No correspondence means that a duty at a given position in one of the timetables is unworkable and a duty at the same position in the other timetable is workable.

[0185] A constraint that allows a workable duty p in the holiday timetable to not correspond to a workable duty in the weekday timetable is represented by Expression 36 below. Expression 35 in the mathematical model described above is replaced with Expression 36.

[Expression 36]

$$\sum_{q \in \mathcal{P}: k_q = 1} h_{qp} = 1 - \omega_p \quad \forall p \in \mathcal{P}: k'_p = 1 \qquad (36)$$

• When a solution satisfying the maximum work interval or the minimum work interval is not found

[0186] When a solution satisfying the maximum work interval is not found, in order to provide a constraint for allowing the interval between work to exceed the maximum work interval, the following symbol is newly defined for each timetable.

[0187] Variable a_p: a variable that takes a value of 0 or 1 representing the presence or absence of a violation against the maximum work interval by the duty p

$$(p \in \mathcal{P})$$

[0188] A constraint for counting the number of days elapsed from a workable duty during which the duty p had exceeded the maximum work interval is represented by Expression 37 below. Expression 29 in the mathematical model described above is replaced with Expression 37.

[Expression 37]

$$d_p \leq d_{max} - 1 + Pa_p \quad \forall p \in \mathcal{P} \qquad (37)$$

[0189] For example, when $a_p=1$ is satisfied by a duty p that satisfies $x_{pq} = 1$ with respect to a duty q (in other words, a duty p on the day preceding the duty q), this means that, at that time point, the work interval at the duty q exceeds the maximum work interval by $(d_p - d_{max} + 1)$-number of days. The number of days a given duty exceeds the maximum work interval also coincides with the number of consecutive duties satisfying $a_p = 1$ immediately preceding the given duty in a rolling stock circulation.

[0190] An expression for calculating a penalty for a violation of the maximum work interval is represented by Expression 38 below. In the mathematical model described above, Expression 38 is to be used as an objective function. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 38 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function. Accordingly, a rolling stock circulation that minimizes a sum of the number of days during which the maximum work interval had been exceeded can be obtained.
[Expression 38]

$$\sum_{p \in \mathcal{P}} a_p \qquad (38)$$

[0191] The output device 500 may output the number of days during which the maximum work interval had been exceeded in association with a corresponding duty or display the corresponding duty by applying hatching thereto.
[0192] Next, handling when a solution satisfying the minimum work interval is not found will be described. When a solution satisfying the minimum work interval is not found, in order to provide a constraint for allowing the interval between work to fall below the minimum work interval, the following symbol is newly defined for each timetable.
[0193] Variable b_p: a variable that takes a value of an integer of 0 or more representing a degree of violation against the minimum work interval by the duty p
[0194] A constraint for counting the number of days elapsed from a workable duty during which the duty p had fallen below the minimum work interval is represented by Expression 39 below. Expression 30 in the mathematical model described above is replaced with Expression 39.
[Expression 39]

$$d_p \geq (d_{min} - 1)x_{pq} - b_p \quad \forall p \neq q \in \mathcal{P}: k_q = 1 \quad (39)$$

[0195] An expression for calculating a penalty for a violation of the minimum work interval is represented by Expression 40 below. In the mathematical model described above, this expression is to be minimized or quasi-minimized as an objective function. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 40 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function. Accordingly, a rolling stock circulation that minimizes or quasi-minimizes a sum of the number of days during which the duty p had fallen below the minimum work interval can be obtained.
[Expression 40]

$$\sum_{t \in \mathcal{T}} \sum_{p \in \mathcal{P}} b_p \qquad (40)$$

[0196] When a solution satisfying $bp \neq 0$ is found, this means that the work interval of the workable duty q satisfying $x_{pq} = 1$ has fallen below the minimum work interval for b_p-number of days. The output device 500 may output information to that effect or display the duty q by applying hatching thereto.

• When a duty corresponding to a workable duty is not present in both directions in the weekday timetable and the holiday timetable

[0197] A description will now be given of the handling of a case where, in a correspondence table, a duty corresponding to a workable duty in one of the weekday timetable and the holiday timetable is not present in the other timetable and, at the same time, a duty corresponding to a workable duty in the other timetable is not present in the one timetable. In other words, handling of a case where neither Expression 34 nor Expression 35 are satisfied will be described. In order to provide a constraint for allowing such a case, the following symbol is newly defined.
[0198] Variable c_p, c'_p: a variable that takes a value of 0 or 1 depending on whether or not a workable duty p in the weekday timetable/holiday timetable does not correspond to a workable duty in the correspondence table

$$(p \in \mathcal{P})$$

[0199] A constraint allowing a workable duty p in one of the weekday timetable and the holiday timetable to not correspond to any of workable duties q in the other timetable and, at the same time, allowing any of the workable duties p in the other timetable to not correspond to the workable duty q in the one timetable is represented by Expression 41 and Expression 42 below. In the mathematical model described above, Expression 34 is replaced with Expression 41 and Expression 35 is replaced with Expression 42.
[Expression 41]

$$\sum_{q \in \mathcal{P}: k'_q = 1} h_{pq} = 1 - c_p \quad \forall p \in \mathcal{P}: k_p = 1 \qquad (41)$$

[Expression 42]

$$\sum_{q \in \mathcal{P}: k_q = 1} h_{qp} = 1 - c'_p \quad \forall p \in \mathcal{P}: k'_p = 1 \qquad (42)$$

[0200] According to the constraint represented by Expression 41 and Expression 42, even a case is allowed where there is not even one solution in which workable duties correspond to each other between the weekday timetable and the holiday timetable.

[0201] A calculation formula of a penalty for a violation in which a periodic condition related to work is no longer satisfied when straddling shunted timetables is represented by Expression 43 below. In the mathematical model described above, this expression is to be used as an objective function to be minimized or quasi-minimized. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 40 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function. Accordingly, the number of sets of duties in which duties of which the propriety of performing work does not coincide with each other are associated with each other in the correspondence table can be minimized or quasi-minimized. Violations of the periodic condition can be reduced even when creating a vehicle operation plan by shunting rolling stock circulations according to the weekday timetable and the holiday timetable.
[Expression 43]

$$\sum_{t \in \mathcal{T}} \sum_{p \in \mathcal{P}} \left(c_p + c'_p \right) \qquad (43)$$

[0202] When a solution of $c_p = 1$ is found, this means that, for example, the duty q in the holiday timetable which corresponds to the workable duty p in the weekday timetable is not workable. The output device 500 may output information to that effect or apply hatching to at least one of the duty p and the duty q and output the same. This similarly applies to the holiday timetable.

[0203] It should be noted that the formulation described above is merely an example and other objective functions and constraint expressions may be used.

<Evaluation method of rolling stock circulation>

[0204] An object of the periodic condition according to the present approach is to uniformly perform work, outside storage, and the like. An example of an index for evaluating an operation plan from the perspective of uniformity is statistics related to intervals of work, outside storage, and the like. The operation plan creator 302 may calculate statistics and evaluate an operation plan. Hereinafter, a method of calculating a dispersion of work intervals as an example of an evaluation index will be described. When shunting timetables by first fitting a timetable into an actual calendar of a certain period (a month, a year, or the like) in order to take aperiodic shunting of timetables due to holidays and the like into consideration, a vehicle operation plan is created by shunting rolling stock circulations in accordance with the shunting of timetables. Intervals of arbitrary workable duties in the operation plan are obtained and a dispersion of the intervals is adopted as an evaluation index of the rolling stock circulation. Statistics are not limited to a dispersion and a mean, a minimum value, a maximum value, or the like may be used.

[0205] Hereinafter, operations of the operation plan creation device 102 shown in FIG. 22 will be described with reference to FIG. 32.

[0206] FIG. 32 is a flow chart of an example of operation plan creation processing executed by the operation plan creation device 102.

[0207] First, the train timetable information input device 160 receives a plurality of pieces of train timetable information (for example, information on a weekday timetable and information on a holiday timetable) via user input or the like, the work information input device 170 receives work information via user input or the like, and the periodic information input device 180 receives periodic information of work via user input or the like (step S201). The train timetable information, work information, and periodic information are respectively stored in the train timetable information storage 260, the work information storage 270, and the periodic information storage 280.

[0208] Next, for each piece of the plurality of pieces of train timetable information stored in the train timetable information storage 260, by combining one or more trips, the duty creator 361 creates a plurality of duties with respect to each of a plurality of train timetables (step S202). Each of the plurality of duties includes one or a plurality of trips.

[0209] Next, the arrival/departure order creator 362 creates an order of arrival and an order of departure (orders of arrival and departure) of the plurality of duties created in step S202 (step S203).

[0210] Next, based on the work information stored in the work information storage 270, the work label creator 370 determines whether or not the plurality of duties satisfy a work condition (refer to FIG. 26). The work condition determines, for example, a condition of a workable location or time slot. The work label creator 370 sets a work label of a duty satisfying the work condition to "1" and a work label of other duties to "0" (step S204).

[0211] Next, the operation plan optimizer 360 generates a constraint condition based on various constraints for creating rolling stock circulations synchronized with each other between a plurality of train timetables and finds a solution satisfying the constraint condition (step S205). Alternatively, the operation plan optimizer 360 generates the constraint condition and an objective function and finds a solution by optimizing or quasi-optimizing the objective function so as to satisfy the constraint condition (step S205). Based on the found solution, the operation plan optimizer 360 acquires a rolling stock circulation for each train timetable and a correspondence table of duties between a plurality of train timetables. The rolling stock circulations and the correspondence table are respectively stored in the rolling stock circulation storage 410 and the correspondence table storage 420.

[0212] The output device 500 reads the rolling stock circulations and the correspondence table stored in the rolling stock circulation storage 410 and the correspondence table storage 420 and displays the same on a screen (step S206). Accordingly, the operation plan creation processing is completed.

[0213] As described above, according to the first configuration example of the second approach, rolling stock circulations for weekdays and holidays which are synchronized with each other can be created while minimizing the number of sets that associate, to each other, duties of which the propriety of performing work does not coincide with each other in a correspondence table of duties for weekdays and holidays. In addition, even when shunting rolling stock circulations according to a weekday timetable and a holiday timetable, a vehicle operation plan with a reduced number of violations of a periodic condition can be created.

[Second configuration example]

[0214] FIG. 33 is a block diagram of an operation plan creation device 102A that is an information processing device according to a second configuration example of the second approach. In addition to the operation plan creation device 102 according to the first configuration example, the operation plan creation device 102A according to the second configuration example further includes an original operation plan information input device 190, an original operation plan storing device 290, and a difference constraint creator 390.

[0215] The original operation plan information input device 190 accepts an input operation of original operation plan information from the user of the operation plan creation device 102A and acquires the original operation plan information. For example, the original operation plan information represents a new rolling stock circulation plan, a rolling stock circulation prior to or after change due to a disruption in a train timetable or vehicle breakdown, or the like.

[0216] The original operation plan storing device 290 stores the original operation plan information acquired by the original operation plan information input device 190.

[0217] Hereinafter, processing of the difference constraint creator 390 shown in FIG. 33 will be described in detail. The difference constraint creator 390 creates a constraint (a difference constraint) for evaluating a difference from a rolling stock circulation to be created based on original operation plan information. Using the difference constraint enables a rolling stock circulation or an operation plan with a small difference from the original operation plan information to be created.

[0218] Hereinafter, a mathematical model in a case where a penalty is to be imposed on a non-coincidence with the original operation plan will be described. A symbol will be newly defined for each train timetable in addition to the mathematical model described in the first configuration example.

[0219] $\hat{x}_{pq}$: a value of variable x_{pq} in original operation plan

$$(p \neq q \in \mathcal{P})$$

Variable z_p: a variable that takes a value of 0 or 1 depending on whether or not a next-day duty of the duty p in the rolling stock circulation is same as in the original operation plan

$$(p \in \mathcal{P})$$

. The variable takes a value of 1 when the next-day duty is the same but takes a value of 0 if not.

[0220] A constraint for adopting z_p = 1 when the next-day duty of the duty p differs from the original operation plan is represented by Expression 44 below. The constraint is added to the mathematical model shown in the first configuration example.

[Expression 44]

$$\left|x_{pq} - \hat{x}_{pq}\right| \geq z_p \quad \forall p \in \mathcal{P}, q \in \mathcal{P} \setminus \{p\} \qquad (44)$$

[0221] An expression for calculating a penalty for a non-coincidence with the original operation plan is represented by Expression 45 below. In the mathematical model described above, this expression is to be used as an objective function to be minimized or quasi-minimized. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 45 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function. Accordingly, a rolling stock circulation in which the number of sets of a duty and a next-day duty in a different order from the original operation plan has been minimized or quasi-minimized is obtained.

$$\sum_{p} z_p \qquad (45)$$

[0222] When the solution of z_p=1 is obtained, this means that the next-day duty (in other words, a duty satisfying x_{pq} = 1) q of the duty p differs from the original operation plan. The output device 500 may output information to that effect. The output device 500 may apply hatching to one of or both of the duties p and q and output the same.

[0223] As described above, according to the second configuration example of the second approach, a rolling stock circulation in which the number of sets of a duty and a next-day duty in a different order from the original operation plan has been minimized or quasi-minimized can be created.

(Third approach)

[0224] In a third approach, a shunting plan of a railway and a rolling stock circulation of the railway are concurrently created based on a combination of the first approach and the second approach.

[0225] Whether or not a constraint of an order of arrival and an order of departure (orders of arrival and departure) on a track that enables storage in tandem is satisfied when performing overnight stay of a plurality of trains is determined by an order of arrival and an order of departure on the following day of the plurality of trains (vehicles). The order of arrival and the order of departure on the following day are determined from an order of arrival of each duty and an order of departure of a next-day duty in a rolling stock circulation. Whether or not a shunting plan with a small number of shunting can be created is determined by the rolling stock circulation. Therefore, by creating the shunting plan concurrently with the rolling stock circulation, it is expected that a more efficient operation plan can be created.

[First configuration example]

[0226] FIG. 34 is a block diagram of an operation plan creation device 103 that is an information processing device according to a first configuration example of the third approach. The operation plan creation device 103 creates a rolling stock circulation and a shunting plan concurrently as a vehicle operation plan based on one or more pieces of train timetable information and route information including a length of a route (track) on which a train (vehicles and the like) can be stored. When a plurality of pieces of train timetable information are provided, the operation plan creation device 103 may further create a correspondence table of duties between train timetables.

[0227] Hereinafter, a case where a vehicle operation plan is to be created for a railway line (target line) will be described. On the target line, two train timetables for weekdays and holidays are provided. Each train timetable includes an ID, a departure location, an arrival location, a departure time, and an arrival time of each of a plurality of trips. In the present approach, there are two arrival and departure locations, namely, a railway yard and a station. Let us assume that there are six trains and that each train has the same number of vehicles for the sake of simplicity. Let us also assume that definitions and contents of train timetable information, work information, and periodic information are the same as those in the second approach.

[0228] FIG. 35 shows an example of track information as route information. An overnight stay zone (target zone) of the target line has one railway yard and one station. The railway yard includes two tracks R1 and R2 and the station includes one track R3. Route lengths or, in other words, the numbers of trains that can be stored in tandem (number of trains stored in tandem) of the tracks R1, R2, and R3 are, respectively, four trains, two trains, and one train. Track types of the tracks R1 and R2 are both the LIFO scheme. When the number of trains is six and one train among the six trains is to be outside storage (station storage), the number of trains to be subjected to overnight stay at the railway yard is five trains and, therefore, the railway yard has an available space for one train.

[0229] Hereinafter, processing in which the operation plan creator 302 shown in FIG. 34 creates a rolling stock circulation will be described. The duty creator 361 shown in FIG. 34 creates a duty in a similar manner to the duty creator 361 shown in FIG. 22. The arrival/departure order creator 362 shown in FIG. 34 calculates orders of arrival and departure of duties in a similar manner to the arrival/departure order creator 362 shown in FIG. 22. The work label creator 370 shown in FIG. 34 creates a work label in a similar manner to the work label creator 370 shown in FIG. 22. As a result of the processing described above, a duty table (refer to FIG. 29) for each of a weekday timetable and a holiday timetable is obtained in a similar manner to the second approach. The duty table includes an ID, an order of departure, an order of arrival, a departure location, an arrival location, and a work label of each duty. The operation plan optimizer 360 shown in FIG. 35 constructs a mathematical model and calculates a solution to the mathematical model in a similar manner to the first approach or the second approach. On the target line, duties to serve as an origin of rolling stock circulations respectively corresponding to the weekday timetable and the holiday timetable are to be the duties L1 and L'1 which both stored at a station. The duties to serve as origins correspond to cities (vertices) to serve as origins where the number of items is reset to zero in the free formulation (ff) described in the explanation of the second approach.

[0230] Symbols for describing the mathematical model will be defined below.

$P = 6$: number of duties (number of trains)

$\mathcal{P}$: set of duties {1, 2, ···, 6}

$\mathcal{T}$: set of tracks {1, 2, 3}

$\mathcal{B}$: set of locations {1 (railway yard), 2 (station)}

t_p^{arv}, t'^{arv}_p : order of arrival of duty p in weekday timetable/holiday timetable

$$(p \in \mathcal{P})$$

t_p^{dep}, t'^{dep}_p : order of departure of duty p in weekday timetable/holiday timetable

$$(p \in \mathcal{P})$$

B_p^{arv}, B'^{arv}_p : arrival location of duty p in weekday timetable/holiday timetable $(B \in \mathcal{B},\ p \in \mathcal{P})$

B_p^{dep}, B'^{dep}_p : departure location of duty p in weekday timetable/holiday timetable $(B \in \mathcal{B},\ p \in \mathcal{P})$

k_p, k'_p: work label of duty p in weekday timetable/holiday timetable $(p \in \mathcal{P})$

c_t: number of units stored in tandem on track t $(t \in \mathcal{T})$

d_{max}, d_{min}: maximum work interval, minimum work interval $p^{railway\ yard}$, $p'^{railway\ yard}$: city to serve as origin ($p^{railway\ yard}$

= p'railway yard = 1) Variable x_{pq}, x'_{pq}: a variable that takes a value of 0 or 1 depending on whether or not a next-day duty of the duty p in the weekday timetable/holiday timetable is duty q $(p \neq q \in \mathcal{P})$
Variable y_{pt}, y'_{pt}: a variable that takes a value of 0 or 1 depending on whether or not duty p in the weekday timetable/holiday timetable is to be stored on track t $(p \in \mathcal{P},\ t \in \mathcal{T})$
Variable z_{pq}, z'_{pq}: a variable that takes a value of 0 or 1 depending on whether or not shunting is unnecessary when the duties p and q in the weekday timetable/holiday timetable are assigned to a same track adopting the LIFO scheme $(p \neq q \in \mathcal{P})$
Variable u_{pq}, u'_{pq}: an auxiliary discrete variable that takes an integer value [0, P - 1] representing the number of items transported by a salesman between cities p and q in the weekday timetable/holiday timetable $(p \neq q \in \mathcal{P})$
Variable d_p, d'_p: a discrete variable that represents number of days elapsed from workable duty in the weekday timetable/holiday timetable $(p \in \mathcal{P})$ Variable h_{pq}: a variable that takes a value of 0 or 1 depending on whether or not the respective duties p and q in the weekday timetable/holiday timetable are to be associated with each other $(p,\ q \in \mathcal{P})$

[0231] Constraints of creating a rolling stock circulation and a shunting plan will be shown below. First, Expression 20 to Expression 25 according to the second approach are used as a constraint for creating the rolling stock circulation. Expression 1 and Expression 2 according to the first approach are used as a constraint for creating the shunting plan. In addition, the constraints described below will be further used.

[0232] A constraint for determining whether or not a need for shunting is to arise when storing trains to which the duties p and q are assigned on a same track adopting the LIFO scheme is represented by Expression 46.
[Expression 46]

$$\sum_{r \in \mathcal{P} \setminus \{q\}} t_q^{dep} x_{qr} - \sum_{r \in \mathcal{P} \setminus \{p\}} t_p^{dep} x_{qr} \leq' P z_{pq} \quad \forall p \neq q \in \mathcal{P} \text{ s.t. } t_p^{arv} < t_q^{arv} \qquad (46)$$

[0233] Whether z_{pq} assumes 1 or 0 when the need for shunting arises differs according to track types. A more detailed description will be given below. As described earlier, a limit is imposed on orders of arrival and departure depending on a track type. Let next-day duties of the duties p and q be respectively denoted by p^{next} and q^{next}. An order of next-day departure is an order of departure of next-day duties and the next-day duty of the duty p is a duty r satisfying $x_{pr} = 1$. Let us assume that the order of arrival and the order of next-day departure have a relationship expressed as $t_p^{arv} < t_q^{arv}$ and $t_{p^{next}}^{dep} < t_{q^{next}}^{dep}$. When a train (described as train p) to which the duty p is assigned and a train (described as train q) to which the duty q is assigned arrive according to the order of arrival, the trains are to be stored in tandem in an order of trains p and q from a distal end of the track (a side that cannot be arrived and departed). Even when desiring to depart according to the order of departure, since the train q is present in a direction of travel of the train p, the train p cannot depart. Therefore, shunting of the trains p and q is required upon arrival of the train q or departure of the train p. The constraint of Expression 46 is a constraint for satisfying variable $z_{pq} = 1$ that corresponds to such a set of duties p and q. On a track adopting the FIFO scheme, when a set of vehicles p and q of which a relationship of order of arrival and order of next-day departure satisfy $t_p^{arv} < t_q^{arv}$ and $t_{q^{next}}^{dep} < t_{p^{next}}^{dep}$ is stored on a same track, shunting is necessary. Therefore, contrary to the track type adopting the LIFO scheme, the vehicles p and q cannot be stored on a same track when $z_{pq} = 0$. Therefore, the constraint of Expression 46 is a constraint for satisfying variable $z_{pq} = 0$ that corresponds to such a set of duties p and q.

[0234] A constraint for not storing, on a same track, a set of trains that requires shunting on a track t adopting the LIFO scheme is represented by Expression 47 below. A set of vehicles p and q which satisfy $z_{pq} = 1$ enables one of the vehicles to be stored on the track t adopting the LIFO scheme.
[Expression 47]

$$y_{pt} + y_{qt} \leq' 2 - z_{pq} \quad \forall t \in \mathcal{T} \text{ s.t. } c_t \geq 2, p \neq q \in \mathcal{P} \text{ s.t. } B_p^{arv} = B_q^{arv} \quad (47)$$

[0235] Since only one of the set of vehicles p and q which satisfy $z_{pq} = 0$ can be stored on the track t adopting the FIFO scheme, a constraint for not storing, on a same track, a set of trains that requires shunting is represented by Expression 48 below.
[Expression 48]

$$y_{pt} + y_{qt} \leq' 1 + z_{pq} \quad \forall t \in \mathcal{T} \text{ s.t. } c_t \geq 2, p \neq q \in \mathcal{P} \text{ s.t. } B_p^{arv} = B_q^{arv} \quad (48)$$

[0236] With a track t adopting the FREE scheme which can be arrived and departed from both ends, a direction of arrival or a direction of departure is also designated. To this end, a variable y_{ptio} is newly adopted as a decision variable in place of the variable y_{pt} in a similar manner to the first approach. The variable y_{ptio} takes a value of 1 when the train p arrives the track t from a direction i to be stored on the track t and departs from a direction o. Expression 49 below represents a constraint for not storing, on a same track, a set of trains that requires shunting on a track t adopting the FREE scheme.
[Expression 49]

$$\sum_{i,o \in \{0,1\}} y_{ptio} + y_{qt01} + y_{qt10} \leq' 1 + z_{pq} \quad \forall t \in \mathcal{T} \text{ s.t. } c_t \geq 2, p \neq q \in \mathcal{P} \text{ s.t. } B_p^{arv} = B_q^{arv},$$
$$\sum_{o \in \{0,1\}} y_{pti0} + \sum_{i \in \{0,1\}} y_{pt0o} \leq' 2 - z_{pq} \quad \forall t \in \mathcal{T} \text{ s.t. } c_t \geq 2, p \neq q \in \mathcal{P} \text{ s.t. } B_p^{arv} = B_q^{arv} \quad (49)$$
$$\sum_{o \in \{0,1\}} y_{pti1} + \sum_{i \in \{0,1\}} y_{pt1o} \leq' 2 - z_{pq} \quad \forall t \in \mathcal{T} \text{ s.t. } c_t \geq 2, p \neq q \in \mathcal{P} \text{ s.t. } B_p^{arv} = B_q^{arv}$$

[0237] Since Expression 47, Expression 48, and Expression 49 can be described for each track, track types may be present in a mixed manner. In addition, when there is a track adopting the FREE scheme, the symbols in Expression 1 and Expression 2 are appropriately changed.

[0238] Expression 50 represents a constraint for making tracks of the duties p and q that correspond to each other between the weekday timetable and the holiday timetable coincide with each other, and Expression 51 represents a constraint for making stacks of the duties p and q that correspond to each other between the weekday timetable and the holiday timetable coincide with each other. As described in the explanation of the second approach, when creating an operation plan using rolling stock circulations for weekdays and holidays, duties that correspond to each other between the weekday timetable and the holiday timetable in the correspondence table are considered the same before and after shunting of timetables. For example, when shunting from the weekday timetable to the holiday timetable, a duty of the holiday timetable after the shunting of timetables is a next-day duty of the duty of the holiday timetable corresponding to a duty of the weekday timetable prior to the shunt. Since a track and a stack of a train to which each duty is to be assigned are determined by the shunting plan, due to the present constraint, respective duties of the weekday timetable and the holiday timetable which are assigned to a same track and a same stack are to correspond to each other.
[Expression 50]

$$|y_{pt} - y'_{qt}| \leq 1 - h_{pq} \quad \forall p, q \in \mathcal{P}, t \in \mathcal{T} \quad (50)$$

[Expression 51]

$$\left|\sum_{r\in\mathcal{P}:t_r^{arv}<t_p^{arv}} y_{rt} - \sum_{r\in\mathcal{P}:t_r^{arv}<t_q^{arv}} y_{rt}\right| \leq' c_t(2 - y_{pt} - h_{pq}) \quad \forall p,q\in\mathcal{P}, t\in\mathcal{T} \ \text{s.t.}\ c_t \geq 2 \qquad (51)$$

[0239] In addition to the constraints described above, Expression 31 and Expression 32 according to the second approach will be adopted as a constraint (a constraint for associating duties in the weekday timetable and the holiday timetable on a one-to-one basis). Furthermore, the constraint of Expression 33 according to the second approach is added as a constraint for associating duties at an equal order as counted from the respective origins of the weekday timetable and the holiday timetable to each other (as a constraint for synchronizing rolling stock circulations with each other).

[0240] Next, a periodic constraint will be described. The periodic constraint creator 380 shown in FIG. 34 creates a periodic constraint based on periodic information. First, Expression 26 to Expression 30 according to the second approach are used as a periodic constraint related to a single rolling stock circulation (a rolling stock circulation for weekdays or holidays). Next, Expression 34 and Expression 35 according to the second approach are adopted as a periodic constraint of a rolling stock circulation straddling timetables.

[0241] When the operation plan optimizer 360 solves the mathematical model based on the information described above, a solution such as $x_{1,5} = 1$, $x_{1,p} = 0 \quad \forall p \in \mathcal{P}$; $p \neq 5$,... is obtained.

[0242] Based on the obtained solution, the operation plan optimizer 360 obtains a shunting plan, a rolling stock circulations, and a correspondence table. The shunting plan is stored in the shunting plan storing device 400. The rolling stock circulations and the correspondence table are stored in a rolling stock circulation/correspondence table storage 413. The output device 500 reads the shunting plan, the rolling stock circulations, and the correspondence table from the storages 400 and 410 and displays the same on a screen.

[0243] FIG. 36A shows a display example of an operation plan (including a shunting plan, a rolling stock circulation, and a correspondence table). A "track" column, a "stack" column, and an "arrival/next-day departure order" column which are the fifth to eighth columns are similar to FIG. 9 according to the first approach. In addition, a "weekday/holiday timetable duty" column, an "arrival location/next-day departure location" column, and a "work label" column which are the first to fourth and ninth columns are similar to FIG. 30A according to the second approach. In the present third approach, since a rolling stock circulation and a shunting plan are to be created concurrently, duties of the weekday timetable and the holiday timetable which are stored on a same track or stack in the shunting plan are to correspond to each other. It is understood that tracks/stacks of the duties of the weekday timetable and the holiday timetable described on a same row in FIG. 36A coincide with and correspond to each other. In other words, a table that laterally couples rolling stock circulations of the weekday timetable and the holiday timetable doubles as a correspondence table. In this manner, rolling stock circulations that are synchronized with each other can be created.

[0244] FIG. 36B shows another display example of an operation plan. "Arrival location/next-day departure location" in FIG. 36A has been changed to "Departure location/arrival location".

[0245] Hereinafter, handling of cases where a solution satisfying the constraints cannot be obtained or, in other words, cases where there is no solution will be described. When the number of workable duties in the weekday timetable is smaller than that in the holiday timetable, Expression 35 is replaced with Expression 42 in a similar manner to the second approach.

[0246] When there is no solution satisfying the maximum work interval, Expression 29 is replaced with Expression 37 in a similar manner to the second approach. Expression 38 is to be used as an objective function to be minimized or quasi-minimized. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 38 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function.

[0247] When there is no solution satisfying the minimum work interval, Expression 30 is replaced with Expression 39 in a similar manner to the second approach. Expression 40 is to be used as an objective function to be minimized or quasi-minimized. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 40 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function.

[0248] When there is no solution that causes workable duties in a plurality of timetables (the weekday timetable and the holiday timetable) to correspond to each other in the correspondence table, Expression 34 is replaced with Expression 41 and Expression 35 is replaced with Expression 42 in a similar manner to the second approach. Expression 43 is to be used as an objective function to be minimized or quasi-minimized. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 43 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function.

[0249] A case where there is no solution that does not require shunting will be described. A symbol will be newly defined for each train timetable. Variable s_{pq}, s'_{pq}: a variable that takes a value of 0 or 1 depending on whether or not trains p and q need to be shunted in the weekday timetable/holiday timetable $(p < q \in \mathcal{P})$

[0250] For example, when a set of vehicles p and q satisfying z_{pq} = 1 (requires shunting) are both stored on a track t adopting the LIFO scheme, s_{pq} = 1 is satisfied.

[0251] Expression 52 represents a constraint for allowing sets of duties of which the need to perform shunting arises to be stored on a same track. In the case of the LIFO scheme, Expression 47 is replaced with Expression 52. Even in the cases of other track types (the FIFO scheme or the FREE scheme), Expression 48 and Expression 49 may be appropriately modified in a similar manner.

[Expression 52]

$$y_{pt} + y_{qt} \leq' 2 - z_{pq} + s_{pq} \quad \forall t \in \mathcal{T} \text{ s.t. } c_t \geq 2, p \neq q \in \mathcal{P} \text{ s.t. } B_p^{arv} = B_q^{arv} \qquad (52)$$

[0252] A penalty with respect to the number of sets of trains that require shunting is represented by Expression 53 below. Expression 53 is to be used as an objective function. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 53 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function.

[Expression 53]

$$\sum_{p<q\in\mathcal{P}} s_{pq} \qquad (53)$$

[0253] A case of creating a rolling stock circulation and a shunting plan from a single train timetable will be described. For example, when creating a rolling stock circulation and a shunting plan of a weekday timetable, symbols with apostrophes corresponding to the holiday timetable are deleted, Expression 46 or 47 or 48 corresponding to the holiday timetable is deleted, and Expression 50 and Expression 51 are deleted.

[0254] In this manner, a single rolling stock circulation and a shunting plan can be created so as to correspond to a line or the like for which only a single train timetable is provided.

[0255] Hereinafter, a mathematical model for creating a rolling stock circulation and a shunting plan having robustness against a disruption in a train timetable or the like will be described. When a change in an arrival time to a trip due to a disruption in a train timetable or the like causes an order of arrival to the trip to change, a need arises to shunt a set of duties that originally did not require shunting. When the set of duties has been stored on a same track in a shunting plan, the number of shunts increases.

[0256] In this case, in place of a set of duties for which a need for shunting arises or a need for shunting is highly likely to arise due to a change in an arrival time, a set of duties (referred to as a candidate set, details will be given later) for which there is no need for shunting or a need for shunting is unlikely to arise are stored on a same track. It is expected that the larger the number of candidate sets, the higher the possibility that any of the candidate sets remains a set of duties with no need for shunting even if a change in arrival time occurs in a plurality of duties. For the sake of simplicity, a track structure with a plurality of tracks of which the numbers of units stored in tandem are one and two will be considered. In this case, avoiding shunting by breaking up a set of duties for which a need for shunting has arisen and storing the duties on different tracks and, in place thereof, storing a candidate set in tandem on a same track, the presence of a shunting plan with an unchanged number of shunting is guaranteed. In this case, a new symbol is defined in addition to the mathematical model described above. When there are three or more types of train timetables, the symbol may be defined for each set of two train timetables. Hereinafter, a case where two duties are interpreted as a single set will be described.

[0257] v_{pg}: a variable that takes a value of 0 or 1 depending on whether or not at least one of the following is true: a set of duties p and q in a weekday timetable is a set for which a need for shunting arises; a set r, s (h_{pr} = h_{qs} = 1) in a holiday timetable respectively corresponding to the duties p and q is a set for which a need for shunting arises; and an order of arrival (which duty arrives first) of the set of duties p and q and an order of arrival of the set of duties r, s do not coincide with each other

$$(p < q \in \mathcal{P})$$

[0258] For example, when the set of duties p $q\ (t_p^{arv} < t_q^{arv})$ in a weekday timetable is a set for which a need for shunting does not arise ($z_{pq} = 0$), the set r, s ($h_{pr} = h_{qs} = 1$) of duties respectively corresponding to the duties p and q is also a set for which a need for shunting does not arise ($z'_{rs} = 0$), and $t'^{arv}_r < t'^{arv}_s$ is true, then $v_{pq} = 0$ is satisfied. At this point, when the set of duties p and q are stored on a same track, the duties are arranged in an order of p, q from a distal end (a side that cannot be arrived and departed) and, similarly, when the set r, s of duties are stored on a same track, the duties are arranged in an order of r, s from the distal end. Therefore, in correspondence to a constraint that corresponding duties are to be stored by making even stacks coincide with each other, it is shown that the duties p, q and the duties r, s can be stored by making even stacks coincide with each other. In other words, it is shown that a shunting plan for storing a set of duties p and q of the weekday timetable satisfying $v_{pq} = 0$ on a same track remains consistent even as a shunting plan for the holiday timetable. Such p and q are referred to as a candidate set.

[0259] A constraint for determining a candidate set on a track adopting the LIFO scheme is represented by Expression 54 to Expression 57 below.

[Expression 54]

$$z_{pq} \leq v_{pq} \quad \forall p \leq' q \in \mathcal{P} \quad (54)$$

[Expression 55]

$$z'_{rs} + h_{pr} + h_{qs} + h_{ps} + h_{qr} - 2 \leq' v_{pq} \quad \forall p \leq' q \in \mathcal{P}, r \leq' s \in \mathcal{P} \quad (55)$$

[Expression 56]

$$h_{pr} + h_{qs} - 1 \leq' v_{pq}\ \forall p \leq' q \in \mathcal{P}, r \leq' s \in \mathcal{P}\ s.t.\ \left(t_p^{arv} - t_q^{arv}\right)\left(t'^{arv}_r - t'^{arv}_s\right) < 0 \quad (56)$$

[Expression 57]

$$h_{ps} + h_{qr} - 1 \leq' v_{pq}\ \forall p \leq' q \in \mathcal{P}, r \leq' s \in \mathcal{P}\ s.t.\ \left(t_p^{arv} - t_q^{arv}\right)\left(t'^{arv}_r - t'^{arv}_s\right) > 0 \quad (57)$$

[0260] A calculation formula of the number of sets of duties that are not candidate sets is represented by Expression 58. Since a rolling stock circulation and a shunting plan with a large number of candidate sets are desirable, Expression 58 will be adopted as an objective function in the present mathematical model. Alternatively, a calculation formula of candidate sets weighted by a difference in arrival times of duties to be described later may be adopted as an objective function. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 58 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function. The objective function is minimized or quasi-minimized based on the constraints described above.

[Expression 58]

$$\sum_{p<q\in\mathcal{P}} v_{pq} \quad (58)$$

[0261] When there is an overlap in the duties that make up candidate sets, only one of the candidate sets can be stored in tandem. For example, when a set of duties p and q and a set of duties p and q' are both candidate sets, since the duty p is an overlapping duty storing one of the candidate sets on a track of which the number of units storable in tandem is two prevents the other candidate set from being stored in tandem. When there is a large number of candidate sets without overlapping duties, the number of candidate sets that can be concurrently stored in tandem increases accordingly. In this case, a new symbol is defined in addition to the mathematical model described above.

[0262] u_{pq}: a variable that takes a value of 0 or 1 depending on whether or not a set of duties p and q is not a candidate set (v_{pq} = 1) or the set of duties p and q is a candidate set but one of the duties p and q overlaps with another candidate set

$$(p < q \in \mathcal{P})$$

[0263] A constraint for determining a non-overlapping candidate set on a track adopting the LIFO scheme is represented by Expression 59 and Expression 60 below. Among candidate sets including the duty p, only one u_{pq} or u_{qp} assumes 0.

[Expression 59]

$$v_{pq} \leq' u_{pq} \quad \forall p < q \in \mathcal{P} \quad (59)$$

[Expression 60]

$$\sum_{q \in \mathcal{P}; q > p} u_{pq} + \sum_{q \in \mathcal{P}; q < p} u_{qp} \geq P - 2 \ \ \forall p \in \mathcal{P} \quad (60)$$

[0264] A calculation formula of a sum of the number of sets of duties that are not candidate sets and the number of candidate sets with overlapping duties is represented by Expression 61 below. Since a rolling stock circulation and a shunting plan with a large number of non-overlapping candidate set are desirable, Expression 61 will be adopted as an objective function in the present mathematical model. Alternatively, a calculation formula of the number of sets weighted by a difference in arrival times of duties to be described later may be adopted as an objective function. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 61 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function. The objective function is minimized or quasi-minimized based on the constraints described above.

[Expression 61]

$$\sum_{p < q \in \mathcal{P}} u_{pq} \quad (61)$$

[0265] It is shown that, by optimizing or quasi-optimizing v_{pq} or u_{pq}, a shunting plan can be readily created even without having to optimize or quasi-optimize variables y_{pt}, y'_{pt} for designating a track for storage. The numbers of tracks of which the number of units storable in tandem are one and two are respectively denoted by T_1 and T_2.

[0266] A constraint that the number of candidate sets without overlapping duties is larger than the number of tracks of which the number of units storable in tandem is two is represented by Expression 62. When the number of candidate sets without overlapping duties is T_2 or more, by selecting T_2-number of candidate sets therefrom, storing the candidate sets on a track of which the number of units storable in tandem is two, and sequentially assigning other duties to Ti-number of tracks of which the number of units storable in tandem is one, a shunting plan can be created.

[Expression 62]

$$\sum_{p < q \in \mathcal{P}} (1 - u_{pq}) \geq T_2 \quad (62)$$

[0267] Hereinafter, a method of selecting a candidate set will be described. When storing duties p, q of a candidate set on a same track, when an order of arrival of p and q changes due to a change in arrival times caused by a disruption in a train timetable or the like, a need for shunting arises. When there is a large difference between arrival times of p and q, it is expected that the likelihood of a change to the order of arrival of p and q due to a disruption in a train timetable or the like declines. In consideration thereof, a difference in arrival times between the duties p and q in each of the weekday timetable and the holiday timetable of all candidate sets is calculated and a sum, a product, or a function constituted of absolute values of the calculated differences is adopted as an evaluation index. T_2-number of candidate sets are selected in a descending order of evaluation indices so that the duties p and q do not overlap with each other.

[0268] Hereinafter, handling of a case where a track structure includes a track of which the number of units storable in tandem is two or more will be described. For example, when three duties p, q, and r are to be stored on a same track of which the number of units storable in tandem is three, a need for shunting does not arise if a set of duties p and q, a set of duties q and r, and a set of duties r and p are respectively candidate sets. In this case, a new symbol is defined in addition to the mathematical model described above. When there are a three or more types of train timetables, the symbol may be defined for each set of two train timetables.

[0269] m_{pqr}: a variable that takes a value of 0 or 1 depending on whether or not a at least one of the set of duties p and q, the set of duties q and r, and the set of duties r and p is not a candidate set

$$(p < q < r \in \mathcal{P})$$

. m_{pqr} takes a value of 0 when all three sets are candidate sets but otherwise takes a value of 1.

[0270] A constraint for determining whether or not each of the sets of duties p and q, q and r, and r and p is a candidate set is represented by Expression 63 below.

[Expression 63]

$$v_{pq} + v_{pq} + v_{qr} \leq' 3m_{pqr} \quad \forall p < q < r \in \mathcal{P} \quad (63)$$

[0271] A calculation formula of the number of combinations of duties such that any of the sets of duties p and q, q and r, and r and p is not a candidate set is represented by Expression 64. Since a rolling stock circulation and a shunting plan with a large number of combinations of three duties for which a need for shunting does not arise even when storing on a same track are desirable, Expression 64 will be adopted as an objective function in the present mathematical model. Alternatively, a calculation formula of the number of combinations having been weighted may be adopted as an objective function. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 64 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function. The objective function is minimized or quasi-minimized based on the constraints described above.

[Expression 64]

$$\sum_{p<q<r\in\mathcal{P}} m_{pqr} \qquad (64)$$

[0272] The number of combinations without overlapping duties among combinations of the three duties p, q, and r which satisfy $m_{pqr} = 0$ can be calculated in a similar manner to the case where the number of units storable in tandem is two. The number of combinations of duties which enable four or more duties to be stored on a same track without the need for shunting can be readily calculated by expanding a case where the number of units storable in tandem is three. In addition, a shunting plan when there is a track of which the number of units storable in tandem is three or more can also be calculated without having to optimize or quasi-optimize variables y_{pt}, y'_{pt}.

[0273] In this manner, a rolling stock circulation and a shunting plan which has robustness against a disruption in a train timetable or the like and which minimizes an increase in the number of shunts even when arrival times change can be created.

[0274] An operation of the operation plan creation device 103 shown in FIG. 34 will be described.

[0275] FIG. 37 is a flow chart of an example of operation plan creation processing executed by the operation plan creation device 103.

[0276] Via user input or the like, the train timetable information input device 160 receives train timetable information, the route information input device 110 receives route information, the work information input device 170 receives work information, and the periodic information input device 180 receives periodic information (step S301). The train timetable information, the route information, the work information, and the periodic information are respectively stored in the train timetable information storage 260, the route information storage 210, the work information storage 270, and the periodic information storage 280.

[0277] Since steps S302, S303, and S304 shown in FIG. 37 are similar to steps S202, S203, and S204 shown in FIG. 32 according to the second approach, a description thereof will be omitted.

[0278] Next, the operation plan optimizer 360 obtains a solution based on a constraint condition that a train to which corresponding duties of the weekday timetable and the holiday timetable in the correspondence table is assigned is to be stored on a same track/stack in the shunting plan (step S305). Alternatively, the operation plan optimizer 360 may generate an objective function in addition to the constraint condition and obtain a solution by optimizing or quasi-optimizing the objective function so as to satisfy the constraint condition (step S305). Based on the obtained solution, the operation plan optimizer 360 obtains rolling stock circulations, a shunting plan, and a correspondence table for weekdays and holidays. The shunting plan is stored in the shunting plan storing device 400 and the rolling stock circulations and the correspondence table are stored in the rolling stock circulation/correspondence table storage 413. Since a set of rolling stock circulations for weekdays and for holidays double as a correspondence table, the correspondence table may not be acquired as an independent piece of data.

[0279] The output device 500 reads the rolling stock circulations and the correspondence table stored in the rolling stock circulation/correspondence table storage 413 and the shunting plan stored in the shunting plan storing device 400 and displays the same on a screen (step S306). Accordingly, the operation plan creation processing is completed.

[0280] As described above, according to the first configuration example of the third approach, by creating a rolling stock circulation and a shunting plan concurrently, a train assigned duties that correspond to each other in a correspondence table in the shunting plan can be stored on a same track/stack and an efficient shunting plan can be realized.

[Second configuration example]

[0281] FIG. 38 is a block diagram of an operation plan creation device 103A that is an information processing device according to a second configuration example of the third approach. In addition to the operation plan creation device 103 according to the first configuration example, the operation plan creation device 103A according to the second configuration example further includes a route connection information input device 130, a route connection information storage 230, an arrival/departure constraint creator 330, a storage condition information input device 140, a storage condition information storage 240, and a storage constraint creator 340.

[0282] The arrival/departure constraint creator 330 shown in FIG. 38 creates an arrival/departure constraint based on the route connection information. Hereinafter, a mathematical model when a track has a tree structure or the like will be described using the example of FIG. 16 according to the first approach. Expression 65 and Expression 66 represent a constraint for not concurrently storing, on a track R1 and a track R2, a set of trains for which a need for shunting arises.

[Expression 65]

$$y_{p2} + y_{q1} \leq' 2 - z_{pq} + s_{pq} \quad \forall t \in \mathcal{T} \text{ s.t. } c_t \geq 2, p \neq q \in \mathcal{P} \text{ s.t. } B_p^{arv} = B_q^{arv} \qquad (65)$$

[Expression 66]

$$y_{p1} + y_{q2} \leq' 2 - z_{pq} + s_{pq} \quad \forall t \in \mathcal{T} \text{ s.t. } c_t \geq 2, p \neq q \in \mathcal{P} \text{ s.t. } B_p^{arv} = B_q^{arv} \qquad (66)$$

[0283] Since Expression 66 can be resolved into an assignment of a track on which shunting must be performed once upon arrival and an assignment of a track on which shunting must be performed twice upon arrival and departure in a similar manner to Expression 12, processing which distinguishes between these assignments or the like may be performed. While the present constraint is represented by expressions related to the track R2 and the track R1, a constraint related to the track R3 and the track R1 is also described in a similar manner. In addition, when the track type is the FIFO scheme or the FREE scheme, the constraint described above is to be appropriately modified.

[0284] The storage constraint creator 340 shown in FIG. 38 creates a storage constraint based on the storage condition information. Expression 2 is replaced with Expression 15 and Expression 16 in a similar manner to the first approach. Expression 17 is to be used as an objective function to be minimized or quasi-minimized. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 17 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function.

[0285] As described above, according to the second configuration example of the third approach, the number of trains to be shunted can be minimized or quasi-minimized even when a track structure has branched tracks.

[Third configuration example]

[0286] FIG. 39 is a block diagram of an operation plan creation device 103B that is an information processing device according to a third configuration example of the third approach. In addition to the operation plan creation device 103A according to the second configuration example, the operation plan creation device 103B according to the third configuration example further includes an original operation plan information input device 190, an original operation plan storing device 290, an original shunting plan information input device 150, and an original shunting plan storing device 250. In addition, the operation plan creator 303 further includes a difference constraint creator 350.

[0287] The difference constraint creator 350 shown in FIG. 39 creates a difference constraint based on an original operation plan (rolling stock circulation) and creates a difference constraint based on original shunting plan information. When a penalty is to be imposed on a non-coincidence with the original shunting plan, Expression 18 is added as a constraint in a similar manner to the first approach. Expression 19 is to be used as an objective function to be minimized or quasi-minimized. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 19 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function. In addition, once a solution is found, similar information to the first approach may be output.

[0288] In a similar manner, when a penalty is to be imposed on a non-coincidence with the original operation plan (rolling stock circulation), Expression 44 is added as a constraint in a similar manner to the second approach. Expression 45 is to be used as an objective function to be minimized or quasi-minimized. Alternatively, a function obtained by weighting, with a coefficient, a term expressed as an objective function in Expression 45 and one or more other terms expressed as an objective function in the present approach or other approaches and then adding up the terms may be adopted as an objective function. In addition, once a solution is found, similar information to the second approach may be output.

[0289] FIG. 40 shows an output example of a shunting plan. Note that the example of output of a rolling stock circulation is similar to FIGS. 30A and 30B and FIG. 31.

[0290] As described above, according to the third configuration example of the third approach, the number of duties that differ from an original operation plan (an original rolling stock circulation) can be minimized. In addition, the number of trains stored on tracks that differ from an original shunting plan can be minimized. Furthermore, these minimizations can be performed concurrently.

(Hardware configuration)

[0291] FIG. 41 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.

[0292] 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.

[0293] 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.

[0294] 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.

[0295] 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.

[0296] 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.

[0297] 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.

[0298] 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.

[0299] 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.

[0300] 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.

[0301] The approaches as described before may be configured as below.

(Clauses)

[0302]

1. An information processing device, comprising:

    a processor (300) configured to acquire

        time information related to arrival times of a plurality of moving objects at a target zone including a plurality of storage sections in which one or more moving objects can be stored and departure times at which the plurality of moving objects depart from the target zone, and
        direction information related to directions in which the plurality of storage sections can be arrived and directions from which the plurality of storage sections can be departed,

    determine a storage section in which the plurality of the moving objects is to be stored among the plurality of storage sections, based on the time information and the direction information.

2. The information processing device according to clause 1, wherein
one or more of the moving objects can be stored in tandem in the storage section.

3. The information processing device according to clause 1 or 2, wherein
the processor (300) is configured to determine a storage section in which the plurality of the moving objects is to be stored based on a constraint for prohibiting shunting of the moving objects in the storage section.

4. The information processing device according to clause 1 or 2, wherein
the processor (300) is configured to calculate a number of sets of the moving object in which shunting of the moving objects occurs in the storage section and to determine a storage section in which the plurality of the moving objects is to be stored based on the number of sets.

5. The information processing device according to any one of clauses 1 to 4, wherein

    there is a need to pass a second storage section in order to arrive a first storage section or to depart the first storage section, and
    the processor (300) is configured to determine a storage section in which the plurality of the moving objects is to be stored based on a constraint for prohibiting shunting of the moving objects between the first storage section and the second storage section.

6. The information processing device according to any one of clauses 1 to 4, wherein

    there is a need to pass a second storage section in order to arrive a first storage section or to depart the first storage section, and
    the processor (300) is configured to calculate a number of sets of the moving object in which shunting of the

moving objects occurs between the first storage section and the second storage section and to determine a storage section in which the plurality of the moving objects is to be stored based on the number of sets.

7. The information processing device according to any one of clauses 1 to 6, wherein
the processor (300) is further configured to determine a storage section in which the plurality of the moving objects is to be stored based on section length information related to section lengths of the plurality of storage sections.

8. The information processing device according to clause 7, wherein
the processor (300) is further configured to determine a storage section in which the plurality of the moving objects is to be stored based on length information of the plurality of moving objects.

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

the moving object includes one or more vehicles, length information of the moving object represents a number of vehicles included in the moving object, and
the section length information represents the number of vehicles that can be stored in the storage section.

10. The information processing device according to any one of clauses 1 to 9, wherein
the direction information indicates any of:

the storage section can be arrived from a first direction, can be departed from the first direction, cannot be departed from a second direction that is opposite to the first direction, and cannot be arrived from the second direction;
the storage section can be arrived from a first direction, cannot be departed from the first direction, can be departed from a second direction that is opposite to the first direction, and cannot be arrived from the second direction; and
the storage section can be arrived from a first direction, can be departed from the first direction, can be departed from a second direction that is opposite to the first direction, and can be arrived from the second direction.

11. The information processing device according to any one of clauses 1 to 10, wherein
the processor (300) is configured to determine an order of arrival in which the plurality of moving objects arrive at the target zone and an order of departure in which the plurality of moving objects depart from the target zone based on the time information and to determine a storage section in which the plurality of the moving objects is to be stored based on the order of arrival and the order of departure.

12. The information processing device according to any one of clauses 1 to 11, wherein

a plurality of store conditions for storing the moving objects in the plurality of storage sections are associated with penalty values when the plurality of store conditions is not satisfied, and
the processor (300) is configured to acquire, when the moving objects are to be stored in storage sections in which the store conditions are not satisfied, the penalty values in accordance with the store conditions that are not satisfied, and to determine a storage section in which the plurality of the moving objects are to be stored based on a sum of the penalty values.

13. The information processing device according to clause 12, wherein

the plurality of storage sections includes a plurality of store positions where the moving objects can be stored,
the store condition determines a penalty value for each of the plurality of store positions, and
the processor (300) is configured to acquire a penalty value in accordance with a store position where the moving objects are to be stored in the storage section.

14. The information processing device according to clause 12 or 13, wherein

the store condition determines a penalty value in accordance with at least one of the arrival time and the departure time for each of the storage sections, and
the processor (300) is configured to acquire a penalty value in accordance with the arrival time or the departure time of the moving object.

15. The information processing device according to any one of clauses 1 to 14, wherein
the processor (300) is configured to calculate a number of moving objects of which a storage section where the plurality of moving objects are to be stored differs from an original shunting plan that determines a storage section where the plurality of moving objects are to be stored, and to determine a storage section in which the moving objects are to be stored based on the number of moving objects.

16. The information processing device according to any one of clauses 1 to 15, wherein

one or more of the storage sections are included in a plurality of the target zones, and
the processor (302) is configured to create, based on
first train operation information having a plurality of first train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone, and
a first constraint that the arrival zone in the first train operation schedule coincides with a departure zone in a next first train operation schedule,
a first rolling stock circulation in which the plurality of the first train operation schedules are arranged in order.

17. The information processing device according to any one of clauses 1 to 15, wherein

one or more of the storage sections are included in a plurality of the target zones, and
the processor (302) is configured to create, based on
first train operation information having a plurality of first train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
second train operation information having a plurality of second train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
a first constraint that the arrival zone in the first train operation schedule coincides with a departure zone in a next first train operation schedule,
a second constraint that the arrival zone in the second train operation schedule coincides with a departure zone in a next second train operation schedule, and
a third constraint that the departure zones are same and the arrival zones are same between the first train operation schedule and the second train operation schedule at mutually corresponding positions,
a first rolling stock circulation in which the plurality of the first train operation schedules are arranged in order and a second rolling stock circulation in which the plurality of the second train operation schedules are arranged in order.

18. The information processing device according to clause 17, wherein
the processor (302) is configured to cyclically assign the plurality of first train operation schedules included in the first rolling stock circulation to the plurality of moving objects, and when shunting the first rolling stock circulation to the second rolling stock circulation, to assign, to the plurality of moving objects, the plurality of second train operation schedules corresponding to positions of the plurality of first train operation schedules to be assigned to the plurality of moving objects.

19. The information processing device according to clause 17 or 18, wherein
the processor (302) is configured to create the first rolling stock circulation and the second rolling stock circulation further based on a fourth constraint related to a period of work that needs to be performed on the plurality of moving objects and a fifth constraint related to at least one of a target zone in which the work can be performed among the plurality of target zones and a time during which the work can be performed.

20. The information processing device according to any one of clauses 17 to 19, wherein

the processor (302) is configured to calculate a sum of:

a number of the first train operation schedules of which a position in the first rolling stock circulation differs from an original first operation circuit schedule in which the plurality of first train operation schedules are arranged in order and
a number of the second train operation schedules of which a position in the second rolling stock circulation

differs from an original second operation circuit schedule in which the plurality of second train operation schedules are arranged in order, and

to create the first rolling stock circulation and the second rolling stock circulation based on the sum.

21. The information processing device according to any one of clauses 17 to 20, wherein
the processor (303) is configured to concurrently perform to create the first rolling stock circulation and the second rolling stock circulation and to determine a storage section where the plurality of moving objects are to be stored based on a sixth constraint that storage sections of moving objects respectively assigned the first train operation schedule and the second train operation schedule at mutually corresponding positions are same.

22. The information processing device according to any one of clauses 1 to 21, comprising
an output device (500) configured to display on a screen, in association with each other, the plurality of storage sections and the plurality of moving objects determined to be stored in the plurality of storage sections.

23. The information processing device according to any one of clauses 1 to 21, comprising

an output device (500) configured to display the first rolling stock circulation and the second rolling stock circulation on a screen, wherein
the output device (500) is configured to display, in association with each other, the plurality of first train operation schedules in the first rolling stock circulation and the plurality of second train operation schedules at same positions as the plurality of first train operation schedules in the second rolling stock circulation.

24. The information processing device according to any one of clauses 1 to 23, wherein

the moving object is a train including one or more vehicles,
the target zone is a railway yard or a station, and
the storage section is a track in the railway yard or the station.

25. An information processing device, comprising

a processor (302) configured to acquire

first train operation information having a plurality of first train operation schedules including a departure zone to be departed among a plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
second train operation information having a plurality of second train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
a first constraint that the arrival zone in the first train operation schedule coincides with a departure zone in a next first train operation schedule,
a second constraint that the arrival zone in the second train operation schedule coincides with a departure zone in a next second train operation schedule, and
a third constraint that the departure zones are the same and the arrival zones are the same between the first train operation schedule and the second train operation schedule at mutually corresponding positions,

create a first rolling stock circulation in which the plurality of the first train operation schedules are arranged in order and a second rolling stock circulation in which the plurality of the second train operation schedules are arranged in order.

26. An information processing method, comprising:

acquiring

time information related to arrival times of a plurality of moving objects at a target zone including a plurality of storage sections in which one or more moving objects can be stored and departure times at which the plurality of moving objects depart from the target zone, and
direction information related to directions in which the plurality of storage sections can be arrived and

directions from which the plurality of storage sections can be departed; and

determining a storage section in which the plurality of the moving objects is to be stored among the plurality of storage sections, based on the time information and the direction information.

27. A computer program which causes a computer to execute to perform processes, comprising:

acquiring

time information related to arrival times of a plurality of moving objects at a target zone including a plurality of storage sections in which one or more moving objects can be stored and departure times at which the plurality of moving objects depart from the target zone, and
direction information related to directions in which the plurality of storage sections can be arrived and directions from which the plurality of storage sections can be departed; and

determining a storage section in which the plurality of the moving objects is to be stored among the plurality of storage sections, based on the time information and the direction information.

28. An information processing method, comprising

acquiring

first train operation information having a plurality of first train operation schedules including a departure zone to be departed among a plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
second train operation information having a plurality of second train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
a first constraint that the arrival zone in the first train operation schedule coincides with a departure zone in a next first train operation schedule,
a second constraint that the arrival zone in the second train operation schedule coincides with a departure zone in a next second train operation schedule, and
a third constraint that the departure zones are the same and the arrival zones are the same between the first train operation schedule and the second train operation schedule at mutually corresponding positions; and

creating a first rolling stock circulation in which the plurality of the first train operation schedules are arranged in order and a second rolling stock circulation in which the plurality of the second train operation schedules are arranged in order.

29. A computer program which causes a computer to execute to perform processes, comprising:

acquiring

first train operation information having a plurality of first train operation schedules including a departure zone to be departed among a plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
second train operation information having a plurality of second train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
a first constraint that the arrival zone in the first train operation schedule coincides with a departure zone in a next first train operation schedule,
a second constraint that the arrival zone in the second train operation schedule coincides with a departure zone in a next second train operation schedule, and
a third constraint that the departure zones are the same and the arrival zones are the same between the first train operation schedule and the second train operation schedule at mutually corresponding positions; and

creating a first rolling stock circulation in which the plurality of the first train operation schedules are arranged in order and a second rolling stock circulation in which the plurality of the second train operation schedules are arranged in order.

Claims

1. An information processing device, comprising:

   a processor (300) configured to acquire

      time information related to arrival times of a plurality of moving objects at a target zone including a plurality of storage sections in which one or more moving objects can be stored and departure times at which the plurality of moving objects depart from the target zone, and
      direction information related to directions in which the plurality of storage sections can be arrived and directions from which the plurality of storage sections can be departed,

   determine a storage section in which the plurality of the moving objects is to be stored among the plurality of storage sections, based on the time information and the direction information.

2. The information processing device according to claim 1, wherein one or more of the moving objects can be stored in tandem in the storage section.

3. The information processing device according to claim 1 or 2, wherein the processor (300) is configured to determine a storage section in which the plurality of the moving objects is to be stored based on a constraint for prohibiting shunting of the moving objects in the storage section.

4. The information processing device according to claim 1 or 2, wherein the processor (300) is configured to calculate a number of sets of the moving object in which shunting of the moving objects occurs in the storage section and to determine a storage section in which the plurality of the moving objects is to be stored based on the number of sets.

5. The information processing device according to any one of claims 1 to 4, wherein

   there is a need to pass a second storage section in order to arrive a first storage section or to depart the first storage section, and
   the processor (300) is configured to determine a storage section in which the plurality of the moving objects is to be stored based on a constraint for prohibiting shunting of the moving objects between the first storage section and the second storage section.

6. The information processing device according to any one of claims 1 to 4, wherein

   there is a need to pass a second storage section in order to arrive a first storage section or to depart the first storage section, and
   the processor (300) is configured to calculate a number of sets of the moving object in which shunting of the moving objects occurs between the first storage section and the second storage section and to determine a storage section in which the plurality of the moving objects is to be stored based on the number of sets.

7. The information processing device according to any one of claims 1 to 6, wherein the processor (300) is further configured to determine a storage section in which the plurality of the moving objects is to be stored based on section length information related to section lengths of the plurality of storage sections.

8. The information processing device according to claim 7, wherein the processor (300) is further configured to determine a storage section in which the plurality of the moving objects is to be stored based on length information of the plurality of moving objects.

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

the moving object includes one or more vehicles, length information of the moving object represents a number of vehicles included in the moving object, and
the section length information represents the number of vehicles that can be stored in the storage section.

10. The information processing device according to any one of claims 1 to 9, wherein
the direction information indicates any of:

the storage section can be arrived from a first direction, can be departed from the first direction, cannot be departed from a second direction that is opposite to the first direction, and cannot be arrived from the second direction;
the storage section can be arrived from a first direction, cannot be departed from the first direction, can be departed from a second direction that is opposite to the first direction, and cannot be arrived from the second direction; and
the storage section can be arrived from a first direction, can be departed from the first direction, can be departed from a second direction that is opposite to the first direction, and can be arrived from the second direction.

11. The information processing device according to any one of claims 1 to 10, wherein
the processor (300) is configured to determine an order of arrival in which the plurality of moving objects arrive at the target zone and an order of departure in which the plurality of moving objects depart from the target zone based on the time information and to determine a storage section in which the plurality of the moving objects is to be stored based on the order of arrival and the order of departure.

12. The information processing device according to any one of claims 1 to 11, wherein

a plurality of store conditions for storing the moving objects in the plurality of storage sections are associated with penalty values when the plurality of store conditions is not satisfied, and
the processor (300) is configured to acquire, when the moving objects are to be stored in storage sections in which the store conditions are not satisfied, the penalty values in accordance with the store conditions that are not satisfied, and to determine a storage section in which the plurality of the moving objects are to be stored based on a sum of the penalty values.

13. The information processing device according to claim 12, wherein

the plurality of storage sections includes a plurality of store positions where the moving objects can be stored,
the store condition determines a penalty value for each of the plurality of store positions, and
the processor (300) is configured to acquire a penalty value in accordance with a store position where the moving objects are to be stored in the storage section.

14. The information processing device according to claim 12 or 13, wherein

the store condition determines a penalty value in accordance with at least one of the arrival time and the departure time for each of the storage sections, and
the processor (300) is configured to acquire a penalty value in accordance with the arrival time or the departure time of the moving object.

15. The information processing device according to any one of claims 1 to 14, wherein
the processor (300) is configured to calculate a number of moving objects of which a storage section where the plurality of moving objects are to be stored differs from an original shunting plan that determines a storage section where the plurality of moving objects are to be stored, and to determine a storage section in which the moving objects are to be stored based on the number of moving objects.

16. The information processing device according to any one of claims 1 to 15, wherein

one or more of the storage sections are included in a plurality of the target zones, and
the processor (302) is configured to create, based on
first train operation information having a plurality of first train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone, and

a first constraint that the arrival zone in the first train operation schedule coincides with a departure zone in a next first train operation schedule,
a first rolling stock circulation in which the plurality of the first train operation schedules are arranged in order.

17. The information processing device according to any one of claims 1 to 15, wherein

one or more of the storage sections are included in a plurality of the target zones, and
the processor (302) is configured to create, based on
first train operation information having a plurality of first train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
second train operation information having a plurality of second train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
a first constraint that the arrival zone in the first train operation schedule coincides with a departure zone in a next first train operation schedule,
a second constraint that the arrival zone in the second train operation schedule coincides with a departure zone in a next second train operation schedule, and
a third constraint that the departure zones are same and the arrival zones are same between the first train operation schedule and the second train operation schedule at mutually corresponding positions,
a first rolling stock circulation in which the plurality of the first train operation schedules are arranged in order and a second rolling stock circulation in which the plurality of the second train operation schedules are arranged in order.

18. The information processing device according to claim 17, wherein
the processor (302) is configured to cyclically assign the plurality of first train operation schedules included in the first rolling stock circulation to the plurality of moving objects, and when shunting the first rolling stock circulation to the second rolling stock circulation, to assign, to the plurality of moving objects, the plurality of second train operation schedules corresponding to positions of the plurality of first train operation schedules to be assigned to the plurality of moving objects.

19. The information processing device according to claim 17 or 18, wherein
the processor (302) is configured to create the first rolling stock circulation and the second rolling stock circulation further based on a fourth constraint related to a period of work that needs to be performed on the plurality of moving objects and a fifth constraint related to at least one of a target zone in which the work can be performed among the plurality of target zones and a time during which the work can be performed.

20. The information processing device according to any one of claims 17 to 19, wherein

the processor (302) is configured to calculate a sum of:

a number of the first train operation schedules of which a position in the first rolling stock circulation differs from an original first operation circuit schedule in which the plurality of first train operation schedules are arranged in order and
a number of the second train operation schedules of which a position in the second rolling stock circulation differs from an original second operation circuit schedule in which the plurality of second train operation schedules are arranged in order, and

to create the first rolling stock circulation and the second rolling stock circulation based on the sum.

21. The information processing device according to any one of claims 17 to 20, wherein
the processor (303) is configured to concurrently perform to create the first rolling stock circulation and the second rolling stock circulation and to determine a storage section where the plurality of moving objects are to be stored based on a sixth constraint that storage sections of moving objects respectively assigned the first train operation schedule and the second train operation schedule at mutually corresponding positions are same.

22. The information processing device according to any one of claims 1 to 21, comprising
an output device (500) configured to display on a screen, in association with each other, the plurality of storage

sections and the plurality of moving objects determined to be stored in the plurality of storage sections.

23. The information processing device according to any one of claims 1 to 21, comprising

an output device (500) configured to display the first rolling stock circulation and the second rolling stock circulation on a screen, wherein
the output device (500) is configured to display, in association with each other, the plurality of first train operation schedules in the first rolling stock circulation and the plurality of second train operation schedules at same positions as the plurality of first train operation schedules in the second rolling stock circulation.

24. The information processing device according to any one of claims 1 to 23, wherein

the moving object is a train including one or more vehicles,
the target zone is a railway yard or a station, and
the storage section is a track in the railway yard or the station.

25. An information processing device, comprising

a processor (302) configured to acquire

first train operation information having a plurality of first train operation schedules including a departure zone to be departed among a plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
second train operation information having a plurality of second train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
a first constraint that the arrival zone in the first train operation schedule coincides with a departure zone in a next first train operation schedule,
a second constraint that the arrival zone in the second train operation schedule coincides with a departure zone in a next second train operation schedule, and
a third constraint that the departure zones are the same and the arrival zones are the same between the first train operation schedule and the second train operation schedule at mutually corresponding positions,

create a first rolling stock circulation in which the plurality of the first train operation schedules are arranged in order and a second rolling stock circulation in which the plurality of the second train operation schedules are arranged in order.

26. An information processing method, comprising:

acquiring

time information related to arrival times of a plurality of moving objects at a target zone including a plurality of storage sections in which one or more moving objects can be stored and departure times at which the plurality of moving objects depart from the target zone, and
direction information related to directions in which the plurality of storage sections can be arrived and directions from which the plurality of storage sections can be departed; and

determining a storage section in which the plurality of the moving objects is to be stored among the plurality of storage sections, based on the time information and the direction information.

27. A computer program which causes a computer to execute to perform processes, comprising:

acquiring

time information related to arrival times of a plurality of moving objects at a target zone including a plurality of storage sections in which one or more moving objects can be stored and departure times at which the plurality of moving objects depart from the target zone, and
direction information related to directions in which the plurality of storage sections can be arrived and

directions from which the plurality of storage sections can be departed; and

determining a storage section in which the plurality of the moving objects is to be stored among the plurality of storage sections, based on the time information and the direction information.

28. An information processing method, comprising

acquiring

first train operation information having a plurality of first train operation schedules including a departure zone to be departed among a plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
second train operation information having a plurality of second train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
a first constraint that the arrival zone in the first train operation schedule coincides with a departure zone in a next first train operation schedule,
a second constraint that the arrival zone in the second train operation schedule coincides with a departure zone in a next second train operation schedule, and
a third constraint that the departure zones are the same and the arrival zones are the same between the first train operation schedule and the second train operation schedule at mutually corresponding positions; and

creating a first rolling stock circulation in which the plurality of the first train operation schedules are arranged in order and a second rolling stock circulation in which the plurality of the second train operation schedules are arranged in order.

29. A computer program which causes a computer to execute to perform processes, comprising:

acquiring

first train operation information having a plurality of first train operation schedules including a departure zone to be departed among a plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
second train operation information having a plurality of second train operation schedules including a departure zone to be departed among the plurality of target zones, a departure time from the departure zone, an arrival zone to arrive at, and an arrival time at the arrival zone,
a first constraint that the arrival zone in the first train operation schedule coincides with a departure zone in a next first train operation schedule,
a second constraint that the arrival zone in the second train operation schedule coincides with a departure zone in a next second train operation schedule, and
a third constraint that the departure zones are the same and the arrival zones are the same between the first train operation schedule and the second train operation schedule at mutually corresponding positions; and

creating a first rolling stock circulation in which the plurality of the first train operation schedules are arranged in order and a second rolling stock circulation in which the plurality of the second train operation schedules are arranged in order.

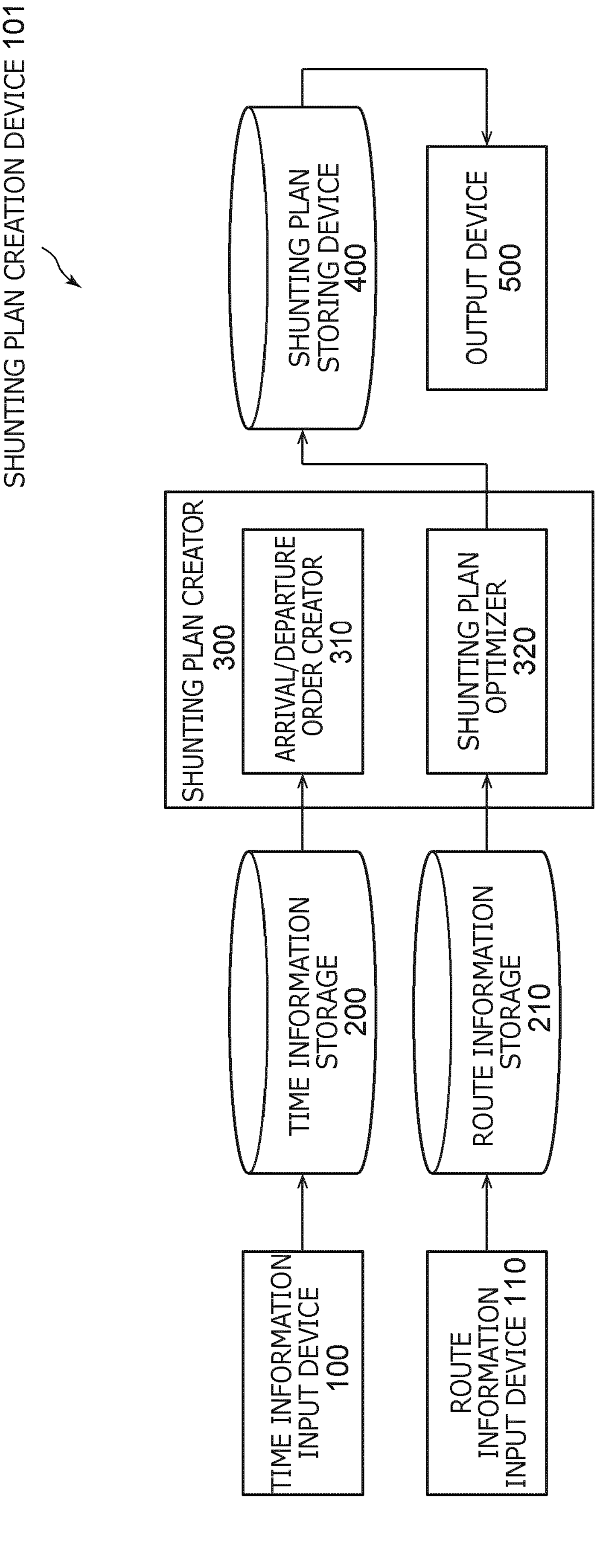
SHUNTING PLAN CREATION DEVICE 101
TIME INFORMATION INPUT DEVICE 100
ROUTE INFORMATION INPUT DEVICE 110
TIME INFORMATION STORAGE 200
ROUTE INFORMATION STORAGE 210
SHUNTING PLAN CREATOR 300
ARRIVAL/DEPARTURE ORDER CREATOR 310
SHUNTING PLAN OPTIMIZER 320
SHUNTING PLAN STORING DEVICE 400
OUTPUT DEVICE 500

FIG. 1

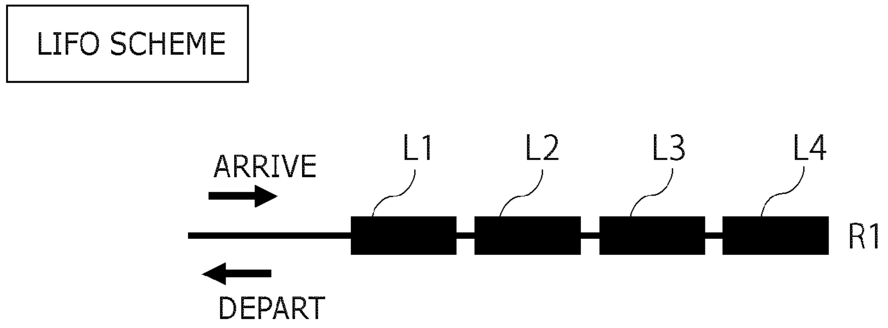

FIG. 2

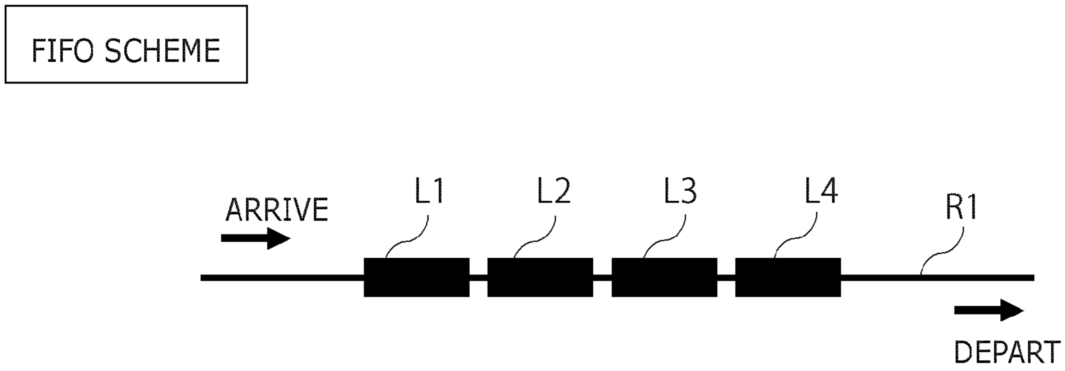

FIG. 3

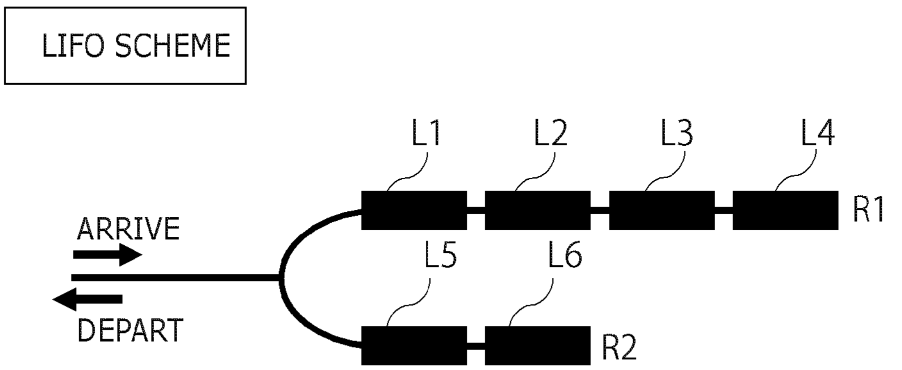

FIG. 4

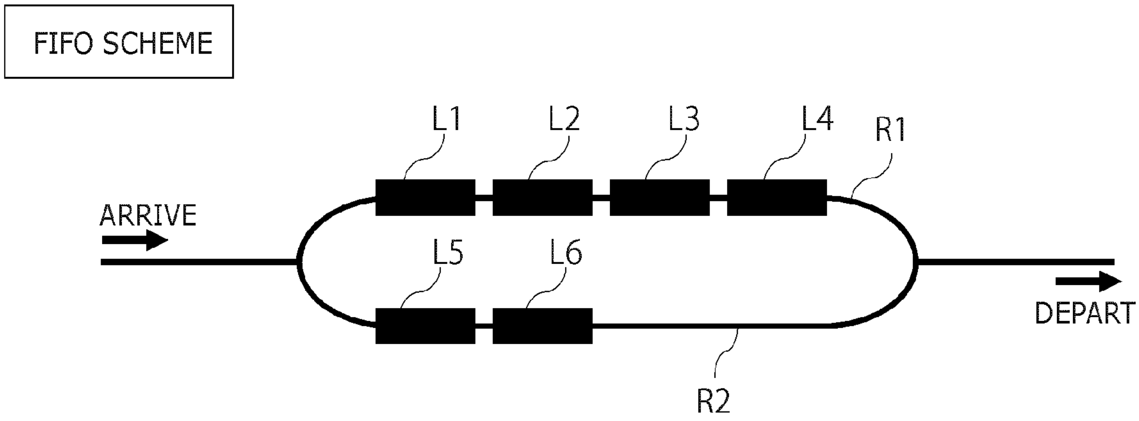

FIG. 5

TRAIN	ARRIVAL TIME	NEXT-DAY DEPARTURE TIME
L1	22:15	6:00
L2	22:30	5:45
L3	23:30	5:15
L4	22:45	5:00
L5	23:00	6:15

FIG. 6

TRAIN	ORDER OF ARRIVAL	ORDER OF NEXT-DAY DEPARTURE
L1	1	4
L2	2	3
L3	5	2
L4	3	1
L5	4	5

FIG. 7

TRACK	NUMBER OF UNITS STORED IN TANDEM (NUMBER OF TRAINS)	TRACK TYPE
R1	4	LIFO SCHEME
R2	2	LIFO SCHEME

FIG. 8

TRAIN	TRACK	STACK	ORDER OF ARRIVAL	ORDER OF NEXT-DAY DEPARTURE
L1	R1	S3	1	4
L2	R1	S2	2	3
L3	R2	S1	5	2
L4	R1	S1	3	1
L5	R2	S2	4	5

FIG. 9

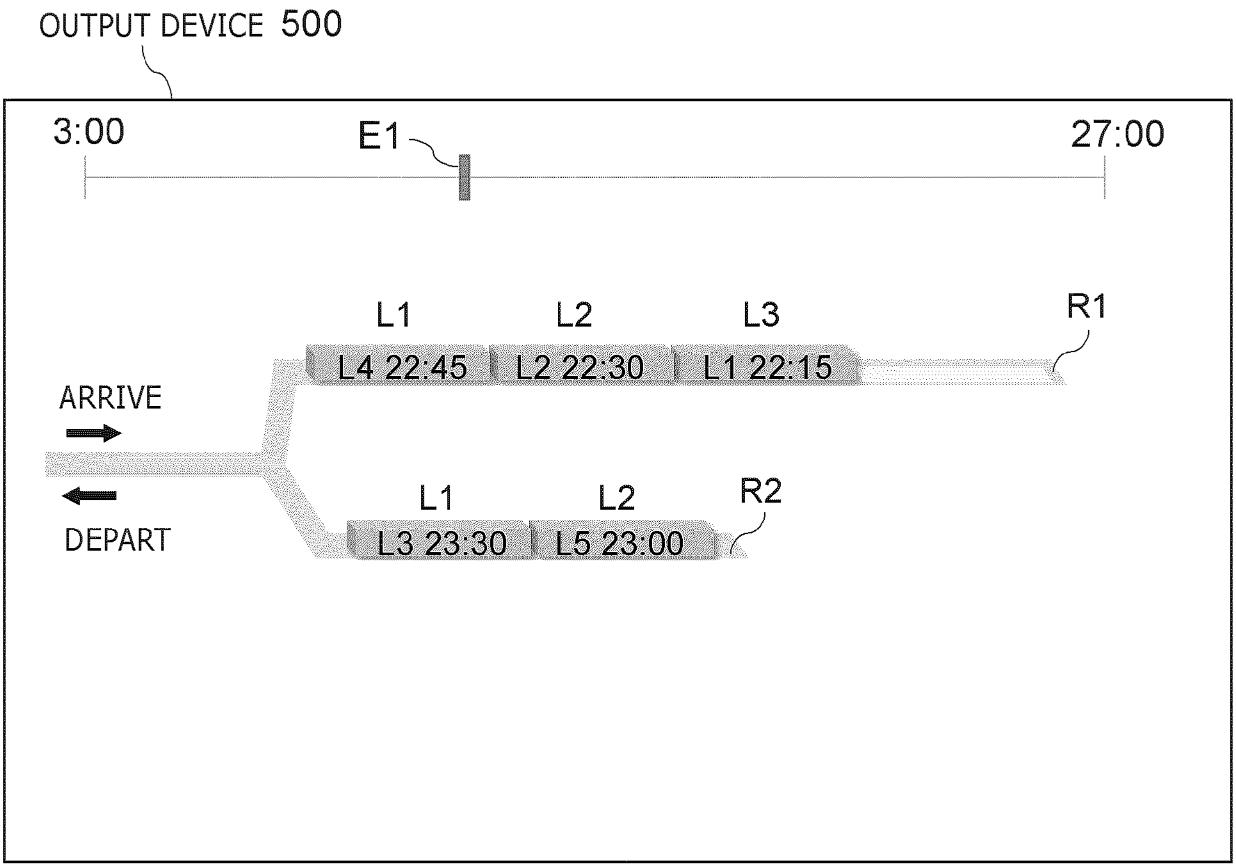
OUTPUT DEVICE 500
3:00
E1
27:00
L1
L2
L3
R1
L4 22:45
L2 22:30
L1 22:15
ARRIVE
DEPART
L1
L2
R2
L3 23:30
L5 23:00

FIG. 10

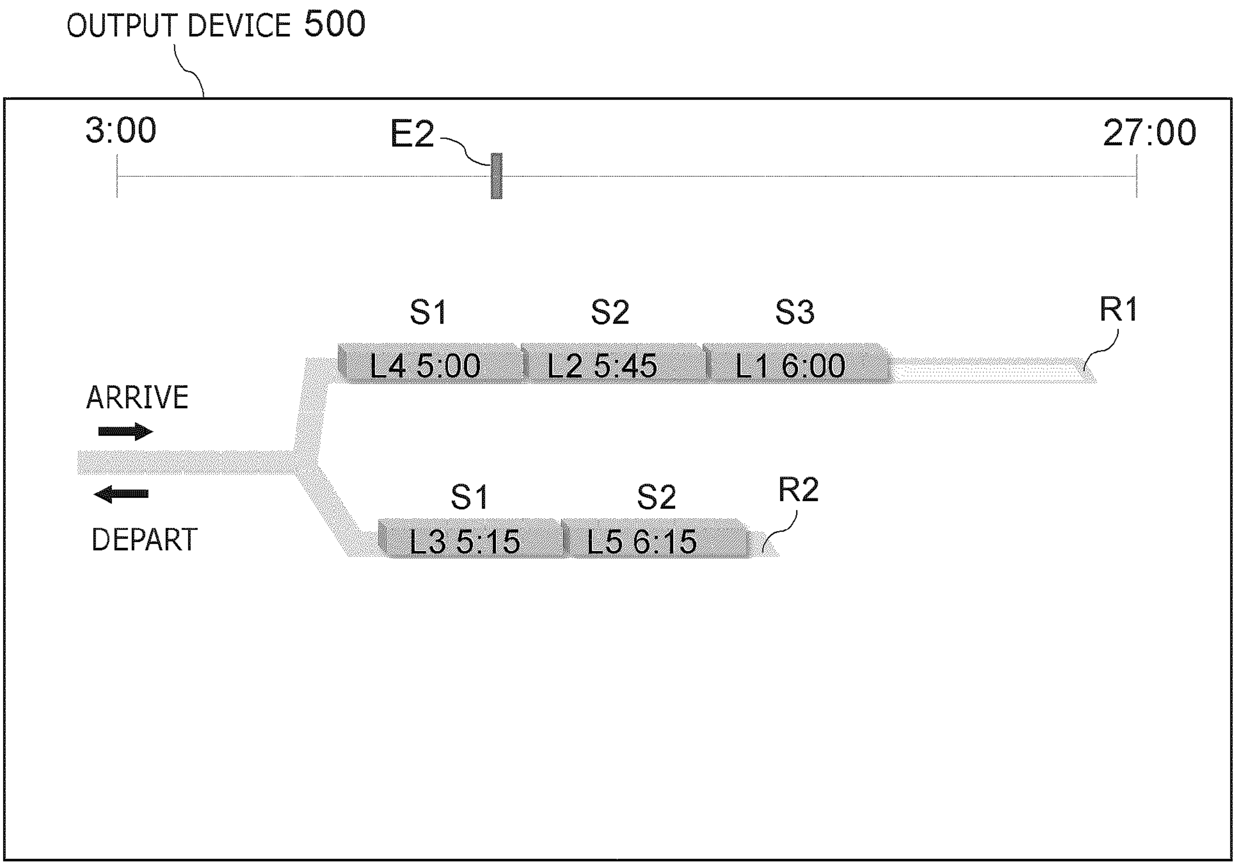
OUTPUT DEVICE 500
3:00
E2
27:00
S1
S2
S3
R1
L4 5:00
L2 5:45
L1 6:00
ARRIVE
DEPART
S1
S2
R2
L3 5:15
L5 6:15

FIG. 11

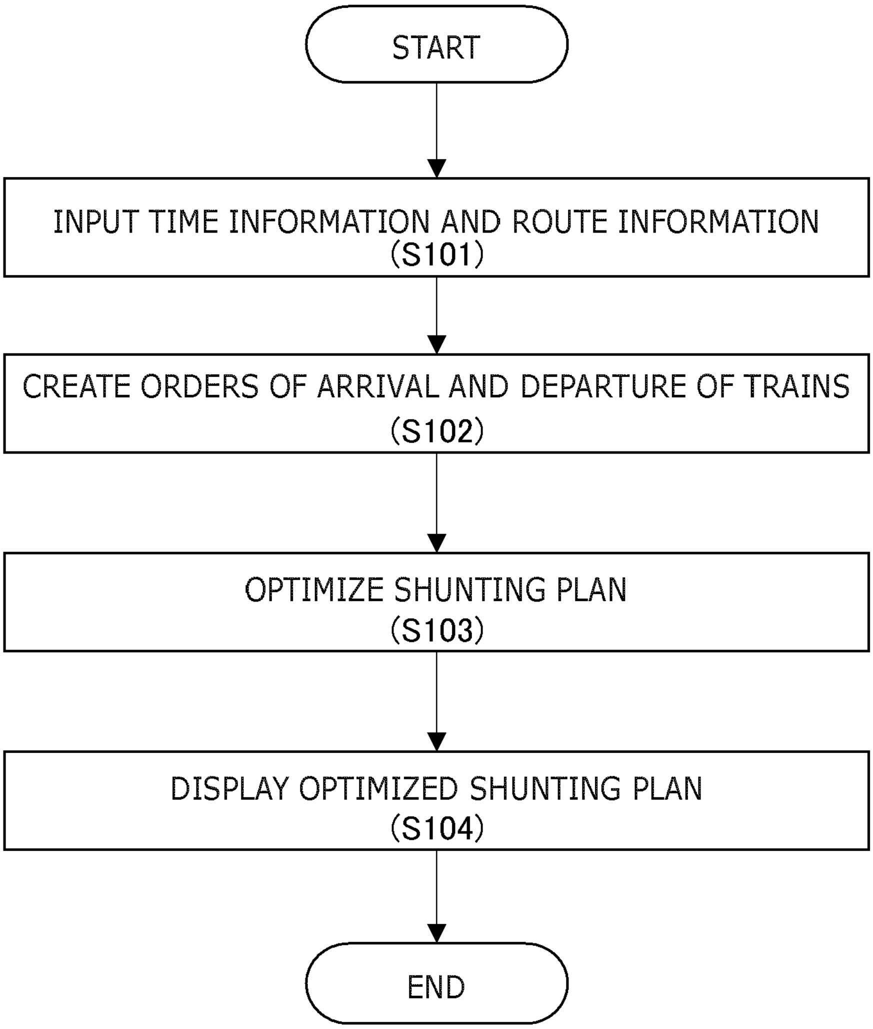
START
INPUT TIME INFORMATION AND ROUTE INFORMATION (S101)
CREATE ORDERS OF ARRIVAL AND DEPARTURE OF TRAINS (S102)
OPTIMIZE SHUNTING PLAN (S103)
DISPLAY OPTIMIZED SHUNTING PLAN (S104)
END

FIG. 12

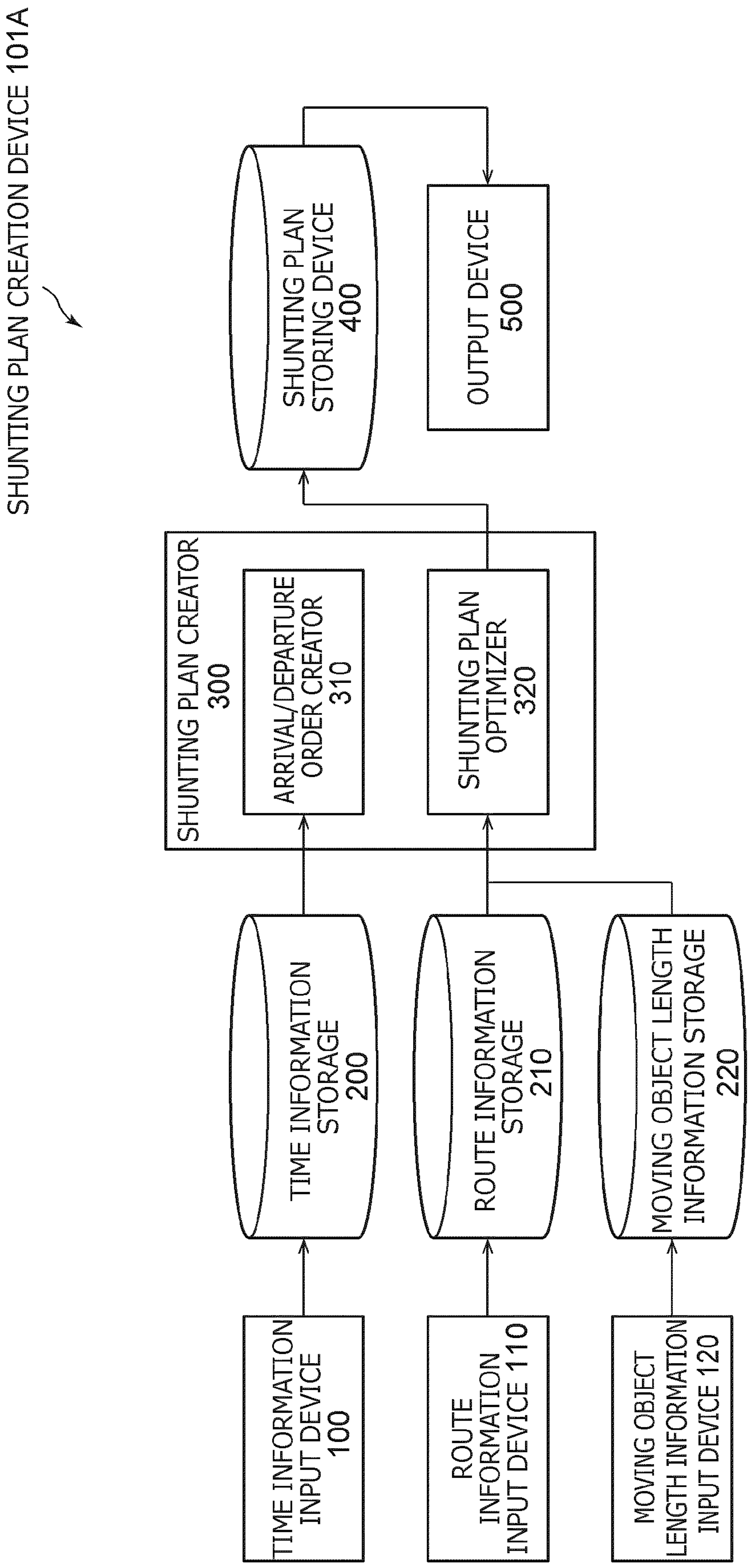
SHUNTING PLAN CREATION DEVICE 101A
TIME INFORMATION INPUT DEVICE 100
ROUTE INFORMATION INPUT DEVICE 110
MOVING OBJECT LENGTH INFORMATION INPUT DEVICE 120
TIME INFORMATION STORAGE 200
ROUTE INFORMATION STORAGE 210
MOVING OBJECT LENGTH INFORMATION STORAGE 220
SHUNTING PLAN CREATOR 300
ARRIVAL/DEPARTURE ORDER CREATOR 310
SHUNTING PLAN OPTIMIZER 320
SHUNTING PLAN STORING DEVICE 400
OUTPUT DEVICE 500

FIG. 13

TRAIN	TRAIN UNIT COUNT
L1	2
L2	2
L3	1
L4	1
L5	1

FIG. 14

TRACK	NUMBER OF UNITS STORED IN TANDEM	TRACK TYPE
R1	5	LIFO SCHEME
R2	3	LIFO SCHEME

FIG. 15

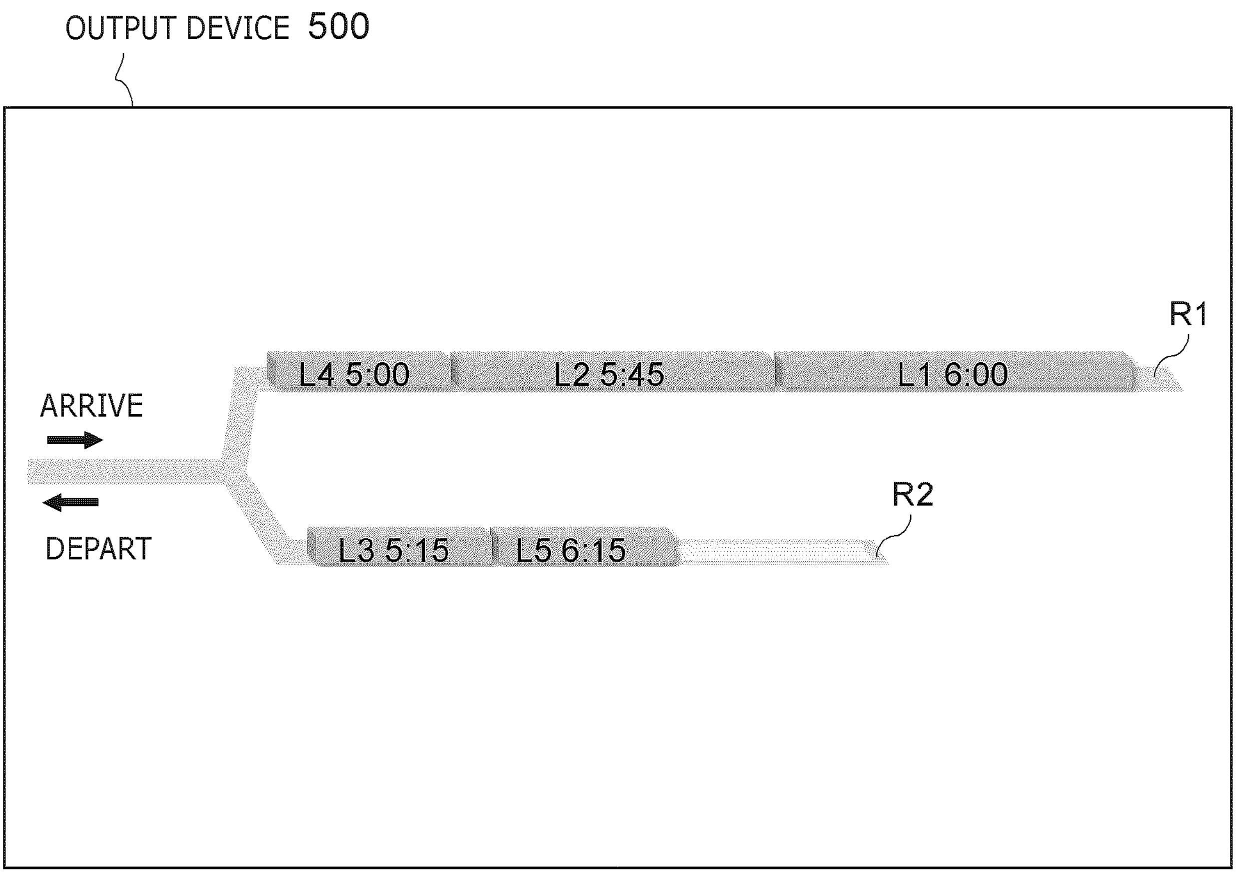
OUTPUT DEVICE 500
R1
L4 5:00
L2 5:45
L1 6:00
ARRIVE
DEPART
R2
L3 5:15
L5 6:15

FIG. 16

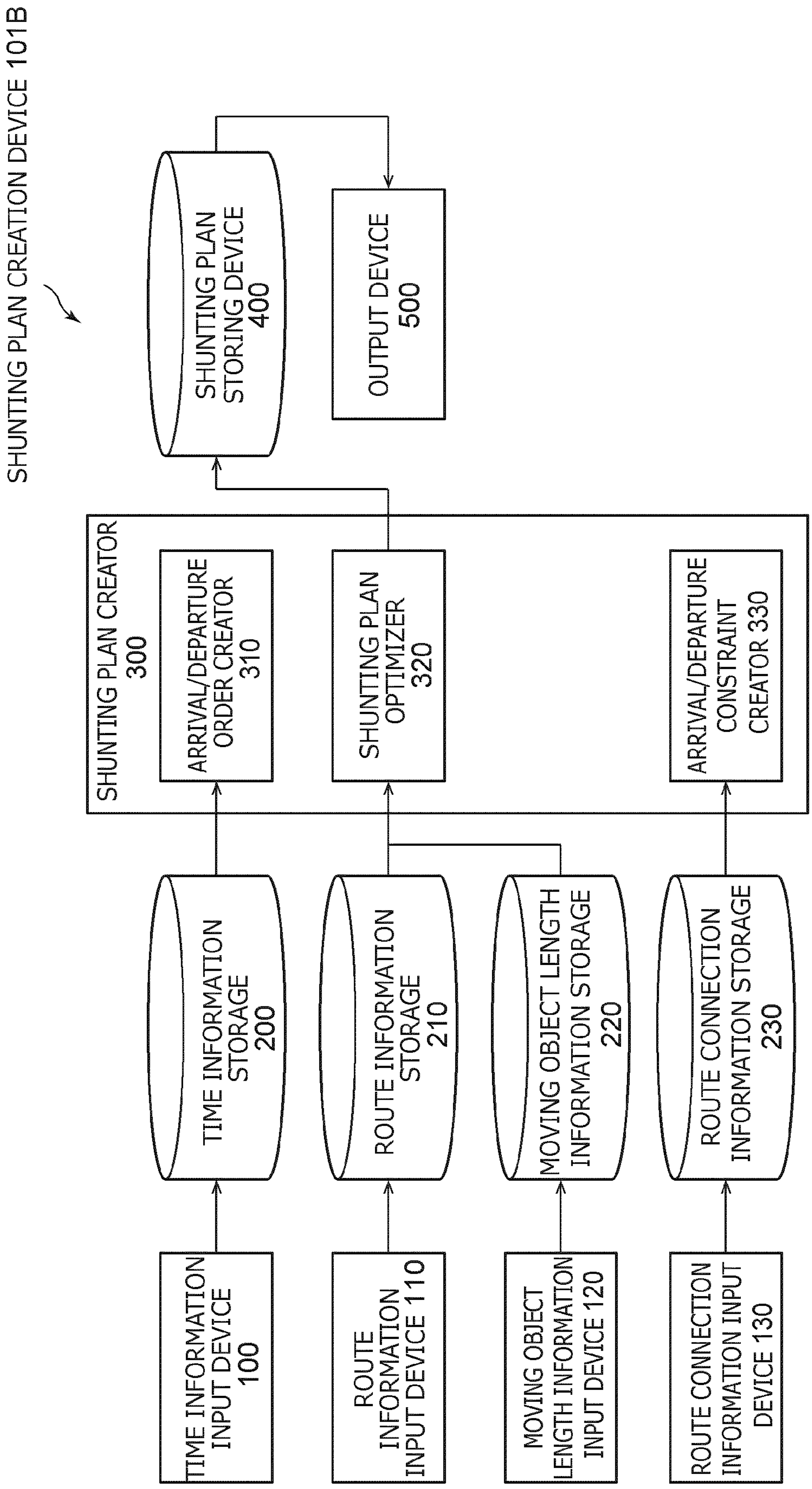
SHUNTING PLAN CREATION DEVICE 101B
TIME INFORMATION INPUT DEVICE 100
ROUTE INFORMATION INPUT DEVICE 110
MOVING OBJECT LENGTH INFORMATION INPUT DEVICE 120
ROUTE CONNECTION INFORMATION INPUT DEVICE 130
TIME INFORMATION STORAGE 200
ROUTE INFORMATION STORAGE 210
MOVING OBJECT LENGTH INFORMATION STORAGE 220
ROUTE CONNECTION INFORMATION STORAGE 230
SHUNTING PLAN CREATOR 300
ARRIVAL/DEPARTURE ORDER CREATOR 310
SHUNTING PLAN OPTIMIZER 320
ARRIVAL/DEPARTURE CONSTRAINT CREATOR 330
SHUNTING PLAN STORING DEVICE 400
OUTPUT DEVICE 500

FIG. 17

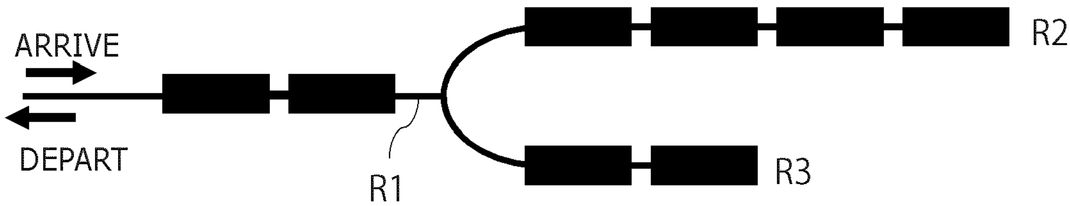

FIG. 18

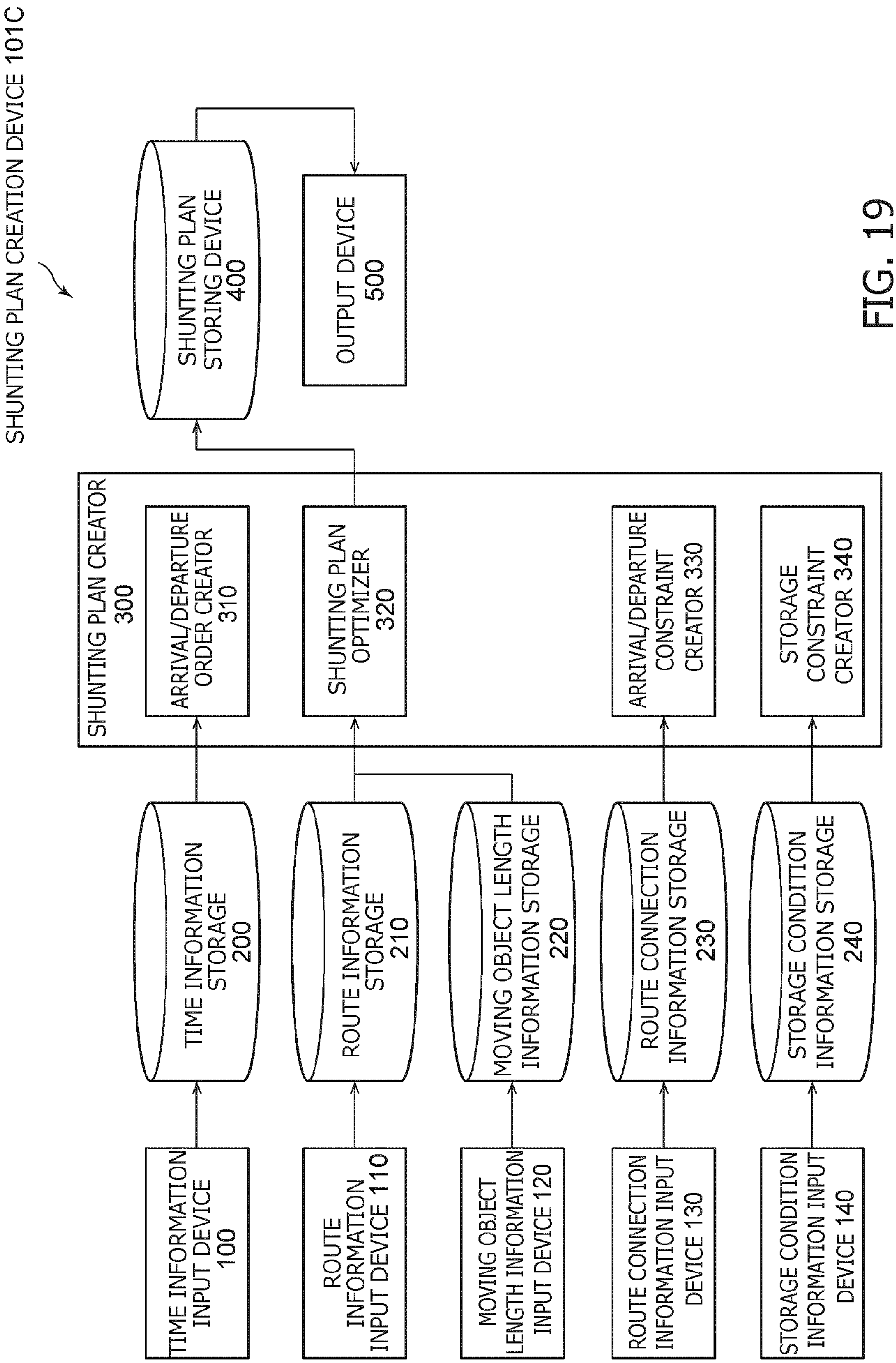
SHUNTING PLAN CREATION DEVICE 101C
SHUNTING PLAN STORING DEVICE 400
OUTPUT DEVICE 500
SHUNTING PLAN CREATOR 300
ARRIVAL/DEPARTURE ORDER CREATOR 310
SHUNTING PLAN OPTIMIZER 320
ARRIVAL/DEPARTURE CONSTRAINT CREATOR 330
STORAGE CONSTRAINT CREATOR 340
TIME INFORMATION STORAGE 200
ROUTE INFORMATION STORAGE 210
MOVING OBJECT LENGTH INFORMATION STORAGE 220
ROUTE CONNECTION INFORMATION STORAGE 230
STORAGE CONDITION INFORMATION STORAGE 240
TIME INFORMATION INPUT DEVICE 100
ROUTE INFORMATION INPUT DEVICE 110
MOVING OBJECT LENGTH INFORMATION INPUT DEVICE 120
ROUTE CONNECTION INFORMATION INPUT DEVICE 130
STORAGE CONDITION INFORMATION INPUT DEVICE 140

FIG. 19

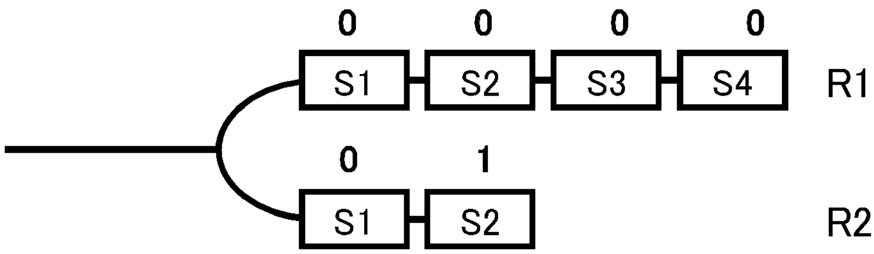

FIG. 20

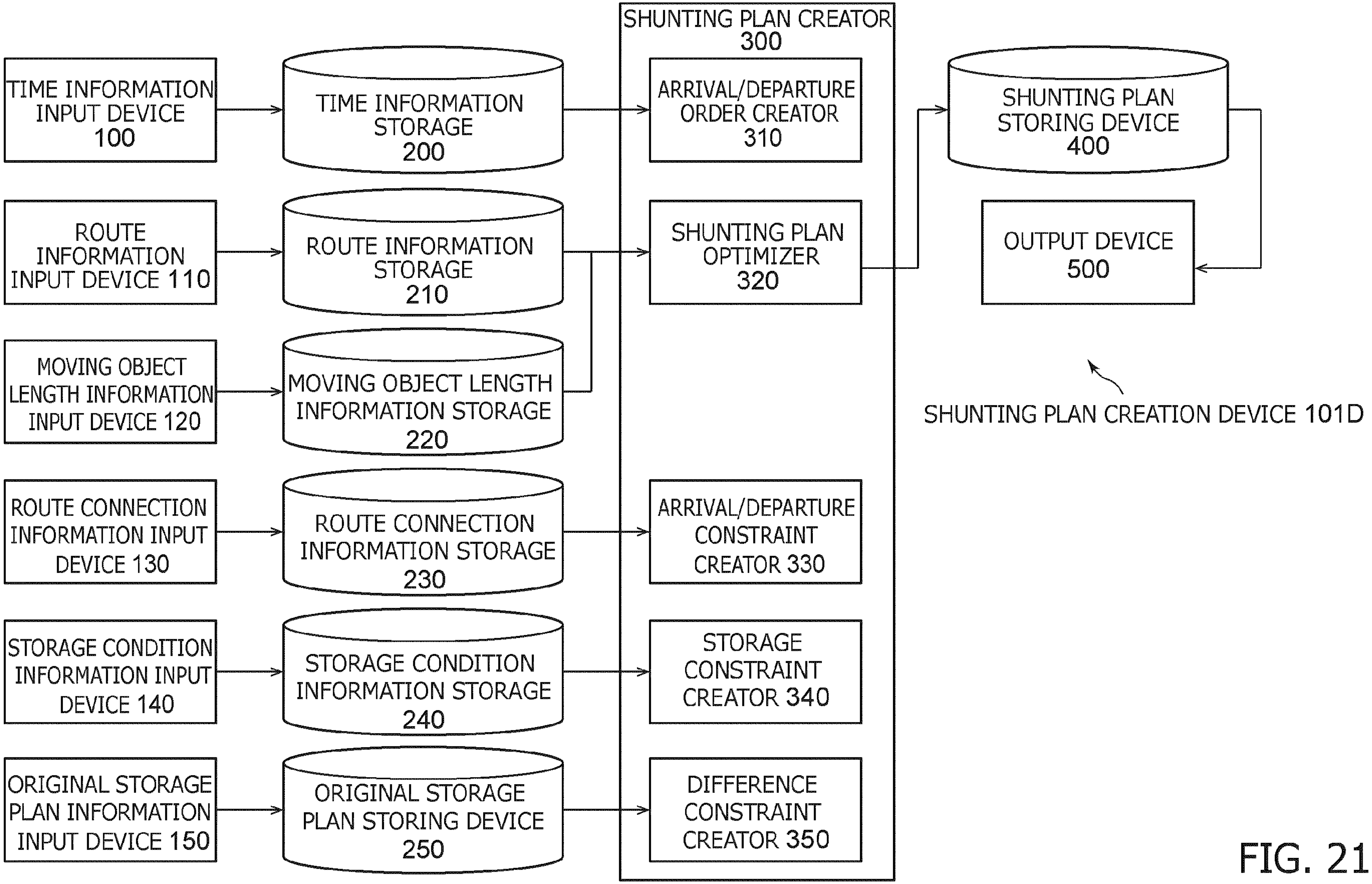
TIME INFORMATION INPUT DEVICE 100
ROUTE INFORMATION INPUT DEVICE 110
MOVING OBJECT LENGTH INFORMATION INPUT DEVICE 120
ROUTE CONNECTION INFORMATION INPUT DEVICE 130
STORAGE CONDITION INFORMATION INPUT DEVICE 140
ORIGINAL STORAGE PLAN INFORMATION INPUT DEVICE 150
TIME INFORMATION STORAGE 200
ROUTE INFORMATION STORAGE 210
MOVING OBJECT LENGTH INFORMATION STORAGE 220
ROUTE CONNECTION INFORMATION STORAGE 230
STORAGE CONDITION INFORMATION STORAGE 240
ORIGINAL STORAGE PLAN STORING DEVICE 250
SHUNTING PLAN CREATOR 300
ARRIVAL/DEPARTURE ORDER CREATOR 310
SHUNTING PLAN OPTIMIZER 320
ARRIVAL/DEPARTURE CONSTRAINT CREATOR 330
STORAGE CONSTRAINT CREATOR 340
DIFFERENCE CONSTRAINT CREATOR 350
SHUNTING PLAN STORING DEVICE 400
OUTPUT DEVICE 500
SHUNTING PLAN CREATION DEVICE 101D

FIG. 21

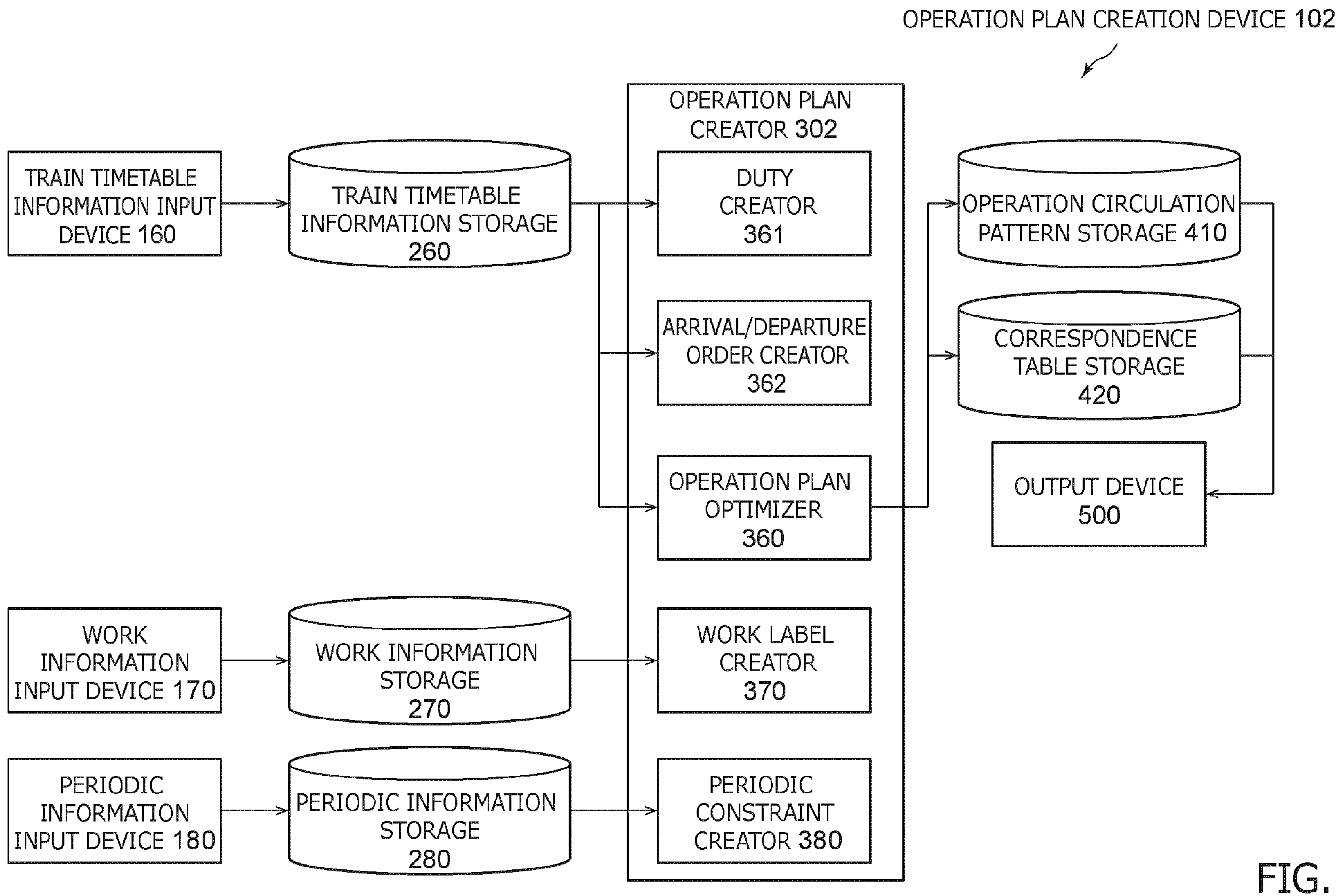
OPERATION PLAN CREATION DEVICE 102
TRAIN TIMETABLE INFORMATION INPUT DEVICE 160
TRAIN TIMETABLE INFORMATION STORAGE 260
WORK INFORMATION INPUT DEVICE 170
WORK INFORMATION STORAGE 270
PERIODIC INFORMATION INPUT DEVICE 180
PERIODIC INFORMATION STORAGE 280
OPERATION PLAN CREATOR 302
DUTY CREATOR 361
ARRIVAL/DEPARTURE ORDER CREATOR 362
OPERATION PLAN OPTIMIZER 360
WORK LABEL CREATOR 370
PERIODIC CONSTRAINT CREATOR 380
OPERATION CIRCULATION PATTERN STORAGE 410
CORRESPONDENCE TABLE STORAGE 420
OUTPUT DEVICE 500

FIG. 22

EXAMPLE OF SINGLE ROLLING STOCK CIRCULATION

INSPECTION/CLEANING : ▲

L3	▲	L6		L1		L2	▲	L5		L4	

PERIODIC VEHICLE OPERATION PLAN USING TWO ROLLING STOCK CIRCULATION

INSPECTION/CLEANING : ▲

DATE	DAY OF WEEK	TRAIN 1		TRAIN 2		TRAIN3		TRAIN4		TRAIN 5		TRAIN 6													
JANUARY 1	MONDAY	L3	▲	L6		L1		L2	▲	L5		L4													
JANUARY 2	TUESDAY	L4		L3	▲	L6		L1		L2	▲	L5		L4											
JANUARY 3	WEDNESDAY	L5		L4		L3	▲	L6		L1		L2	▲	L5		L4									
JANUARY 4	THURSDAY	L2	▲	L5		L4		L3	▲	L6		L1		L2	▲	L5		L4							
JANUARY 5	FRIDAY	L1		L2	▲	L5		L4		L3	▲	L6		L1		L2	▲	L5		L4					
JANUARY 6	SATURDAY	L'6		L'1		L'2	▲	L'5		L'4		L'3	▲	L'6		L'1		L'2	▲	L'5		L'4			
JANUARY 7	SUNDAY	L'3	▲	L'6		L'1		L'2	▲	L'5		L'4		L'3	▲	L'6		L'1		L'2	▲	L'5		L'4	

FIG. 23

OPERATION CIRCULATION PATTERN

WEEKDAYS/ DUTY	WEEKDAYS/ ARRIVAL LOCATION	HOLIDAYS/ DUTY	HOLIDAYS/ ARRIVAL LOCATION
L1	STATION X	L'1	STATION X
L3	RAILWAY YARD Y	L'4	RAILWAY YARD Y
L2	RAILWAY YARD Y	L'3	RAILWAY YARD Y
L5	STATION X	L'5	STATION X
L4	RAILWAY YARD Y	L'2	RAILWAY YARD Y

CORRESPONDENCE BETWEEN DUTIES OF WEEKDAY TIMETABLE AND HOLIDAY TIMETABLE

INSPECTION/CLEANING : ▲

DATE	DAY OF WEEK	TRAIN 1		TRAIN 2		TRAIN 3		TRAIN 4		TRAIN 5													
JANUARY 1	MONDAY	L1		L3	▲	L2		L5	▲	L4													
JANUARY 2	TUESDAY	L4		L1		L3	▲	L2		L5	▲	L4											
JANUARY 3	WEDNESDAY	L5	▲	L4		L1		L3	▲	L2		L5	▲	L4									
JANUARY 4	THURSDAY	L2		L5	▲	L4		L1		L3	▲	L2		L5	▲	L4							
JANUARY 5	FRIDAY	L3	▲	L2		L5	▲	L4		L1		L3	▲	L2		L5	▲	L4					
JANUARY 6	SATURDAY	L'1		L'4	▲	L'3		L'5	▲	L'2		L'1		L'4	▲	L'3		L'5	▲	L'2			
JANUARY 7	SUNDAY	L'2		L'1		L'4	▲	L'3		L'5	▲	L'2		L'1		L'4	▲	L'3		L'5	▲	L'2	

FIG. 24

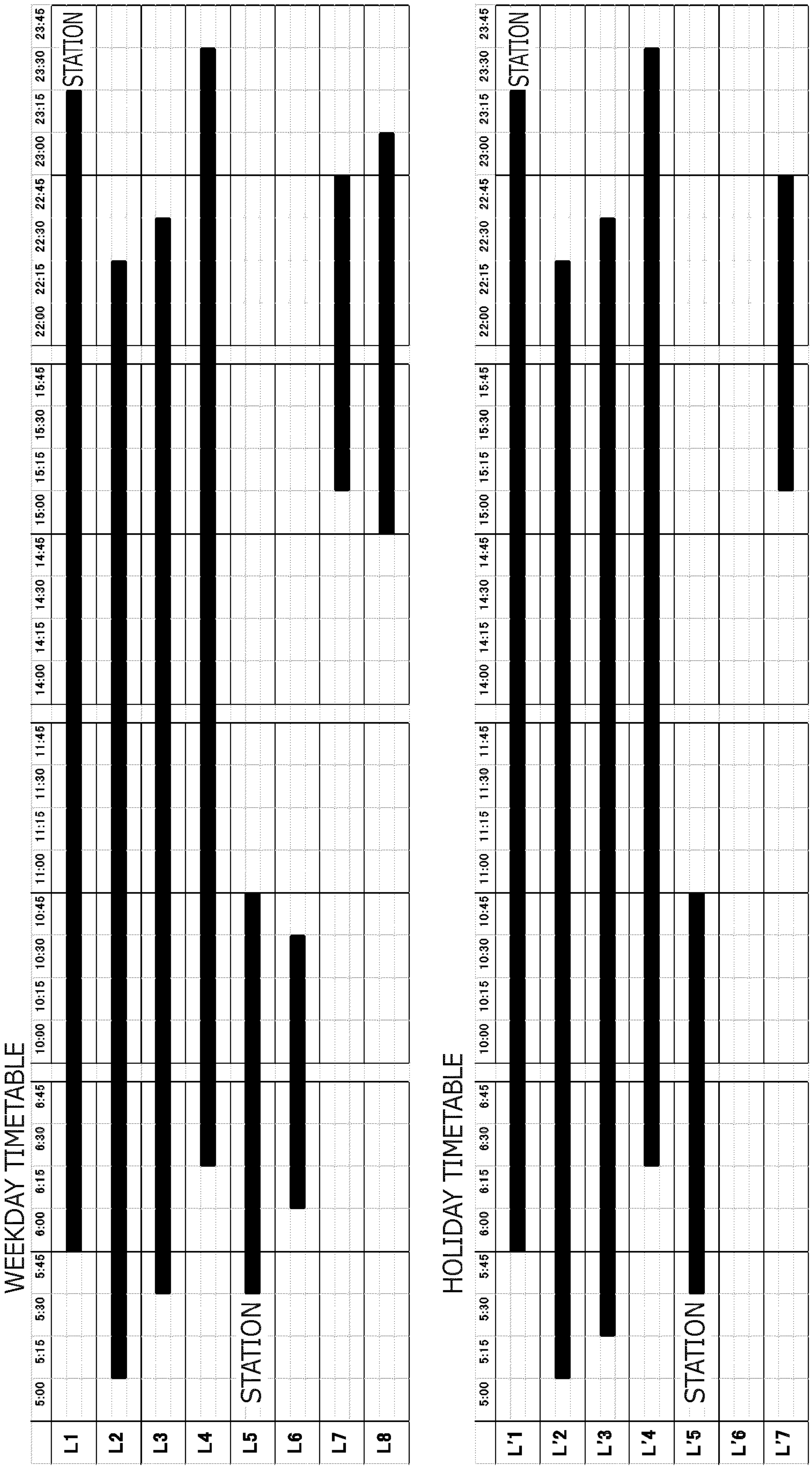
WEEKDAY TIMETABLE
HOLIDAY TIMETABLE
STATION
STATION
STATION
STATION
L1
L2
L3
L4
L5
L6
L7
L8
L'1
L'2
L'3
L'4
L'5
L'6
L'7
5:00 5:15 5:30 5:45 6:00 6:15 6:30 6:45
10:00 10:15 10:30 10:45 11:00 11:15 11:30 11:45
14:00 14:15 14:30 14:45 15:00 15:15 15:30 15:45
22:00 22:15 22:30 22:45 23:00 23:15 23:30 23:45

FIG. 25

WORK LOCATION	WORK TIME SLOT
RAILWAY YARD	11:00～15:00

FIG. 26

MAXIMUM WORK INTERVAL	MINIMUM WORK INTERVAL
4	2

FIG. 27

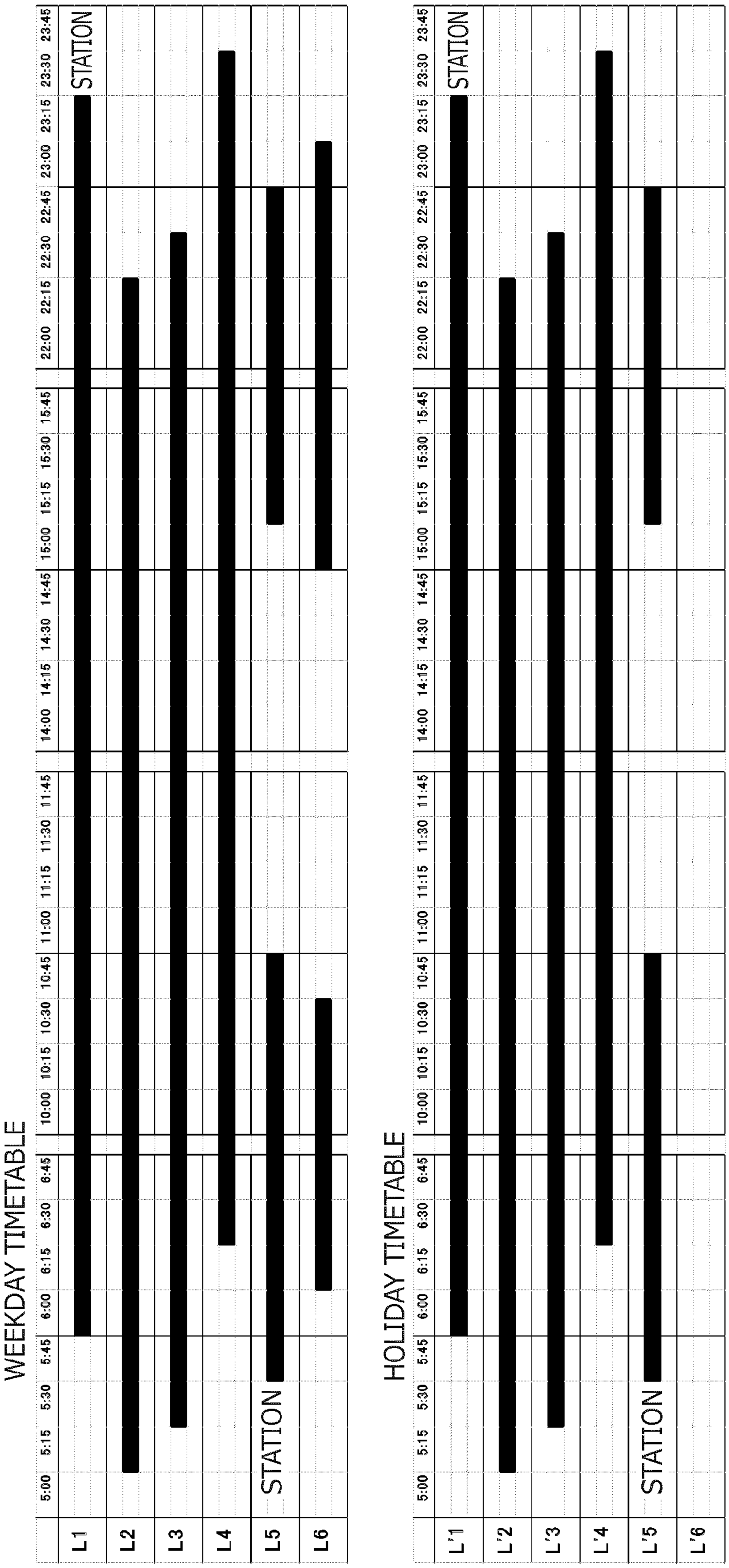
WEEKDAY TIMETABLE
HOLIDAY TIMETABLE
STATION
STATION
STATION
STATION
L1
L2
L3
L4
L5
L6
L'1
L'2
L'3
L'4
L'5
L'6
5:00 5:15 5:30 5:45 6:00 6:15 6:30 6:45
10:00 10:15 10:30 10:45 11:00 11:15 11:30 11:45
14:00 14:15 14:30 14:45 15:00 15:15 15:30 15:45
22:00 22:15 22:30 22:45 23:00 23:15 23:30 23:45

FIG. 28

WEEKDAY TIMETABLE

ID	ORDER OF DEPARTURE	ORDER OF ARRIVAL	DEPARTURE LOCATION	ARRIVAL LOCATION	WORK LABEL
L1	4	5	RAILWAY YARD	STATION	0
L2	1	1	RAILWAY YARD	RAILWAY YARD	0
L3	2	2	RAILWAY YARD	RAILWAY YARD	0
L4	6	6	RAILWAY YARD	RAILWAY YARD	0
L5	3	3	STATION	RAILWAY YARD	1
L6	5	4	RAILWAY YARD	RAILWAY YARD	1

HOLIDAY TIMETABLE

ID	ORDER OF DEPARTURE	ORDER OF ARRIVAL	DEPARTURE LOCATION	ARRIVAL LOCATION	WORK LABEL
L'1	4	5	RAILWAY YARD	STATION	0
L'2	1	2	RAILWAY YARD	RAILWAY YARD	0
L'3	2	3	RAILWAY YARD	RAILWAY YARD	0
L'4	5	6	RAILWAY YARD	RAILWAY YARD	0
L'5	3	4	STATION	RAILWAY YARD	1
L'6	6	1	RAILWAY YARD	RAILWAY YARD	1

FIG. 29

WEEKDAY TIMETABLE DUTY	HOLIDAY TIMETABLE DUTY	ARRIVAL LOCATION	NEXT-DAY DEPARTURE LOCATION	WORK LABEL
L1	L'1	STATION	STATION	0
L5	L'5	RAILWAY YARD	RAILWAY YARD	1
L4	L'2	RAILWAY YARD	RAILWAY YARD	0
L3	L'3	RAILWAY YARD	RAILWAY YARD	0
L6	L'6	RAILWAY YARD	RAILWAY YARD	1
L2	L'4	RAILWAY YARD	RAILWAY YARD	0

FIG. 30A

WEEKDAY TIMETABLE DUTY	HOLIDAY TIMETABLE DUTY	DEPARTURE LOCATION	ARRIVAL LOCATION	WORK LABEL
L1	L'1	RAILWAY YARD	STATION	0
L5	L'5	STATION	RAILWAY YARD	1
L4	L'2	RAILWAY YARD	RAILWAY YARD	0
L3	L'3	RAILWAY YARD	RAILWAY YARD	0
L6	L'6	RAILWAY YARD	RAILWAY YARD	1
L2	L'4	RAILWAY YARD	RAILWAY YARD	0

FIG. 30B

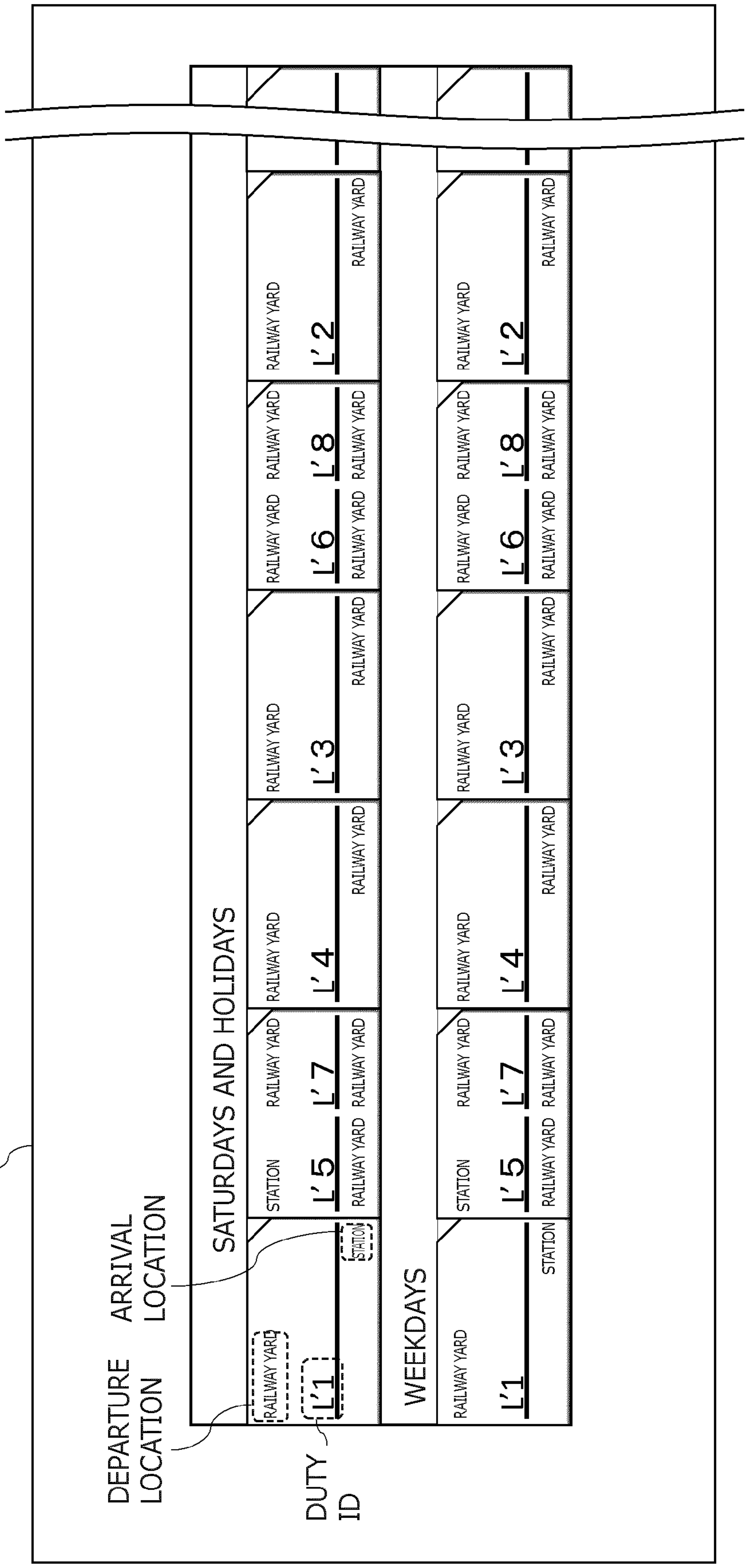
OUTPUT DEVICE 500
DEPARTURE LOCATION
ARRIVAL LOCATION
DUTY ID
SATURDAYS AND HOLIDAYS
WEEKDAYS
RAILWAY YARD
STATION
L'1
L'5
L'7
L'4
L'3
L'6
L'8
L'2

FIG. 31

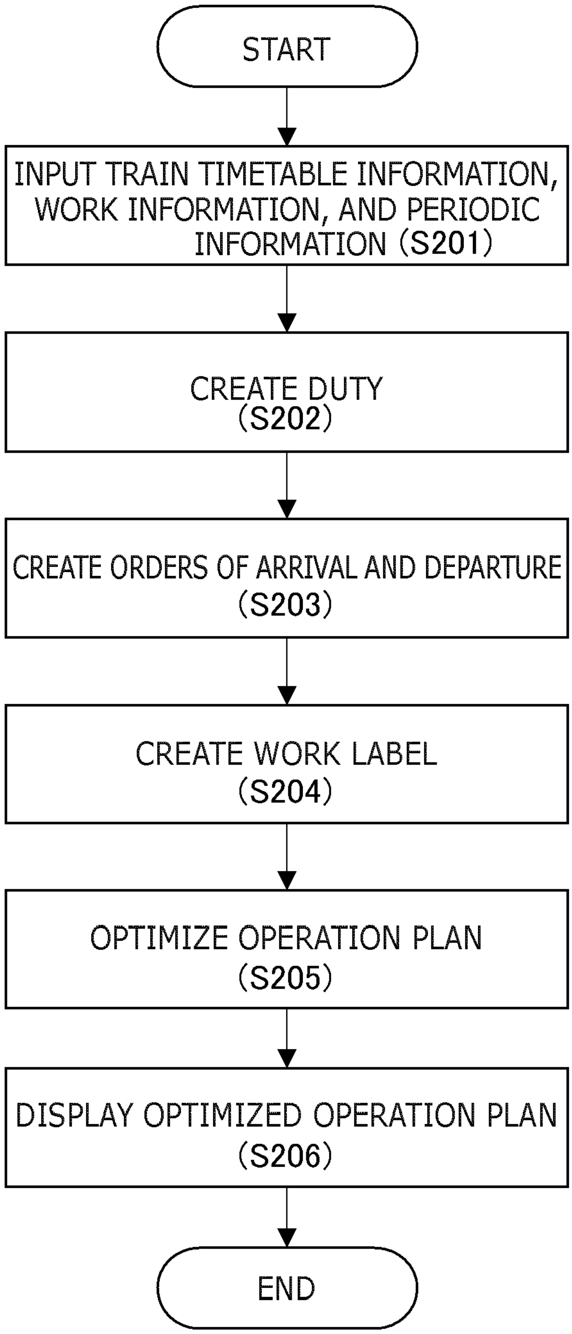
START
INPUT TRAIN TIMETABLE INFORMATION, WORK INFORMATION, AND PERIODIC INFORMATION (S201)
CREATE DUTY (S202)
CREATE ORDERS OF ARRIVAL AND DEPARTURE (S203)
CREATE WORK LABEL (S204)
OPTIMIZE OPERATION PLAN (S205)
DISPLAY OPTIMIZED OPERATION PLAN (S206)
END

FIG. 32

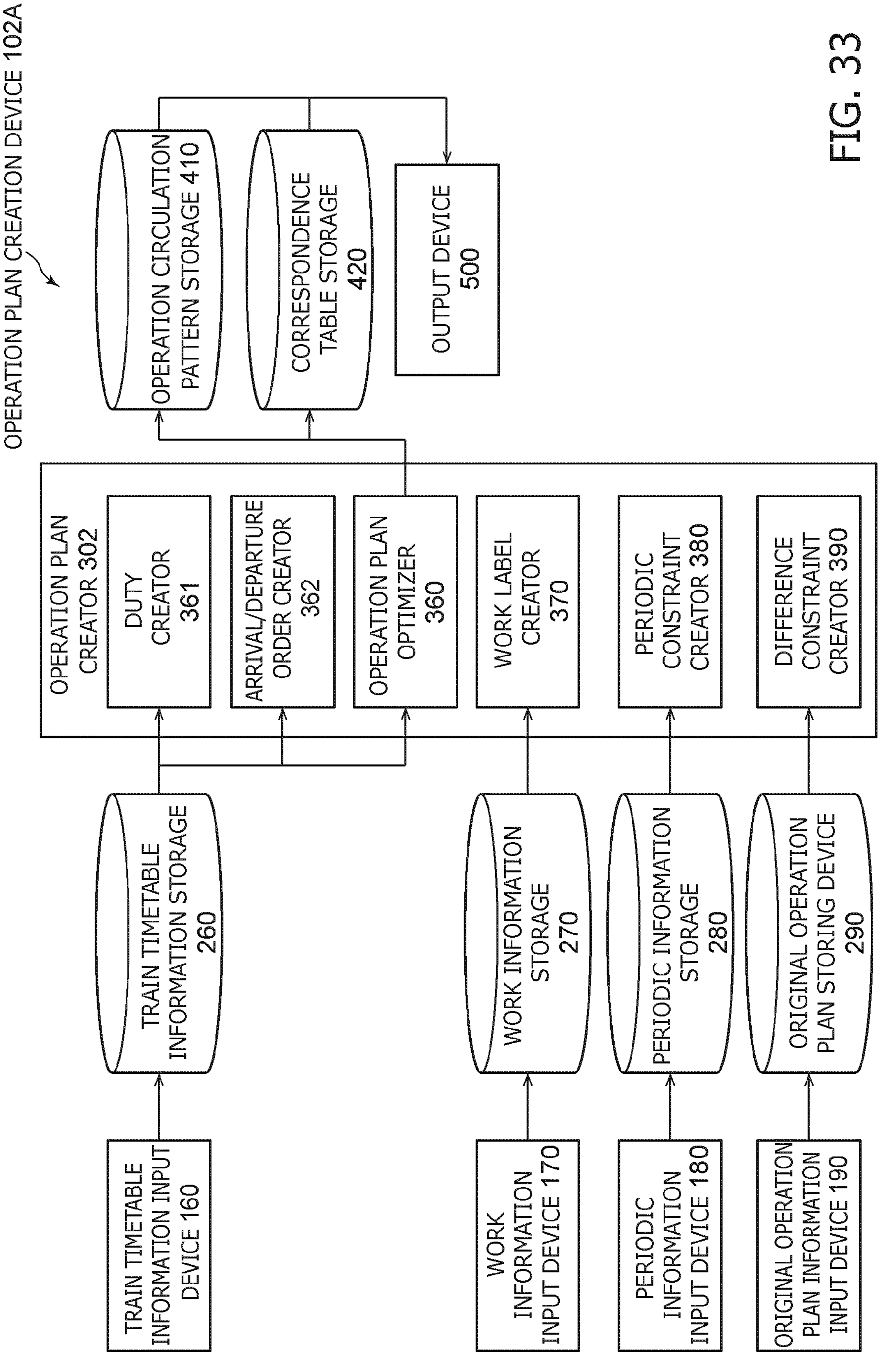
OPERATION PLAN CREATION DEVICE 102A
TRAIN TIMETABLE INFORMATION INPUT DEVICE 160
TRAIN TIMETABLE INFORMATION STORAGE 260
WORK INFORMATION INPUT DEVICE 170
WORK INFORMATION STORAGE 270
PERIODIC INFORMATION INPUT DEVICE 180
PERIODIC INFORMATION STORAGE 280
ORIGINAL OPERATION PLAN INFORMATION INPUT DEVICE 190
ORIGINAL OPERATION PLAN STORING DEVICE 290
OPERATION PLAN CREATOR 302
DUTY CREATOR 361
ARRIVAL/DEPARTURE ORDER CREATOR 362
OPERATION PLAN OPTIMIZER 360
WORK LABEL CREATOR 370
PERIODIC CONSTRAINT CREATOR 380
DIFFERENCE CONSTRAINT CREATOR 390
OPERATION CIRCULATION PATTERN STORAGE 410
CORRESPONDENCE TABLE STORAGE 420
OUTPUT DEVICE 500

FIG. 33

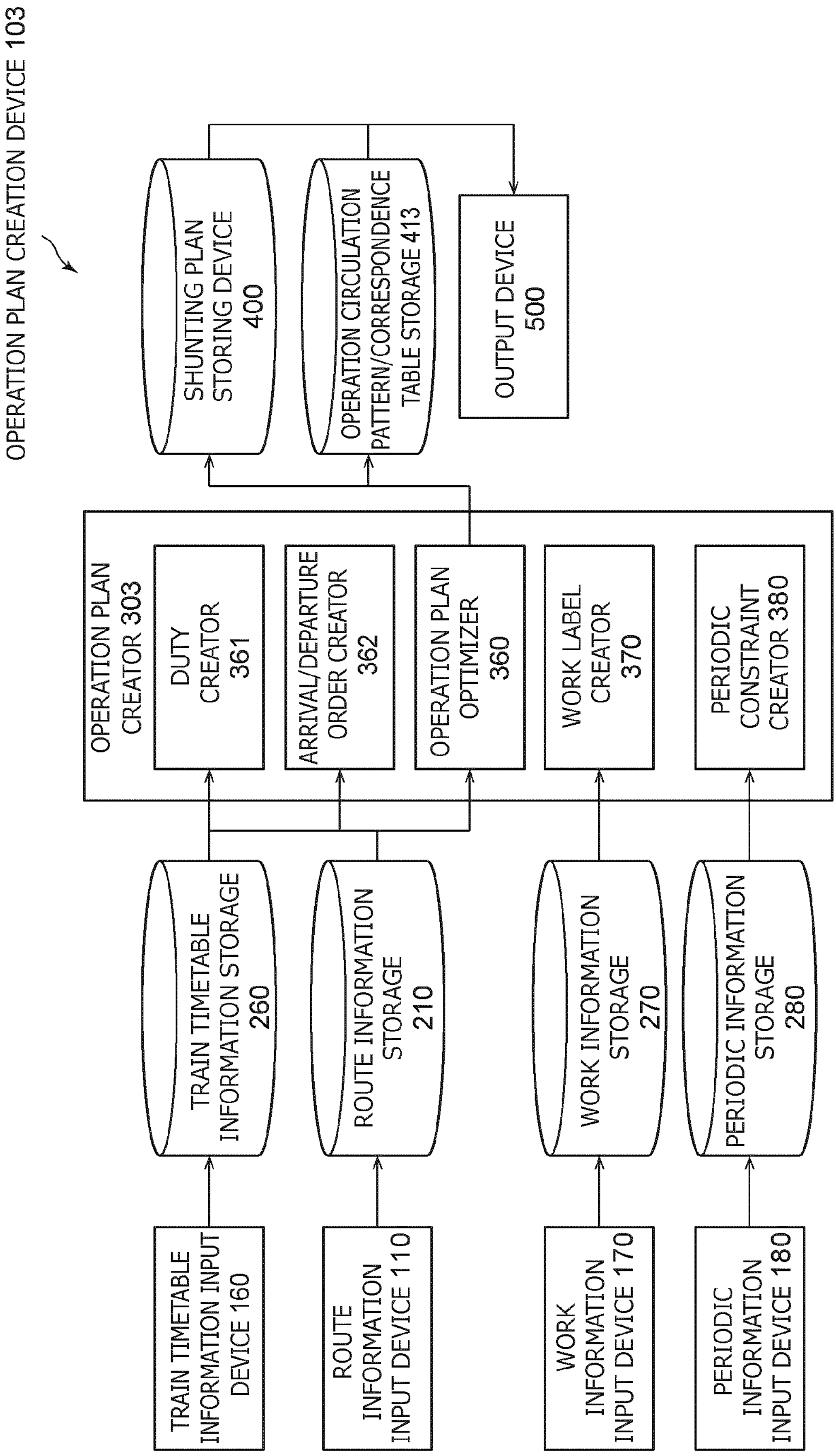
OPERATION PLAN CREATION DEVICE 103
TRAIN TIMETABLE INFORMATION INPUT DEVICE 160
ROUTE INFORMATION INPUT DEVICE 110
WORK INFORMATION INPUT DEVICE 170
PERIODIC INFORMATION INPUT DEVICE 180
TRAIN TIMETABLE INFORMATION STORAGE 260
ROUTE INFORMATION STORAGE 210
WORK INFORMATION STORAGE 270
PERIODIC INFORMATION STORAGE 280
OPERATION PLAN CREATOR 303
DUTY CREATOR 361
ARRIVAL/DEPARTURE ORDER CREATOR 362
OPERATION PLAN OPTIMIZER 360
WORK LABEL CREATOR 370
PERIODIC CONSTRAINT CREATOR 380
SHUNTING PLAN STORING DEVICE 400
OPERATION CIRCULATION PATTERN/CORRESPONDENCE TABLE STORAGE 413
OUTPUT DEVICE 500

FIG. 34

OVERNIGHT STAY	TRACK	NUMBER OF UNITS STORED IN TANDEM (NUMBER OF TRAINS)	TRACK TYPE
RAILWAY YARD	R1	4	LIFO SCHEME
	R2	2	LIFO SCHEME
STATION	R3	1	-

FIG. 35

WEEKDAY TIMETABLE DUTY	HOLIDAY TIMETABLE DUTY	ARRIVAL LOCATION	NEXT-DAY DEPARTURE LOCATION	TRACK	STACK	ORDER OF ARRIVAL	ORDER OF NEXT-DAY DEPART	WORK LABEL
L1	L'1	STATION	STATION	R3	S1	5	3	0
L5	L'5	RAILWAY YARD	RAILWAY YARD	R1	S1	3	1	1
L2	L'2	RAILWAY YARD	RAILWAY YARD	R1	S3	1	5	0
L6	L'6	RAILWAY YARD	RAILWAY YARD	R2	S2	4	6	1
L4	L'4	RAILWAY YARD	RAILWAY YARD	R2	S1	6	2	0
L3	L'3	RAILWAY YARD	RAILWAY YARD	R1	S2	2	4	0

FIG. 36A

WEEKDAY TIMETABLE DUTY	HOLIDAY TIMETABLE DUTY	ARRIVAL LOCATION	NEXT-DAY DEPARTURE LOCATION	TRACK	STACK	ORDER OF ARRIVAL	ORDER OF NEXT-DAY DEPART	WORK LABEL
L1	L'1	RAILWAY YARD	STATION	R3'	S1	5	3	0
L5	L'5	STATION	RAILWAY YARD	R1	S1	3	1	1
L2	L'2	RAILWAY YARD	RAILWAY YARD	R1	S3	1	5	0
L6	L'6	RAILWAY YARD	RAILWAY YARD	R2	S2	4	6	1
L4	L'4	RAILWAY YARD	RAILWAY YARD	R2	S1	6	2	0
L3	L'3	RAILWAY YARD	RAILWAY YARD	R1	S2	2	4	0

FIG. 36B

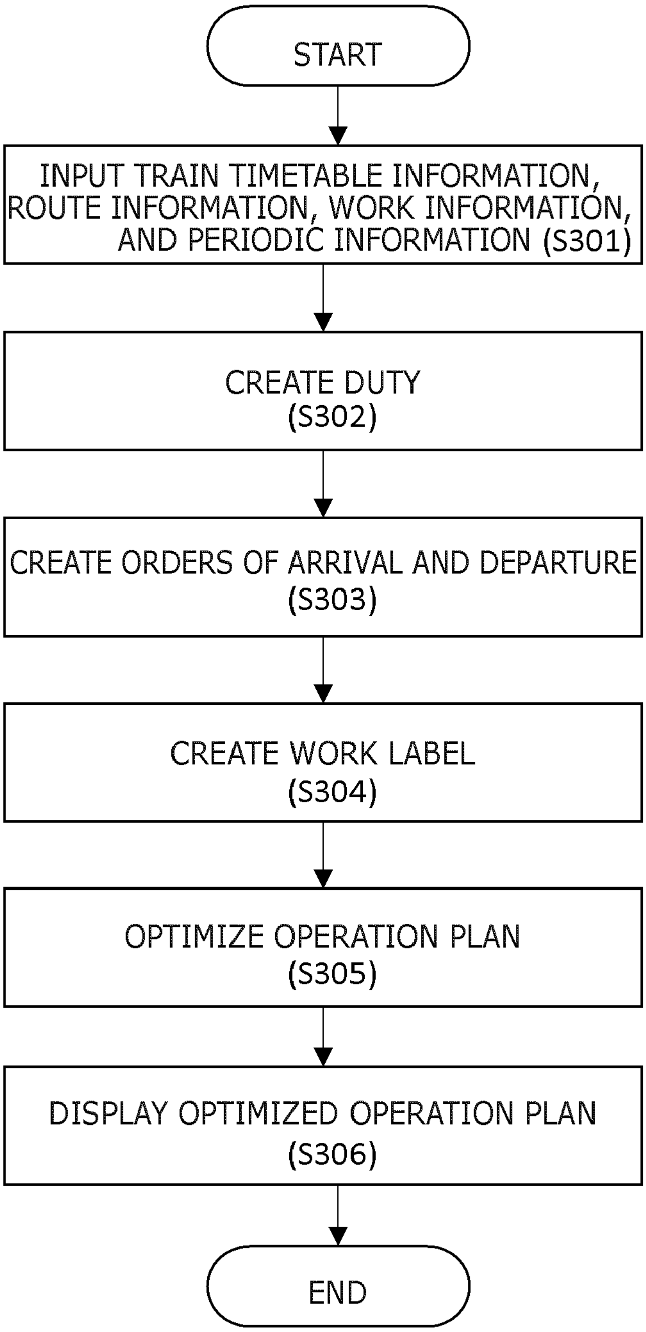
START
INPUT TRAIN TIMETABLE INFORMATION, ROUTE INFORMATION, WORK INFORMATION, AND PERIODIC INFORMATION (S301)
CREATE DUTY (S302)
CREATE ORDERS OF ARRIVAL AND DEPARTURE (S303)
CREATE WORK LABEL (S304)
OPTIMIZE OPERATION PLAN (S305)
DISPLAY OPTIMIZED OPERATION PLAN (S306)
END

FIG. 37

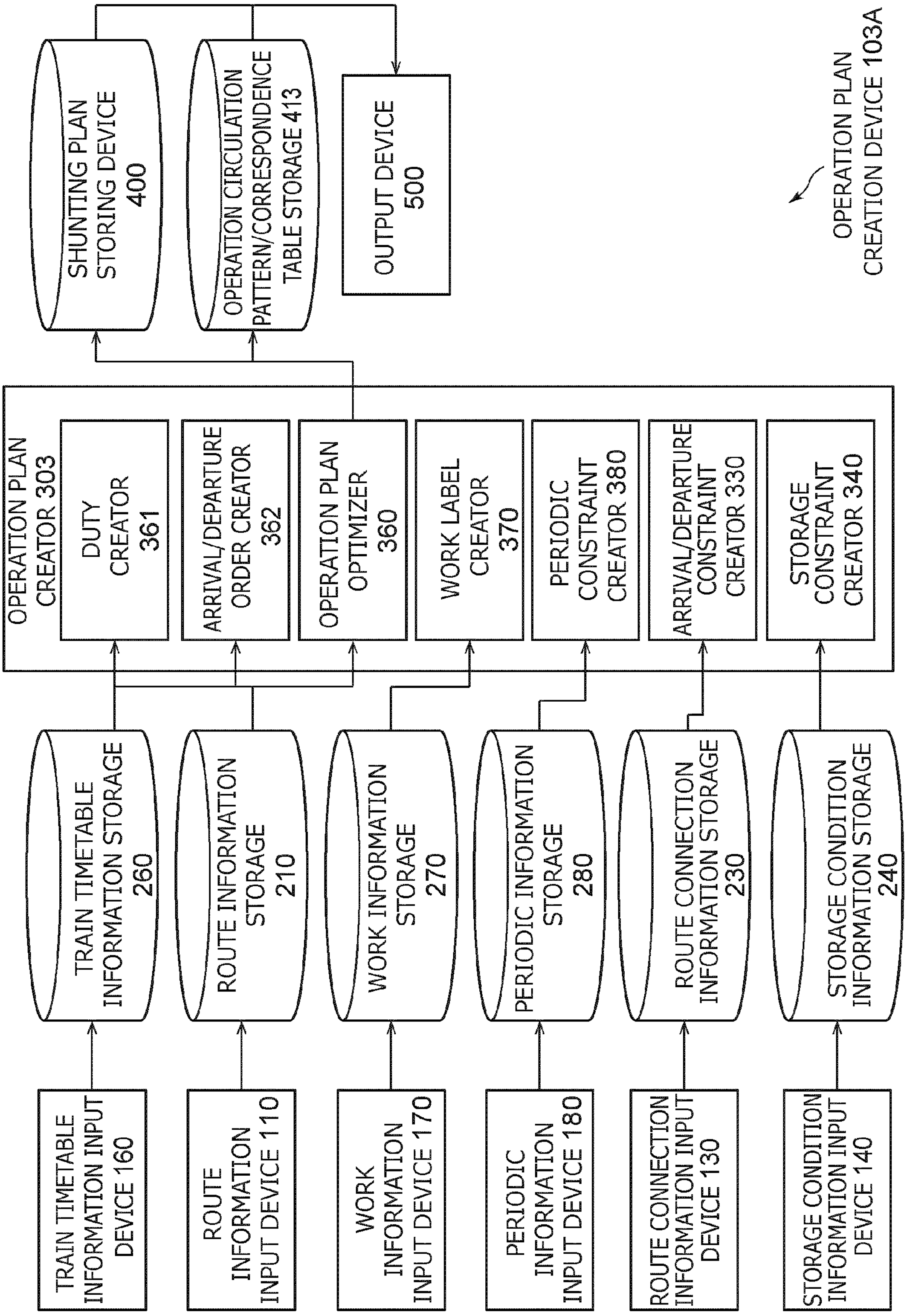
TRAIN TIMETABLE INFORMATION INPUT DEVICE 160
ROUTE INFORMATION INPUT DEVICE 110
WORK INFORMATION INPUT DEVICE 170
PERIODIC INFORMATION INPUT DEVICE 180
ROUTE CONNECTION INFORMATION INPUT DEVICE 130
STORAGE CONDITION INFORMATION INPUT DEVICE 140
TRAIN TIMETABLE INFORMATION STORAGE 260
ROUTE INFORMATION STORAGE 210
WORK INFORMATION STORAGE 270
PERIODIC INFORMATION STORAGE 280
ROUTE CONNECTION INFORMATION STORAGE 230
STORAGE CONDITION INFORMATION STORAGE 240
OPERATION PLAN CREATOR 303
DUTY CREATOR 361
ARRIVAL/DEPARTURE ORDER CREATOR 362
OPERATION PLAN OPTIMIZER 360
WORK LABEL CREATOR 370
PERIODIC CONSTRAINT CREATOR 380
ARRIVAL/DEPARTURE CONSTRAINT CREATOR 330
STORAGE CONSTRAINT CREATOR 340
SHUNTING PLAN STORING DEVICE 400
OPERATION CIRCULATION PATTERN/CORRESPONDENCE TABLE STORAGE 413
OUTPUT DEVICE 500
OPERATION PLAN CREATION DEVICE 103A

FIG. 38

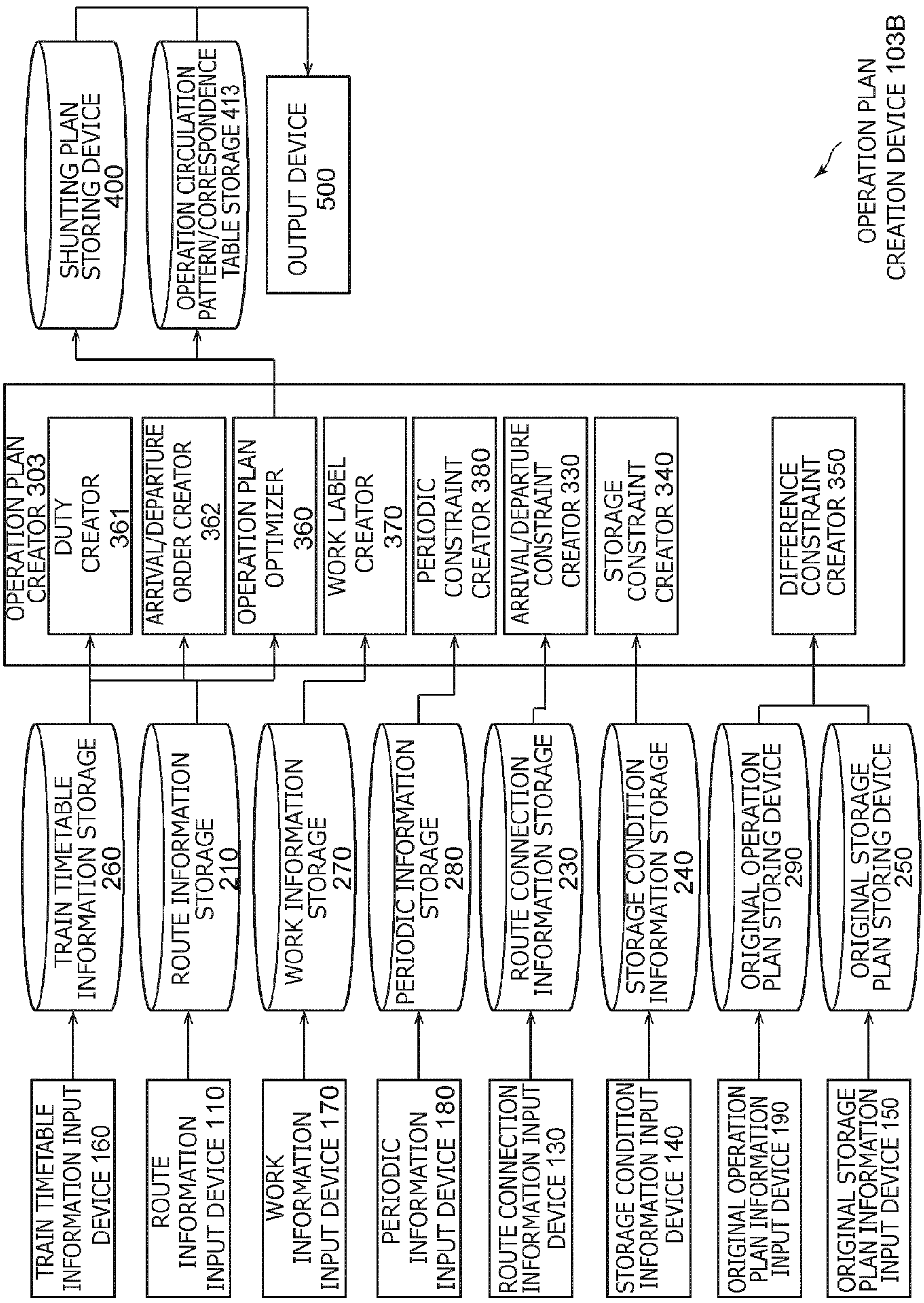
TRAIN TIMETABLE INFORMATION INPUT DEVICE 160
ROUTE INFORMATION INPUT DEVICE 110
WORK INFORMATION INPUT DEVICE 170
PERIODIC INFORMATION INPUT DEVICE 180
ROUTE CONNECTION INFORMATION INPUT DEVICE 130
STORAGE CONDITION INFORMATION INPUT DEVICE 140
ORIGINAL OPERATION PLAN INFORMATION INPUT DEVICE 190
ORIGINAL STORAGE PLAN INFORMATION INPUT DEVICE 150
TRAIN TIMETABLE INFORMATION STORAGE 260
ROUTE INFORMATION STORAGE 210
WORK INFORMATION STORAGE 270
PERIODIC INFORMATION STORAGE 280
ROUTE CONNECTION INFORMATION STORAGE 230
STORAGE CONDITION INFORMATION STORAGE 240
ORIGINAL OPERATION PLAN STORING DEVICE 290
ORIGINAL STORAGE PLAN STORING DEVICE 250
OPERATION PLAN CREATOR 303
DUTY CREATOR 361
ARRIVAL/DEPARTURE ORDER CREATOR 362
OPERATION PLAN OPTIMIZER 360
WORK LABEL CREATOR 370
PERIODIC CONSTRAINT CREATOR 380
ARRIVAL/DEPARTURE CONSTRAINT CREATOR 330
STORAGE CONSTRAINT CREATOR 340
DIFFERENCE CONSTRAINT CREATOR 350
SHUNTING PLAN STORING DEVICE 400
OPERATION CIRCULATION PATTERN/CORRESPONDENCE TABLE STORAGE 413
OUTPUT DEVICE 500
OPERATION PLAN CREATION DEVICE 103B

FIG. 39

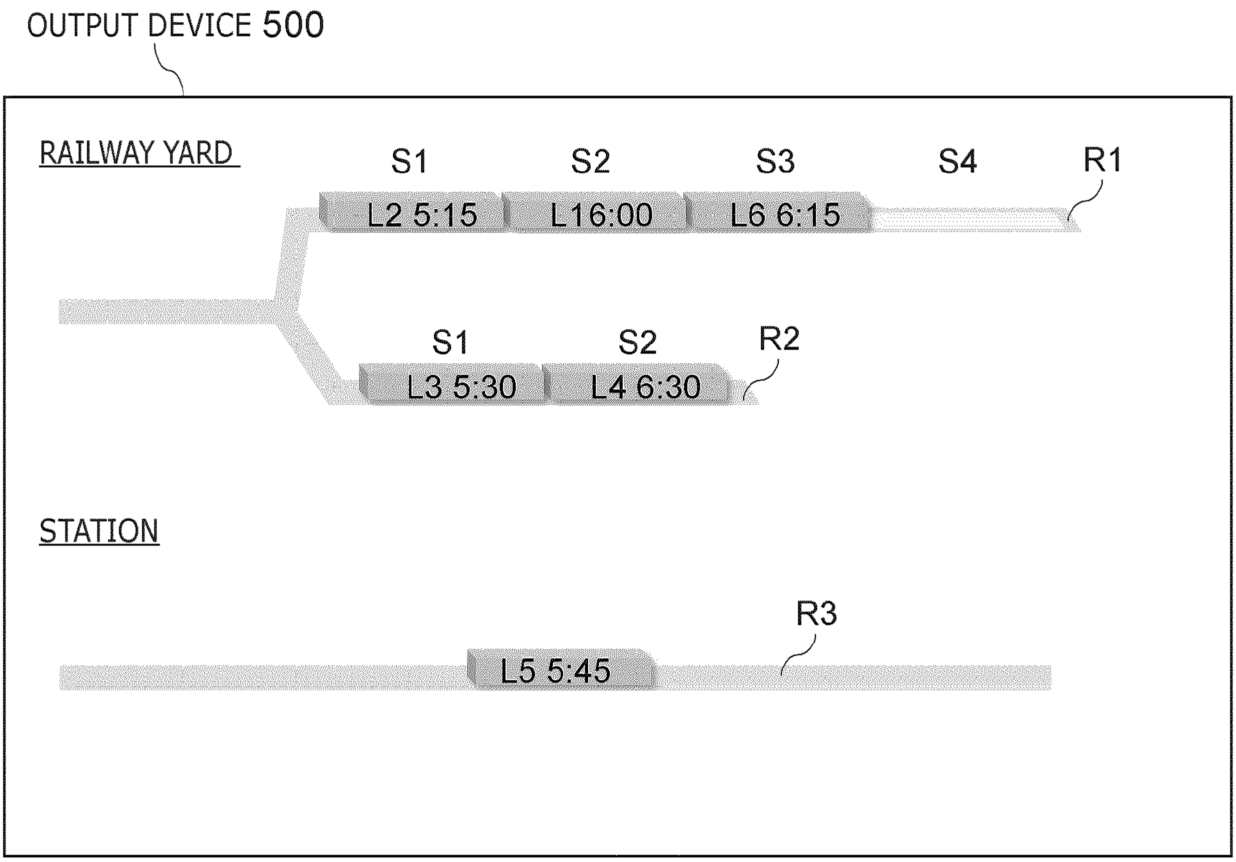
OUTPUT DEVICE 500
RAILWAY YARD
S1
S2
S3
S4
R1
L2 5:15
L16:00
L6 6:15
S1
S2
R2
L3 5:30
L4 6:30
STATION
R3
L5 5:45

FIG. 40

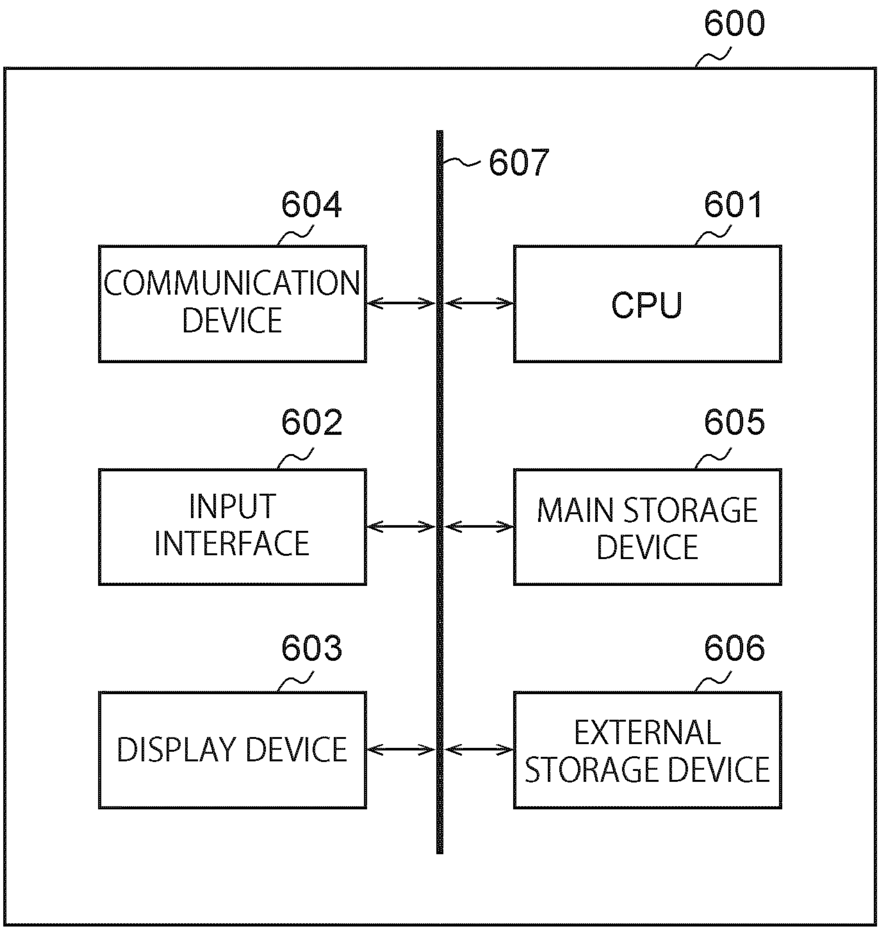
600
607
604
COMMUNICATION DEVICE
601
CPU
602
INPUT INTERFACE
605
MAIN STORAGE DEVICE
603
DISPLAY DEVICE
606
EXTERNAL STORAGE DEVICE

FIG. 41

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 22 19 4351

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	HAAHR JØRGEN THORLUND ET AL: "Optimization methods for the Train Unit Shunting Problem", EUROPEAN JOURNAL OF OPERATIONAL RESEARCH, ELSEVIER, AMSTERDAM, NL, vol. 262, no. 3, 31 March 2017 (2017-03-31), pages 981-995, XP085053076, ISSN: 0377-2217, DOI: 10.1016/J.EJOR.2017.03.068 * page 981 - page 994 * * figures 1-3 * * tables 2-5 *	1-29	INV. B61L27/12 B61L27/16
A	CN 106 741 019 A (SICHUAN HIGH - TECH RAIL TRANSIT IND TECH RES INST ET AL.) 31 May 2017 (2017-05-31) * paragraphs [0009] - [0021]; figures 1-2 *	1-29	
A	CN 212 289 875 U (SICHUAN HIGH TECH RAIL TRANSIT INDUSTRIAL TECH RESEARCH INSTITUTE ET A) 5 January 2021 (2021-01-05) * paragraphs [0002] - [0025]; figures 1-2 *	1-29	TECHNICAL FIELDS SEARCHED (IPC) B61L
A	US 2006/212184 A1 (PHILP JOSEPH W [US] ET AL) 21 September 2006 (2006-09-21) * paragraphs [0018] - [0024], [0028] - [0033]; figure 1 *	1-29	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	9 June 2023	Massalski, Matthias

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 22 19 4351

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

09-06-2023

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
CN 106741019	A	31-05-2017	NONE			
CN 212289875	U	05-01-2021	NONE			
US 2006212184	A1	21-09-2006	AU	2007210229	A1	09-08-2007
			BR	PI0706960	A2	12-04-2011
			CA	2637482	A1	09-08-2007
			CN	101529205	A	09-09-2009
			EP	1987321	A2	05-11-2008
			US	2006212184	A1	21-09-2006
			WO	2007089440	A2	09-08-2007
			ZA	200807061	B	25-11-2009

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82