Title of the Invention: Timetable replanning apparatus and method

Abstract Title: Timetable replanning to restore normal running

A timetable replanning apparatus 100 for managing the operation of vehicles (e.g. a train after a delay) and performing timetable replanning depending on circumstances comprises a conflict information management means 102 for determining the level or severity of a conflict affecting vehicle traffic based on conflict information about the conflict having occurred on site, a vehicle priority level management means 103 generating vehicle priority level information about each vehicle in timetable replanning regarding the conflict, based on passenger information constituted by real-time information about at least either a vehicle congestion rate of each vehicle or a passenger station congestion rate at each passenger station and on the basis of a real-time location of each vehicle, a predicted data management means 101 generating a timetable replanning candidate for each vehicle upon replanning of a predicted timetable, with reference to timetable replanning pattern information in which the timetable replanning candidates are recorded in relation to the conflict level and the vehicle priority level information based on whether or not each candidate was approved in the past, and on the basis of the conflict level and the vehicle priority level information.
FIG. 2

IS CONFLICT INFORMATION RECEIVED? S101

DETERMINE CONFLICT LEVEL S102

ACQUIRE PASSENGER INFORMATION AND TRAIN LOCATION INFORMATION S103

GENERATE TRAIN PRIORITY LEVEL INFORMATION S104

REFERENCE TIMETABLE REPLANNING PATTERN S105

GENERATE AND SUGGEST TIMETABLE REPLANNING CANDIDATES S106

UPDATE TIMETABLE REPLANNING PATTERN INFORMATION S107
<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>TIMETABLE REPLANNING CANDIDATE</th>
<th>CL</th>
<th>PL</th>
<th>SUGGESTION APPROVAL RATE</th>
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<tr>
<td>A</td>
<td>CHANGE TIME</td>
<td>1</td>
<td>3</td>
<td>90%</td>
</tr>
<tr>
<td>B</td>
<td>CHANGE TRAIN ORDER</td>
<td>3</td>
<td>7</td>
<td>60%</td>
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<tr>
<td>C</td>
<td>CHANGE PLATFORM</td>
<td>3</td>
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<tr>
<td>D</td>
<td>CHANGE LINE</td>
<td>8</td>
<td>2</td>
<td>60%</td>
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<tr>
<td>E</td>
<td>CANCEL OPERATION</td>
<td>7</td>
<td>3</td>
<td>65%</td>
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<tr>
<td>F</td>
<td>CHANGE TURNAROUND</td>
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<td>3</td>
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</tr>
<tr>
<td>G</td>
<td>ADD NEW TRAIN</td>
<td>9</td>
<td>6</td>
<td>60%</td>
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### Fig. 5

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### Fig. 6

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</tr>
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</tr>
<tr>
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### Fig. 7

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<tr>
<td>TRAIN B</td>
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<td>10</td>
</tr>
<tr>
<td>TRAIN Z</td>
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<td>7</td>
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<tr>
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<td>2</td>
</tr>
<tr>
<td>TRAIN C</td>
<td>10</td>
<td>1</td>
</tr>
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</table>
FIG. 8C

CURRENT TIMELINE

PLANNED TIMETABLE FOLLOWING APPROVAL OF
SUGGESTED CANDIDATE (TRAIN A: PRIORITY LEVEL LOW)
ACTUAL TIMETABLE (TRAIN A: PRIORITY LEVEL LOW)
PLANNED TIMETABLE (TRAIN B: PRIORITY LEVEL HIGH)

〈PAST〉 〈FUTURE〉

STATION α

TRAIN B

ACTUAL DELAY

TRAIN A

STATION β

TRAIN A
TITLE OF THE INVENTION

TIMETABLE REPLANNING APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

The present invention relates to a technique for managing the operation of a plurality of pieces of equipment in planned fashion. More particularly, the invention relates to a technique for timetable replanning to be performed when equipment in operation has incurred a delay.

In train traffic management, a conflict that may occur on a train route causing a delay of the train in operation is subjected to timetable replanning to restore normal running. In such a case, given notification that a conflict has taken place, an operator of the train traffic management system refers to a predicted timetable displayed on a timetable replanning terminal of the system and estimates the degree of the impact of the conflict on the delay of the train by taking into account the severity of the conflict, before deciding on timetable replanning measures and replanning accordingly the timetable through the timetable replanning terminal.

There has also been proposed an apparatus that supports the operator in timetable replanning (see JP-2008-222004-A; called Patent Literature 1 hereunder). The
timetable replanning suggestion apparatus proposed in Patent Literature 1 improves the accuracy in operation prediction upon disruption of the timetable and suggests timetable replanning candidates in order under the circumstances. This helps restore the disrupted timetable to normal running efficiently. The order of the timetable replanning candidates being suggested is adjusted on the basis of a recorded history of whether the suggestions were each approved by the operator in the past.

SUMMARY OF THE INVENTION

However, particularly in a section where trains run in a highly concentrated manner, there develop rapid changes in the circumstances over time following the occurrence of a conflict. For example, a delayed train can trigger abrupt changes in the vehicle occupancy of trains, in the rate of congestion on platforms, in train locations, and in inter-train distances. In this regard, the technology of Patent Literature 1 does not take into consideration the situations of passengers and of trains at the time of the conflict in the order of timetable replanning candidates. Thus there is a possibility that timetable replanning candidates suitable for the circumstances may not be suggested.
It is therefore an object of the present invention to provide a technique for suggesting timetable replanning candidates suitable for the circumstances in support of timetable replanning.

In carrying out the present invention and according to one aspect thereof, there is provided a timetable replanning apparatus for managing the operation of vehicles and performing timetable replanning depending on circumstances. The timetable replanning apparatus includes: conflict information management means which, based on conflict information received from on-site equipment concerning a conflict having occurred on site, determines a conflict level indicative of the degree of impact of the conflict on the operation of vehicles; vehicle priority level management means which generates vehicle priority level information indicative of the priority level of each of the vehicles in timetable replanning with regard to the conflict, based on passenger information constituted by real-time information about at least either a vehicle congestion rate that is the rate of congestion of passengers in each of the vehicles or a passenger station congestion rate that is the rate of congestion of passengers at each of passenger stations, and on the basis of vehicle location information constituted by a real-time location of each of the vehicles; and predicted
data management means which generates a timetable replanning candidate for each of the vehicles upon replanning of a predicted timetable, with reference to timetable replanning pattern information in which the timetable replanning candidates are recorded in relation to the conflict level and the vehicle priority level information based on whether or not each timetable replanning candidate was approved in the past, and on the basis of the conflict level determined by the conflict information management means and of the vehicle priority level information generated by the vehicle priority level management means.

According to the present invention, it is possible to suggest timetable replanning candidates suitable for the circumstances in support of timetable replanning of vehicles.

According to a second aspect of the present invention, there is provided a timetable replanning method for managing the operation of vehicles and performing timetable replanning depending on circumstances, said timetable replanning method comprising:

a first step of, based on conflict information received from on-site equipment concerning a conflict having occurred on site, determining a conflict level
indicative of the degree of impact of said conflict on the operation of vehicles;

a second step of generating vehicle priority level information indicative of the priority level of each of the vehicles in timetable replanning with regard to said conflict, based on passenger information constituted by real-time information about at least either a vehicle congestion rate that is the rate of congestion of passengers in each of the vehicles or a passenger station congestion rate that is the rate of congestion of passengers at each of passenger stations, and on the basis of vehicle location information constituted by a real-time location of each of the vehicles, and

a third step of generating a timetable replanning candidate for each of the vehicles upon replanning of a predicted timetable, with reference to timetable replanning pattern information in which the timetable replanning candidates are recorded in relation to the conflict level and the vehicle priority level information based on whether or not each timetable replanning candidate was approved in the past, and on the basis of said conflict level determined in said first step and of said vehicle priority level information generated in said second step.

The method of the second aspect corresponds to the apparatus of the first aspect. Optional features of the
apparatus of the first aspect thus pertain also to the method of the second aspect.

Further aspects of the present invention provide: (i) a computer program comprising code which, when run on a computer, causes the computer to perform the method of the second aspect, and (ii) a computer readable medium storing a computer program comprising code which, when run on a computer, causes the computer to perform the method of the second aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an overall structure of a timetable replanning apparatus as one embodiment of the present invention;

Fig. 2 is a flowchart showing the operation of the timetable replanning apparatus embodying the present invention;

Fig. 3 is a block diagram showing a configuration of a train traffic management system also embodying the present invention;

Fig. 4 is a tabular view listing typical data recorded in a past timetable replanning result database;

Fig. 5 is a tabular view listing a typical pattern matrix;
Fig. 6 is a tabular view listing typical information indicative of the conflict level and priority level of each of trains;

Fig. 7 is a tabular view listing information in which the trains shown in Fig. 6 are sorted in descending order of trail priority level;

Fig. 8A is a diagram for explaining a process in which a timetable replanning candidate is suggested;

Fig. 8B is a diagram for explaining another process in which the timetable replanning candidate is suggested; and

Fig. 8C is a diagram for explaining another process in which the timetable replanning candidate is suggested.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Some preferred embodiments of the present invention are explained below with reference to the accompanying drawings.

The timetable replanning apparatus embodying the present invention is an apparatus that manages and replans the operation of railway trains, buses, and other vehicles carrying passengers who get on and off the vehicle at passenger stations. Although the ensuing description of the embodiments of this invention refers to railway trains
as a typical vehicle, the invention can also be applied to other vehicles.

Fig. 1 is a block diagram showing an overall structure of a timetable replanning apparatus 100 as one embodiment of the present invention. The timetable replanning apparatus 100 includes a predicted data management device 101, a conflict information management device 102, a vehicle priority level management device 103, and a traffic management device 104.

The timetable replanning apparatus 100 manages the operation of vehicles (trains) and performs timetable replanning as needed under the circumstances.

The conflict information management device 102 receives conflict information from on-site equipment such as signals along the route on which trains run, the information concerning a conflict having taken place on site. Upon receipt of the conflict information, the conflict information management device 102 determines accordingly a conflict level (CL) indicative of the degree of impact of the conflict on the operation of trains. Typically, the longer the presumed delay time, the higher the conflict level is determined to be.

The vehicle priority level management device 103 acquires, from trains and from station equipment, passenger information constituted by real-time information about at
least either a vehicle congestion rate that is the rate of congestion of passengers in each of the trains (train congestion rate) or a passenger station congestion rate (platform congestion rate) that is the rate of congestion of passengers at each of passenger stations (station platforms), and vehicle location information (train location information) constituted by a real-time location (train location) of each of the trains. On acquiring these items of information, the vehicle priority level management device 103 generates accordingly vehicle priority level information (train priority level information) indicative of the priority level (PL) of each train in timetable replanning with regard to the conflict.

Although the example shown above is one in which the vehicle priority level information is generated based on the passenger information and the train location information, this is not limitative of the present invention. Furthermore, in determining a vehicle priority level, it is possible to use train type such as whether the train of interest is a local train or a limited express.

The predicted data management device 101 manages timetable replanning pattern information in which timetable replanning candidates are recorded in relation to conflict levels and vehicle priority level information based on whether or not the timetable replanning candidates were
each approved in the past. By referring to such timetable replanning pattern information and based on the conflict level determined by the conflict information management device 102 and on the vehicle priority level information generated by the vehicle priority level management device 103, the predicted data management device 101 generates a timetable replanning candidate for each of the trains in replanning the predicted timetable. The timetable replanning candidates thus generated are suggested to an operator on a display screen or the like. In turn, the operator views the timetable replanning candidates and determines accordingly whether or not to approve each of the suggestions. If approved, the suggestion is used as the basis for timetable replanning. It is the traffic management device 104 that manages the actual operation of the trains.

According to the above structure, when timetable replanning candidates are to be determined with regard to a conflict having taken place, passenger information and train location information are employed in addition to the conflict level in effect. This makes it possible to suggest timetable replanning candidates that are well suited for the circumstances in support of timetable replanning.
Also, the traffic management device 104 records actual delay information indicative of actual delays incurred by each of the trains because of the conflict. The predicted data management device 101 predicts a presumed delay time, i.e., a delay time presumed for each of the trains as a result of the conflict having occurred, and generates, according to the presumed delay time, a presumed delay-based predicted timetable that is a predicted timetable taking the presumed delay time into account. The conflict information management device 102 determines the conflict level based on the relations among the conflict information, the presumed delay-based predicted timetable, and the actual delay information. When the conflict level as the degree of impact of the delay is determined with the estimated and actual delays taken into consideration in this manner, the conflict level can be determined with higher accuracy.

Also, the vehicle priority level management device 103 may include a timetable management device (not shown) which, based on the inter-train distances obtained from the real-time locations of the trains, calculates the density of trains in a given area (e.g., a predetermined range of the railway) and includes the calculated density into the train location information before notifying the vehicle priority level management device 103 of that information.
In this case, the vehicle priority level management device 103 determines the priority level of each of the trains using the train density. Since the priority level of each train is determined in this manner with the density of trains in a given area taken into consideration, the priority level can be determined with higher accuracy.

Also, the predicted data management device 101 may update the timetable replanning pattern information every time an event occurs in which a timetable replanning candidate is suggested and approved or not approved, the update being made based on the suggested timetable replanning candidate and on whether or not the timetable replanning candidate is approved. Where the timetable replanning pattern information is updated in this manner whenever a timetable replanning candidate is suggested and approved or not approved, the timetable replanning pattern information can be always brought up to date. Thus, the timetable replanning pattern can be maintained in a latest state.

Fig. 2 is a flowchart showing the operation of the timetable replanning apparatus embodying the present invention.

It is assumed that the timetable replanning apparatus 100 retains beforehand the timetable replanning pattern information in which timetable replanning
candidates are recorded in relation to conflict levels and vehicle priority level information based on whether or not the timetable replanning candidates were each approved in the past.

Upon receipt of conflict information from on-site equipment (step S101), the timetable replanning apparatus 100 determines accordingly the conflict level indicative of the impact of the conflict that occurred on the operation of vehicles (step S102).

Also, the timetable replanning apparatus 100 acquires passenger information and train location information (step S103) and, based on the acquired passenger information and train location information, generates train priority level information about each train in timetable replanning with regard to the conflict (step S104). In this case, the timetable replanning apparatus 100 may alternatively acquire the passenger information and train location information upon occurrence of a conflict. As another alternative, the timetable replanning apparatus 100 may periodically acquire the passenger information and train location information and use the information in effect upon occurrence of a conflict.

The timetable replanning apparatus 100 proceeds to reference the timetable replanning pattern information (step S105), and based on the conflict level determined in
step S102 and the train priority level information generated in step S104, generates a timetable replanning candidate for each of the trains in replanning the predicted timetable (step S106). The timetable replanning candidate thus generated is suggested to an operator and approved or not approved by the operator.

Finally, the timetable replanning apparatus 100 updates the timetable replanning pattern information based on whether or not the timetable replanning candidate has been approved by the operator (step S107).

One preferred embodiment has been outlined above. Explained below with reference to the accompanying drawings is a more specific embodiment of this invention.

Fig. 3 is a block diagram showing a configuration of a train traffic management system embodying the present invention.

Referring to Fig. 3, the train traffic management system includes a timetable replanning terminal 6, a predicted data management device 1, a traffic management device 5, a conflict information management device 4, and a train priority level management device 3. The predicted data management device 1 is connected with the timetable replanning terminal 6, traffic management device 5, conflict information management device 4, and train priority level management device 3. A man-machine
interface 27 of the predicted data management device 1 is connected to the timetable replanning terminal 6.

The predicted data management device 1 is a device that includes a predicted data database 16 and a past timetable replanning result database 20 and, using the data stored in these databases, executes a prediction calculation function 10, a timetable replanning suggestion function 25, and a pattern matrix generation function 23.

The prediction calculation function 10 is a function that generates the predicted timetable based on a planned timetable 13 and an actual timetable 12 supplied from the traffic management device 5 and on a presumed delay time 11 input from the timetable replanning terminal 6. If a delay is presumed to exist, a presumed delay-based predicted timetable is generated with the delay taken into account.

The prediction calculation function 10 calculates the delay time of a given train based on its planned departure time and actual departure time at the station where the actual departure time of the train in question was most recently acquired. Furthermore, a predicted timetable 15 is calculated based on the delay time of the train, the planned arrival and departure times of the train at each of the stations involved, a minimum dwell time at station, a minimum running time between stations, and a minimum headway of trains. The minimum dwell time at
station is a minimum time period during which the train needs to stop at a station. The minimum running time between stations is a minimum time period required for the train to run between stations. The minimum headway of trains is a minimum time period required between running trains. The calculation of the predicted timetable is performed at predetermined intervals and is also carried out when the operator inputs the execution of timetable replanning through the timetable replanning terminal 6.

The predicted timetable 15 thus generated is stored into the predicted data database 16. The predicted data database 16 also stores the conflict level information 17 generated by the conflict information management device 4 and the train priority level information 18 generated by the train priority level management device 3.

The pattern matrix generation function 23 is a function that generates timetable replanning pattern information in matrix form (pattern matrix) based on the timetable replanning candidates suggested in the past and stored in the past timetable replanning result database 20 and on the basis of whether or not the timetable replanning candidates were each approved.

The timetable replanning suggestion function 25 is a function that generates a timetable replanning candidate suitable for the conditions of the conflict and of the
equipment on site and the situations of the trains and of the passengers at the stations, based on diverse prediction information 19 stored in the predicted data database 16 and on the basis of the pattern matrix information 24 generated by the pattern matrix generation function 23. Timetable replanning suggestion information 26 containing the timetable replanning candidates thus generated is sent via the man-machine interface 27 to the timetable replanning terminal 6 and suggested to the operator. The generation of timetable replanning candidates is performed by the timetable replanning suggestion function 25 at the same intervals as the calculation of predicted timetables by the prediction calculation function 10.

The traffic management device 5 is a device that manages a planned timetable 52 and an actual timetable 51 and controls the traffic of trains based on information about the timetables and on timetable replanning information 28. In this case, the traffic management device 5 causes the actual delay acquired of the train to be reflected in the actual timetable 51 and notifies the conflict information management device 4 of the acquired actual delay as actual delay information 41.

The conflict information management device 4 includes a conflict information database 42 that stores the conflict information about the conflicts having occurred
and the actual delay information 41 coming from the traffic management device 5, and executes a conflict level information generation function 43 using the stored data. The conflict level information generation function 43 is a function that determines the conflict level of a conflict that has taken place. The conflict level is determined based on the relations among the conflict information, presumed delay-based predicted timetable 14, and actual delay information 41.

The train priority level management device 3 is a device that includes a passenger information management device 31 and a timetable management device 33 and executes a train priority level generation function 36.

The passenger information management device 31 is a device that manages the passenger information acquired from train equipment. The passenger information is real-time information constituted by a train congestion rate that is the rate of passenger congestion in each train and by a platform congestion rate that is the rate of congestion on the platform at each station. The timetable management device 33 is a device which manages a train traffic timetable and which acquires train location information from station equipment for use in timetable management. The train location information is information about the real-time location of each train. The train location
information may be constituted by either the real-time location of each train or train density information acquired from the real-time location of each train. The train location information may alternatively include both the real-time location of each train and the train density information. The passenger information management device 31 stores the passenger information 32 into a train priority level information database 35, and the timetable management device 33 stores the train location information 34 into the train priority level information database 35.

The train priority level generation function 36 determines the priority level of each train in timetable replanning by use of the information stored in the train priority level information database 35, and notifies the predicted data management device 1 of the train priority level thus determined as the train priority level information 18.

What follows is a further explanation of the configuration of the train traffic management system embodying the present invention.

The timetable management device 33 manages train type information about each train included in the planned timetable 52 managed by the traffic management device 5. For example, the train types include the category of operational trains such as limited expresses, local trains
and rapid trains, and the category of non-operational trains such as empty coaching stock and freight trains. Also, the timetable management device 33 acquires train location information indicative of the real-time location of each train from on-site equipment, calculates the density of trains based on inter-train distances or on the number of trains occupying tracks, and manages the train density information using a database. In this manner, the train type information and the train density information are stored into the train priority level information database 35 as the train location information 34.

Meanwhile, the passenger information management device 31 measures in real time a platform congestion rate using the technique of recognizing people through a pattern matching process treating the images taken by cameras installed on the platform of each station to thereby measure the number of passengers in each platform. Using similar techniques, the passenger information management device 31 may alternatively measure the number of passengers in each train by processing the images taken inside each train by cameras. As another alternative, the passenger information management device 31 may calculate the number of passengers in each train using weight sensors on the train and, using techniques of wirelessly receiving data from each train, measure in real time a train
congestion rate of each train. The platform congestion rate and train congestion rate thus measured are stored into the train priority level information database 35 as the passenger information 32.

The train priority level information database 35 receives the train location information 34 including the train type information and train density information from the timetable management device 33 as well as the passenger information 32 including a platform passenger count, the platform congestion rate and train congestion rate from the passenger information management device 31, and retains the received information by train, by station, and by section. Furthermore, the train priority level management device 3 allows the train priority level generation function 36 to set a weighting function that has as its parameters the data from the train priority level information database 35, and calculates the train priority level of each train accordingly. The result of the calculation is sent to the predicted data database 16 of the predicted data management device 1 as the train priority level information 18.

Meanwhile, the conflict information management device 4 includes the conflict level information generation function 43 and the conflict information database 42. Upon receipt of conflict information from on-site equipment and a presumed delay time 11 from the timetable replanning
terminal 6, the conflict information database 42 updates accordingly the presumed delay-based predicted timetable 14 predicted through calculation by the prediction calculation function 10 of the predicted data management device 1 and the actual delay information 41 acquired by the traffic management device 5. In this case, the presumed delay time 11 is a recovery time, presumed by the operator, required for recovery under the circumstances of the conflict having occurred along the train route. The conflict level information generation function 43 calculates conflict levels by train, by station, and by section based on the conflict information managed by the conflict information database 42.

The train priority level information 18 from the train priority level management device 3 and the conflict level information 17 from the conflict information management device 4 are then stored into the predicted data database 16.

The traffic management device 5 retains the actual timetable 51 including actual train run results and the planned timetable 52 including train arrival and departure times at each of predetermined stations. In this case, the planned timetable 52 may be changed through the input made by the operator for timetable replanning in accordance with the timetable replanning information 28. Also, the actual
timetable 12 and planned timetable 13 are sent to the predicted data management device 1 for use by the prediction calculation function 10 in calculating the predicted times of each train. Furthermore, the traffic management device 5 generates the actual delay information 41 including the delay time of each train based on the actual timetable 51 and planned timetable 52, and sends the generated information to the conflict information database 42.

The man-machine interface 27 of the predicted data management device 1 receives the input of timetable replanning made by the operator through the timetable replanning terminal 6 for changing the planned timetable 13. Also, the man-machine interface 27 acquires input information regarding the operator’s approval 63 or non-approval 64 of the timetable replanning suggestion information 26 generated by the timetable replanning suggestion function 25. Approval/non-approval information 21 indicative of the operator’s approval or non-approval is managed by the past timetable replanning result database 20 and used as an element for determining the next and subsequent timetable replanning candidates 62 to be presented to the operator.

When the operator performs presumed delay input 60, the input information is received by the man-machine
interface 27 for use by the prediction calculation function 10 in calculating presumed delays.

Also, the operator can verify resulting changes in the timetable when the candidates 62 have been approved (63) through timetable verification 61 on the timetable replanning terminal 6.

The pattern matrix generation function 23 acquires actual suggestion information 22 from the past timetable replanning result database 20, extracts from the information the timetable replanning candidates that were suggested in the past and most frequently approved (having high approval rates) with regard to the combinations of the conflict level and train priority level of each of the trains, and associates the most often approved timetable replanning candidates (with the highest approval rates) with the corresponding conflict levels and train priority levels to generate the pattern matrix information 24. The pattern matrix information 24 is a matrix for identifying the timetable replanning candidates suitable for the conflict level and priority level of the train of interest. Incidentally, the timetable replanning candidates suggested by this system include a change-time candidate 91, a change-train-order candidate 92, a change-platform candidate 93, a change-line candidate 94, a cancel-operation candidate 95, a change-turnaround candidate 96,
and an add-new-train candidate 97 with respect to the train.

The timetable replanning suggestion function 25 acquires the predicted timetable 15, conflict level information 17, and train priority level information 18 from the predicted data database 16 as the prediction information 19. The timetable replanning suggestion function 25 then sorts the prediction information 19 in descending order of train priority level, and determines the timetable replanning candidates to be suggested by searching through the pattern matrix information 24 using conflict level and train priority level as the search keys. The timetable replanning candidates are sent through the man-machine interface 27 to the timetable replanning terminal 6 and suggested to the operator as the timetable replanning suggestion information 26.

The timetable replanning suggestion information 26 is displayed via the man-machine interface 27 on the timetable replanning terminal 6 in tabular form. The operator views what is suggested and selects approval or non-approval of the candidates. When a timetable replanning candidate is given the operator’s approval 63, that timetable replanning candidate may be used to change the timetable with a view to recovering from the delay of the train caused by a conflict. In this case, the traffic
management device 5 performs a final rational check for timetable change on the timetable replanning information 28 received via the man-machine interface 27 of the predicted data management device 1. The rational check involves checking to see whether the order of trains is consistent, whether there is a conflict between platforms used by trains, whether arrival or departure times are consistent, and whether there exists any item yet to be operated on.

When not adopting the suggested timetable replanning candidate 62, the operator may select his or her non-approval 64. The predicted data management device 1 does not send what is suggested by the timetable replanning candidate that is not approved (64) to the traffic management device 5. Given the operator’s non-approval, the timetable replanning candidate in question is recorded as a non-approved timetable replanning candidate in the past timetable replanning result database 20.

As long as the trains are operated according to the planned timetable, the traffic management device 5 automatically controls signal equipment as planned. Thus there is little need for the predicted data management device 1 to suggest timetable replanning candidates to the operator or for the operator to carry out timetable replanning. Mostly, the operator need only monitor the timetable replanning terminal 6.
The flow of the operation performed by the system of this embodiment is explained below.

Fig. 4 is a tabular view listing typical data recorded in the past timetable replanning result database 20. In Fig. 4, previously suggested timetable replanning candidates, conflict levels (CL), and train priority levels (PL) are shown related to one another, and their combinations are recorded in association with the corresponding suggestion approval rates. The conflict levels are generated by the conflict information management device 4 and the train priority levels by the train priority level management device 3. The content of the past timetable replanning result database 20 is updated every time a timetable replanning candidate is suggested and is approved or not approved.

The predicted data management device 1 allows the pattern matrix generation function 23 to generate a pattern matrix, i.e., timetable replanning pattern information in matrix form based on the content of the past timetable replanning result database 20. Fig. 5 is a tabular view listing a typical pattern matrix. In Fig. 5, the matrix is shown denoting conflict levels on the vertical axis and train priority levels on the horizontal axis. Each quadrant of the matrix is set with the timetable replanning
candidate classified to have the highest past suggestion approval rate.

If a conflict occurs somewhere, the conflict information management device 4 generates conflict level information 17 and notifies the predicted data management device 1 thereof, while the train priority level management device 3 generates train priority level information 18 and notifies the predicted data management device 1 thereof. Fig. 6 is a tabular view listing typical information indicative of the conflict level and priority level of each of trains. For example, a train A has the conflict level (CL) 1 and train priority level (PL) 2.

The predicted data management device 1 allows the timetable replanning suggestion function 25 to sort the trains whose information is shown in Fig. 6 in descending order of train priority level. Fig. 7 is a tabular view listing information in which the trains shown in Fig. 6 are sorted in descending order of trail priority level. In Fig. 7, a train B with a high train priority level is shown at the top of the list. Then, the predicted data management device 1 generates timetable replanning candidates for the trains in descending order of train priority level. Because timetable replanning candidates are generated for the trains in descending order of train priority level, the trains desired to recover from their
delays at the earliest possible time may be preferentially subjected to timetable replanning. In generating timetable replanning candidates, the predicted data management device 1 selects those which are highly likely to be approved by the operator and which are well suited for the circumstances. In this case, the predicted data management device 1 determines the timetable replanning candidates to be suggested by searching through the pattern matrix such as one shown in Fig. 5 using conflict level and train priority level as the search keys.

Although this embodiment was explained above using an example in which only one timetable replanning candidate with the highest approval rate is set for each quadrant of the pattern matrix, this is not limitative of the present invention. Alternatively, a plurality of timetable replanning candidates may be set for each quadrant in descending order of approval rate. In such a case, the timetable replanning candidate with the highest approval rate may be suggested first. If this timetable replanning candidate is not approved, then the timetable replanning candidate with the next-highest approval rate may be suggested, and so on.

Also with this embodiment, the timetable replanning candidate set for each quadrant of the pattern matrix is determined based on approval rate, this is not limitative
of the present invention. Alternatively, the timetable replanning candidate expected to entail the shortest train delay time upon approval may be set instead.

Explained next are some processes in which a specific timetable replanning candidate involving changing the order of trains is suggested.

Figs. 8A through 8C are diagrams for explaining the typical processes of suggesting a timetable replanning candidate.

In this case, it is assumed that a train A with a low train priority level has incurred a delay of a low conflict level at a station β. In Fig. 8A, the train A is shown arriving at the station β with a certain actual delay at the present time. The normal predicted timetable in this situation is as shown in Fig. 8A subsequent to the present time. That is, the train A leaves the station β with a presumed delay, before another train B arrives at the station β. Although the train B arrives at and leaves the station β at planned times of the timetable, the train B runs to a station α at a speed lower than the planned timetable, affected by the delay of the train A.

In this case, as shown in Figs. 6 and 7, the train A has a higher train priority level than the train B, and it is strongly desired that the train B should be operated according to the planned timetable. For these reasons,
there was a high approval rate in the past for the actual timetable replanning candidate involving changing the order of trains, given the same conflict level and train priority level as at the present time.

In that case, based on the past timetable replanning candidates and on whether they were each approved or not approved in the past, in order to operate the train B according to the planned timetable, a timetable replanning candidate is suggested to change the train order so that the train A should leave the station α after the train B. Fig. 8B shows a timetable (suggested timetable) that contains the suggested change in the train order. In Fig. 8B, the train A is shown arriving at the station β at present following a certain actual delay. The timetable suggested for the train A is that the train A should stay at the station β until the train B runs past the station β and that the train A should leave the station β following the train B. If the operator approves this suggested timetable, the suggested timetable becomes the newly planned timetable. Fig. 8C shows the suggested timetable becoming the newly planned timetable. In Fig. 8C, the planned timetable is shown having the train A staying at the station β until after the train B runs past the station β, the train A leaving the station β after the train B.
In another example of a low conflict level where the actual delay of the train A is short and so is the presumed delay of the train B, the appropriate timetable replanning candidate is frequently one which involves changing times so as to shorten the time required for the train A to run between the station α and the station β. Also, if a conflict occurs on the train route at the yard of a given station, or if a delay of the train ahead makes it difficult to use the same platform as planned in the timetable, it is often effective to change platforms for use by trains with the change-platform candidate implemented.

In this manner, there exists the tendency for certain timetable replanning candidates to be often used when the conflict level is low. Specifically, the change-time candidate, change-train-order candidate, and change-platform candidate for timetable replanning are used frequently in conjunction with relatively low conflict levels.

Meanwhile, there may be a case of a high conflict level where a large-scale wreck of the segment in which a train was supposed to run incurs a situation in which trains cannot be operated for an extended period of time. In that case, if there exists an alternative track such as multiple lines, the change-line strategy may be adopted as
an effective timetable replanning candidate. If there is no alternative track, the change-turnaround candidate may be effectively adopted so that trains in both directions may be turned around at the stations immediately beyond and this side of the location of the conflict. In this case, however, the two stations involved must be turnaround-capable stations. Also, when the change-line or change-turnaround candidate is adopted, the cancel-operation candidate needs to be also suggested for the previously planned but currently disrupted section. If large-scale cancellations or delays of trains continue for an extended time period, the platform congestion rate at stations can increase. In such a case, adopting the add-new-train candidate for timetable replanning can be effective in lowering the platform congestion rate.

As described, there also exists the tendency for certain timetable replanning candidates to be often used when the conflict level is high. Specifically, the change-line candidate, cancel-operation candidate, change-turnaround candidate, and add-new-train candidate for timetable replanning are used frequently in conjunction with relatively high conflict levels.

For this embodiment, the quadrants in the pattern matrix shown in Fig. 6 are set with all timetable replanning candidates in descending order of approval rate.
However, this is not limitative of the present invention. Alternatively, the timetable replanning candidates to be set in the quadrants of the pattern matrix may be limited depending on the conflict level in effect. For example, in a quadrant where the conflict level is below a predetermined value, only a plurality of timetable replanning candidates often used in connection with low conflict levels may be set.

In a situation where train delays expand upon occurrence of a conflict, the embodiment above can suggest timetable replanning candidates highly likely to be adopted by the operator on the basis of the conflict level and train priority level in effect of each train and based on past timetable replanning candidates and on whether they were each approved or not approved by the operator in the past under similar circumstances. The embodiment thus makes it possible to alleviate workload on the operator, render train operation more efficient, and recover quickly from delays of a group of trains upon occurrence of a conflict.

Although the above-described embodiments of the present invention were each shown as a typical train traffic management system, this is not limitative of the present invention. Alternatively, the invention may be
applied extensively to other vehicles such as buses that transport passengers.

While preferred embodiments of this invention have been described using specific terms, such description is for illustrative purposes only, and it is to be understood that changes and variations may be made by those skilled in the art without departing from the spirit or scope of the claims that follow.
Claims:

1. A timetable replanning apparatus for managing the operation of vehicles and performing timetable replanning depending on circumstances, said timetable replanning apparatus comprising:

   conflict information management means which, based on conflict information received from on-site equipment concerning a conflict having occurred on site, determines a conflict level indicative of the degree of impact of said conflict on the operation of vehicles;

   vehicle priority level management means which generates vehicle priority level information indicative of the priority level of each of the vehicles in timetable replanning with regard to said conflict, based on passenger information constituted by real-time information about at least either a vehicle congestion rate that is the rate of congestion of passengers in each of the vehicles or a passenger station congestion rate that is the rate of congestion of passengers at each of passenger stations, and on the basis of vehicle location information constituted by a real-time location of each of the vehicles; and

   predicted data management means which generates a timetable replanning candidate for each of the vehicles upon replanning of a predicted timetable, with reference to
timetable replanning pattern information in which the timetable replanning candidates are recorded in relation to the conflict level and the vehicle priority level information based on whether or not each timetable replanning candidate was approved in the past, and on the basis of said conflict level determined by said conflict information management means and of said vehicle priority level information generated by said vehicle priority level management means.

2. The timetable replanning apparatus according to claim 1, further comprising traffic management means which manages the operation of vehicles to record actual delay information indicative of an actual delay incurred by each of the vehicles as a result of a conflict;

wherein said predicted data management means predicts a presumed delay time presumed for each vehicle regarding said conflict and, based on said presumed delay time, generates a presumed delay-based predicted timetable taking said presumed delay time into account, and

wherein said conflict information management means determines said conflict level based on the relations among said conflict information, said presumed delay-based predicted timetable, and said actual delay information.

3. The timetable replanning apparatus according to claim 1 or 2, further comprising timetable management means
which calculates the density of vehicles in a given area based on inter-vehicle distances obtained from the real-time location of each vehicle and which allows the vehicle density to be included in said vehicle location information before notifying said vehicle priority level management means thereof;

wherein said vehicle priority level management means determines said priority level of each vehicle using said vehicle density.

4. The timetable replanning apparatus according to any one of the previous claims, wherein said predicted data management means updates said timetable replanning pattern information every time an event occurs in which a timetable replanning candidate is suggested and approved or not approved, the update being made based on the suggested timetable replanning candidate and on whether or not the timetable replanning candidate is approved.

5. A timetable replanning method for managing the operation of vehicles and performing timetable replanning depending on circumstances, said timetable replanning method comprising:

a first step of, based on conflict information received from on-site equipment concerning a conflict having occurred on site, determining a conflict level
indicative of the degree of impact of said conflict on the operation of vehicles;

a second step of generating vehicle priority level information indicative of the priority level of each of the vehicles in timetable replanning with regard to said conflict, based on passenger information constituted by real-time information about at least either a vehicle congestion rate that is the rate of congestion of passengers in each of the vehicles or a passenger station congestion rate that is the rate of congestion of passengers at each of passenger stations, and on the basis of vehicle location information constituted by a real-time location of each of the vehicles, and

a third step of generating a timetable replanning candidate for each of the vehicles upon replanning of a predicted timetable, with reference to timetable replanning pattern information in which the timetable replanning candidates are recorded in relation to the conflict level and the vehicle priority level information based on whether or not each timetable replanning candidate was approved in the past, and on the basis of said conflict level determined in said first step and of said vehicle priority level information generated in said second step.
6. A computer program comprising code which, when run on a computer, causes the computer to perform the method of claim 5.

7. A computer readable medium storing a computer program comprising code which, when run on a computer, causes the computer to perform the method of claim 5.