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(54) Elevator group management system and control method therefor

Steuersystem und -verfahren für Aufzugsgruppen

Système de commande et méthode de contrôle des groupes d’ascenseurs

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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an elevator group management system and a control method therefor, and more particularly, to an elevator group management system and a control method therefor for improving system performance evaluations and elevator allocation control responsive to hall calls.

[0002] An elevator group management system provides an efficient operation service for users by handling a plurality of elevator cages in one unit. Specifically, a plurality of elevator cages (generally ranging from three to eight) are managed in one group, such that an appropriate cage is selected from among this group in response to a new hall call generated at a certain floor to allocate the hall call to that cage.

[0003] A current group management system is based on allocation control that relies on an evaluation function based on a forecasted waiting time. For example, when a new hall call is generated, the hall call is allocated to a cage which minimizes a forecasted waiting time of a hall call serviced by each cage, a cage which minimizes a maximum waiting time, or a cage which minimizes an average waiting time. This allocation control based on the forecasted waiting time is a basic scheme employed in group call control of every elevator manufacturer, but has the following two problems.

1) The allocation control offers an optimal cage allocation for previously generated hall calls and does not sufficiently take into consideration the influence of hall calls which can be generated in the future.
2) A forecasted waiting time is indexed for allocation of a cage, without taking into consideration the positional relationship among respective cages.

[0004] A variety of control schemes have been so far proposed in order to solve such problems of the allocation scheme based on a forecasted waiting time. Their basic concepts can be summarized into control intended to move respective elevator cages at equal time intervals. Supposing that respective elevator cages are not even in position, i.e., when there is a longer time interval between certain two cages, if a new hall call is generated at a floor between the cages, the call is likely to suffer from a long waiting time. It has been traditionally known that long waiting times can be restrained if respective cages can be disposed at equal time intervals. The following conventional control schemes are intended to the disposition of cages at equal time intervals.

1) Representation of Interval between Cages in Coefficient (JP-B-7-12890)
An allocation evaluation function Φk is represented by the following equation:

$$\Phi k = \alpha k \cdot Tk \qquad \ldots (1)$$

where Tk indicates a forecasted time of arrival of a K-th call at a floor at which a new hall call was generated, and αk indicates a coefficient, the value of which is determined from intervals between cages. Tk corresponds to a forecasted waiting time index, and is intended to adjust a forecasted waiting time in accordance with the intervals for evaluation using the product of the cage interval index and forecasted waiting time.

2) Allocation Evaluation Control which Takes Temporal Equal Interval State into Index (JP-B-7-72059) :
The position of each cage is forecasted at a future time point to predict time intervals between the respective cages at that time point. An allocation limit evaluation value is calculated from the forecasted cage intervals to control the allocation in such a manner that cages are partially allocated to a particular floor range. As a result, JP-B-7-72059 is intended to bring the intervals between the respective cages to an equal time interval.

3) Equal Internal Preference Zone Control (JP-A-1-226676 corresponding to US 4947965):

Floors serviced by cages are classified into a preferential zone and a limited zone, and an allocation evaluation value is manipulated such that a cage is more likely to be allocated when a new hall call is generated in the preferential zone, and is less likely to be allocated when it is in the limited zone. In this way, JP-A-1-226676 is intended to bring the intervals between the respective cages to an equal time interval.

4) Temporally Equal Interval Allocation Zone Control (JP-A-7-61722):

Like the prior art 3) described above, floors serviced by cages are classified into a preferential zone and a limited zone, and an allocation evaluation value is manipulated such that a cage is more likely to be allocated when a new hall call is generated in the preferential zone, and is less likely to be allocated when it is in the limited zone. In this way, JP-A-7-61722 is intended to bring the intervals between the respective cages to an equal time interval.

5) Allocation Scheme Based on Position Evaluation Value (JP-A-2000-118890):

This scheme calculates a position evaluation value for preventing respective cages from partially concentrating in position, and determines the allocation to a hall call based on an allocation evaluation value which takes into account the position evaluation value. This position evaluation value is calculated on the basis of a relationship between an absolute position of a car and an average value of absolute positions of the remaining cars when a hall call is generated. This scheme is also intended to bring the intervals between the respective cages to an equal time interval.

6) Evaluation of Evenness in Forecasted Position (JP-A-8-175769):

A forecasted position of each cage after the lapse of a predetermined time is calculated to select one which is most evenly spaced from among the forecasted positions, and a cage corresponding to this forecasted position is allocated to a new hall call.

7) "Method of Calculating Forecasted Time of Arrival Using Dynamic Planning Method (2003 Institute of Electrical Engineers of Japan, Electronics, Information and Systems Society Conference, GS-18-3, pp.1099-1102 (whole)):

An approach is disclosed for estimating a floor at which a cage call is generated through n unserved ad-hoc call, using a dynamic planning method in order to accurately finding a forecasted waiting time.
JP-B-7-72059 described above has a key factor in predicting the position of each cage in the future to determine the allocation from time intervals between respective cages at that time. However, this method simply evaluates the spatial position for each cage at a certain time point (sometimes at certain time points) in the future, and lacks for information for analyzing the contents of the evaluation. Specifically, an analysis on the cause of the allocation evaluation must involve individually analyzing information on the spatial positions of cages at a certain time point, giving rise to difficulties in macroscopic analysis. Also, since the position is individually forecasted on a stage-by-stage basis, another problem experienced herein is a low forecast accuracy. Particularly, in a building which has a long interval between floors, the forecast accuracy affects the control performance.

[0005] "Method of Calculating Forecasted Time of Arrival Using Dynamic Planning Method (2003 Institute of Electrical Engineers of Japan, Electronics, Information and Systems Society Conference, GS-18-3, pp.1099-1102 (whole)) in turn is intended to improve a method of estimating a forecasted time of arrival to provide a reasonable forecasted waiting time mentioned above, and is not related to the forecast of positioning for each cage.

[0006] Neither JP-B-7-12890, JP-A-1-226676, JP-A-7-61722, nor JP-A-2000-118890 is related to the forecast of positioning for each cage.

[0007] WO 2005/042389 A1 discloses an elevator group management system with which the invention has the features recited in the pre-characterising first part of claim 1 in common. In the system of that prior art, a target value is set for the time needed to service a call. When calls are received, alternative routes of the elevators are evaluated and a solution is selected which comes close to the target value for the service time and minimises energy consumption.

[0008] EP 1 719 727 A2 is prior art under Article 54(3) EPC and relates to an elevator group management system which predicts route data of each elevator on the basis of averaged stopping probability data.

[0009] US 4 982 817 discloses an elevator group management system making a prediction of elevator positions and directions.

[0010] Generally, the performance of an elevator group management system is evaluated in regard to a short average waiting time, a low probability of a long waiting time after a call, and the like. However, difficulties are often experienced in making detailed evaluations on the system under a variety of varying traffic demands within a building due to unknown reasons for which the control performance differs.

SUMMARY OF THE INVENTION

[0011] It is an object of the invention to provide an elevator group management system with improved accuracy of the forecast operation of the elevators. This object is solved by the system of claim 1. The dependent claims relate to preferred embodiments of the invention.

[0012] Further objects to be solved by embodiments of the invention are as follows:

[0013] It is a first object to provide a system which supports evaluations on system control performance in an elevator group management system.

[0014] Also, in the prior art techniques listed above, an important key for determining the control performance is balanced evaluations on a waiting time to a hall call and on a positional relationship (intervals) among respective cages. As has been previously described, the evaluation on a waiting time to a hall call corresponds to an evaluation for a hall call which has been actually made (hereinafter called the "actual call"), while the evaluation on the intervals between respective cages corresponds to a hall call which can be made in the future (hereinafter called the "future call"). Therefore, the aforementioned balancing involves balancing the actual call with the future call.

[0015] The following three general classifications can result from a review on how the above listed prior art techniques accomplish the balanced evaluations. (A) There is no balancing means. (B) Two evaluations are weighted for balancing. However, there is no means for adjusting the weighting values. (C) Two evaluations are weighted for balancing. Weighting values are determined by repeatedly simulating the group management control for a traffic flow in a building. Specifically, Prior Art Techniques 1) and 6) fall under the classification (A); Prior Art Techniques 2), 4), and 5) fall under the classification (B); and Prior Art Technique (3) falls under the classification (C).

[0016] For a reduction in waiting times of all users, balancing through the weighting of the actual call and future call is indispensable, and the weighting must be further adjusted in accordance with elevator used situations. Therefore, Prior Art Technique (3) which falls under the classification (C) alone satisfies this condition. However, this method must repeatedly execute the simulation to find weights suitable for a particular traffic flow, and therefore takes a long time until appropriate weights are found. The weights can be set with a delay because the traffic flow in a building is a flow of persons and varies at all times. Also, in a transient state in which appropriate weights have not been found, a problem arises in how weights should be set in order to guarantee the performance. Further, immediately after the introduction of a group management, in the event of a replacement of a tenant in a building, on the occurrence of a special event, and the like, a long time is required for setting weights due to the lack of accumulated past traffic flows, giving rise to a challenge of how the weights should be set in the so far transient state.

[0017] It is a second object to promptly set weights for balancing an evaluation on a waiting time with an evaluation on a positional relationship (for example, intervals) between respective elevator cages to appropriate weights corresponding to variations in used situations for an evaluation on the allocation of a new hall call.

[0018] Also, in the prior art techniques described above, the allocation control for allocating a hall call to an elevator cannot always appropriately control the intervals for a varying traffic flow in a building to possibly cause a long average waiting time.

[0019] It is a third object to provide an elevator group management system and a control method therefor which comprises hall call allocation control capable of accomplishing appropriate interval control for a varying traffic flow in a building to reduce an average waiting time.

(Means for Achieving First Object)

[0020] To achieve the first object, one preferred embodiment of the present invention is characterized by comprising forecasted trajectory creating means for creating a forecasted trajectory indicative of movements of a forecasted position of each elevator on a time axis for a predetermined period from a current time point to the near future.

(Means for Achieving Second Object)

[0021] To achieve the second object, a preferred embodiment of the present invention provides an elevator group management system for managing a plurality of elevators which service a plurality of floors. The system calculates a plurality of evaluation values for a generated hall call, calculates a general evaluation value by weighting and adding the plurality of evaluation values, calculates the value of a weight used by the general evaluation value calculating means, allocates a hall call to an elevator in accordance with the general evaluation value by calculating the value of the weight based on a function which continuously changes an output value in response to a change in an input.

[0022] Stated another way, the value of the weight is calculated on the basis of a function which is applied with a real number which continuously changes the value.

[0023] Also, in a preferred embodiment of the present invention, weight calculating means calculates the value of the weight by a linear function or a function of a plurality of orders or a polynomial function.

[0024] Further, in a preferred embodiment of the present invention, the input of the function is a value related to the number of generated hall calls.

(Means for Achieving Third Object)

[0025] For an evaluation for a positional relationship between respective cages, for example, an interval, it is important to evaluate the interval at which time point, which has been found to largely affect the performance of the group management system. For example, when a cage interval is evaluated, for example, at an immediately near time point, a cage can pass another at a later time, resulting in an inversion of the cage interval therebetween. On the other hand, when a cage positional relationship (interval) is evaluated at an extremely far future time point, a large number of calls can be generated after the evaluation, causing a forecasted interval to largely deviate. The aforementioned prior art techniques do not specifically disclose an important time point at which the cage interval should be evaluated, so that the evaluated cage interval can have a large error, possibly failing to demonstrate sufficient group management control performance.

[0026] Accordingly, to achieve the third object, a preferred embodiment of the present invention provides an elevator group management system which forecasts the position of each elevator, evaluates the positional relationship between the respective cages from after a predetermined time from the forecasted position of each cage, and allocates a hall call to an elevator in accordance with the evaluation value, where the predetermined time is set in accordance with a situation of a generated hall call and/or a cage call. In other wards, in interval evaluation time is set in accordance with a call generation state.

[0027] Also, in a preferred embodiment of the present invention, the evaluation time for a forecasted interval between the respective cars in the future is set in accordance with the longest forecasted arrival time of all hall calls and cage calls.

[0028] Further, in a preferred embodiment of the present invention, the evaluation time for the forecasted interval between the respective cages in the future is set in accordance with a measured traffic flow in a building.

[0029] Specifically, it is contemplated to set the evaluation time for the forecasted interval between the respective cages in the future at a forecasted arrival time of a call having the longest forecasted arrival time in all hall calls and cage calls, or the vicinity thereof, or one round time of each elevator.

[0030] According to the elevator group management system according to the preferred embodiment for achieving the first object, the elevator group management control can be properly evaluated from a forecasted trajectory of each elevator on the time axis. Also, from this, it is possible to provide technical supports for the evaluation and improvements, such as giving a suggestion to necessary improvements. For example, when there is a large forecast error, it can be determined from the slope of the forecasted trajectory whether or not this is due to an error in an estimation of a traffic demand, and the like.

[0031] According to the preferred embodiment for achieving the second object, against an evaluation for allocating an elevator cage for new hall call, an appropriate weight can be immediately set depending on changing situation as a weight which balances an evaluation for waiting time and an evaluation for each elevator cage interval. Especially, in case of soon after an introduction of a group control system, a change of a tenant, or a generation of a special event and so on, an appropriate weight can be immediately set even if there are few stocks of traffic flows of the past.

[0032] Also, according to the preferred embodiment for achieving the third object, the positional relationship between the respective cages can be evaluated at an appropriate time point in order to allocate an elevator to a hall call. It is therefore possible to provide an elevator group management system and a control method therefor which comprises hall call allocation control which accomplish appropriate interval control and is capable of reducing an average waiting time.

[0033] Other objects and features according to the present invention will become apparent from the following description of embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034]

Fig. 1 is a control conceptual diagram of an elevator group management system according to the present invention;

Fig. 2 is a control functional block diagram of an elevator group management system according to one embodiment of the present invention;

Fig. 3 is a control processing flow diagram of the elevator group management system according to one embodiment of the present invention;

Fig. 4 is a graph for describing a method of setting weighing coefficients according to one embodiment of the present invention;

Fig. 5 is a conceptual diagram of an optimal solution search method for weighting coefficients according to one embodiment of the present invention;

Fig. 6 is an explanatory diagram of how to think an exemplary traffic flow and weighting in a building having six floors;

Fig. 7 is a diagram for describing an example of a weighting coefficient setting method when an input is handled in a traffic flow;

Fig. 8 is a diagram for comparing one embodiment of the present invention with a conventional weighting coefficient setting method;

Fig. 9 is a processing flow diagram of a weighting coefficient setting method according to one embodiment of the present invention;

Fig. 10 is a processing flow diagram of an optimal solution search method for weighting coefficients according to one embodiment of the present invention;

Fig. 11 is a diagram showing exemplary data within an input information storage unit 2 shown in Fig. 2;

Fig. 12 is a diagram illustrating in detail the configuration of a cage interval evaluation value processing unit 4 shown in Fig. 2;

Fig. 13 is a processing flow diagram for setting an interval evaluation time tref;

Fig. 14 is an explanatory diagram of how to think the setting of an interval estimation time according to one embodiment of the present invention;

Fig. 15 is a functional block diagram of a second embodiment of the interval evaluation value processing unit which is substituted for the counterpart illustrated in Fig. 12;

Fig. 16 is a functional block diagram of a third embodiment of the interval evaluation value processing unit which is substituted for the counterpart illustrated in Fig. 12;

Fig. 17 is a functional block diagram of a fourth embodiment of the interval evaluation value processing unit which is substituted for the counterpart illustrated in Fig. 12;

Fig. 18 is a general processing flow diagram of a forecasted trajectory creation method according to one embodiment of the present invention;

Fig. 19 is a processing flow diagram for creating an arrival forecasted time table of a plurality of cycles according to one embodiment of the present invention;

Fig. 20 is a processing flow diagram of an arrival forecasted time table calculation routine (FB04 in Fig. 19);

Fig. 21 is an explanatory diagram for a stop time, a stop probability, and a stop time expected value table for each floor;

Fig. 22 is a diagram showing a specific example of the arrival forecasted time table of a plurality of cycles using values shown in Fig. 21;

Fig. 23 is a diagram showing an example of the arrival forecasted time table eventually crated in accordance with one embodiment of the present invention;

Fig. 24 is a forecasted position calculation conceptual diagram which is based on a forecasted trajectory according to one embodiment of the present invention;

Fig. 25 is a processing flow diagram (No. 1) for creating a forecasted trajectory table according to one embodiment of the present invention;

Fig. 26 is a processing flow diagram (No. 2) for creating the forecasted trajectory table according to one embodiment of the present invention;

Fig. 27 is a flow diagram of a forecasted trajectory creation process without direction;

Fig. 28 is a diagram showing an exemplary forecasted trajectory which is created by a forecasted trajectory creation method according to one embodiment of the present invention;

Fig. 29 is an explanatory diagram of a forecasted trajectory, involving a waiting time, which places importance on an inactive period;

Fig. 30 is a second example of the forecasted trajectory crated by the forecasted trajectory creation method according to one embodiment of the present invention;

Fig. 31 is a third example of the forecasted trajectory crated by the forecasted trajectory creation method according to one embodiment of the present invention;

Fig. 32 is a fourth example of the forecasted trajectory crated by the forecasted trajectory creation method according to one embodiment of the present invention;

Fig. 33 is a fifth example of the forecasted trajectory crated by the forecasted trajectory creation method according to one embodiment of the present invention;

Fig. 34 is sixth example of the forecasted trajectory crated by the forecasted trajectory creation method according to one embodiment of the present invention;

Fig. 35 is a seventh example of the forecasted trajectory crated by the forecasted trajectory creation method according to one embodiment of the present invention;

Fig. 36 is a processing flow diagram for calculating a forecasted interval value according to one embodiment of the present invention;

Fig. 37 is an explanatory diagram for calculating a forecasted interval value from a forecasted route according to one embodiment of the present invention;

Fig. 38 is an explanatory diagram of a process for calculating a forecasted interval according to one embodiment of the present invention;

Fig. 39 is a diagram of an exemplary comparison of cage operation trajectories before and after employment of one embodiment of the present invention;

Fig. 40 is a conceptual diagram of an example of target route control according to one embodiment of the present invention;

Fig. 41 is an explanatory diagram of how a hall call is allocated to an elevator in accordance with a target route;
Fig. 42 is a general explanatory diagram of a target route creation process according to one embodiment of the present invention;
Fig. 43 is a diagram of exemplary route shapes before and after an adjustment according to one embodiment of the present invention;
Fig. 44 is a functional block diagram of an exemplary target route creation unit according to one embodiment of the present invention;
Fig. 45 is a control functional block diagram of an elevator group management system according to a second embodiment of the present invention;
Fig. 46 is a graph of an example of a weighting coefficient calculation function used by a weighting coefficient calculation unit 5 in Fig. 45;
Fig. 47 is a control functional block diagram of an elevator group management system according to a third embodiment of the present invention;
Fig. 48 is a detailed functional block diagram of an interval evaluation value calculation unit according to one embodiment of the present invention;
Fig. 49 is a diagram showing an example of screen output data displayed in accordance with one embodiment of the present invention;
Fig. 50 is a diagram showing a second example of screen output data displayed in accordance with another embodiment of the present invention;
Fig. 51 is a diagram showing a third example of screen output data displayed in accordance with another embodiment of the present invention;
Fig. 52 is a processing flow diagram of a forecasted trajectory display method according to one embodiment of the present invention; and
Fig. 53 is a processing flow diagram of a forecasted trajectory display method according to another embodiment of the present invention.

DESCRIPTION OF THE INVENTION

[0035] In the following, embodiments of the present invention will be described with reference to the accompanying drawings.

[0036] To begin with, the concept of control underlying an elevator group management system in the present invention will be described with reference to Fig. 1. Figs. 1(a), 1(b), 1(c) are control conceptual diagrams of the elevator group management system according to the present invention. The description will be begun with Fig. 1(a). Fig. 1(a) represents a scenario immediately after a new hall call has been made, where a cage is going to be allocated in response to the hall call. This Fig. 1(a) represents an elevator operation diagram, where the horizontal axis represents the time, and the vertical axis represents floor positions in a building. The time axis represents future time beginning from the current time. In other words, this diagram represents an elevator forecasted operation diagram in the future. The elevator comprises two cages, i.e., a first car and a second car. It can be seen from Fig. 1(a) that the first car is located near the third floor and is moving upward at the current time. The second car is located near the fifth floor and is moving upward. Forecasted trajectories of the respective cages are represented by lines on the diagram. The two forecasted trajectories are close to each other, from which it is understood that the two cages are operated in bunch. Consider that a new hall call is made on the eighth floor for an upward transportation in such a situation.

[0037] Fig. 1(b) represents a forecasted trajectory of each cage when the newly generated hall call is preliminarily allocated to the first car. As seen in the forecasted trajectory of the first car, the first car is stopped on the eighth floor for upward movement in order to service the new hall call. As a result, the subsequent forecasted trajectories of the first car and second car are spaced more from the previous state shown in Fig. 1(a). When this interval between the forecasted trajectories is evaluated using a positional relation evaluation time tref after the lapse of a predetermined time period from the current time, it can be clearly appreciated that the interval has extended in Fig. 1(b), as compared with Fig. 1 (a). A representative example of the positional relationship between the respective cages is the interval, and in the following, the positional relationship evaluation time tref is simply called the "interval evaluation time tref."

[0038] Fig. 1(c) represents a forecasted trajectory of each cage when a newly generated hall call is preliminary assigned to the second car. It can be seen from the forecasted trajectory of the second car that the second car is stopped on the eighth floor for upward movement in order to service the new hall call. As a result, the subsequent forecasted trajectories of the first car and second car are spaced less than the previous state of Fig. 1(a), to end up in a completely bunch operation state.

[0039] From a comparison between the intervals between the respective cages at the interval evaluation time tref in the scenario of Fig. 1(b) where the new hall call is preliminarily allocated to the first car, and in the scenario of Fig. 1(c) where the new hall call is preliminarily allocated to the second car, it can be understood that the allocation to the first car results in an approach to an equidistant state. It can therefore be evaluated that the allocation to the first car is better in order to approach to the equidistance state. Such a sequence of evaluation methods is the concept of group management control according to one embodiment of the present invention. As a result of such control, appropriate intervals can be maintained at all time to reduce an unnecessary long waiting time. For this purpose, it is necessary to find a forecasted trajectory of each elevator for a predetermined time interval from that time point. Fig. 1 illustrates by the length of the horizontal axis in accordance with the necessity, where the length of the predetermined time is set to a time longer than an average periodic time of the elevator at that time point.

[0040] Fig. 2 is a control block diagram of the whole elevator group management system according to one embodiment of the present invention. The operations of N elevator cars 32A, 32B, 32C, ... are controlled by associated elevator car control apparatuses 31A, 31B, 31C, ... and a group management control unit 1 totally controls these car control apparatuses.

[0041] The group management control unit 1 performs the following processes. First, information on a hall call button (41A, 41B) on each floor, and information on each of N elevator car apparatuses 31A, 31B, 31C are stored in an input information storage unit 1. Here, if a new hall call is generated, a waiting time evaluation value calculation unit 3 calculates a forecasted waiting time for each hall call, including previously generated hall calls, using the information in the input information storage unit 1, and calculates a waiting time evaluation value W based on this. An interval evaluation value calculation unit 4 in turn forecasts a positional relationship between the respective elevator cages in the future, as described in connection with Fig. 1, and calculates an interval evaluation value E based on this. A weighting coefficient setting unit 8 sets a weighting coefficient WT corresponding to a situation at a particular time point. A feature in this embodiment lies in a method of setting this weighting coefficient, the detail of which will be described later. A general evaluation value calculation unit 6 calculates a general evaluation value Φ by deriving a weighting sum of the waiting time evaluation time and interval evaluation time from the waiting time evaluation time, interval evaluation time, and weighting coefficient. The general evaluation value Φ is represented, for example, by the following equation:

$$\Phi = W + WT \cdot E \qquad \ldots\ldots (2)$$

[0042] This general evaluation value is calculated for a scenario where each cage is preliminary allocated to a new hall call. An allocated elevator determination unit 7 determines a cage to be allocated which exhibits the highest evaluation in regard to the waiting time and cage interval uniformity.

[0043] Here, a description will be given of the key to the weighting coefficient setting method which is a feature of this embodiment. The setting of the weighting coefficient in accordance with this embodiment is roughly composed of two methods. A first method determines a current traffic flow, repeatedly executes a group management control simulation based on the traffic flow, and finds the most appropriate value for the weighting coefficient through a search. A second method forecasts the number of hall calls which can be possibly generated, and finds a weighting coefficient setting range and an initial value for setting. Particularly, the latter (second method) constitutes the key to this embodiment.

[0044] In the following, the respective methods will be described in a specific manner. First, in the first method, a traffic flow determination unit 20 determines a current traffic flow from information in input information storage unit 2, and a weighting coefficient optimal solution search unit 21 searches for the value of the weighting coefficient most suitable for the traffic flow. Here, the search for the optimal solution for the weighting coefficient is conducted by repeatedly executing the group management control simulation under a traffic flow condition at a particular time. This group management control simulation is executed in a simulation unit 22. The weighting coefficient optimal solution search may be conducted on line or may be conducted off line (for example, during the night). When executed off line, a main traffic flow (hereinafter called the "traffic flow mode") of a building concerned has been previously extracted to executes the group management control simulation off-line for this traffic flow mode.

[0045] Next, in the second method, a hall call count calculation unit 10 calculates the number of times hall calls are generated or an amount related to the number of times hall calls are generated based on input information in the input information storage unit 2. Then, a weighting coefficient initial value calculation unit 12 and a weighting coefficient range calculation unit 11 calculate an initial value for the weighting coefficient and a range (an upper limit value and a lower limit value), respectively, based on the number of times hall calls are generated.

[0046] There are two flows for the calculated initial value for the weighting coefficient: a flow to the weighting coefficient setting unit 8, and a flow to the weighting coefficient optimal solution search unit 21. The initial value sent to the weighting coefficient optimal solution search unit 21 is used as an initial value for a search (initial value when a search is made in regard to the first traffic flow). The initial value sent to the weighting coefficient setting unit 8 is set as a weighting coefficient which is actually used when the weighting coefficient optimal solution search is not converged for a traffic flow which is emerging at a particular time point, or when a traffic flow emerging at a particular time point is completely the first traffic flow.

[0047] Fig. 3 is a control processing flow diagram of the elevator group management system according to the one embodiment of the present invention illustrated in Fig. 2. In the following, the flow will be described with reference to Fig. 3.

[0048] It is first determined whether or not the weighting coefficient optimal solution search should be made (ST001). This is processing performed when the weighting coefficient search is made through an off-line simulation. For example, it is determined whether or not the weighting coefficient optimal solution search should be made based on the state of a load on a processing apparatus such as a microcomputer or a personal computer, and temporal information such as day time or night. When determined that the search should be made, an optimal solution for the weighting coefficient is searched in regard to a previously extracted traffic flow mode (ST002). The search method at this time may involve a search for all values which can be taken by the weighting coefficient (actually, all values which fall under a certain range), a branch limit method, a mountain descending method, a neural net based search, an inheritance algorithm based search, or the like. After the execution of the weighting coefficient optimal solution search (including the case where the search is interrupted halfway without finding an optimal solution), or when the search is not made, input information is inputted from the input information storage unit (2 in Fig. 1) (ST003). After the input information has been acquired, it is checked whether or not a cage allocation process has been invoked (ST004). The processing flow returns to the processing at ST001 when the allocation process is not invoked, and proceeds to the next processing when the allocation process is invoked.

[0049] When the cage allocation process has been invoked, each elevator cage is preliminarily allocated to a hall call (generally, a newly generated hall call) intended for the allocation, and a cage loop process (ST005) is executed for calculating an evaluation value for that case. This involves changing Ka from one to N in order (N designates the number of group managed elevators), where Ka represents a preliminarily allocated cage.

[0050] A forecasted trajectory is first calculated for the preliminary allocated cage of the Ka-th car (ST006). This forecasted trajectory of the preliminary allocated cage corresponds to the forecasted trajectory of the first car in Fig. 1 (b). Next, a forecasted trajectory is calculated for a cage K car (each car which satisfies $K \neq Ka$) other than the preliminarily allocated cage (ST007). This trajectory corresponds to the forecasted trajectory of the second car in Fig. 1(b). Then, the interval evaluation time tref is calculated (ST008) (an example of tref is shown in Fig. 1(b)), and a forecasted interval value Bm (m=1, 2, ..., N) is calculated for each cage at the time point tref (ST009). While a method of calculating the forecasted interval value will be described later, the forecasted interval can be calculated from a temporal distance or a spatial distance between respective positions based on the forecasted position of each cage resulting from tref. Once the forecasted interval value has been calculated for each cage, an interval evaluation value is calculated on the basis of the forecasted interval values (ST010). This is represented by E(Ka) for the interval evaluation value when a Ka-th car is preliminarily allocated. By repeating the preliminarily allocated cage loop process, E(Ka=1), E(Ka=2), ... are calculated one by one.

[0051] As the interval evaluation value has been calculated, next calculated is a waiting time evaluation value W(Ka) when the Ka-th car is preliminarily allocated (ST011). A method of determining the waiting time evaluation value may involve using a waiting time for a hall call, for setting the waiting time evaluation value, when the Ka-th car is allocated to the hall call, or setting the waiting time evaluation value to a maximum waiting time within hall calls served by the Ka-th car. Further alternative methods may include a method of setting the waiting time evaluation value to an average waiting time of hall calls served by all cars including the Ka-th car, a method of setting the waiting time evaluation value to a square sum of waiting times associated with hall calls served by all the cars including the Ka-th car, and the like.

[0052] After the interval evaluation value E(Ka) and waiting time evaluation value W(Ka) have been calculated, the weighting coefficient WT is calculated (ST012). A weighting coefficient calculation method has been generally described in connection with Fig. 2, and will be again described later in greater detail.

[0053] Next, a general evaluation value, which serves as an index for determining the allocation, is calculated on the basis of the interval evaluation value, waiting time evaluation value, and weighting coefficient (ST013). The general evaluation value is represented by the following equation:

$$\Phi(Ka) = FT(W(Ka),\ E(Ka),\ WT) \qquad \text{....} \ (3)$$

where FT represents a function. More specifically, the general evaluation value is represented by an equation of a linear sum, for example, like the following equation:

$$\Phi(Ka) = W(Ka) + WT \cdot E(Ka) \qquad \text{....} \ (4)$$

[0054] A sequence of processing from ST005 to ST013 described above is executed until the preliminary cage allocation loop is completed (until the preliminarily allocation process is executed for all the cages) (ST014). When not yet completed, a preliminarily allocated cage is updated to the next car (ST015), and the process is executed from ST006 for the updated preliminarily allocated cage of the Ka-th car. When the preliminary cage allocation loop has been completed, the general evaluation values $\Phi(Ka=1)$, $\Phi(Ka=2)$, ..., $\Phi(Ka=N)$ are compared to determine an allocated elevator for the cage which has the best evaluation value (ST016). After the determination of the allocation, the flow returns to the first processing ST001 to repeatedly execute the process described above.

[0055] Next, a weighting coefficient setting method according to the present invention will be described with reference to Fig. 4.

[0056] Fig. 4 is a graph for describing a weighting coefficient setting method according to one embodiment of the present invention, where the horizontal axis represents the number of hall calls generated per round of an elevator, and the vertical axis represents the weighting coefficient. Here, the number of hall calls generated per round of an elevator represents an average of the number of hall calls which can be generated while each of elevators managed in group makes a round once (for example, from the lowest floor in the upward direction to the lowest floor in the downward direction). A larger number of hall calls are generated per round during a traffic jam, while a smaller number of hall calls are generated in an inactive period.

[0057] While the graph of Fig. 4 has lines drawn to represent input/output characteristics of three functions which includes a line F01 which represents a function for determining an appropriate initial value WT_0 for the weighting coefficient; a line F02 which represents a function for determining an appropriate upper limit value WT_{upper} limit for the weighting coefficient; and a line F03 which represents a function for determining an appropriate lower limit value WTlower limit for the weighting coefficient. The function (line F01) for determining an appropriate initial value for the weighting coefficient is used by the weighting coefficient initial value calculation unit 12 in Fig. 2, while the function (line F02) for determining an appropriate upper limit value for the weighting coefficient and the function (line F03) for determining an appropriate lower limit value are used by the weighting coefficient range calculation unit 11 in Fig. 2.

[0058] The three functions for determining the weighting coefficient have the following four major features.

1) The ability to immediately find an initial value, an upper limit value, and a lower limit value for an appropriate weighting coefficient from the number of generated hall calls.
2) The ability to continuously determine the value for the weighting coefficient, which is the output, in response to continuous variations in the number of hall calls generated per round, which is an input variable.
3) The input variable is a scalar value (single variable).
4) The input variable can continuously take real numbers.

[0059] In other words, the value of the weight is calculated on the basis of functions which continuously vary output values in response to variations in the input. Stated another way, the value of the weight is calculated on the basis of functions which receive real numbers and continuously vary the value. The advantages resulting from these features will be described in connection with Fig. 8 in comparison with other setting methods (Figs. 6 and 7).

[0060] As shown in the graph of Fig. 4, when the number of hall calls generated per round is, for example, NA, the initial value WT_0 for the weighting coefficient is equal to $F_0(NA)$, and the upper limit value $WT_{upper\ limit}$ and lower limit value $WT_{lower\ limit}$ are equal to $F_{upper\ limit}$ (NA) and $F_{lower\ limit}$ (NA), respectively. Irrespective of how NA varies due to variations in traffic demand, WT_0, $WT_{upper\ limit}$, and $WT_{lower\ limit}$ can be immediately found. This constitutes a major characteristic. Also, each function presents the value of zero on the vertical axis at all times for smaller values on the horizontal axis from a value at which the value of zero on the vertical axis intersects the horizontal axis.

[0061] While the graph of Fig. 4 shows an example in which the horizontal axis represents the number of hall calls generated per round, similar effects can be provided as well with a value based on the number of generated hall calls (for example, the number of hall calls generated for a predetermined time, or the like), not limited to the shown example. Further, similar effects can be provided as well using an index of a scalar value related to traffic demand, not limited to the number of generated hall calls. For example, similar effects can be provided as well with a value based on the number of users, a value based on the total value of the number of generated hall calls and the number of generated cage calls, an average waiting time, and the like.

[0062] The following description will be made on the reason for which an appropriate weighting coefficient can be found by the functions as shown in Fig. 4 by entering the number of hall calls generated per round of the elevator. The interval evaluation value (previously described in connection with Fig. 2) is an index which evaluates a temporal interval between cages, and this temporal interval between cages corresponds to a maximum waiting time for a hall call possibly generated in the future. Therefore, the importance of the interval evaluation value is strongly related to the number of hall calls possibly generated in the future. For example, as a larger number of hall calls are generated in the future, the interval should be made as temporally even as possible, so that the interval evaluation value should be forced to more strongly act. Here, it is assumed that the number of hall calls possibly generated in the future has a high correlation with the number of hall calls generated per round at a particular time point or a time point subsequent thereto. Therefore, a certain relationship is established between the number of hall calls generated per round and an appropriate weighting efficient value, and by representing this as functions as shown in Fig. 4, an appropriate weighting coefficient (actually, an appropriate initial value and range) can be determined from the number of hall calls generated per round of the elevator.

[0063] Fig. 5 is a conceptual diagram of an optimal solution search method for the weighting coefficient according to one embodiment of the present invention. In Fig. 5, the horizontal axis represents the value of the weighting coefficient, and the vertical axis represents an average waiting time resulting from the execution of the group management control simulation. For each value of the weighting coefficient WT on the horizontal axis, a curve 901 represents the characteristic of the average waiting time when the group management control of the present invention illustrated in Fig. 2 is simulated. In the event of an optimal solution search for the weighting coefficient through repetitions of the simulation, or in the event of a weighting coefficient optimal solution search through the simulation shown in Fig. 2 (components designated by reference numerals 20, 21, 22 in Fig. 2), an arbitrary location on this characteristic curve 901 provides an initial value (starting point). As such, a certain extent of time is required until an optimal solution is reached. Particularly, for a traffic flow which appears for the first time, the performance demonstrated in an initial stage (average waiting time) can largely vary depending on where the initial value (starting point) is determined. Also, in a transient period of the search, the search can be made in a wrong direction, on the contrary, due to an insufficient number of times of the simulation. Accordingly, in this embodiment, an appropriate initial value 902 for the weighting coefficient can be immediately determined from the number of generated hall calls at a particular time by using the continuous functions shown in Fig. 4, and an appropriate upper limit value 903 and lower limit value 904 can also be immediately determined in a similar manner. These actions are implemented by functional elements designated by reference numerals 10, 11, 12, and 8 in Fig. 2. Further, after determining the appropriate initial value and range, the optimal solution search is made within the range based on the initial value, the optimal solution can be promptly and stably found.

[0064] In this connection, since the initial value WT_0, upper limit value WT_{upper} limit, and lower limit value WT_{lower} limit are determined in correspondence to the number of generated hall calls, these values are variably adjusted in accordance with a traffic demand state at a particular time point.

[0065] In the following, a description will be given of the superiority of the method of setting the weighting coefficient using the function of the number of generated hall calls as shown in Fig. 4, with a comparison with a method of setting the weighting coefficient by entering a traffic flow and repeating a simulation. However, prior to the description, a traffic flow will be outlined with reference to Fig. 6, and an example of a weighting coefficient setting method will be described for the case where the traffic flow is entered, with reference to Fig. 7.

[0066] Fig. 6 is a diagram showing an example of a weighting approach for a traffic flow in a building having six floors. The leftmost table in Fig. 6 shows an OD (Origin-Destination) matrix representative of a traffic flow. This OD matrix includes the origin represented in a column direction (horizontal direction), and the destination in a row direction (vertical direction), where each element in the matrix indicates the number of passengers corresponding to elements of the row and column to which the element belong. For example, the number of passengers who take the elevator on the second floor and get off the elevator at the fifth floor is found to be three from the table. Also, the OD matrix has six rows and six columns because the building has six floors. The traffic flow refers to an integrated whole which represents the number of passengers on each floor, and can be represented by such an OD matrix (the OD matrix is actually used for traffic analysis intended for roads).

[0067] The second table (OD matrix) from the left in Fig. 6 represents the number of passengers in each element in the form of variables tr1, tr2, ..., and presents a 30-adic vector (tr1, tr2, tr3, ..., tr30). When one attempts to find the weighting coefficient using such a traffic flow as it is, a 30-adic function must be found as shown in the following equation:

$$WT = F(tr1,\ tr2,\ tr3,\ \ldots,\ tr30) \qquad \ldots.\ (5)$$

[0068] This is a very complicated function, and it can be said that this function cannot be actually analyzed. As such, instead of handling the 30-adic vector space as it is, consider that it is divided into several main fragmental spaces. In doing so, a finite number of fragmental spaces can be handled, which facilitates the handling. These fragmental spaces correspond to traffic flow modes. In the following, this will be described with reference to Fig. 7.

[0069] Fig. 7 is an explanatory diagram of an example of the weighting coefficient setting method when a traffic flow is handled in an input. A building having two floors is given herein as an example for simplifying the description. For a building having two floor, an associated OD matrix is simply a 2x2 matrix as shown in Fig. 7(a), and the traffic flow is represented by a two-dimensional vector (tr1, tr2). Here, the traffic flow is represented by a two-dimensional graph as shown in Fig. 7(c), where tr1 and tr2 are indicated on the horizontal axis and vertical axis, respectively. A point on the graph of Fig. 7(c) represents a traffic flow. For example, a traffic flow having large tr1 (large upward movements from the ground floor to the first floor) and small tr2 (small upward movements from the first floor to the ground floor), such as office-going time, is represented by the point as shown in the graph. Even for a simple traffic flow in a building having two floors as shown in Fig. 7(c), a two-dimensional plane of (tr1, tr2) is involved, and a complicated function must be handled if one attempts to handle this with a function having two-dimensional variables as represented by Equation (6):

$$WT = F(tr1,\ tr2) \qquad .... (6)$$

[0070] As such, representative traffic flows are collected into a single mass for the two-dimensional plane of tr1, tr2 in Fig. 7(c). Fig. 7(d) shows an example, where the two-dimensional plane of tr1, tr2 is divided into four areas. Then, representative traffic flow vectors V1, V2, V3, V4 are defined for the four areas, respectively. V1, V2, V3, V4 denote traffic flows representative of the whole, and correspond to the aforementioned traffic flow modes. In this connection, the plane is not divided in a single way, but a variety of divisions are contemplated in accordance with the characteristics of a particular traffic demand in each building.

[0071] With the representation in traffic flow modes, a suitable weighting coefficient may be defined for each traffic mode flow, as shown in Fig. 7(e). This optimal solution can be found by repeatedly executing the simulation of the group management control for the traffic flow modes while changing the weighting coefficients. For example, in a scenario of Fig. 7(e), by repeatedly executing the simulation for a traffic flow mode V3 while changing the weighting coefficients, an optimal weighting coefficient for reducing an average waiting time can be determined to be WT=5.6. As an optimal weighting coefficient is determined for each traffic flow mode through the simulation in a similar manner, a resulting table shows the relationship between the traffic flow modes and weighting coefficient, as shown in Fig. 7(f).

[0072] In summarizing the foregoing, when the traffic flow is handled in the input, a multi-dimensional vector must be handled as it is, if any technique is not employed therefor, and complicated processes are involved, so that the multi-dimensional vector is represented by principal traffic flow modes, such that a weighting coefficient is set to each of the modes by repeatedly executing the simulation.

[0073] Fig. 8 is a diagram showing a comparison of one embodiment of the present invention with a conventional weighting coefficient setting method, where comparisons are made according to several items for summarization. This table compares, for example, a setting method disclosed in JP-A-1-226676 with the setting method of this embodiment with respect to five items. In the following, comparisons are made from the first item. First, for input variables, the prior art uses a traffic flow vector or traffic flow modes which are main components extracted from the traffic flow vector. In contrast, this embodiment uses the number of generated hall calls. The nature of the respective input variables is a multi-dimensional vector, for example, a vector such as tr1, tr2, tr3, ... in the prior art, but is a single variable, in other words, a scalar value in this embodiment. Also, in regard to how to determine a weighting coefficient which is an output value, the prior art selects a weighting coefficient through a search by repeatedly executing a simulation of group management control, whereas this embodiment sets a weighting coefficient using continuous functions as shown in Fig. 4. Accordingly, the prior art is characterized by a certain time required until the selection of a value, whereas this embodiment is characterized by the ability to instantaneously determine a weighting coefficient.
This characteristic makes the method of this embodiment more advantageous over the prior art in that an appropriate weighting coefficient (more precisely, an appropriate initial value for the weighting coefficient) can be immediately set for a variety of changes in traffic flow to stably exert the control performance.

[0074] Fig. 9 is a processing flow diagram which summarizes the weighting coefficient setting method according to one embodiment of the present invention so far described. This sequence of processing is executed in the hall call count calculation unit 10, weighting coefficient range calculation unit 11, weighting coefficient initial value calculation unit 12, traffic flow determination unit 20, weighting coefficient optimal solution search unit 21, simulation unit 22, and weighting coefficient setting unit 8. The sequence of processing will be described below in order. First, input information is entered (ST101), and the number NA of hall calls generated per round is calculated on the basis of the input information (ST102). This value can be calculated, for example in the following manner. NA is calculated by the following equation:

$$NA = NH/\{(NR/2)+1\} \qquad .... (7)$$

where NH represents the total number of hall calls generated for a predetermined time which is set to a longer time than an average round time of the elevator at a particular time point, and NR represents the total number of direction inversions.

[0075] The demoninator in Equation (7) corresponds to the total number of rounds of all elevators for a predetermined time.

[0076] As the number NA of hall calls generated per round has been calculated, an initial value WT_0 for the weighting coefficient is calculated by the function $WT_0=F_0(NA)$ based on the number NA (ST103). Then, a traffic flow mode prevailing at that time is determined (ST104), and it is determined whether or not a weighting coefficient optimal solution search has been previously made for that traffic flow mode (ST105). When the optimal solution search has been made to find the value of the weighting coefficient which provides a better result than the initial value, the weighting coefficient is set to this value (optimal solution at that time) (ST106). When the optimal solution search has not been made, or when a value has not been found for the weighting coefficient which provides a better result than the initial value, the value of the weighting coefficient is set to the initial value WT_0 (ST107).

[0077] Since the weighting coefficient is set through the processing flow as illustrated in Fig. 9, an appropriate weighting coefficient value can be immediately set based on the initial value WT_0 determined by the function even for a traffic flow which appears for the first time in a building of interest. Also, even in an initial stage of operation in a building, an appropriate weighting coefficient value can be immediately set based on the initial value WT_0 determined by the function. Further, an appropriate weighting coefficient value can be immediately set based on the initial value WT_0 determined by the function even when the optimal solution search has not been converged and an appropriate solution has not been found.

[0078] Fig. 10 is a processing flow diagram which summarizes the weighting coefficient optimal solution search method according to one embodiment of the present invention. This sequence of processing is performed by the hall call count calculation unit 10, weighting coefficient range calculation unit 11, weighting coefficient initial value calculation unit 12, traffic flow determination unit 20, weighting coefficient optimal solution search unit 21, and simulation unit 22. The sequence of processing will be described below in order. First, traffic flow mode data is entered (ST201), and it is determined whether or not the optimal solution search process has been executed for the traffic flow mode (ST202). When the process has been executed, an initial value for the search is set to an optimal value found in the previous search (ST208). When the search process has not been executed, the number NA of hall calls generated per round in that traffic flow mode is calculated (ST203), and an initial value WT_0 for the weighting coefficient is calculated on the basis of the value NA (ST204), an upper limit value $WT_{\text{upper limit}}$ it is calculated (ST205), and a lower limit value $WT_{\text{lower limit}}$ is calculated (ST206). Then, the initial value for the search is set to WT_0.

[0079] The simulation of the group management control for the determined traffic flow mode is executed for the set initial value, and the simulation is repeated while changing the initial value to execute the optimal solution search (ST209). After the execution of this optimal solution search (or halfway in the search), it is determined whether or not the resulting optimal weighting coefficient falls within a range between the upper limit value $WT_{\text{upper limit}}$ and lower limit value $WT_{\text{lower limit}}$ (ST210). When the optimal weighting coefficient falls within the range, this weighting coefficient value provides the optimal solution. When not within the range, the weighting coefficient value is set to the upper limit value $WT_{\text{upper limit}}$ or the lower limit value $WT_{\text{lower limit}}$ or an optimal solution found in the previous search (ST211).

[0080] Since the weighting coefficient optimal solution search is made through the processing flow as illustrated in Fig. 10, the initial value for the search can be determined to be an appropriate value using the function of the number of generated hall calls even for a traffic flow which appears for the first time. As a result, the optimal solution search can be made in a more efficient manner. Also, since the range of the search is determined to be a proper range using the function of the number of generated hall calls, the optimal solution search can be more efficiently made without searching inappropriate regions even in an initial stage of the search or in a transient state. It should be noted that these advantages have been described in Fig. 5 by showing a search concept.

[0081] Fig. 11 illustrates in greater detail the input information storage unit 2 shown in Fig. 2. The input information storage unit 2 stores the following data. First, the data includes building facility data 201, group management elevator facility data 202, and current group management elevator state data 203.

Next, the data includes group management elevator state data statistics 204, state data 205 on each hall in a building at a current time point, a building traffic flow data 206, and temporal information data 207. The building facility data 201 stores such data as the number of floors in a building, floor height of each floor, floors intended for the service of the group management, and the like. The group management elevator facility data 202 stores such data as the number of elevators managed in group, a rated speed of each elevator car, a number limit of a cage, a door open/close speed, a standard door open time, and the like. The current group management elevator state data 203 includes such data as the positions of cages, information on the direction, information on the speed, information on a load within a cage, allocated hall call information, cage call information, information on stop floors, hall call continuation time information on each hall call, a round time of each cage, and the like. The group management elevator state data statistics 204 store such data as the number of hall calls generated for a predetermined time , the number of generated cage calls, the number of users, an average hall call continuation time, the number of times of direction inversions, an average load, an average round time, and the like. The state data 205 on each hall in a building at a current time point stores such data as information on hall call buttons 41A, 41B, information on cameras 51A, 51B of hall waiting customers, and the like. The building traffic flow data 206 stores building traffic flow data such as that shown by the OD matrix in Fig. 6. The temporal information data 207 stores calendar information such as information by a clock, year, month, day, day of the week, holidays, days on which special events take place, and the like. The input information storage unit 2 stores all the data listed above. In this connection, the input information storage unit 2 does not necessarily aggregate these data, but the data may be distributively stored. In this event, the input information storage unit 2 may be regarded as a virtual aggregate of these data.

[0082] The foregoing description has been so far made on the method of setting the weighting coefficient. Next, a method of calculating a cage interval evaluation value will be described in detail with reference to Fig. 12. The key to the method of calculating the cage interval evaluation value is a method of setting a time for evaluating an interval.

[0083] Fig. 12 illustrates in detail the configuration of the cage interval evaluation value calculation unit 4 shown in Fig. 2. First, the cage interval evaluation value calculation unit 4 comprises a forecasted trajectory calculation unit 401 for calculating a forecasted trajectory of each cage in the future, and a forecasted cage interval calculation unit 402 for calculating a cage interval after a predetermined time (interval evaluation time tref, later described) based on the forecasted trajectory. Next, the cage interval evaluation value calculation unit 4 comprises cage interval evaluation value calculation unit 403 for calculating the cage interval evaluation value, and a furthest call search unit 404 for finding the temporally furthest call (calls including hall calls and cage calls) through a search. The cage interval evaluation value calculation unit 4 further comprises an interval evaluation time setting unit 405 for finding the interval evaluation time tref based on a forecasted arrival time for the furthest call, i.e., a maximum forecasted arrival time.

[0084] In the following, the actions of the respective components in the interval evaluation value calculation unit 4 of Fig. 12 sill be described with reference to Fig. 1 which has been previously described. In Fig. 1(b), the forecasted trajectory calculation unit 401 in Fig. 12 calculates forecasted trajectories (solid trajectories from a current time point in the future direction in the diagram) of the first car and second car. The interval evaluation time setting unit 405 sets the interval evaluation time tref in Fig. 1(b). The forecasted cage interval calculation unit 402 in Fig. 12 finds a forecasted position at the interval evaluation time from the forecasted trajectory of each cage, i.e., the positions of the first car and second car drawn on the interval evaluation time in Fig. 1(b), and finds a temporal interval or a spatial interval of each cage from this forecasted position. The cage interval evaluation value calculation unit 403 calculates an evaluation value for evaluating a cage interval uniformity from the cage interval value. For example, when Fig. 1(b) is compared with Fig. 1(c), Fig. 1(b) presents a higher cage interval uniformity, and the cage interval evaluation value calculation unit 403 evaluates the uniformity.

[0085] One of important factors in calculating the cage interval evaluation value is a method of setting a time at which the cage interval is estimated. This setting method also constitutes a feature of this embodiment, so that the method of setting an interval evaluation time will be described below with reference to Figs. 13 to 16.

[0086] Fig. 13 is a processing flow diagram for setting the interval evaluation time tref. This sequence of processing is executed in the furthest call search unit 404 and interval evaluation time setting unit 405 in Fig. 12. First, a cage loop process is executed for searching each cage in order (ST501). Here, a cage intended for the search is a K-th car (K=1, 2, ..., N). The initial value for K is one. First, all hall calls allocated to the K-th car are searched to select a maximum forecasted arrival time ART_H(K) (ST502). Next, all cage calls served by the K-th car are searched to select a maximum forecasted arrival time ART_C(K) (ST503). Subsequently, ART_H(K) is compared with ART_C(K) to employ the larger one for a forecasted arrival time ART_MAX(K) of the furthest call associated with the K-th car (ST504). This forecasted arrival time is represented by the following equation:

$$\mathrm{ART\_MAX}(K) = \mathrm{MAX}\{\mathrm{ART\_H}(K),\ \mathrm{ART\_C}(K)\} \quad .... \quad (8)$$

[0087] It is determined whether or not the foregoing processing has been performed for all elevator cars by checking whether or not K is equal to N (ST505). When not equal, the value of K is incremented by one (ST506), followed by a return to the previous processing (ST502). When the forecasted arrival times of the furthest calls have been calculated for all the elevator cars, a maximum value of the forecasted arrival times of the furthest calls associated with all the elevator cars is set to the interval evaluation time tref (ST507). The interval evaluation time tref is represented by the following equation:

$$\mathrm{tref} = \mathrm{MAX}\{\mathrm{ART\_MAX}(K)\} \qquad .... \quad (9)$$

[0088] In this way, a call which causes the maximum forecasted arrival time (the furthest call for all cars) is selected for hall calls and cage calls served by all the elevators at that time point, and the forecasted arrival time for the call is defined to be the interval evaluation time. Advantages provided by determining the interval evaluation time in this way will be described in connection with Fig. 14.

[0089] The value of the forecasted arrival time of the furthest call for all cars varies from one allocation to another because new calls are generated over time (for example, in course of approximately 20 seconds) to cause change in the value. As a result, the interval evaluation time also varies in value each time the allocation is processed. This shows that the situation of previously generated calls (situation of the number of currently generated calls, and the like) varies from time to time, the interval evaluation time is responsively adjusted as appropriate.

[0090] Fig. 14 shows the idea for the setting of the estimated interval time. The graph of Fig. 14(a) represents a time axis on the horizontal axis on which a current time is placed at the origin, and the floor position on the vertical axis. In the graph of Fig. 14(a), two trajectories drawn in solid line represents forecasted trajectories of the first car and second car, respectively. F10 represents the forecasted trajectory of the first car, while F11 represents the forecasted trajectory of the second car. The key to the interval evaluation time setting lies in at which time to evaluate the interval between the two forecasted trajectories, where the interval evaluation time has the nature as described below.

[0091] First, when the interval evaluation time is set in a region temporally close to the current time, a problem is the inability to take into consideration the influence of calls (hall calls or cage calls) previously accepted and to be served at later times. This influence is particularly grave when passing occurs in the middle. For example, assuming in the graph of Fig. 14(a) that the interval evaluation time is set at a time indicated by reference numeral F12, it is determined that the subsequent second car approaches to the preceding first car to result in a bunch state. Thus, if an evaluation was made with the cage interval at this time (time F12), good control would involve advancing the first car (allocation is restrained), and delaying the second car (allocation is promoted). However, it can be seen from the forecasted trajectories that the second car subsequently passes the first car, so that if the second car is delayed, the bunch state will remain longer, on the contrary. In this way, when the interval evaluation time is set in a region close to the current time point, a larger influence is exerted due to a failure in taking into consideration those calls which have been previously served by each elevator.

[0092] Next, assuming that the interval evaluation time is set in a region temporally far away from the current time point, this scenario, which may come out in the future, is highly susceptible to new hall calls and cage calls which can be generated at subsequent times, so that the forecasted trajectories can largely change. For example, supposing in Fig. 14(a) that the interval evaluation time is set at a time indicated by reference numeral F13, new hall calls and cage calls are likely to be generated by this time, possibly resulting in large uncertainty of the cage interval and large variations in value in this scenario.

[0093] Fig. 14(b) is a graph showing the characteristic of the interval evaluation time described above. In the graph of Fig. 14(b), the horizontal axis represents the interval evaluation time, and the vertical axis represents a forecast accuracy when the cage interval is estimated by a corresponding interval evaluation time. In a region where the interval evaluation time is close to zero (corresponding to the current position), the forecast accuracy for the cage interval is low, and the forecast accuracy increases as the value of the interval evaluation time becomes larger from there. Then, the forecast accuracy reaches a maximum at a certain value, and subsequently falls more as the value becomes larger. The location at which the forecast accuracy reaches the maximum is thought to be near the previously mentioned forecasted arrival time of the furthest call for all the cars. This is because all hall calls and cage calls which have previously been generated are included until the forecasted arrival time for the furthest call so that all of them can be taken into consideration. Since there is no call which has been previously generated at a time prior to this time, no reliable information is available so that the forecast accuracy is simply lower.

[0094] Therefore, by setting the interval estimation time at or near the forecasted arrival time of the furthest call for all cars, the cage interval evaluation can be made with a high accuracy. As a result, the allocation can be carried out to more reliably approach to an equidistance state, thus restraining a long waiting time.

[0095] Fig. 15 is a functional block diagram of a second embodiment of the cage interval evaluation value calculation unit different from Fig. 12. In Fig. 15, components identical to those shown in Fig. 12 are designated the same reference numerals, and a description thereon is omitted. Fig. 15 differs from Fig. 12 in that the interval evaluation time is set by a traffic flow mode which is prevailing at a particular time point. Specifically, a traffic flow mode determination unit 406 determines a traffic flow mode which is prevailing at a particular time point as a representative traffic flow vector of traffic flow vectors which have previously prevailed in the building in the past. Then, an interval evaluation time suitable for the traffic flow mode is referenced in an interval evaluation time database 407 for the traffic flow mode to set a value therefor. Here, the interval evaluation time database 407 for the traffic flow mode is a database which arranges previously extracted traffic flow mode of the building and interval evaluation times corresponding thereto in a tabular form. By using this, if the traffic flow mode is determined, the interval evaluation time corresponding thereto can be set by referencing the table.

[0096] Since the traffic flow is related to calls, an appropriate interval evaluation time can be determined as well using the traffic flow mode instead of the forecasted arrival time of the furthest call, and similar advantages can be expected.

[0097] In this connection, a time interval at which the interval evaluation time is set is substantially equal to a time constant of a traffic flow change.

[0098] Fig. 16 is a functional block diagram of a third embodiment of the cage interval evaluation value calculation unit different from Fig. 12. In Fig. 16, components shown in Fig. 12 are designated the same reference numerals, and a description thereon is omitted. Fig. 16 differs from Fig. 12 in that the interval evaluation time is determined on the basis of an average round time at a particular time point. Specifically, an average round time calculation unit 408 calculates an average round time T for all elevators at a particular time point based on input information (entered from input information storage unit 2 in Fig. 1). Based on the average round time T, an interval evaluation time setting unit 405 determines the interval evaluation time tref according to the following equation:

$$tref = F(T) \qquad \ldots. \ (10)$$

where F(T) represents a function of T. Equation (10) is represented, for example, as follows:

$$tref = \alpha \cdot T \qquad \ldots. \ (11)$$

where α represents a constant.

[0099] Similar to the traffic flow, the average round time is also related to calls, so that an appropriate interval evaluation time can be determined as well using the average round time instead of the forecasted arrival time of the furthest call, and similar advantages can be expected.

[0100] As is the case with the aforementioned method of setting the interval evaluation time, an important key for setting the interval evaluation value is a method of creating a forecasted trajectory. The creation of the forecasted trajectory is performed in a forecasted trajectory calculation unit 401 in Fig. 12, Fig. 15 or Fig. 16, or in a forecasted route creation unit 411 in Fig. 17.

[0101] Fig. 17 is a functional block diagram of a fourth embodiment for the cage interval evaluation value calculation unit 4 which substitutes for Fig. 12. While a representation with a forecasted route is used herein, this forecasted route refers to the same as the forecasted trajectory which has been so far described. Fig. 17 will be described later in greater detail. In the following, the method of creating a forecasted trajectory, which is a key of this embodiment, will be described with reference to Fig. 18.

[0102] Fig. 18 illustrates a general processing flow of a forecasted trajectory creation method. In the following, the flow will be described. First, a variable K indicative of a number of an elevator car is set to one (FA01). Next, it is determined whether or not the K-th car is intended for the group management (FA08). Since elevator cars which are separated from the group management for reasons such as a dedicated operation are operated independently of the remaining elevators which are managed in group, such elevators are removed from those intended for the creation of forecasted trajectory through such processing. Next, it is determined whether or not the K-th car has a direction (FA02). Here, the determination as to whether or not the K-th car has a direction is, if in a different expression, equivalent to a determination made as to whether or not the K-th car is servicing a hall call or a cage call. Accordingly, when the K-th car is servicing a hall call or a cage call (when the K-th car has a direction), the processing flow proceeds to a plural round forecasted arrival time table creation process (FA03). When the K-th car is not servicing either a hall call or a cage call (when the K-th car does not have a direction), the processing flow proceeds to non-direction forecasted trajectory table creation process (FA05).

[0103] In the plural round forecasted arrival time table creation process (FA03), a forecasted arrival time table is created for a plurality of rounds, for example, three or more rounds. In the following, the forecasted arrival time tables for plural rounds are represented by a variable tar_table(i, j, c, K), where i indicates a floor, j indicates a direction, c indicates the number of rounds, and K indicates the name of a car. The creation of the forecasted arrival time tables for plural rounds will be described later in greater details in connection with Fig. 33. Once the forecasted arrival time tables have been created for plural rounds, a forecasted trajectory table is created for an elevator car having a direction, based on this table. The forecasted trajectory table for an elevator car having a direction is represented by two variables ir(t, K) and jr(t, K). Ir(t, K) represents a cage position of the K-th car t seconds after a current time point, and jr(t, K) represents a cage direction of the K-th car t seconds from the current time point. The creation of the forecasted trajectory table for the elevator cage having a direction will be described later in greater detail in connection with Figs. 25 and 26.

[0104] When the K-th car has no direction at the processing FA02, a forecasted trajectory table is created for the car having no direction (FA05). Likewise, in this event, the forecasted trajectory table is represented by the two variables ir (t, K) and jr(t, K). The creation of the forecasted trajectory table for the elevator cage having no direction will be described later in greater detail in connection with Fig. 27.

[0105] After the forecasted trajectory table has been created for the K-th car when it has a direction or when it has no direction, K is incremented by one (FA06), and the processing flow returns to processing FA08 to repeat the foregoing processing for a new K-th car. This is executed for all cars intended for the group management (FA07).

[0106] There are two major features in the creation of the forecasted trajectory according to this embodiment: 1) the forecasted arrival time table is created for a plurality of rounds; and 2) the forecasted trajectory is created individually for a car which has a direction and a car which has no direction. For example, in regard to 1), the creation of a forecasted arrival time differs in accordance with the number of rounds (described later in greater detail). In regard to 2), on the other hand, a trajectory of a cage having a direction (trajectory FJ03 in Fig. 30) and a trajectory for a cage having no direction (trajectory FJ02 in Fig. 30) are created in different shapes, respectively, as shown in Fig. 30 (described later in greater detail). As a result, highly accurate forecasted trajectories can be created in consideration of the state of each car at a particular time point, and the state of traffic demand.

[0107] Fig. 19 is a processing flow diagram for creating the forecasted arrival time tables for plural rounds according to one embodiment of the present invention. As previously described, the forecasted arrival time table is represented by the variable tar_table(i, j, c, K). Details are shown in Fig. 21, later described, which illustrates the creation of exemplary forecasted arrival time tables for plural rounds, showing a forecasted arrival time table FG02 for the first round, a forecasted arrival time table FG03 for the second round, and a forecasted arrival time table FG04 for the third round. Such forecasted arrival time tables are created through the flow chart of Fig. 19.

[0108] First, initial values are set for a forecasted arrival time tar, variable i indicative of the floor position of a K-th car, and a variable j indicative of the direction of the K-th car (FB01). Specifically, tar is set to zero; i to a current cage position of the K-th car; and j to a current cage direction of the K-th car. Next, a variable c indictive of the number of rounds is set to one (FB02). This means that the forecasted arrival time table is created from the first round. Next, a variable n indicative of number of scans when each floor is scanned in order is reset to zero. This variable n is incremented one by one (FB05), such that the process is repeated in loop until n exceeds (n_{max}-1) (FB06). Here, n_{max} indicates total floor elements passed by the K-th car, and is represented by the following equation:

$$n_{max} = \text{Highest Floor in Service Zone of K-th Car - Lowest Floor + 1} \qquad .... (12)$$

[0109] The meaning represented by the value of 2(n_{max}-1) will be described in connection with the leftmost table FG01 in Fig. 22. The leftmost table in Fig. 22 indicates the floor in the row direction, and the upward direction and downward direction in the column direction, where a display method is such an elevator is represented by a ring which makes a round. In this table, there are six floors, but the upward direction on the fifth floor, which is the highest floor, and the downward direction on the ground floor, which is the lowest floor, are omitted because they are substantially meaningless. As a result, the number of effective floors is calculated to be 34 (6x6-2=34). This matches the value derived from 2(n_{max}-1) when n_{max}=6. Stated another way, n indicates a floor to be scanned when the floors are scanned on a floor-by-floor basis on the assumption that one round of the elevator complies with the leftmost table of Fig. 22, where 2(n_{max}- 1) indicates the number of all floors which are scanned per round.

[0110] Forecasted arrival time tables tar_table (i, j, c, K) for plural rounds are calculated for each n (FB04). This is executed in a forecasted arrival time table calculation routine, later described (described later in connection with Fig. 20). As described above, this process is executed 2(n_{max}- 1) times (FB06), followed by the calculation for the next round, so that the variable c indicative of the number of rounds is incremented by one. In this way, a forecasted arrival time table tar_table (i, j, c=1, K) for c=1 (first round), and a forecasted arrival time table tar-Table (i, j, c=2, K) for c=2 (second round) are calculated. Further, a forecasted arrival time table tar_ table (i, j, c=3, K) for c=3 (third round) is c alculated, and the process is repeated until a forecasted arrival time on the final arrival floor in each round exceeds t_{max} (FB08).

[0111] In the sequence of processing described above, the forecasted arrival time tables for plural rounds can be created, as shown in Fig. 22. In the following, the forecasted arrival time table calculation routine (FB04 in Fig. 19) will be described in greater detail with reference to Fig. 20.

[0112] Fig. 20 illustrates a processing flow diagram of the forecasted arrival time table calculation routine (FB04 in Fig. 19). First, a rough flow of processing will be verbally described. 1) A variable tar is established for a forecasted arrival time. 2) The next move floor is set (the floor number is decremented by one when in the upward direction, and incremented by one when in the downward direction). 3) it is determined whether or not the number of rounds is the first round or second round. 4) When in the first round, a stop time is added to tar when a call stop is present on a floor of interest, and a stop probability is added to tar when no call stop is present. 5) Wen in the second round onward, the stop probability is added to tar. 6) A time required for a movement to the next floor is added to tar. 7) the value tar_table (i, j, c, K) of the forecasted arrival time table of the floor of interest is set in tar.

[0113] Fig. 20, in which a rough flow of processing is as described above, will be described in greater detail. Here, a floor to be scanned for a K-th car is indicated by i, and the direction is indicated by j. First, in a process of each scan of the K-th car of interest (floors are scanned in a ring shape), it is determined whether or not the cage direction j is the upward direction (FC01). When in the upward direction, a floor resulting from a subtraction of one from the variable i indicative of the cage position during a scan is a next move floor i2 (FC02). When in the downward direction, a floor resulting from an addition of one to i is i2 (FC03). It is determined whether or not the next move floor i2 is a direction inversion floor of the K-th car (for example, the highest floor or lowest floor) (FC04). When i2 is a direction inversion floor, the direction j2 on the next move floor is set to the direction opposite to j (FC05). The setting of the direction inversion floor on a car-by-car basis in this way is one key of the present invention. When i2 is not a direction inversion floor, i2 is set to the same direction as j (FC14).

[0114] It is determined whether or not the floor/direction (i, j) which are being scanned are a floor serviced by the K-th car (FC06). When the floor/direction (i, j) are not a floor not serviced by the K-th car, no call stop will occur, the processing flow skips processing associated with the following stop, and goes to processing FC11.

[0115] When the floor/direction (i, j) are a floor serviced by the K-th car, it is next determined whether or not the number of rounds c of the forecasted arrival time table creation is two or more (FC07). When c is the second round or later, an expected stop time value calculated from a stop probability is used for all floors serviced by the K-th car, on the assumption that no call stop will occur in that round (FC10). This corresponds to a forecasted stop time which is forecasted by probability. This is a key of this embodiment. Specifically, the expected stop time value for the (i, j) floor/direction is added to the variable tar indicative of the forecasted arrival time.

[0116] When c is the first round, it is determined whether or not a stop is caused by a hall call or a cage call for the floor/direction (i, j) which are being scanned (FC08). When there is a call stop, a stop time at that floor is added to tar (FC09). When there is no call stop, an expected stop time value of (i, j) floor/direction is added to tar (FC10). One key of the present invention lies in that the expected stop time value is considered for the first round as well for a serviced floor without call stop. In this connection, the stop time of each floor/direction and expected stop time value are updated at all times corresponding to a change in the traffic flow (FC15). For example, during an office-going rush hours, the expected stop time value of each floor/upward direction is increased, while during semi-rush hours before lunch time, the expected stop time value of each floor/downward direction is increased.

[0117] Upon completion of the foregoing processing associated with reflection of the call stop, a move time tmv (i2, j2), which is taken when a movement is made from (i,j) floor/direction to (i2, j2) floor/direction, is added to tar (FC11). In this way, the stop time and move time are added to calculate a forecasted arrival time to (i2, j2) floor/direction of the destination. I is updated to i2, and j to j2 (FC12), and the value tar_table (i, j, c, K) of the forecasted arrival time table for a new (i, j) floor/direction is set to tar (FC13). The foregoing process is the process of the forecasted arrival time table calculation table, and is recursively executed while changing i, j, c, K in the loop process of Fig. 19 to complete the forecasted arrival time tables tar_table (i, j, c, K).

[0118] The features of the forecasted arrival time tables for plural rounds described above may be summarized in the following manner. 1) A direction inversion floor is set for each car. 2) For the forecasted arrival time table for the first round, a stop time associated with a currently generated call (hall call, cage call) is used together with the expected stop time value for a call which has not been generated. 3) In the second round onward, the expected stop time value is used on the assumption that no call has been generated. 4) The stop time and expected stop time values have set values for each combination of floor/direction. 5) The stop time and expected stop time value vary (are updated) corresponding to a traffic flow. Since forecasted trajectories are created in one embodiment of the present invention based on the forecasted arrival time tables for plural rounds, which have the features as listed above, elaborate forecasted trajectories can be created with a high forecast accuracy in accordance with the characteristics of each ar, state of call stop, and traffic flow state. As a result, it is possible to accurately evaluate the cage interval and the like based on the forecasted trajectories and reduce a waiting time.

[0119] In the following, specific examples of the forecasted arrival time tables for plural rounds will be described with reference to Figs. 21 and 22. First, Fig. 21 shows (a) a stop time table, (b) a stop probability table, and (c) an expected stop time value table in each of floors and directions, respectively. First, the stop time table of Fig. 21(a) indicates stop times for each of the floors and directions. In this example, the same stop time (eight seconds) is set on all the floors in both directions, but different stop times may be defined on a floor-by-floor and/or direction-by-direction basis.

[0120] The stop probability table of Fig. 21(b) indicates the stop probability for each of the floors and directions. For example, the stop probability on the third floor in the upward direction is set to 0.6, which means that the elevator can be stopped by a call with a probability of 0.6 while it makes a round. In the example of Fig. 21(b), the stop probability is different between the upward and downward directions in order to reflect the fact that the traffic demand at that time point tends to stop in the upward direction. In this way, the stop probability reflects the traffic demand (or traffic flow) at a particular time point, so that the value of each floor/direction of the stop probability varies in response to a change in the traffic demand.

[0121] The expected stop time value table of Fig. 21(c) indicates the expected stop time value for each of the floors and directions. This expected stop time value is calculated by multiplying the stop time by the stop probability. In this embodiment, this value is used as a forecasted stop time (expected value for the stop time) for a floor on which no hall call or a cage call has been generated.

[0122] Fig. 22 shows a specific example of the forecasted arrival time tables for plural rounds which are calculated using the stop time table, stop probability table, and expected stop time table shown in Fig. 21. First, the leftmost table (FG01) of Fig. 22 represents a situation of the first car at a current time. The first car (FG05) is positioned on the first floor toward the upward direction (FG05), and is going to serve a hall call in the upward direction on the second floor (FG06) a cage call on the fourth floor (FG07), and a hall call in the downward direction on the fourth floor (FG08). Accordingly, the first car stops on the second floor in the upward direction, the fourth floor in the upward direction, and the fourth floor in the downward direction, respectively.

[0123] The forecasted arrival time tables for the first round, second round, and third round of the first car are indicated by reference numerals FG02, FG03, FG04, respectively, in Fig. 22. First, in the forecasted arrival time table (FG02) for the first round, since the first car is currently positioned on the first floor in the upward direction, the table begins with the second floor in the upward direction and makes a round to end with the first floor in the upward direction (FG10). The forecasted arrival time on the second floor in the upward direction is two seconds because only a movement is involved, whereas the forecasted arrival time on the third floor in the upward direction is 12 seconds which is calculated by adding ten seconds (8+2=10) because the first car must stop on the second floor. The forecasted arrival time on the fourth floor in the upward direction is calculated to be 18.8 seconds by adding the expected stop time value and a time required for a movement (4.8+2=6.8) to 12 seconds. The forecasted arrival time on the fifth floor in the downward direction is calculated to be 28.8 seconds by adding ten seconds (8+2=10) because the first car must stop on the fourth floor in the upward direction. The forecasted arrival time on the fourth floor in the downward direction is calculated to be 32.4 seconds by adding the expected stop time value and the time required for the movement (1.6+2=3.6 seconds) to 28.8 seconds. Subsequently, similar calculations are repeated to complete the forecasted arrival time table for the first round. This sequence of processing is the same as the flow chart of Fig. 20. The forecasted arrival time table (FG03) for the second round, as the table for the first round, begins with the second floor in the upward direction (FG11), and make a round to end with the first floor in the upward direction (FG12). In this second round, the forecasted arrival times are all calculated using the expected stop time values associated therewith. For example, the forecasted arrival time on the third floor in the upward direction in the second round is calculated to be 73.6 seconds by adding 6.8 seconds (4.8+2=6.8) to the forecasted arrival time 66.8 seconds on the second floor in the upward direction. In a similar manner, the forecasted arrival time table (FG04) for the third round is calculated as shown.

[0124] Next, the creation of the forecasted trajectory table for an elevator car having a direction (process FA04 in Fig. 18), described in connection with Fig. 18, will be described in detail. While this creation process is illustrated by processing flows in Figs. 25 and 26, later described, a general flow of the process will be first described roughly with reference to Figs. 23 and 24

[0125] First, Fig. 23 shows an example of a finally created forecasted trajectory table. As shown, the forecasted trajectory table stores, for each car (a column designated FH02 for the first car, and a column designated FH03 for the second car), data on a forecasted position (FH04 for the first car) of each car at each time (column FH01), and the direction (FH05 for the first car). By tracing the data on the time axis, a forecasted trajectory can be created for each car.

[0126] The forecasted trajectory table of Fig. 23 is created from the data in the forecasted arrival time tables for plural rounds in Fig. 22. Specifically, a forecasted position at each time can be calculated through interpolation from forecasted arrival times of adjacent ones of respective floors and directions. This calculation method is conceptually shown in Fig. 24.

[0127] In Fig. 24, the right-hand figure shows a graph which indicates the time on the horizontal axis, and floor positions on the vertical axis. A line FF01 on this graph is drawn by connecting points (tx, ix) representative of each floor/direction of a K-th car and its forecasted arrival time on a two-dimensional coordinates, with line segments. This line FF01 is the original shape of the forecasted trajectory. The left-hand figure indicates the position and direction (FF02) of the K-th car at a current time, from which it can be seen that the K-th car is positioned on the first floor in the upward direction. Accordingly, the line FF01 in the right-hand figure has a point FF02 plotted at first floor/upward direction at time zero (current time).

[0128] On the line FF01, a point FF03 represents the position and forecasted arrival time of the K- th car on the second floor in the upward direction, and a point FF03 represents the position and forecasted arrival time of the K-th car on the adjacent third floor in the upward direction. Assuming that the coordinates of the point FF03 are preliminarily designated by (tA, iA), and the coordinates of the point FF04 by (tB, iB), an arbitrary point (t, ir(t, K)) on a line segment which connects these two points can be represented by the following equation:

$$ir(t, K) = \{(iB-iA)/(tB-tA)\}(t-tA) + iA \quad .... (13)$$

[0129] Stated another way, under a condition $tA \leqq t \leqq tB$, a forecasted position ir(t, K) of a cage at a time t can be calculated once t is determined. Also, a forecasted cage direction jr(t, K) can also be calculated from the slope of that section. Here, two points are defined on the second floor in the upward direction and the third floor in the upward direction. As this is shifted one by one, a forecasted position ir(t, K) and direction jr(t, K) of a corresponding cage can be calculated for all times t. This idea is relied on to create the forecasted trajectory table of Fig. 23 from the data in the forecasted arrival time tables for plural rounds as shown in Fig. 22. In summary, a forecasted position ir(t, K) at a time t between two corresponding times is calculated in accordance with Equation (13) from data on the direction and forecasted arrival time of two adjacent floor/direction in the forecasted arrival time tables for plural rounds as shown in Fig. 22. The floor/direction is shifted one by one to find t, ir(t, K), jr(t, K) over regions of plural rounds. This results in the forecasted trajectory table as shown in Fig. 23.

[0130] A rough concept of the creation of the forecasted trajectory table has been described above. In the following a specific processing flow will be described with reference to Figs. 25 and 26. Figs. 25 and 26 illustrate the flow of the creation of a forecasted trajectory table divided into two pieces.

[0131] Referring first to Fig. 25, initial values are first set (FD01). Here, a time variable parameter t of the forecasted trajectory table is set to zero, and a variable parameter c indicative of the number of rounds to zero. Also, a flag variable z indicative of whether or not calculations have been completed for initial floors (which require special processing for adding a time origin) is set to zero, and a variable parameter i indicative of the position of a scanned floor is set to a cage position of a K-th car at a current time, and a variable parameter j indicative of the direction of a scanned floor is set to a direction at the current time point. Next, a variable n indicative of the number of a scanned floor is set to zero. The meaning of this n is the same as the n used in Fig. 19, where when the value of n reaches $2(n_{max-1})$, floors in one round have just been scanned. This addition of n is performed in processing FD24 in Fig. 26, and a determination as to one round has been reached (whether or not $n=2(n_{max}-1)$ is established) is made in processing FD13, FD25. Nest, it is determined whether or not the flag variable z is zero (FD03). When the flag variable z is zero, the first floor is being processed, in which case alone different processing is performed.

[0132] When the flag variable z is zero, the variable iA is set to i (currently scanned floor), the variable jA is set to j (the direction of the currently scanned floor) (FD04), and tA is set to zero (FD05). When the flag variable z is not zero, the variable iA is set to i, and the variable jA to j (FD06), and tA is set as shown in the following equation based on the forecasted arrival time tables for plural rounds (FD07).

$$tA = tar\_table(iA, jA, c, K) \quad .... (14)$$

[0133] In other words, tA is set to a forecasted arrival time on a floor (iA, jA) for the K-th car in a c-th round. The variables iA, tA correspond to iA, tA shown in Fig. 24, respectively (corresponding to the point FF03 in Fig. 23). It should be noted that jA represents a direction for iA. In other words, from two points (tA, iA) and (tB, iB), a time t between them, and a forecasted arrival time ir (t, K) are calculated, where a starting point of the two points is defined.

[0134] Next, it is determined whether or not the direction j of the currently scanned floor is the upward direction (FD08). The variable iB is decremented by one when in the upward direction (FD9), and incremeneted by one when in the downward direction (FD10). Here, the variable iB corresponds to iB shown in Fig. 24 (point FF04 in Fig. 24). This indicates the position of the end point out of the two points. It is determined whether or not iB is a direction inversion floor for the K-th car (FD11). The variable jB is set to the direction opposite to j when iB is a direction inversion floor (FD12), and otherwise set to the same direction as j (FD27). Further, it is determined whether or not the variable n indicative of the number of scanned floor reaches $2(n_{max}-1)$ (FD13). As has been previously described, this determination is made to see whether or not all floors included in one round have been scanned. When the number of scanned floors is less than the number of floors in one round, tB is set to tar_table(iB, jB, c, K) (FD14). When the number of scanned floors is equal to the number of floors in one round, tB is set to tar_table(iB, jB, c+1, K) (FD15). The latter case means that since floors in one round have been scanned, a value is reference for tB from a forecasted arrival time table tar_table (iB, jB, c+1, K) by adding one to c. The following processing continues on (b) in Fig. 26.

[0135] The process following (b) in Fig. 26 will be described below. Since (tA, iA) and (tB, iB) have been respectively set, the value of ir(t, K) is calculated by equation (13) (FD16). This is the same as the calculation of the value of the point (t, ir(t, K)) on the line segment (tA, iA) - (tB, iB) by equation (13) in Fig. 24. Next, the direction jr(t, K) is determined to be in the same direction as jA (FD17).

[0136] Once ir(t, K) and jr(t, K) have been calculated for t, Δt is added to t to update t (FD18), and ir(t, K) and jr(t, K) are calculated for the new t). Here, when t exceeds t_{max}, the process for creating the forecasted trajectory table is terminated (FD19). t_{max} corresponds to a time width of the forecasted trajectory, and has been previously set to a predetermined value. A specific value for t_{max} is preferably larger than the interval evaluation time tref described in connection with Fig. 12, and is therefore preferably longer than the forecasted arrival time of the furthest call. When the control is conducted in accordance with a forecasted trajectory of a long term, to some degree, t_{max} is preferably equal to or longer than a time required for one round of the elevator (for example, 60 seconds or longer).

[0137] When t is equal to or larger than tB (FD20), i is set to iB, and j is set to jB (FD22). This corresponds to a procedure, when considering in Fig. 24, in which t is started from tA and advanced by adding Δt, and when t exceeds tB, the process goes to the next section. Also, in this event, it is determined whether or not the flag variable z is zero (FD22), and z is set to one when flag variable z is zero (FD23). This processing means that a section in which the time zero is started has been left out, so that this is indicated by the flag variable z. A change to a section means a transition of a scanned floor to the next floor on the forecasted arrival time table, and n is incremented by one (FD24). Further, it is determined whether or not n exceeds $2(n_{max}-1)$, and the variable c indicative of the number of rounds is incremented by one when n exceeds $2(n_{max}-1)$. This means a transition to the forecasted arrival time table for the next round.

[0138] Finally, turning back to Fig. 18, the process for creating the forecasted trajectory when an elevator car has no direction (serves neither a hall call nor a cage call), shown at FA05 in Fig. 18, will be described in greater detail. A flow diagram of the process for creating the forecasted trajectory when an elevator car has no direction is illustrated in Fig. 27.

[0139] The process in Fig. 27 will be described below. First, in initial settings, the variable parameter t indicative of the time is set to zero (FE01). Next, the variable ir(t, K) indicative of the cage position of the K-th car in the time t is set to the cage position at a current time, and the variable jr(t, k) indicative of the cage direction is set to non-direction (FE02). Δt is added to the value of t (FE03), and the processing FE02, FE03 is repeated until t exceeds t_{max} (FE04). Such a process is performed on the assumption that a non-direction elevator remains stand-by at the current position.

[0140] Through the sequence of the processes illustrated in Figs. 18 - 20 and Figs. 25 - 27, data can be created for the forecasted arrival time tables for plural rounds (one example of which is shown in Fig. 22), and data can also be created for the forecasted trajectory table (one example of which is shown in Fig. 23). Data for the forecasted trajectory table shows the position and direction of each elevator car from the current time point to each time advance, as shown in Fig. 23, and this corresponds to the forecasted trajectory. The creation method shown in this embodiment is a distinctive creation method which more copes with an actual situation in order to increase the forecast accuracy, and for this reason, the forecasted trajectory also exhibits a distinctive shape. In the following, the features of the forecasted trajectory which can be created by this embodiment will be described with reference to Figs. 28 to 35.

[0141] Fig. 28 shows diagrams of an example of the forecasted trajectories which are created by the forecasted trajectory creation method shown in this embodiment. Here, a right-hand diagram FI01 shows forecasted trajectories of the first car and second car, respectively. The forecasted trajectory of the first car is represented by a solid line FI02, and the forecasted trajectory of the second car is represented by a broken line FI03. Also, the state of the first car at a current time point, i.e., the cage position/direction, and a hall call and cage call served situation are shown in the leftmost table designated by reference numeral FI04, and the state of the second car at the current time point is shown in the left-hand table designated by reference numeral FI05.

[0142] Referring first to the forecasted trajectory FI02 of the first car, stops caused by a hall call and a cage call are represented by changes in sloping angle in the first round, i.e., from the first floor in the upward direction to the ground floor in the upward direction. However, in the second round onward, the forecasted trajectory is represented by straight lines FI106, FI107 and is represented only by the expected stop time value based on the stop probability. As a result, as shown, in contrast to the trajectory in the first round, the trajectory in the second round onward has the same shape in each round. Also, since the stop probability is reflected, the upward slope (FI06) is different from the downward slope (FI07) for the trajectory in the second round onward. The slop of the trajectory reflects the stop probability, and the stop probability is set in correspondence to a change in the traffic flow, where the slope varies in accordance with the traffic flow. If the stop probability is not reflected, the slope of the forecasted trajectory is determined only by the speed of the elevator, resulting in the same or symmetric slopes of the trajectory in the upward direction and downward direction. It should be noted that data on the stop time, stop probability, and expected stop time value used in the forecasted trajectories of Fig. 28 are those shown in Fig. 21.

[0143] Also, the respective forecasted trajectories present trajectories which invert in direction on the highest floor and lowest floor. One reason for creating such trajectories which invert in direction on the extreme floors (highest floor or lowest floor) is that the evaluation based on the forecasted trajectory of each car aims at a temporally equidistant state, which is particularly effective during rush hours. It is anticipated that a large number of hall calls and cage calls are generated during rush hours, and as a result, actual operation trajectories also invert to the opposite direction on the extreme floors, as shown in Fig. 28. Accordingly, the forecasted trajectories are also created to invert in direction on the extreme floors.

[0144] Fig. 29 is an explanatory diagram for forecasted trajectories which place importance on inactive hours, where the elevator cars can remain stand-by. During inactive hours, the forecasted trajectories need not invert on the extreme floors at all time as shown in Fig. 28, but may be created such that elevator cars remains stand-by at a forecasted floor at which a call service is over after a forecasted time at which the call service is over, as shown in Fig. 29. Specifically, a forecasted trajectory creating means creates a forecasted trajectory of an elevator which does not have a hall call or a cage call allocated thereto to be parallel with the time axis. In this event, the forecasted trajectory creating means estimates a final cage call floor from a traffic demand at a particular time, and creates a forecasted trajectory which forces the elevator to subsequently wait at that floor. For example, in the case of Fig. 29, it is forecasted that the first car (forecasted trajectory FQ01) will be on the first floor in the downward direction after serving the last cage call, and the resulting forecasted trajectory [FQ02] shows that the first car subsequently remains stand-by on the first floor in the downward direction. Likewise, it is forecasted that the second car (forecasted trajectory FQ03) will be on the fourth floor in the upward direction after serving the last cage call, and the resulting forecasted trajectory [FQ04] shows that the second car subsequently remains stand-by on the fourth floor in the upward direction.

[0145] Turning back to Fig. 28, reviewing the forecasted trajectory FI02 of the first car and the forecasted trajectory FI03 of the second car in Fig. 28, they are substantially equidistantly spaced in terms of the position at the current time point, but it is anticipated that they will come close to each other from then on depending on a subsequent serving situation and an expected stop time value situation.

By thus drawing the forecasted trajectories, it is possible to forecast beforehand a situation which can occur at a future time by creating the forecasted trajectory of each car, and by reflecting this information to the hall call allocation, the actual trajectories can be properly controlled. For example, by evaluating the interval between the forecasted trajectory FI02 of the first car and the forecasted trajectory FI03 of the second car (a quantitative evaluation can be made with an area sandwiched by the trajectories) before and after the assignment of each car, it is possible to evaluate the degree of deviation between two cars in the future. Also, by reviewing the tendency (temporal change) of the interval between the forecasted trajectories of the two cars, it is possible to evaluate a temporal change in the interval between the trajectories (for example, approaching to a bunch operation state or the like).

[0146] As described above, the forecasted trajectories according to this embodiment can be created with a high forecast accuracy because a stop caused by a currently generated call and a probabilistic stop possibly caused by a call not generated are taken into consideration, and are reflected to the trajectories by a method which follows the actuality.

[0147] Fig. 30 shows a second example of forecasted trajectories by the creation method shown in this embodiment. A forecasted trajectory of the first car is represented by a solid line FJ02, and a forecasted trajectory of the second car is represented by a broken line FJ03. Also, a situation of the first cage at a current time point, i.e., the cage position/direction and a hall call and cage call serving situation are shown in a table designated by reference numeral FJ04, and a situation of the second cage is shown in a table designated by reference numeral FJ05.

[0148] As can be understood from reference numeral FJ04 in Fig. 30, the first car remains stand-by on the third floor without having a call service. Therefore, the forecasted trajectory FJ02 of the first car shows that the first car remains stand-by on the third floor. This trajectory of the car having no direction is first sent to the forecasted trajectory table creation process (FA05 in Fig. 18) for an elevator car having no direction by the general processing flow of the forecasted trajectory creation illustrated in Fig. 18, and detailed data are crated by the processing flow for a car having no direction, illustrated in Fig. 27.

[0149] Fig. 31 shows a third example of forecasted trajectories according to the creation method shown in this embodiment. In this example, examples of forecasted trajectories are shown when the stop probability differs among respective floors/directions. The left-hand diagram (FK04) in Fig. 31 shows the cage position and direction at a current time, where the first car (FK05) and second car (FK06) are at the positions toward the directions shown in the diagram, respectively. It should be noted that in this diagram (FK04), calls served by each car are omitted.

[0150] The right-hand diagram (FK01) in Fig. 31 shows forecasted trajectories of the two elevator cars. The forecasted trajectory of the first car is represented by a solid line FK02, and the forecasted trajectory of the second car is represented by a broken line FK03. The forecasted trajectories in Fig. 31 differ from the forecasted trajectories in Fig. 28 in that the slopes of the forecasted trajectories are different for each floor/direction because of a difference in the stop probability among the respective floors/directions in the forecasted trajectories of Fig. 31. Generally, the stop probability differs because the trend of users differs among respective floors/directions. Accordingly, it an be said that the shape of the forecasted trajectories in Fig. 31, which reflect respective stop probabilities to the respective floors/directions provides the highest accuracy. Further, since the stop probability for each floor/direction varies following variations in the traffic flow, forecasted trajectories are created in a variety of shapes, reflecting the variations in the traffic flow.

[0151] Further, in the forecasted trajectories based on the individual stop probabilities determined for the respective floors and directions, since the shape of the forecasted trajectory is precisely defined for each floor/direction, the evaluation can be made with a higher accuracy than when the interval between forecasted trajectories of respective cars is evaluated.

Accordingly, by using the forecasted trajectories based on the individual stop probabilities determined for the respective floors and directions, it is possible to increase the accuracy of interval evaluation, provide more proper allocation in controlling the interval, and reduce a long waiting time.

[0152] Fig. 32 shows a fourth example of the forecasted trajectory according to the creation method shown in this embodiment. The forecasted trajectory in Fig. 32 differ from the forecasted trajectories in Fig. 28 in that they are in such shapes that explicitly reveal elements of stops caused by calls on the forecasted trajectories and probabilistic stops determined by the stop probability. In the forecasted trajectory FL02 in Fig. 32, a portion of a call stop is indicated by an element (FL03) on a horizontal section of the trajectory on the fourth floor in the downward direction in the first round, and a portion of a probabilistic stop is indicated by an element (FL04) on a horizontal section of the trajectory on the third floor in the upward direction in the first round. An element (FL05) represented by an oblique line segment indicates a downward movement state.

[0153] One advantage of the forecasted trajectory shown in Fig. 32 is that a highly accurate forecasted trajectory which reflects an actual shape can be created by dividing three elements, stop caused by a call, probabilistic stop, and movement in detail. Actual movements of an elevator does not match the trajectory represented by an oblique line on the time axis as shown in Fig. 28, but involves horizontal sections because the elevator must stop. As such, the forecasted trajectory in Fig. 32 more reflects the actual state. Also, another advantage of the forecasted trajectory in Fig. 32 is the ability to visually readily classify the three elements, i.e., call stop, probabilistic stop, and movement. With such a shape, it is possible to understand where a call stop is present, how the situation of the stop probability is for each floor/direction, and how the call stop and stop probability affect the trend of the trajectory at first sight. For example, when the forecasted trajectories of the first car and second car shows that the first car and second car will fall into a bunch operation in the future, it can be understood whether this is caused by impartial stop probabilities in the floor/direction or allocation of call stops.

[0154] For the forecasted trajectory as shown in Fig. 32, the creation of data of the forecasted trajectory data may be divided into stop, probabilistic stop, and movement. For example, in course of creating the forecasted arrival time table for plural rounds, a process of adding a call stop time or an expected stop time value, and adding a move time, where they may be separately stored in data.

[0155] Fig. 33 shows a fifth example of the forecasted trajectories according to the forecasted trajectory creation method shown in this embodiment. The forecasted trajectories shown in Fig. 33 differ from the forecasted trajectories shown in Fig. 28 in that the forecasted trajectories in Fig. 33 are represented by rough trajectories according to the direction, i.e., in the upward and downward directions. Specifically, the forecasted trajectories in Fig. 33 can be created by connecting points on the highest floor with points on the lowest floor of the forecasted trajectories in Fig. 28. They correspond to forecasted trajectories which are based on data resulting from accumulating times of call stop, probabilistic stop, and movement for each floor/direction according to the direction.

[0156] Though the forecasted trajectories in Fig. 33 are rough in shape, they are advantageous in that the required number of data can be largely reduced because forecasted arrival times on the highest floor and lowest floor in each round are only required. Therefore, when one uses a microcomputer which is inexpensive but provides low processing performance, it can be said that such a simple version of forecasted trajectories are effective.

[0157] When forecasted trajectory data (forecasted trajectory table) is recorded as a log of allocation control contents each time a hall call allocation is performed, for example, when a log of data for one week is to be recorded, an immense amount of data will be recorded. In such an event, when the data is preserved in the form of the forecasted trajectories as shown in Fig. 33, the amount of recorded data can be largely reduced. It is also contemplated forecasted trajectories in detailed shape as shown in Fig. 28 or 31 may be actually used for the control, while the forecasted trajectories in Fig. 33 may be used for purposes of data preservation. In this event, the accuracy of the forecasted trajectories is not degraded in the control, while the data of the forecasted trajectories for preservation can be compressed. The data preserved/recorded in this way can be relied on to analyze which trajectory was forecasted when the allocation evaluation is checked at a later time, and is therefore effective. The configuration of an embodiment for recording the forecasted trajectory data will be described later with reference to Fig. 47.

[0158] Fig. 34 shows a sixth example of forecasted trajectories according to the forecasted trajectory creation method shown in this embodiment. The forecasted trajectories shown in Fig. 34 differs from the forecasted trajectories in Fig. 28 in that the forecasted trajectories in Fig. 34 correspond to a higher floor zone (a zone of a plurality of non-stop floors located in the middle).

[0159] Fig. 34(a) shows an example of a forecasted trajectory in a higher floor zone which is created in accordance with the same way as Fig. 28. The left-hand diagram in Fig. 34(a) indicates a current cage position and direction, where a shaded area FN02 in the diagram (eight floors from the first floor to the ninth floor) is designated to be the higher floor zone. The forecasted trajectory for the elevator in the right-hand diagram in Fig. 34(a) is a forecasted trajectory FN01 in the left-hand diagram in Fig. 34(a). The stop probability is zero in the high floor zone because the elevator is not stopped due to a call, so that the slope of the forecasted trajectory is a steep and constant slope. The forecasted trajectory shown in Fig. 34(a) is an example when all floors are shown.

[0160] On the other hand, Fig. 34(b) shows the section of the higher floor zone represented by a single floor. Specifically, as shown in the left-hand diagram, the first to ninth floors are represented by a single floor FN04. A forecasted trajectory in this event is a trajectory FN03 in the right-hand diagram of Fig. 34(b). As shown, the forecasted trajectory can be precisely represented even if the higher floor zone is represented by a single floor, as long as a pass time of that zone is matched. The matching of the zone pass time can be confirmed by the pass time of the higher floor zone in Fig. 34 (a) which matches the pass time of the higher floor zone in Fig. 34(b).

[0161] One advantage of the forecasted trajectory as shown in Fig. 34(b) is a deletion of redundant data. For example, in the shown example, information on the trajectory from the first to ninth floors is redundant because any call is not generated therefrom. Important areas are located in floors located on the upper and lower sides of the higher floor zone, and a section of the trajectory in the important areas can be emphasized by the representation of the trajectory, as done in Fig. 34(b), to evaluate the trajectory. Also, since data on the first to ninth floors can be deleted, the data is effectively compressed.

[0162] Fig. 35 shows a seventh example of the forecasted trajectories according to the creation method shown in this embodiment. The forecasted trajectories in Fig. 35 differ from the forecasted trajectories in Fig. 28 in that the forecasted trajectories in Fig. 35 are forecasted trajectories when respective elevator cars are assigned to services of different floor zones. Specifically, a floor zone serviced by the first car extends over all floors from B1 floor to thirteenth floor, as shown in the leftmost diagram FP03, while a floor zone serviced by the second car extends from the first floor to the ninth floor, as shown in the second diagram FP04. In this way, even when the respective cars service different floor zones, the resulting forecasted trajectories reflect the floor zones serviced by the respective cars, as represented by the forecasted trajectories on the rightmost diagram. Specifically, the forecasted trajectory of the first car is a trajectory FP01, and the forecasted trajectory of the second car is a trajectory FP02.

[0163] The reason for the ability to create such forecasted trajectories lies in the fact that direction inversion floors are identified for each car in the flow chart of the forecasted arrival time table calculation routine illustrated in Fig. 20. In the example of Fig. 35, the first car inverts the direction on the B1 floor and thirteenth floor, while the second car inverts the direction on the first and tenth floors. By thus identifying the floors on which each car inverts the direction, forecasted trajectories can be created so as to correspond to different service zones. As a result, it is possible to create more precise forecasted trajectories in accordance with the characteristics of the respective cars.

[0164] By now, the forecasted trajectory creation method (executed by the forecasted trajectory calculation unit in Fig. 12), and examples of created forecasted trajectories have been described in detail. The forecasted trajectory creation method according to this embodiment is a creation method which copes with the realities (reflects the realities), and as a result, can create a variety of highly accurate forecasted trajectories as shown in Figs. 28 to 35. It is therefore possible to make allocations which more properly control the cage interval (in consideration of the interval uniformity), properly maintain the cage interval, and restrain a long waiting time with high evaluation accuracy such as in interval evaluation between forecasted trajectories.

[0165] Figs. 36 to 38 show details on a forecasted interval value calculation process. In the following, a method of calculating a forecasted interval value will be described with reference to a flow chart of Fig. 36. First, a phase time value tp of each cage at an interval evaluation time tref is calculated using a forecast route of each cage, the creation method of which has been previously described (ST801 in Fig. 36). Here, the interval evaluation time tref has been set by the previously described setting method. The calculation of the phase time value of each car will be described in greater detail with reference to Figs. 37, 38.

[0166] Fig. 37 shows how the forecasted interval value is calculated from a forecast route. Here, Fig. 37 shows a group management for three elevators, where the left-hand diagram in Fig. 37 shows the positions and directions of elevator cages at a current time point in a ring representation. From the left-hand diagram in Fig. 37, the first car 610 is moving between the sixth floor and seventh floor in the upward direction, and the second car 611 is moving between the fourth floor and fifth floor in the upward direction. The third car 612 in turn is moving downward from the second floor to the first floor. The right-hand diagram in Fig. 37 represents forecasted routes of the respective cages, where the horizontal axis indicates the time, and the vertical axis indicates the position. The origin of the time axis represents the current time point. A cage position 600 of the first car, a cage position 601 of the second car, and a cage position 602 of the third car at the current time point are indicated, respectively, on the diagram (a forecasted route 603 of the first car, a forecasted route 604 of the second car, and a forecasted route 605 of the third car). The cage position at the interval evaluation time tref (606 in Fig. 37) can be forecasted from the forecasted route of each cage. For example, a forecasted position and direction of the first car at the interval evaluation time tref are the sixth floor and upward direction (607 in Fig. 37); a forecasted position and direction of the second car are the third floor and upward direction (609 in Fig. 37); and a forecasted position and direction of the third car are the fifth floor and downward direction (608 in Fig. 37). Forecasted intervals between the respective cages can be found from such the forecasted positions and directions of the respective cages.

[0167] Fig. 38 shows a process of finding a forecasted interval. The left-hand diagram in Fig. 38 indicates the forecasted positions and directions of the three cages at the interval evaluation time tref shown in Fig. 37. The right-hand diagram in Fig. 38 indicates a phase time value on the horizontal axis, and the position on the vertical axis. Here, the phase time value refers to a time value normalized by a time of one round (same as the period) (refers to a time value having a similar meaning to the phase). This phase time value is calculated on the basis of an average round trajectory (703 on the right-hand diagram in Fig. 38) for a traffic flow at a current time point. By mapping the forecasted position of each cage indicated on the left-hand diagram in Fig. 38 onto the average round trajectory, the forecasted position can be converted to a phase time value. For example, a time phase value of the first car 705 can be found as tp (k=1) from the average round trajectory 703 in Fig. 38. In a similar manner, a time phase value of the second car 704 can be found as tp (k=2), and a time phase value of the third car 706 can be found as tp (k=3). In this way, the reason for converting from a forecasted position to a time phase value lies in that intervals between the respective cages are expressed by time interval values in units of times.

[0168] A time phase value is found from the forecasted position of each cage (ST801 in Fig. 36), and then, the respective cages are sorted in an order according to the magnitude of the phase time value (ST802 in Fig. 36). For example, in the case of Fig. 38, the magnitudes of the phase time values of the respective cages are in the following relationship:

$$tp\ (k=2) < tp\ (k=1) < tp\ (k=3) \qquad .... \ (15)$$

[0169] Accordingly, when a label variable indicative of the rank is represented by m, m=1 is satisfied by the second car; m=2 by the first car; and m=3 by the third car.

[0170] A forecasted interval value Bm between the respective cages is found in accordance with the order of rank m of this phase time values (ST803). For example, in the case of Fig. 38, the forecasted interval time between the cages of m=1 and m=2 is Bm=1 (corresponding to an interval value in a section 707 in Fig. 38); and the forecasted interval time between the cages of m=2 and m=3 is Bm=2 (corresponding to an interval value in a section 708 in Fig. 38). Likewise, the forecasted interval value between the cages of m=3 and m=1 is Bm=3 (corresponding to an interval value in a section 709 in Fig. 38). The respective forecasted interval values are represented by the following equations:

$$Bm=1 = tp(k=1) - tp(k=2) \qquad .... \ (16)$$

$$Bm=2 = tp(k=3) - tp(k=1) \qquad .... \ (17)$$

$$Bm=3 = \{T-tp(k=3) + tp(k=2) \qquad .... \ (18)$$

Where T in Equation (18) represents the period of an average round trajectory.

[0171] In the foregoing manner, the forecasted interval of each cage is calculated using the phase time value based on the average round trajectory for the traffic flow at the current time point, so that a more proper time interval can be found in accordance with a traffic flow at a particular time. For example, at the start of a lunch time, a large number of hall calls are generated for the downward direction, resulting in the average round trajectory which has a slow slope of a line segment toward the downward direction, and a longer phase time value per floor as compared with a line segment toward the upward direction. Therefore, when two cages are spaced apart, for example, by two floors, an evaluation is made to result in different interval values for the upward direction and downward direction. Since cages going downward are more likely to stop, they are evaluated to be more spaced even on the same first floor. In this way, the time interval can be properly evaluated in accordance with the traffic flow.

[0172] Fig. 39 compares trajectories of elevator cages on the time axis in an scenario of a group management for three cars between the result before the implementation of the control according to this embodiment and the result after the implementation of the control according to this embodiment. Fig. 39(a) shows trajectories of the elevator cages on the time axis before the implementation of the control according to this embodiment. It can be seen from these trajectories that the trajectories of the three cars often overlap, showing the occurrence of a low-efficient bunch operation.

[0173] On the other hand, Fig. 39(b) shows trajectories of the elevator cages on the time axis after the implementation of the control according to this embodiment. It can be seen that the trajectories of the three cages maintain equal phases, just like a three-phase alternate current, i.e., a temporally equidistant state. In this way, since the temporally equidistant state can be maintained, an elevator cage can immediately arrive in response to a hall call which is generated on whichever floor and in whichever direction, thus making it possible to restrain a long waiting time.

[0174] Now turning back to Fig. 17, a description will be made of another exemplary configuration of the cage interval evaluation value calculation unit 4 shown in Fig. 2. The configuration in Fig. 17 is intended to evaluate a cage interval from a deviation between a target route and a forecasted route (forecasted trajectory) with reference to the target route (target trajectory) which is an ideal route (trajectory) in a temporally equidistant state. The use of this target route is a feature of the configuration illustrated in Fig. 17.

[0175] While the target route will be described later in greater detail, the configuration of Fig. 17 can evaluate each cage interval uniformity over a wide time region because the target route serves as a detailed reference for a higher time interval uniformity.

[0176] First, a target route creation unit 410 creates an ideal route in a temporally equidistant state for each cage based on input information (entered from the input information storage unit 2 in Fig. 2), and a forecasted route creation unit 411 creates a forecasted route for each cage. A method of creating the forecasted route is the same as the previously described method, and the creation of the target route will be described later with reference to Figs. 42 to 44. A route deviation calculation unit 414 calculates a deviation of the forecasted route from the target route for each cage. This deviation can be calculated, for example, using the area of a difference between the two routes. A cage interval evaluation value calculation unit 415 calculates a cage interval evaluation value (cage interval evaluation value when each cage is preliminary allocated to a hall call) for each cage based on the calculated inter-route deviation. Based on the cage interval evaluation values, a hall call is allocated to the cage having the highest evaluation value. An average round time calculation unit 412 calculates an average round time based on the input information, and an adjusted reference time setting unit 413 determines the value of an adjusted reference time based on the average round time T. The set adjusted reference time is used during the creation of the target route. The creation of the target route will also be described later in greater detail with reference to Figs. 42 to 44.

[0177] In the following, the allocation evaluation control based on the target route (one of evaluation functions for a future call), shown in Fig. 17, will be described in greater detail. As has been previously described in connection with Fig. 17, the allocation evaluation control based on the target route comprises three fundamental components, i.e., the target route creation unit 410, forecasted route creation unit 411, and inter-route deviation calculation unit 412.

[0178] First, an operational concept of the target route control (control principles) will be described with reference to Figs. 40, 41. Fig. 40 includes diagrams showing an example of the control concept of the target route control. In Fig. 40, the left-hand diagram is a diagram conceptually showing cross-sections of elevator paths (vertical direction) within a building, and the states of elevator cars moving therein. The right-hand diagram indicates the time axis on the horizontal axis (A01), and the axis of floors of the building on the vertical axis (A02), where trajectories of the operations of the respective elevator cages are represented on the time axis (generally called the operation diagram). The diagram shows a situation of the elevator group management for two cars by way of example. From the left-hand diagram, a first car (cage designated by 1) has inverted the direction on the ground floor and is operating toward the upward direction, wile a second car (cage designated by 2) is operating toward the downward direction from the first floor. When this situation is seen in the right-hand operation diagram, it can be seen that in the left direction from an axis (A02) indicative of a current time point, both the first car (A03) and second car (A04) are operating toward the downward direction, and are positioned on the ground floor and first floor, respectively. In other words, in the right-hand operation diagram, a trajectory of each elevator cage on the left side of the current time point represents an actual trajectory. For example, the actual trajectory of the first car is a trajectory A031, and the actual trajectory of the second car is a trajectory A041.

[0179] A key to this embodiment is trajectories drawn on the time axis in the future on the right side of the current time point. They represent "target trajectories" which should be traced by the respective cages. In the following, the target trajectory is called the "target route." A feature of the allocation control based on the target route is that the operation of each elevator cage (more precisely, the allocation) is controlled to follow the target route. Specifically, the target routes for the respective cages are a target route A032 for the first car, and a target route A042 for the second car. The introduction of the target (or reference) trajectory which should be traced by each car on the time axis into the control is a feature unique to the present invention, which has not been found in the conventional group management control.

[0180] Fig. 41 includes diagrams showing how the allocation of an elevator cage is determined for a hall call in accordance with the target routes. Fig. 41 includes basically the same diagrams, where the left-hand diagram shows the states of elevators on a vertical section of elevator paths, and the right-hand diagram represents an operation diagram. Assume first that a new hall call is generated on the second floor for an upward movement. See the left-hand diagram of Fig. 41. In response to this hall call, the group management control allocates an appropriate car from the first car (B03) and second car (B04). Here, note movements of the first car (BD3). The target route of the first car is a trajectory B032. Forecasted route of the first car (forecasted trajectory in the future from the current time point. This forecasted trajectory is hereinafter called the "forecasted route") is a route B033 (forecasted route 1) when the first car is allowed to pass without allocated a new hall call. Therefore, when a new hall call is allocated to the first car, a route

B034 (forecasted route 2) is employed instead. Here, in the group management control of this embodiment, movements of each car are moved to follow the target route. As such, the forecasted route 1 B033 is closer to the target route, i.e., the route on which the first car is allowed to pass without allocated a hall call, so that the first car is not allocated any hall call. As a result, the actual trajectory of the first car operates to follow the target route.

[0181] According to the control based on the target route, the target route is drawn such that each elevator cage follows a temporally equidistant trajectory in the future. In this way, the actual trajectory of the cage follows its target route, and as a result, each cage can be controlled to maintain the temporally equidistant trajectory with stability for a long term. For example, in the case of Fig. 41, it can be seen that the actual trajectories of the fist car (B03) and second car (B041) up to the current time point, i.e., the trajectory (B031) of the firs car and the trajectory (B041) of the second car are close to each other, and therefore, they are in a bunch operation state. Here, if a new hall call generated on the third floor in the upward direction is allocated to the second car, the distance between the first car (B03) and second car (B04) still remain close to each other, and the bunch operation continues. However, when the first car and second car are separated away from each other and controlled to follow the target routes which are set to make the respective trajectories temporally equidistant, the first car (B03) is not allocated, and following the target routes, they approach to the temporally equidistant state.

[0182] In the following, the feature of the control principles of the elevator group management system according to this embodiment will be summarized with reference to Figs. 40 and 41.

1) As shown in Fig. 40, a target trajectory on the time axis, i.e., a target route is set for each cage.
2) As shown in Fig. 41, the target route and forecasted route are compared, and the allocation of a hall call is determined to a cage which more approaches to the target, such that the trajectory of each cage follows the target route.
3) As a result, each cage operates to follow the target route.
4) Here, the target route is basically set such that the trajectory of each cage becomes temporally equidistant, so that each cage is controlled to be in a temporally equidistant state with stability for a long term.

[0183] Fig. 42 shows an outline of a target route creation process. Fig. 42 shows a target creation process which utilizes an adjustment area (later described). A graph D01 indicates the time on the horizontal axis, and floor positions in a building on the vertical direction, with a current time point defined at the origin (D03) of the time axis. While no graph is drawn in Fig. 42, a target route, as shown in Fig. 43, will be drawn therein by way of example.

[0184] Fig. 43 shows an example of target route shapes before and after an adjustment according to one embodiment of the present invention. A target route creates a route to accomplish a temporally equidistant state at a predetermined time in the future, and this predetermined time corresponds to an adjusted reference time axis D04. The target route is represented by a route which represents a transient state until the temporally equidistant state prevails in an area between the time axis D03 at the current time point and the adjusted reference time axis D04 (called the "adjustment area"), and is represented as a route which enters the temporally equidistant state after the adjusted reference time axis D04.

[0185] Such a target creation process is composed of the following four processes.

1) A forecasted route at a current situation is drawn (ST701 in Fig. 42).
2) The phase time value of each cage in the current situation on the adjusted reference time axis is calculated (ST702).
3) The amount of adjustment is calculated for each cage, based on the phase time value in the current situation, so as to accomplish the temporal equidistance (ST703).
4) A grid of the forecasted route within the adjustment area is adjusted in accordance with the amount of adjustment, and this is used for a target route (ST704).

[0186] Fig. 44 shows an example of the configuration of the target route creation unit. The configuration of the illustrated target route creation unit is generally composed of the following four components:

1) a target route update determination unit 103A;
2) a current phase time value calculation unit 103B;
3) an adjustment amount calculation unit 103C for the phase time value of each cage; and
4) an adjusted route creation unit 103D.

[0187] First, a control concept will be described in terms of actions of the foregoing four components. The target route update unit 103A determines whether or not a current target route should be updated. When it is determined that the target route should be updated, the current phase time value calculation unit 103B at the next stage evaluates an interval state of the route of each cage with an index called a "phase time value" for a forecasted route of each elevator cage at that time point. The reason for the use of the concept of "phase" is based on the fact that when the waveform of a three-phase alternate current of a sinusoidal wave is considered in the electric circuit theory, for example, a state in which the phases of the respective phases are uniformized is a state in which the phase of each phase is in an equal phase state by 2π/3(rad) each. In other words, when the route of each cage is regarded as a waveform, and a "phase-like index" is used for the waveform, an interval state for each route is readily evaluated. This "phase-like index" corresponds to the index called the "phase time value" used in this embodiment. The phase time value will be described later. After the current phase time value calculation unit 103B has calculated the phase time value at that time point, a phase time value adjustment amount for each cage is calculated in the adjustment amount calculation unit 103C for the phase time value of each cage in order to make the phase time value uniform. Based on the adjustment amount calculated above, the adjusted route creation unit 103D adjusts the time phase value of the original forecasted route 103B of each cage. The route resulting from the adjustment serves as a target route.

[0188] The operation for the general control configuration described above will be described with reference to an operational concept in Fig. 43. Fig. 43 is an operational conception diagram of a target route creation process executed by the target route creation unit shown in Fig. 44. Described herein first is the operational concept of the control based on the previously described general control contents. First, the diagram (target route shape before the adjustment) of Fig. 43(a) corresponds to a forecasted route of each cage at a current time point which is based to create a target route. Here, an elevator group management system for three cars is considered. In Fig. 43(a), a cage C010 of a first car, a cage C020 of a second car, and a cage C030 of a third car are descending the eighth floor, descending the second floor, and descending the third floor, respectively, on a axis C050 at the current time point. Forecasted routes (forecasted trajectories) of the three cages subsequent to the current time point are indicated by a solid line trajectory C011 for the first car, a one-dot chain line trajectory C031 for the second car, and a dotted-line trajectory C031 for the third car, respectively. In this connection, a forecasted route creation method will be described in detail in a section of a description of the forecasted route creation unit. These trajectories are apparently close to one another, from which it is understood that the three cages are close to a bunch operation state. Turning back to the control configuration of the target route creation unit in Fig. 44, first, when the target route update determination unit 103A determines an update of target routes, the current phase time calculation unit 103B regards the forecasted routes C011, C021, C031 of the respective cages in Fig. 43(a) as one type of waveforms, and calculates their respective phase time values. The phase time values are calculated at intersections at which an adjusted reference time axis C040 in the diagram of Fig. 43(a) intersects the forecasted routes of the respective cages. Next, based on the phase time values, the adjustment amount calculation unit 103C for the phase time value of each cage calculates the amounts of adjustment for the respective forecasted routes to be in an equidistant state. The amounts of adjustment are represented as three black circular points on the adjusted reference time axis C040 in Fig. 43(a). For example, in regard to the first car, a point C01A is a point which reflects the amount of adjustment, and the forecasted route C011 of the first car is adjusted in the next processing to pass this point C01A. Likewise, a forecasted route C021 of the second car is adjusted in the next processing so as to pass a point C02A, and a forecasted route C032is adjusted in the next processing so as to pass a point C03A. It is the adjusted route creation unit 103D in Fig. 44 that performs this adjustment processing, and the forecasted routes are adjusted on the basis of the amounts of adjustment to create new target routes. The results are the trajectories shown in Fig. 43(b). Fig. 43(b) is a diagram showing new target routes which are created on the basis of the forecasted routes shown in Fig. 43(a). For the three cages C010, C020, C030, a target route of the first car C010 is a solid line trajectory C011N, a target route of the second car C020 is a one-dot chain line trajectory C021N, and a target route of the third car C030 is a dotted line trajectory C031N . A feature of the trajectories of the target routes lies in that the route of each cage is drawn so as to guide to the temporally equidistant state, as shown in Fig. 43(b). Specifically, in Fig. 43(b), the target routes of the three cages are in the temporally equidistant state, respectively, after the adjusted reference axis C040. In a time period between the axis C050 indicative of the current time point and the adjusted reference time axis C040 (a time area labeled the "adjustment area" in Fig. 42), the trajectory is drawn such that each cage is guided to such a temporally equidistant state. Based on the forecasted routes shown in Fig. 43(a), the respective routes are adjusted such that each route passes the point found with the amount of adjustment, i.e., the point C01A, C02A, C03A on the adjusted reference axis. In this way, the target routes can be created as shown in such Fig. 43(b).

[0189] In the following, the components in the target route creation unit illustrated in Fig. 44 will be described in detail. The current phase time value calculation unit 103B comprises an initial state route creation unit 103B1, an adjusted reference axis setting unit 103B2, a phase time value calculation unit 103B3 for calculating the phase time value of each car on the adjusted reference axis, and a phase time value order sorting unit 103B4. The initial state route creation unit 103B1 creates a forecasted route for each cage at a particular time point for use as a route in an initial state. This route in the initial state corresponds to the target route shape before adjustment shown in Fig. 43(a). The adjusted reference axis setting unit 103B2 sets the adjusted reference time axis. The phase time value calculation unit 103B3 for calculating the phase time value of each axis on the adjusted reference axis calculates a phase time value of each cage on the adjusted reference time axis. Specifically, the phase time value is calculated for an intersection of the forecasted route of each cage with the adjusted reference time axis (corresponding to a forecasted position of each cage on the adjusted reference time axis). After calculating the phase time value of each cage in the phase time value calculation unit 103B3 for calculating the phase time value of each axis on the adjusted reference axis, the phase time value order sorting unit 103B4 sorts the phase time values for the respective cages in the order of the phase time value. In the following, this order is called the "phase order." For example, giving as an example the cage state of three cars in the target route shapes before the adjustment (corresponding to the forecasted routes) in Fig. 43(a), from the intersections of the adjusted reference axis C040 with the forecasted routes C011, C021, C031 of the respective cages, the order of the phase time values of the respective cages are in the phase order of the third car, second car, and first car from the smallest one. The phase time value order sorting unit 103B employs a sorting algorithm, for example, a direct selection method, a bubble sort or the like to find such a phase order.

[0190] The adjustment amount calculation unit 103C for the phase time value of each cage calculates the intervals between the respective cages using the phase time values based on the calculated phase time values of the respective cages and the phase order thereof, compares the values with a reference values for providing an equidistance, and calculates the amount of adjustment for the phase time values of the respective cages, as represented by the differences therebetween. Here, the concept is that the intervals between the respective cages (evaluated by the phase time value) are found from the forecasted routes, and they are compared with the reference value for providing the equidistance, and the differences therebetween are used for the amount of adjustment to be adjusted from there. Giving Fig. 43(a) as an example, a description will be given of processing contents of the adjustment amount calculation unit 103C for the phase time value of each cage. As described above, in Fig. 43(a), the phase order of the phase time values on the adjusted reference time axis C040 of the forecasted routes C011, C021, C031 of the respective cages is in the order of the third car, second car, and first car. When one round time of the forecasted route is represented by T (the three cars are equal in round time to one another), a phase time value tp(k) of a k-th car is tp(3)=0.09 for the third car, tp(2)=0.17T for the second car, and tp(1)=0.77T for the first car. Calculating the intervals between the respective cages in the phase order, the interval between the second car and third car is 0.08T (tp(2)-tp(3)); the interval between the first car and second car is 0.6T (tp(1)-tp(2)); and the interval between the third car and first car is 0.32T (tp(3)-tp(1)+T). In this way, by quantifying the intervals between the respective cages using the phase time values, it is possible to quantitatively evaluate the intervals between the respective cages. For example, it is understood from the foregoing result that the interval between the second car and third car is very close. Since one round time is designated by T in the phase time value, the intervals between respective cages in the intended temporally equidistant state can be represented by T/N in a group management for N cars. In the example of Fig. 43(a), where three cars are intended for the group management, a target interval between cages is T/3=0.33T. The difference between this target interval and the current interval between the respective cages is an interval to be adjusted. For example, between the second car and third car, +0.25T (=0.33T-0.08T) is an interval value to be adjusted. Likewise, interval values to be adjusted are -0.27T(=0.33T-0.6T) between the first car and second car, and +0.01T(=0.33T-0.32T) between the first car and second car), respectively. In the foregoing, the positive sign represents an increase in interval, where the current interval must be extended for the target. On the other hand, the negative sign represents a decrease in interval, where the current interval must be reduced for the target. Based on the interval values to be adjusted, the amount of adjustment to the phase time value is adjusted for each cage. This can be found in accordance with the following algorithm. For example, assume that in a group management for three cars, an A-car, a B-car, and a C-car are arranged in this order. For generalizing, the names of cars are given in alphabet. From the foregoing, $0 \leqq tp(A) \leqq tp(B) \leqq tp(C) < T$ is established. Here, the amount of adjustment to the phase time value for each car is represented by $\Delta tp(k)$ (k indicates that a cage is a k-th car). First, the following equations must be established in order to satisfy an interval of T/3 which is the target of adjusted intervals of the respective cages:

$$(tp(B)+\Delta tp(B)) - (tp(A)+\Delta tp(A)) = T/3 \quad \ldots. (19)$$

$$(tp(C)+\Delta tp(C)) - (tp(B)+\Delta tp(B)) = T/3 \quad \ldots. (20)$$

$$(tp(A)+\Delta tp(A)) - (tp(C)+\Delta tp(C)) + T = T/3 \qquad .... (21)$$

[0191] For example, with respect to Equation (19), the adjusted phase time value is represented by tp(B)+Δtp(B) for the current phase time value tp(B). As such, Equation (19) represents that the difference between the adjusted phase time value of the B-car and the adjusted phase time value of the A-car, i.e., the interval satisfies T/3. Here, since the three equations are not independent of one another, Δtp(A), Δtp(B), Δtp(C) cannot be solved with the three equations alone. Thus, another condition is added that a positional barycenter as viewed in the current phase time value of each cage matches a positional barycenter as viewed in the adjusted phase time value of each cage. This condition is represented by the following equation:

$$(tp(A)+tp(B)+tp(C)/3 = \{(tp(A)+\Delta tp(A)) + (tp(B)+\Delta tp(B)) + (tp(C)+\Delta tp(C))\}/3 \qquad .... (22)$$

[0192] Equation (22) is arranged to derive Equation (23) :

$$\Delta tp(A)+\Delta tp(B)+\Delta tp(C) = 0 \qquad .... (23)$$

[0193] Solving Equations (19), (20), (21), (23) for Δtp(A), Δtp(B), Δtp(C), the following equations are derived:

$$\Delta tp(A) = (-2/3)tp(A) + (1/3)tp(B) + (1/3)tp(C) + (-1/3)T \qquad .... (24)$$

$$\Delta tp(B) = (1/3)tp(A) + (-2/3)tp(B) + (1/3)tp(C) \qquad .... (25)$$

$$\Delta tp(C) = (1/3)tp(A) + (1/3)tp(B) + (-2/3)tp(C) + (1/3)T \qquad .... (26)$$

[0194] In conclusion, for three cages A-car, B-car, C-car which have the phase time values that satisfy 0≦tp(A)≦tp(B)≦tp(C)<T, it is possible to find the amounts of adjustment Δtp(A), Δtp(B), Δtp(C) which are at equal intervals after adjustment, and satisfy the condition that the positional barycenters of the three cars do not change. These amounts of adjustment Δtp(A), Δtp(B), Δtp(C) can be calculated by Equations (24), (25), (26), respectively. For example, giving Fig. 43(a) as an example, The A-, B-, C-cars are the third, second, first cars, respectively. Therefore, tp(A)=tp(3)=0.09T, tp(B)=tp(2)=0.17T, and tp(C)=tp(1)=0.77T. Accordingly, the amounts of adjustment to the respective cages are calculated by Equations (24) - (26) as Δtp(A)=Δtp(3)=-0.081T, Δtp(B)=Δtp(2)=0.177T, and Δtp(C)=-0.096T. For confirmation, the respective phase time values are calculated after the adjustment:

$$tp(A)+\Delta tp(A)=tp(3)+\Delta tp(3)=0.010T,$$

$$tp(B)+\Delta tp(B)=tp(2)+\Delta tp(2)=0.343T,$$

and

$$tp(C)+\Delta tp(C)=tp(1)+\Delta tp(1)=0.677T$$

[0195] Stated another way, the intervals between the respective cages are 0.33T and can therefore satisfy the condition for the equal intervals.

[0196] Next, a detailed description will be given of a process for creating an adjusted route by the adjusted route creation unit 103D using the amounts of adjustment calculated by the adjustment amount calculation unit 103C for the phase time value of each cage. In the adjusted route creation unit, an adjustment amount calculation unit 103D1 for a grid on the route of each cage calculates the amount of adjustment to a grid on the target route before adjustment (corresponding to the forecasted route) of each cage. The grid is defined to be a direction inversion point of the route intended in the adjustment area. By adjusting the position of the grid in the horizontal direction, it is possible to adjust the phase time value of the route of interest. The amount of adjustment to each grid is determined by a method of assigning from a grid close to a current time point in order to a value which exceeds a limiter value set for that grid, with the amount of adjustment to the cage as a total amount. Here, the limiter value for the amount of adjustment to each cage is set by a grid limiter value setting unit 103D2. An adjusted grid position calculation unit 103D3 calculates a grid position gp_N(k, i) after the adjustment from the amount of adjustment Δgtp(k, i) to each grid and the position gp(k, i) of the grid before the adjustment. For example, with k=second car, and the number of grid equal to three (i=1, 2, 3), equations of the respective grids are as follows:

$$gp\_N(k=2,\ i=1) = gp(k=2,\ i=1) + \Delta gtp(k=2,\ i=1) \quad .... (27)$$

$$gp\_N(k=2,\ i=2) = gp(k=2,\ i=2) + \Delta gtp(k=2,\ i=1) + \Delta gtp((k=2,\ i=2) \quad .... (28)$$

$$gp\_N(k=2,\ i=3) = gp(k=2,\ i=3) + \Delta gtp(k=2,\ i=1) + \Delta gtp(k=2,\ i=2) + \Delta gtp(k=2,\ i=3) \quad .... (29)$$

[0197] The amount of adjustment to a grid is taken over to subsequent grids, so that the last grid is adjusted in position by the total amount of adjustment to the phase time value for an associated cage. In the foregoing manner, a new target route can be created by connecting the positions of the respective adjusted grids. A target route data calculation unit 103D4 calculates and updates new target route data.

[0198] A newly updated target route (adjusted target route) passes an adjusted target point set to the amount of adjustment to the phase time value. Since the route of each cage is adjusted to pass the adjusted target point, the result of collecting the three cars is as shown in Fig. 43(b), from which it can be seen that the target routes C011N, C021N, C031N of the three cars are in a temporally equal interval state. Of course, each route C011N, C021N, C031N passes the respective adjusted target point C01A, C02A, C03A. It can be also seen that the target route within the adjustment area adjusted by the grid plays an role of a transient guide for accomplishing the temporally equal interval state after the adjusted reference time axis. The foregoing is a detailed description on the target route creation process.

[0199] Fig. 45 illustrates a second embodiment which is different from Fig. 2 of control blocks in the overall elevator group management system according to the present invention. In Fig. 45, components identical to those in Fig. 2 are designated the same reference numerals, and a description thereon is omitted here. Fig. 45 differs from Fig. 1 in that the weighting coefficient is directly determined from the number of generated hall calls. Specifically, a hall call count calculation unit 10 calculates the number of generated hall calls, and based on this, a weighting coefficient calculation unit 5 calculates the weighting coefficient directly from the number of generated hall calls.

[0200] Fig. 46 shows an example of a function for use by the weighting coefficient calculation unit 5 for finding the weighting coefficient. In Fig. 46, the horizontal axis indicates the number of hall calls generated per round, and the vertical axis indicates the weighting coefficient. Here, the number of hall calls generated per round refers to an average number of hall calls which are generated during one round (for example, from the lowest floor in the upward direction to the lowest floor in the downward direction) of each of elevators which are managed in group.

[0201] In Fig. 46, the function for determining the weighting coefficient is represented by a curve F04. This function has the following four features.

1) The function can immediately find an appropriate value of the weighting coefficient from the number of generated hall calls.
2) the value of the weighting coefficient, which is the output, is continuously determined following a continuous change in the number of hall calls generated per round, which is an input variable.
3) The input variable is a scalar value (one variable).
4) The input variable can continuously take values as real numbers.

[0202] From the graph of Fig. 46, when the number of hall calls generated per round is NA, for example, the weighting coefficient is WT=F(NA). Irrespective of how NA changes due to a change in traffic demand, WT can be immediately determined. This constitutes a large feature. Also, the weighting coefficient value is always zero for a value on the horizontal axis at which the zero value on the vertical axis intersects.

[0203] As previously described, the reason for which the appropriate weighting coefficient can be found by specifying the number of hall calls generated per round of an elevator lies in that the importance of the interval evaluation value is strongly related to the number of hall calls possibly generated in the future. For example, as a larger number of hall calls are generated in the future, the interval should be made as temporally even as possible, so that the interval evaluation value should be forced to more strongly act. Here, it is assumed that the number of hall calls possibly generated in the future has a high correlation with the number of hall calls generated per round at a particular time point or a time point subsequent thereto. Therefore, a certain relationship is established between the number of hall calls generated per round and an appropriate weighting efficient value, and by representing this as functions as shown in Fig. 10, an appropriate weighting coefficient can be determined from the number of hall calls generated per round of the elevator.

[0204] It should be noted that the graph in Fig. 46 shows an example in which the horizontal axis indicates the number of hall calls generated per round, but may indicate, not limited to this, a value based on the number of generated hall calls, for example, the number of hall calls generated for a predetermined time. Further alternatively, the horizontal axis may indicate an index of a scalar value related to traffic demand, not limited to the number of generated hall calls. For example, the horizontal axis may indicate the number of users, or a value based on the total value of the number of generated hall calls and the number of generated cage calls.

[0205] From the foregoing, the configuration of Fig. 45 is advantageous over the configuration of Fig. 2 in that an appropriate weighting coefficient can be promptly set by a simpler configuration. As a result, stable performance can be maintained even using a microcomputer, a processor, or the like which is expensive but provide low processing capabilities.

[0206] Fig. 47 illustrates a third embodiment which is different from Figs. 2 and 45 of the elevator group management systems according to the present invention. In Fig. 47, components identical to those in Fig. 2 are designated the same reference numerals, and a description thereon is omitted. Fig. 47 differs from Fig. 2 in that an assignment evaluation information display processing unit H01 is additionally provided. This assignment evaluation information display processing unit H01 is characterized by recording internal information such as an evaluation value which is relied on to determine an allocation of a hall call, intermediate information thereof, and the like, displaying the contents as required, transferring to the outside, and recording them on a recording medium. The purposes are to analyze, for each allocation process, which factor caused the allocation, and to reveal, when a long waiting occurred, for example, in which situation the long waiting was reached. Particularly, such a display processing means is effective because the elevator group management system according to the present invention can visually indicates the will of the group management control side through forecasted trajectories and target routes.

[0207] In the following, the configuration of the allocation evaluation information display processing unit H01 will be described. The allocation evaluation information display processing unit H01 is composed of a determination unit H02, a recording unit H03, a drawing processing unit H04, a recording medium H05, and an output unit H06. The determination unit H02 is a component for determining whether or not evaluation value information should be recorded, and is configured to record information on allocation variation in the recording unit H03 when a recording enable signal is generated from the determination unit H02. This determination may involve, for example, a particular time zone, a particular traffic flow, the occurrence of an average waiting time equal to or larger than a predetermined value, and the occurrence of an average hall call continuation time equal to or larger than a predetermined value. The recording unit H03 records variety of data associated with the allocation evaluation calculated by the group management control unit 1. For example, the recording unit H03 records a waiting time evaluation value calculated b the waiting time evaluation value 3, the output of the cage interval evaluation calculation unit 4, the weighting coefficient set by the weighting coefficient setting unit 8, the output of the general evaluation value calculation unit 6, and the name of car to which an allocation is determined, which is the output of the allocated elevator determination unit 7. For the cage interval evaluation value calculation unit 4, its detailed functions have been shown in Fig. 48, and will be described later in greater detail. The drawing processing unit H04 performs a drawing data creation process for drawing information related to allocations recorded in the recording unit H03 on a screen. The output unit H06 displays drawing data on the screen. The recording medium H05 preserves data recorded by the recording medium H03. The recording medium H05 used herein may be a floppy disk, a memory card, a USB memory, a hard disk or the like. The drawing data created by the drawing processing unit H04 is transferred to the outside through a communication network H07, so that the drawing data can be remotely displayed on a screen or recorded.

[0208] Fig. 48 is a detailed functional block diagram of the interval evaluation value calculation unit 4, showing the flow of data information recorded by the recording unit H03. The configuration of Fig. 48 is based on Fig. 12, so that components identical to those in Fig. 12 are designated the same reference numerals, and a description thereon is omitted here. Data sent to the recording unit H03 includes the interval evaluation time tref calculated by the interval evaluation time setting unit 405, which is outputted from an interval evaluation time data output unit 4Z2. Further, there is forecasted car trajectory data (specifically, the forecasted trajectory table of Fig. 23) created by the forecasted trajectory calculation unit 401, outputted by a forecasted trajectory data output unit 4Z3. Since the forecasted trajectory data is large in amount as it is, it may be converted, for example, to a simple version of forecasted trajectories as shown in Fig. 33 to compress the data amount, and can therefore be limited to an appropriate data amount. Such a conversion process is performed by a forecasted trajectory data conversion unit 4Z1. Otherwise, forecasted cage interval data calculated by the forecasted cage interval processing unit 402 (outputted from an output unit 4Z5), interval evaluation value data calculated by the interval evaluation value calculation unit 403 (outputted from an output unit 4Z6), and the like are outputted to the recording unit H03 for recording.

[0209] Fig. 49 shows an example of screen output data created by the drawing processing unit H04 and displayed by the output unit H06 in Fig. 47. Screen output elements in Fig. 49 can be generally classified into the following four groups:

1) a group L001 for displaying information related to forecasted trajectories;
2) a group L002 for displaying information related to a hall call intended for allocation;
3) a group L003 for displaying evaluation value information; and
4) a group L004 for displaying detailed information on interval evaluation values.

[0210] In the following, the respective groups will be described in detail.

[0211] First, the group L001 for displaying information related to forecasted trajectories is characterized by collectively displaying the following data on a graph L006 which represents the time and floor positions on the two axes. Data displayed on the graph may include forecasted trajectories of respective cars (a forecasted trajectory L010 of a first car, and a forecasted trajectory L011 of a second car), an interval evaluation time L012, and cage positions of the respective cars at an interval evaluation time (a cage position L015 of the first car and a cage position L016 of the second car). Such a display can show in detail how the forecasted trajectory of each car is like, at which time point a cage interval of each car is evaluated, and how the positional relationship between the cages are like at that time. As a result, how the cage interval evaluation has acted can be visually and readily confirmed together with the cage interval evaluation value, later described. Particularly, in the present invention, the interval evaluation time is adaptively adjusted in accordance with a situation of call making and a situation of traffic flow, so that it is important to explicitly display which time point was selected to be the interval evaluation time in the event of that allocation. In addition, an upper left drawing L005 (a cage L007 of the first car, a cage L008 of the second car, and a hall call L009), which displays a cage state and a call state at the allocation time, is displayed. They are effective in supporting information on the forecasted trajectories. For example, it is possible to understand a basis of a forecasted trajectory drawn from which call occurrence state.

[0212] Next, the group L002 for displaying information related to a hall call intended for allocation displays time information L017 on a time at which the hall call was generated, hall call floor information L018, and hall call direction information L019. Details on the hall call intended for allocation can be confirmed from these pieces of information.

[0213] The group L003 for displaying evaluation value information displays each information of an allocated car name L020, waiting time evaluation value L021 at a particular time point, a cage interval evaluation value L022, a weighting coefficient value L023, and a general evaluation value L024. All these pieces of information are important information which plays an important role in determining the allocation, and by displaying them one by one, it is possible to know from which factor the allocation was determined. In other words, the factor of determining the allocation can be roughly estimated from the information displayed in the group L003 which displays evaluation value information. For example, the waiting time evaluation value strongly acted in order to avoid a long waiting time, an exacerbation of the cage interval evaluation value was avoided, the weighting coefficient value was large at a certain time point so that the cage interval evaluation value was regarded as important, and the like, which can support a search for the allocation determination factor. Also, by displaying these pieces of information together with the information of the group L001 which displays information related to the forecasted trajectories, the contents of the cage interval evaluation value, which is difficult to understand with numbers alone, can be more intuitively understood.

[0214] The group L004 for displaying detailed information on the cage interval evaluation value displays detailed information internal to a process calculated in calculating the cage interval evaluation value. Specifically, information including an interval evaluation time value L025, a forecasted cage position L026 of each car at the interval evaluation time, and the forecasted cage interval L027 is displayed. Since the cage interval evaluation value is information which aggregates all, the basis of being an evaluation value can be hard to understand in a quantitative sense. In such an event, a further detailed analysis can be made from the aforementioned detailed information.

[0215] The foregoing description has been made on an example of screen output data created by the drawing processing unit H04 and displayed by the output unit H06 in Fig. 47. A principal feature of the screen output data is that the forecasted trajectory of each car, the interval evaluation time which is the time at which the cage position is forecasted on the forecasted trajectory, the forecasted cage position and direction of each car at the cage interval evaluation time are collectively displayed on a single graph. Further, the screen output data features in that a waiting time evaluation value of a car intended for allocation evaluation, a cage interval evaluation value, a weighting coefficient value, and a general evaluation value are displayed in parallel as evaluation value information. As a result of such a display, it is possible to visually clearly demonstrate the forecasted trajectory of each car for allocation of interest, a time point at which a cage interval is forecasted on the forecasted trajectory, and the cage position at that time. It is therefore possible to display in a readily understandable manner a situation (forecasting situation) which is based on to evaluate the cage interval. For example, it is also possible to readily show under which situation such an allocation was made for a user who is in doubt about the basis of a certain allocation, by visually displaying the forecasted trajectory, the time point of the forecast (interval evaluation time), and a forecasted cage position.

Also, since breakdowns of the evaluation value are shown, it is possible to readily know which of the waiting time evaluation value and cage interval evaluation value is a factor to result in determination of allocation. Considering that the waiting time evaluation value is an evaluation value for an actual call which has been previously generated, while the cage interval evaluation value is an evaluation value for a future call which has not been generated, it can be said that these pieces of information show which of the actual call and feature call was a factor that resulted in allocation. In other words, a basic intention for the allocation can be known.

[0216] Fig. 50 shows an embodiment of display output data different from Fig. 49. In Fig. 50, elements identical to those in Fig. 49 are designated the same reference numerals, and a description thereon is omitted here. Fig. 50 differs from Fig. 49 in that a forecasted trajectory before hall call allocation (a forecasted trajectory L010 of a first car), indicated by a solid line, is superimposed on a forecasted trajectory after the hall call allocation (a forecasted trajectory L101 of the same first car), indicated by a broken line, in the display. The forecasted trajectory L101 after the hall call allocation includes a stop caused by the hall call allocation which appears on the trajectory. Specifically, this is a horizontal trajectory section indicated by reference numeral L102. In this connection, a hall call L009 at this time is generated on the twelfth floor in the upward direction.

[0217] By superimposing the forecasted trajectories before and after the hall call allocation in the display, as shown in Fig. 50, it is possible to more specifically display how the cage interval changes due to the allocation. In the example of Fig. 50, the cage interval extends to the forecasted trajectory L101 after the allocation of the first car with respect to a forecasted trajectory L011 of the second car, indicated by a one-dot chain line. In other words, the cage interval changes in a desired direction in view of the cage interval evaluation. Particularly, since the cage intervals can be compared before and after the allocation, the effect produced by the allocation can be quantitatively displayed in a readily understandable manner. This is effective in analyzing a factor of allocation and understanding the basis of allocation.

[0218] Fig. 51 shows a third example of the screen output data which is different from Fig. 49. In Fig. 51, elements identical to those in Fig. 49 are designated the same reference numerals, and a description thereon is omitted here. Fig. 51 differs from Fig. 49 in that actual operation trajectories of respective cages before a time point at which allocation was performed are displayed side by side together with forecasted trajectories of the respective cars. Specifically, in Fig. 51, the actual operation trajectory of the first car is represented by a trajectory L201 indicated by a solid line, and the actual operation trajectory of the second car is represented by a one-dot chain line L202. An allocation performed time point is on an axis L203. Centered on this axis, the actual operation trajectories are displayed on the left side, and the forecasted trajectories are displayed on the right side. In the actual trajectories, all stops of the cages have actually occurred, and reference numeral L204 shown halfway on the actual operation trajectory L201 of the first car indicates that the first car has actually stopped on the second floor in the upward direction. In other words, no probabilistic stop exists. This is an apparent difference between the actual operation trajectory and forecasted trajectory.

[0219] By displaying the forecasted trajectories together with (in connection with) the actual operation trajectories before the time point at which the allocation is made for the respective cars as shown in Fig. 51, changes in the interval between the respective cages before the allocation can be seen in comparison with future forecasts. As a result, it can be seen, for example, that a bunch operation state has so far prevailed, but an action is taken to avoid the bunch operation with the aid of the forecasted trajectories, or on the contrary, that a temporally equal interval state has so far prevailed, but is gradually approaching to a bunch operation in the future, as can be seen from the forecasted trajectories. Therefore, it can also be confirmed that an allocation is intentionally performed to space apart for protection in order to avoid this.

[0220] From the foregoing, by displaying the forecasted trajectories together with (in connection with) the actual operation trajectories as shown in Fig. 51, changes in the cage interval, as viewed on the time axis, can be shown in a readily understandable manner. Also, a situation in which the cage interval is changing, and past particulars can be readily understood to more readily analyze a factor of allocation.

[0221] Fig. 52 illustrates an example of a processing flow of a forecasted trajectory display method. This example assumes a method of displaying a forecasted trajectory for each preliminarily allocated car. The flow of the process will be described below in a specific manner. First, necessary data is read (L301), and a display format is next selected (L302). This selection of the display format can involve, for example, a selection of items to be displayed, and a setting of a range for a display time. Next, a hall call to be displayed is selected (L303). Next, a variable K indicative of a preliminary allocated car is initially set to one (K=1) (L304). Subsequently, display data (A) on a forecasted trajectory of a K-th car when the K-th car is preliminarily allocated to the selected hall call is created (L305). Further, display data (B) on each car other than the K-th car is created (L306). Next, display data (C) on an interval evaluation time is created (L307). After the completion of the foregoing processing, a screen which is a combination of the foregoing (A), (B), (C) is stored as a display or a data, as image data of the forecasted trajectory of each car when the K-car is preliminarily allocated to the hall call (L308).

[0222] Next, K is incremented by one (L309), the foregoing process is repeatedly executed for the next car, and is repeated until it has been executed for all cars (L310). By performing such a process, the display screen data described in connection with Figs. 49 - 51 can be created.

[0223] Fig. 53 illustrates an example of a processing flow of the forecasted trajectory display method, which is different from Fig. 52. This example shows a method of displaying a forecasted trajectory of a car to which a call is allocated. The flow of the process will be described below in a specific manner.

[0224] First, necessary data is read (L401), and a display format is next selected (L402). This selection of the display format can involve, for example, a selection of items to be displayed, and a setting of a range for a display time. Next, a database which records hall calls which have been generated in the past is searched for a hall call H to be displayed (L403). Next, a past database is searched for a K-th car which is determined to be actually allocated to the retrieved hall call H (L404). Subsequently, display data (A) on a forecasted trajectory of the K-th car, when the selected hall call is allocated to the K-th car, is created (L405). Further, display data (B) on a forecasted trajectory of each car other than the K-th car is created (L406). Further, display data (C) on an interval evaluation time is created (L407). After the completion of the foregoing process, a screen which is a combination of the foregoing (A), (B), (C) is stored as a display or a data, as image data of the forecasted trajectories of the allocated car (K) for the hall call and other cars (L408). By performing such a process, the display screen data can be created as shown in Fig. 49 - 51.

[0225] According to the embodiment described above, by providing forecasted trajectory creating means for creating a forecasted trajectory indicative of a movement of a forecasted position of each elevator on a time axis for a predetermined period from a current time point to a near future, and forecasted trajectory display means for displaying the forecasted trajectory of each car, a factor of allocation evaluation can be analyzed from a more macroscopic view in the allocation evaluation for controlling the respective cages to be arranged at equal intervals.

[0226] Also, according to the embodiment described above, by providing forecasted trajectory creating means for creating a forecasted trajectory indicative of a forecasted position of each elevator for a time axis for a predetermined period in the future, evaluation value calculating means for calculating an evaluation value related to a positional relationship between the forecasted trajectories of the respective elevators, and allocating means for allocating a hall call to an elevator, more detailed information can be analyzed for the arrangement of each car, and the information can be utilized for allocation as well.

Claims

1. An elevator group management system for managing a plurality of elevators which service a plurality of floors, based on information on hall and cage calls having been generated,
characterised by means (401, 411) for creating:

for each elevator having a direction among said elevators, a forecast trajectory indicating a forecast position and direction of the elevator at each time within a predetermined period from the current time into the future, by means for forecasting the stop probability by a new hall or cage call for a floor for which no hall or cage call has been generated and means for creating the forecast trajectory based on said stop probability and on stop information for said generated hall and cage calls, and
for each elevator having no direction among said elevators, a forecast trajectory indicative of the elevator remaining on stand-by.

2. A system according to claim 1 adapted to manage the elevators so as to equalise the time intervals between their forecast trajectories.

3. A system according to claim 1 or 2, adapted to calculate an interval between the forecast trajectories as an area of a region between the trajectories.

4. A system according to claim 3, adapted to evaluate the operational state of the elevator group on the basis of the temporal change of the calculated interval.

5. A system according to claim 3, comprising means (7) for allocating an elevator to a hall call on the basis of the calculated interval.

6. A system according to any preceding claim, adapted to set the predetermined period longer than the maximum of forecast arrival times for all hall and cage calls.

Patentansprüche

1. Aufzugsgruppen-Verwaltungssystem zur Verwaltung mehrerer Aufzüge, die mehrere Stockwerke bedienen, aufgrund von Informationen über abgegebene Stockwerks- und Kabinenrufe,
gekennzeichnet durch eine Einrichtung (401, 411), um
für jeden der Aufzüge, der eine Richtung aufweist, eine vorhergesagte Bewegungsbahn zu erzeugen, die innerhalb einer vorbestimmten Zeitspanne von der gegenwärtigen Zeit in die Zukunft hinein einen vorhergesagten Ort und eine vorhergesagte Richtung des Aufzugs angibt, indem eine Einrichtung zum Vorhersagen der Haltewahrscheinlichkeit **durch** einen neuen Stockwerks- oder Kabinenruf für ein Stockwerk, für das kein Stockwerks- oder Kabinenruf abgegeben wurde, und eine Einrichtung zum Erzeugen der vorhergesagten Bewegungsbahn aufgrund der Haltewahrscheinlichkeit und einer Halteinformation für die abgegebenen Stockwerks- und Kabinenrufe verwendet werden, und
für jeden der Aufzüge, der keine Richtung aufweist, eine vorhergesagte Bewegungsbahn zu erzeugen, die angibt, dass der Aufzug in Bereitschaft bleibt.

2. System nach Anspruch 1, das eingerichtet ist, die Aufzüge so zu verwalten, dass die Zeitintervalle zwischen ihren vorgesagten Bewegungsbahnen ausgeglichen werden.

3. System nach Anspruch 1 oder 2, das eingerichtet ist, ein Intervall zwischen den vorhergesagten Bewegungsbahnen als Fläche eines Bereichs zwischen den Bewegungsbahnen zu berechnen.

4. System nach Anspruch 3, das eingerichtet ist, den Betriebszustand der Aufzugsgruppe aufgrund der zeitlichen Änderung des berechneten Intervalls zu beurteilen.

5. System nach Anspruch 3, mit einer Einrichtung (7) zum Zuordnen eines Aufzugs zu einem Stockwerksruf aufgrund des berechneten Intervalls.

6. System nach einem der vorhergehenden Ansprüche, das eingerichtet ist, die vorbestimmte Zeitspanne länger als das Maximum der vorhergesagten Ankunftszeiten für alle Stockwerks- und Kabinenrufe festzulegen.

Revendications

1. Système de gestion de groupe d'ascenseurs pour gérer une pluralité d'ascenseurs qui desservent une pluralité d'étages, sur la base d'informations d'appels de hall ou de cabine générées,
   caractérisé par des moyens (401, 411) destinés à créer :

   pour chaque ascenseur ayant une direction parmi lesdits ascenseurs, une trajectoire prévue indiquant une position et une direction prévues de l'ascenseur à chaque instant dans une période prédéterminée depuis l'instant courant jusque dans le futur, par l'intermédiaire de moyens destinés à prévoir la probabilité d'arrêt par l'intermédiaire d'un nouvel appel de hall ou de cabine pour un étage pour lequel aucun appel de hall ou de cabine n'a été généré et des moyens destinés à créer la trajectoire prévue sur la base de ladite probabilité d'arrêt et des informations d'arrêt pour lesdits appels de hall et de cabine générés, et
   pour chaque ascenseur n'ayant pas de direction parmi lesdits ascenseurs, une trajectoire prévue indicative de l'ascenseur restant en attente.

2. Système selon la revendication 1 adapté pour gérer les ascenseurs de manière à égaliser les intervalles de temps entre leurs trajectoires prévues.

3. Système selon la revendication 1 ou 2, adapté pour calculer un intervalle entre les trajectoires prévues en tant que zone d'une région entre les trajectoires.

4. Système selon la revendication 3, adapté pour évaluer l'état opérationnel du groupe d'ascenseurs sur la base du changement temporel de l'intervalle calculé.

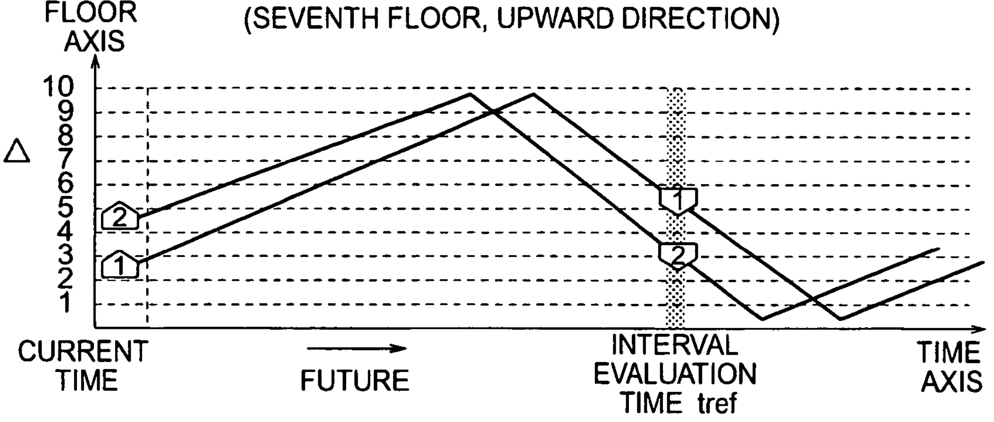
5. Système selon la revendication 3, comportant des moyens (7) pour attribuer un ascenseur à un appel de hall sur la base de l'intervalle calculé.

6. Système selon l'une quelconque des revendications précédentes, adapté pour définir la période prédéterminée comme étant plus longue que le maximum d'heures d'arrivée prévues pour tous les appels de hall et de cabine.

FIG. 1

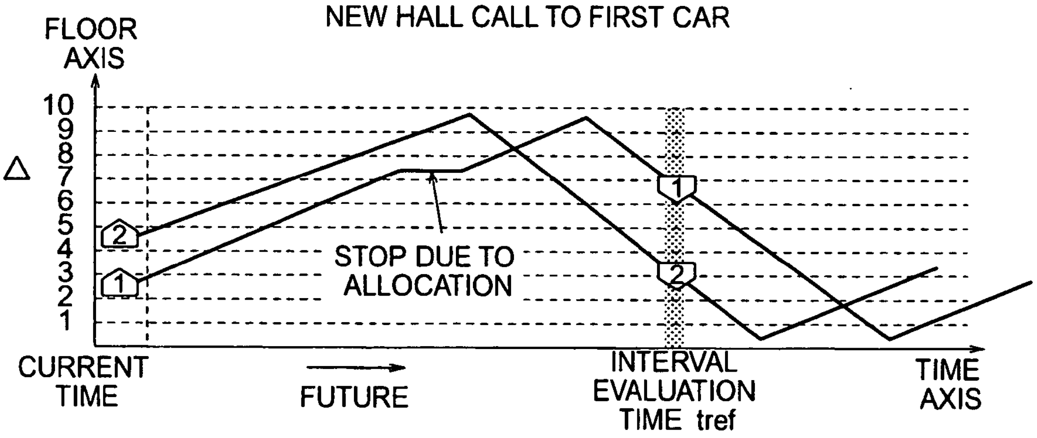
(a)

BEFORE ALLOCATION OF NEW HALL CALL (SEVENTH FLOOR, UPWARD DIRECTION)



(b)

PRELIMINARY ALLOCATION OF NEW HALL CALL TO FIRST CAR



(c)

PRELIMINARY ALLOCATION OF NEW HALL CALL TO SECOND CAR

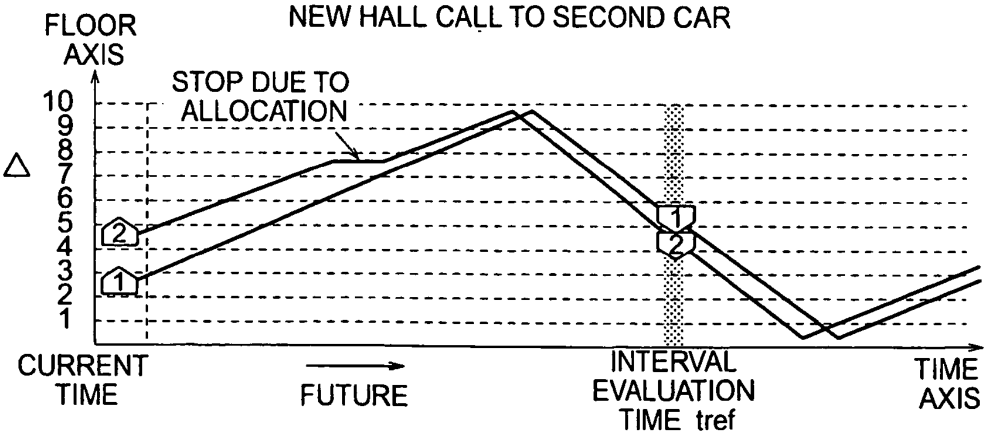


FIG. 2

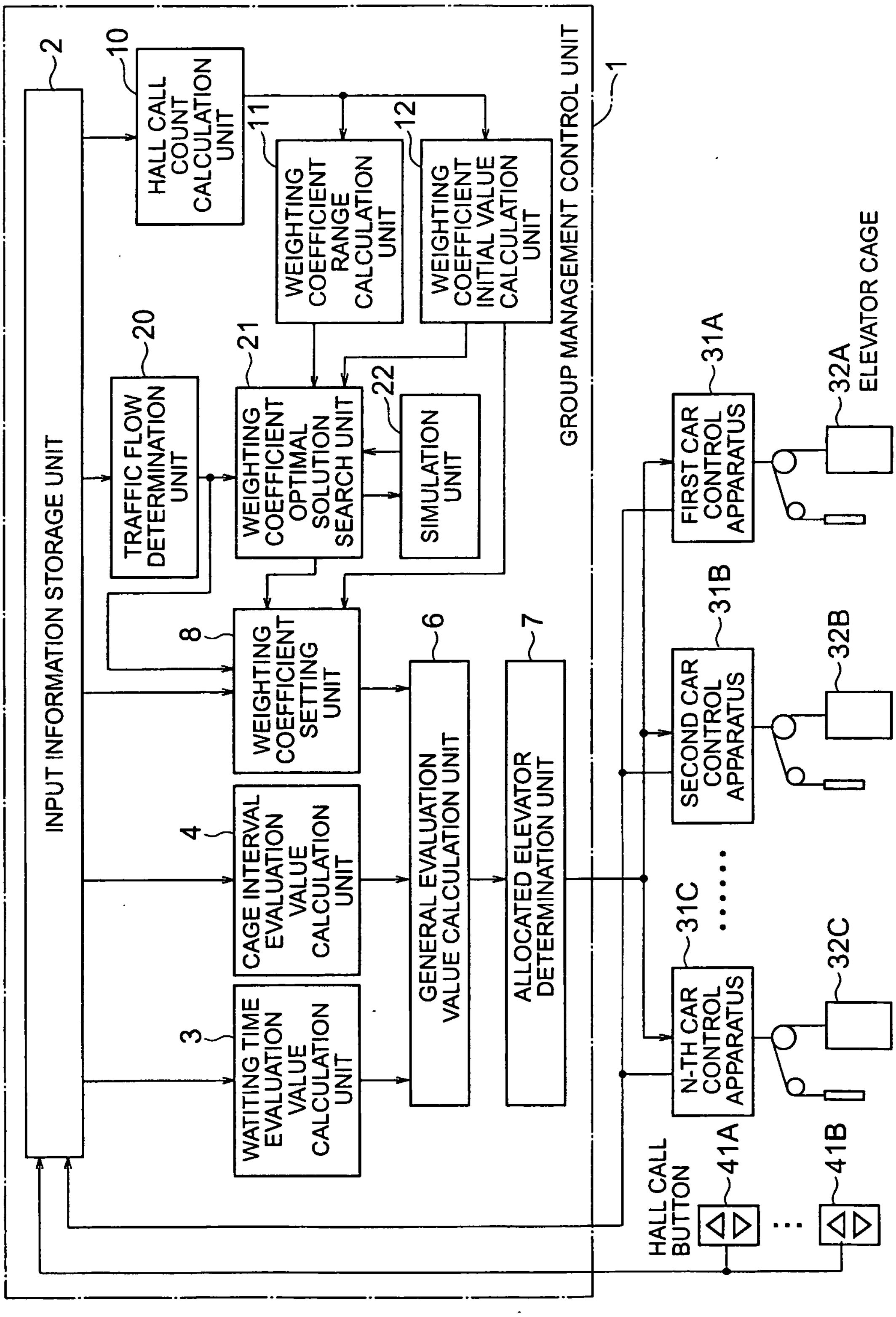

GROUP MANAGEMENT CONTROL UNIT
1
INPUT INFORMATION STORAGE UNIT
2
HALL CALL COUNT CALCULATION UNIT
10
WEIGHTING COEFFICIENT RANGE CALCULATION UNIT
11
WEIGHTING COEFFICIENT INITIAL VALUE CALCULATION UNIT
12
TRAFFIC FLOW DETERMINATION UNIT
20
WEIGHTING COEFFICIENT OPTIMAL SOLUTION SEARCH UNIT
21
SIMULATION UNIT
22
WEIGHTING COEFFICIENT SETTING UNIT
8
CAGE INTERVAL EVALUATION VALUE CALCULATION UNIT
4
WATITING TIME EVALUATION VALUE CALCULATION UNIT
3
GENERAL EVALUATION VALUE CALCULATION UNIT
6
ALLOCATED ELEVATOR DETERMINATION UNIT
7
FIRST CAR CONTROL APPARATUS
31A
SECOND CAR CONTROL APPARATUS
31B
N-TH CAR CONTROL APPARATUS
31C
32A
ELEVATOR CAGE
32B
32C
HALL CALL BUTTON
41A
41B

FIG. 3

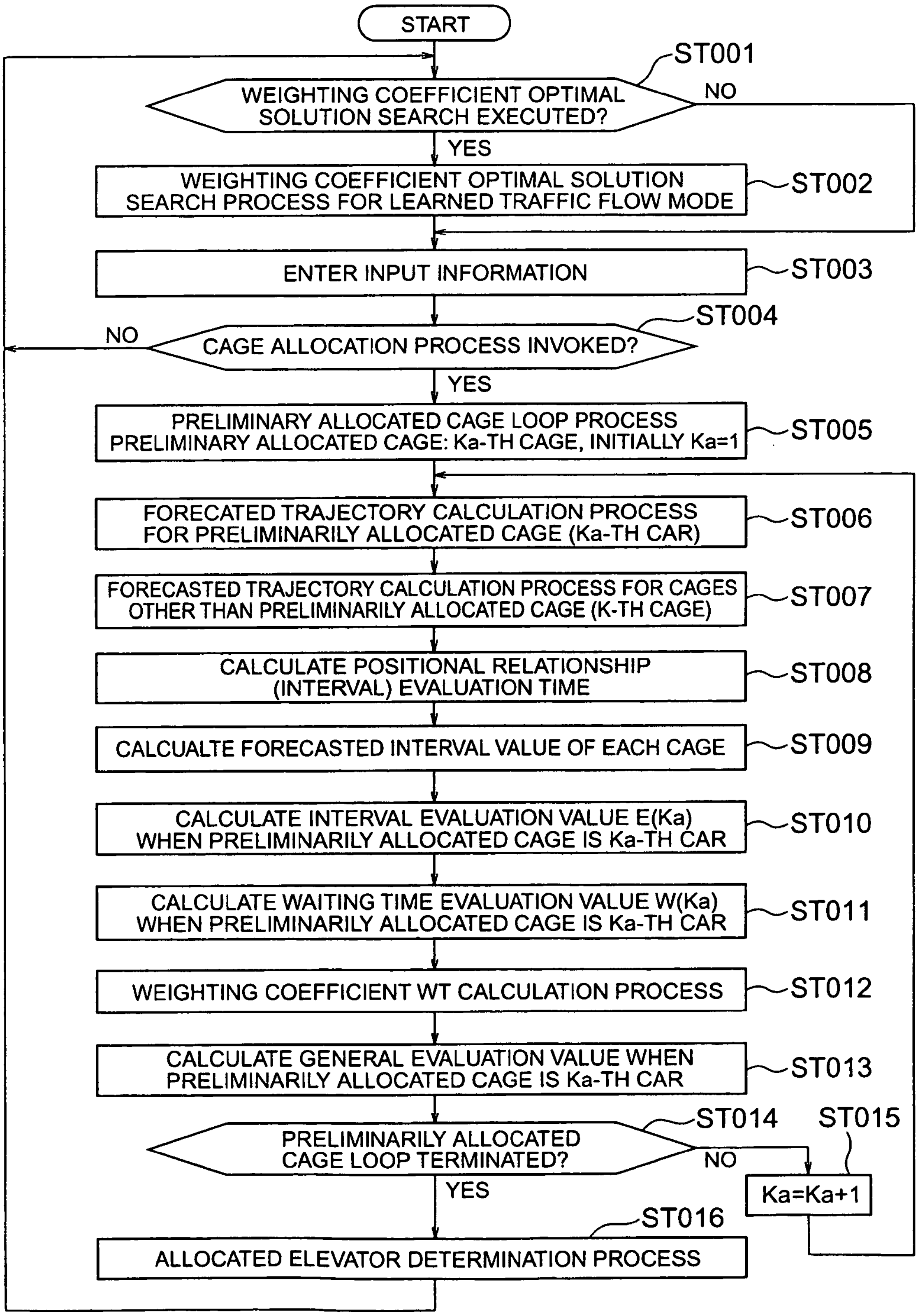

START
ST001
WEIGHTING COEFFICIENT OPTIMAL SOLUTION SEARCH EXECUTED?
NO
YES
WEIGHTING COEFFICIENT OPTIMAL SOLUTION SEARCH PROCESS FOR LEARNED TRAFFIC FLOW MODE
ST002
ENTER INPUT INFORMATION
ST003
ST004
NO
CAGE ALLOCATION PROCESS INVOKED?
YES
PRELIMINARY ALLOCATED CAGE LOOP PROCESS PRELIMINARY ALLOCATED CAGE: Ka-TH CAGE, INITIALLY Ka=1
ST005
FORECATED TRAJECTORY CALCULATION PROCESS FOR PRELIMINARILY ALLOCATED CAGE (Ka-TH CAR)
ST006
FORECASTED TRAJECTORY CALCULATION PROCESS FOR CAGES OTHER THAN PRELIMINARILY ALLOCATED CAGE (K-TH CAGE)
ST007
CALCULATE POSITIONAL RELATIONSHIP (INTERVAL) EVALUATION TIME
ST008
CALCUALTE FORECASTED INTERVAL VALUE OF EACH CAGE
ST009
CALCULATE INTERVAL EVALUATION VALUE E(Ka) WHEN PRELIMINARILY ALLOCATED CAGE IS Ka-TH CAR
ST010
CALCULATE WAITING TIME EVALUATION VALUE W(Ka) WHEN PRELIMINARILY ALLOCATED CAGE IS Ka-TH CAR
ST011
WEIGHTING COEFFICIENT WT CALCULATION PROCESS
ST012
CALCULATE GENERAL EVALUATION VALUE WHEN PRELIMINARILY ALLOCATED CAGE IS Ka-TH CAR
ST013
ST014
ST015
PRELIMINARILY ALLOCATED CAGE LOOP TERMINATED?
NO
YES
Ka=Ka+1
ST016
ALLOCATED ELEVATOR DETERMINATION PROCESS

FIG. 4

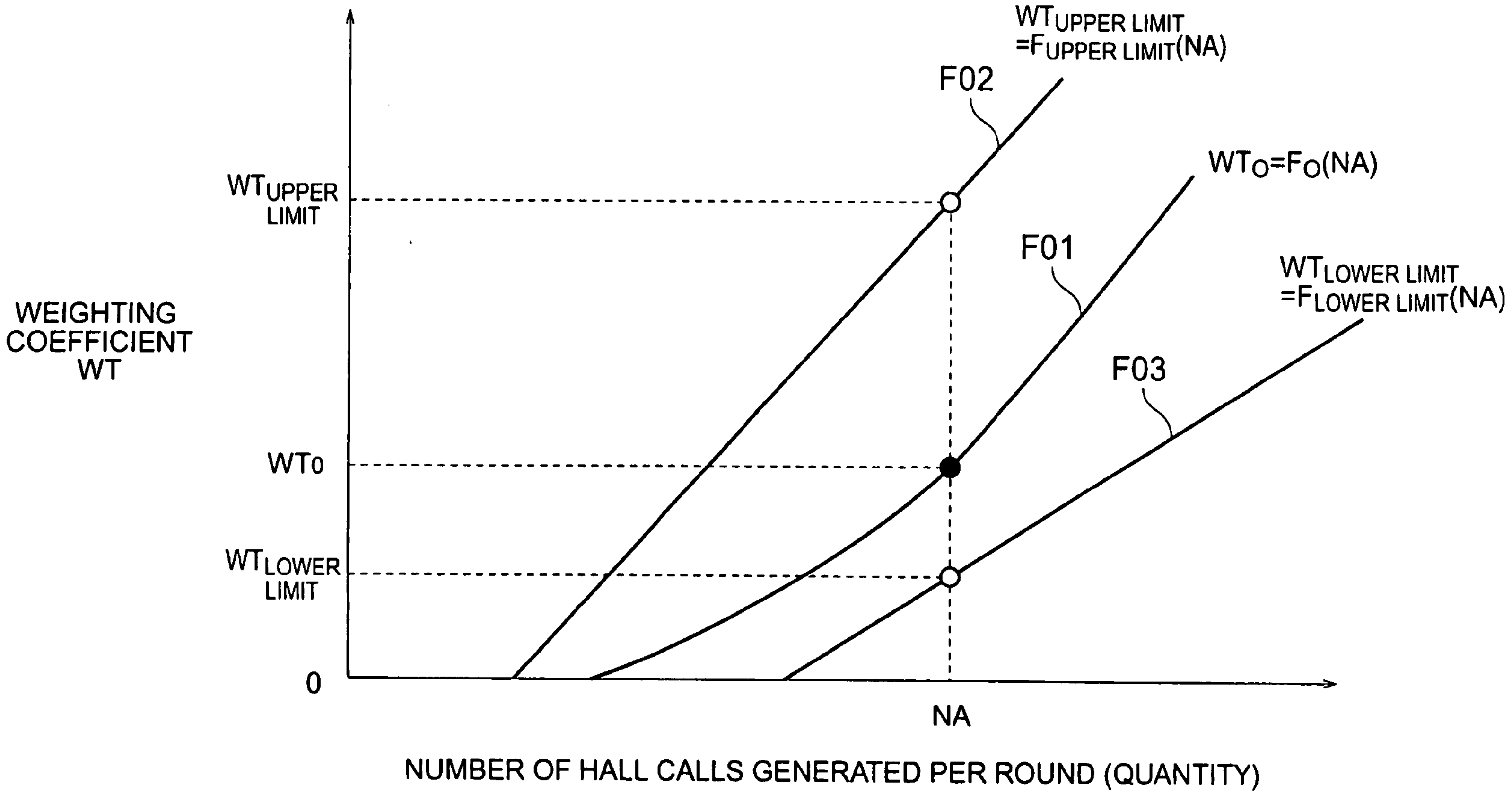

WEIGHTING
COEFFICIENT
WT
$WT_{UPPER\ LIMIT}$
WT_0
$WT_{LOWER\ LIMIT}$
0
NA
NUMBER OF HALL CALLS GENERATED PER ROUND (QUANTITY)
F02
$WT_{UPPER\ LIMIT} = F_{UPPER\ LIMIT}(NA)$
F01
$WT_O = F_O(NA)$
F03
$WT_{LOWER\ LIMIT} = F_{LOWER\ LIMIT}(NA)$

FIG. 5

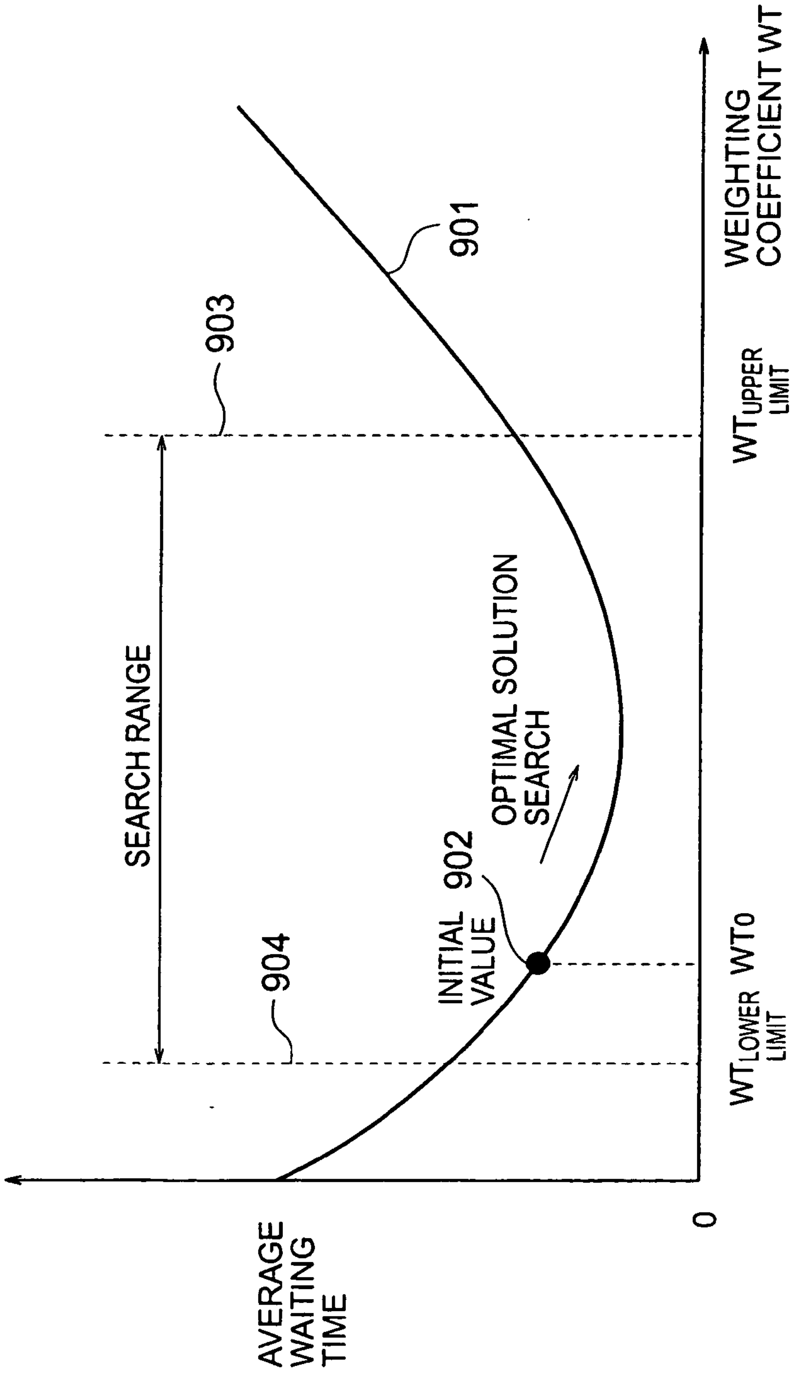
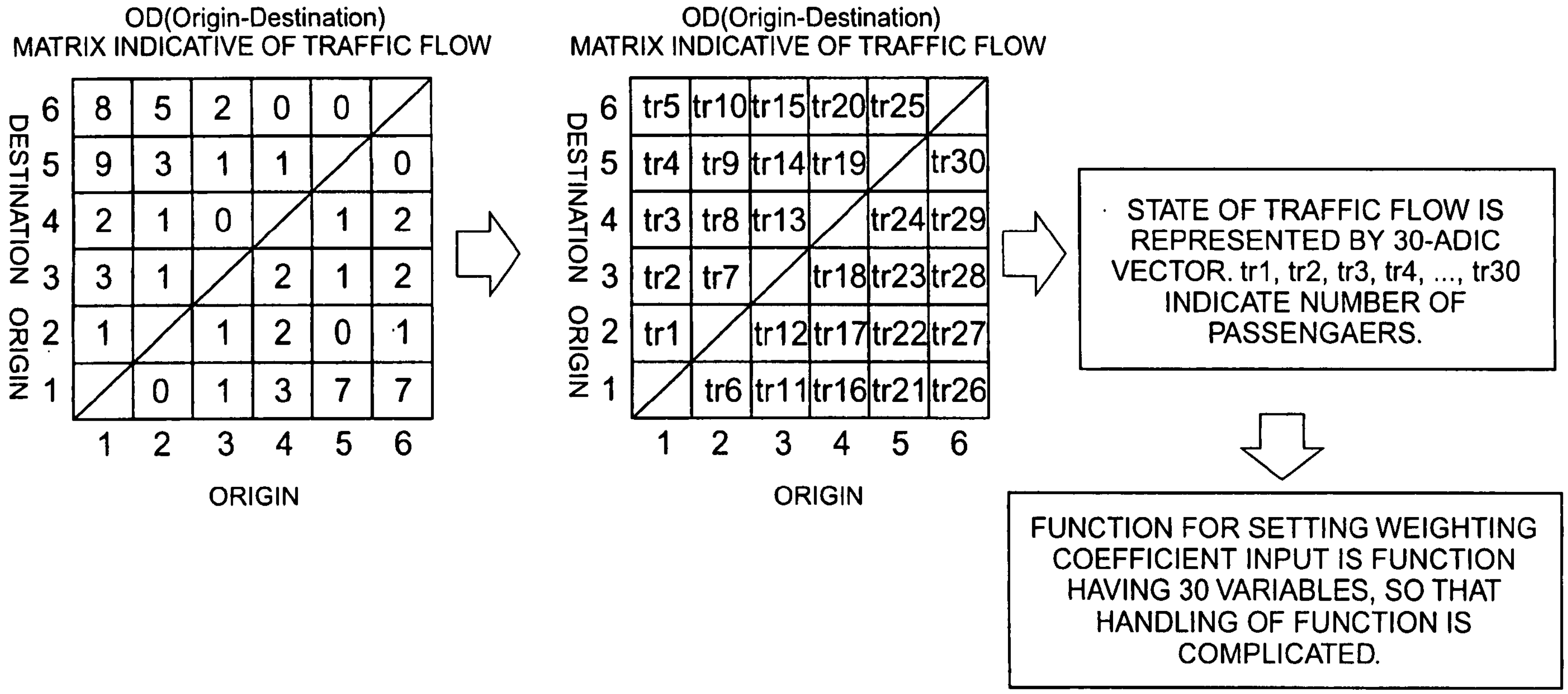

AVERAGE WAITING TIME
0
WEIGHTING COEFFICIENT WT
901
902
903
904
SEARCH RANGE
INITIAL VALUE
OPTIMAL SOLUTION SEARCH
WT_{LOWER LIMIT}
WT0
WT_{UPPER LIMIT}

FIG. 6



OD(Origin-Destination)
MATRIX INDICATIVE OF TRAFFIC FLOW

	1	2	3	4	5	6
6	8	5	2	0	0	
5	9	3	1	1		0
4	2	1	0		1	2
3	3	1		2	1	2
2	1		1	2	0	1
1		0	1	3	7	7

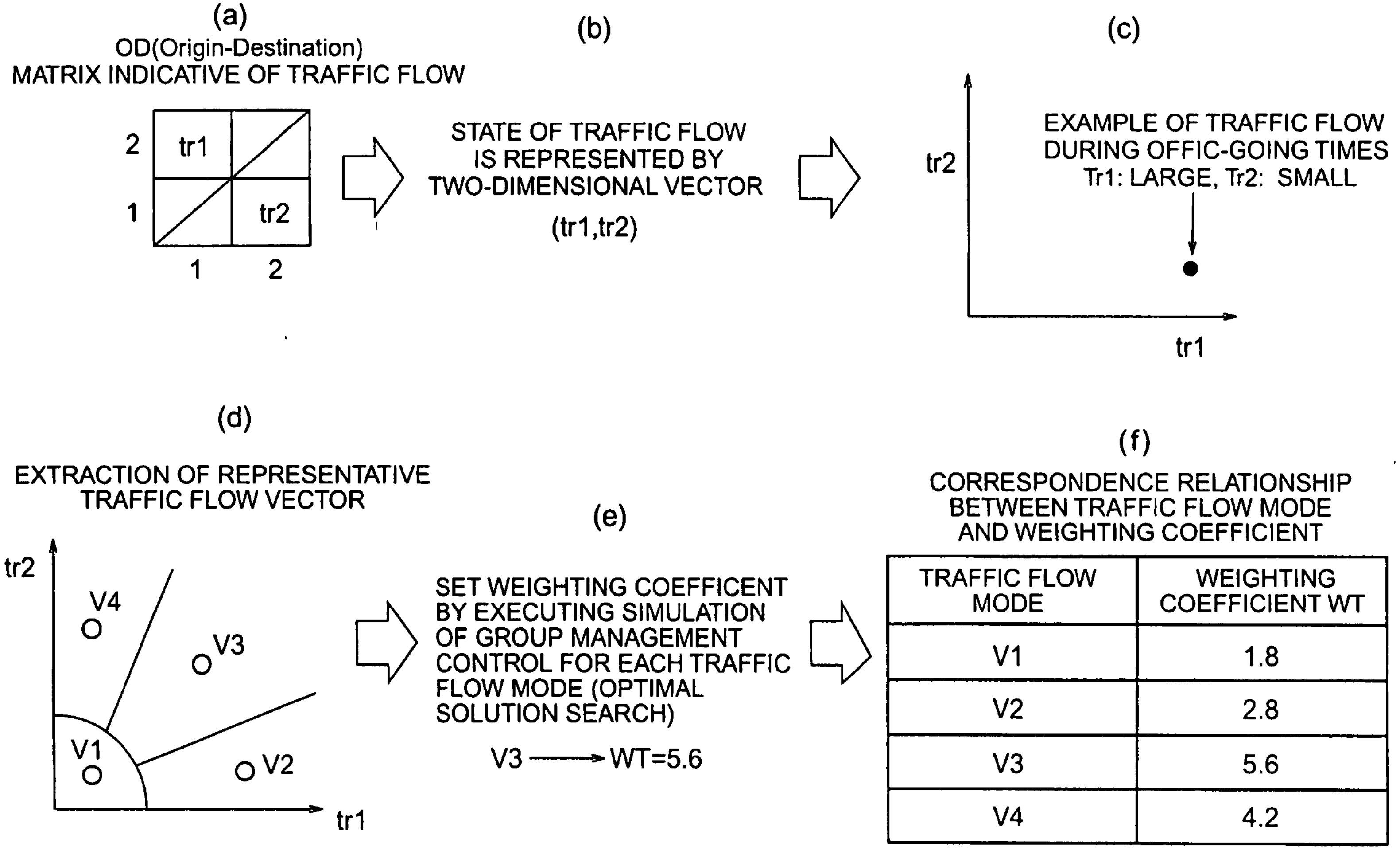
OD(Origin-Destination)
MATRIX INDICATIVE OF TRAFFIC FLOW

	1	2	3	4	5	6
6	tr5	tr10	tr15	tr20	tr25	
5	tr4	tr9	tr14	tr19		tr30
4	tr3	tr8	tr13		tr24	tr29
3	tr2	tr7		tr18	tr23	tr28
2	tr1		tr12	tr17	tr22	tr27
1		tr6	tr11	tr16	tr21	tr26

STATE OF TRAFFIC FLOW IS REPRESENTED BY 30-ADIC VECTOR. tr1, tr2, tr3, tr4, ..., tr30 INDICATE NUMBER OF PASSENGAERS.

FUNCTION FOR SETTING WEIGHTING COEFFICIENT INPUT IS FUNCTION HAVING 30 VARIABLES, SO THAT HANDLING OF FUNCTION IS COMPLICATED.

FIG. 7



TRAFFIC FLOW MODE	WEIGHTING COEFFICIENT WT
V1	1.8
V2	2.8
V3	5.6
V4	4.2

FIG. 8

COMPARISON OF WEIGHTING COEFFICIENT SETTING METHODS

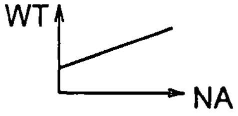
	PRIOR ART	PRESENT INVENTION
INPUT VARIABLE	TRAFFIC FLOW VECTOR OR TRAFFIC FLOW MODE	NUMBER OF GENERATED HALL CALLS
NATURE OF INPUT VARIABLE	MULTI-DIMENSIONAL VECTOR (tr1,tr2,tr3,tr4,....)	SCALAR VALUE
METHOD OF DETERMINING OUTPUT VALUE	SELECTION BY REPEATEDLY EXECUTE SIMULATION OF GROUP MANAGEMENT CONTROL	DETERMINATION BASED ON CONTINUOUS FUNCTION 
FEATURES	LONG TIME REQUIRED TO SELECT VALUE	VALUE IS INSTANTANEOUSLY DETERMINED
EFFECT		PERFORMANCE CAN BE IMMEDIATELY DEMONSTRATED FOR VARIATIONS IN TRAFFIC FLOW

FIG. 9

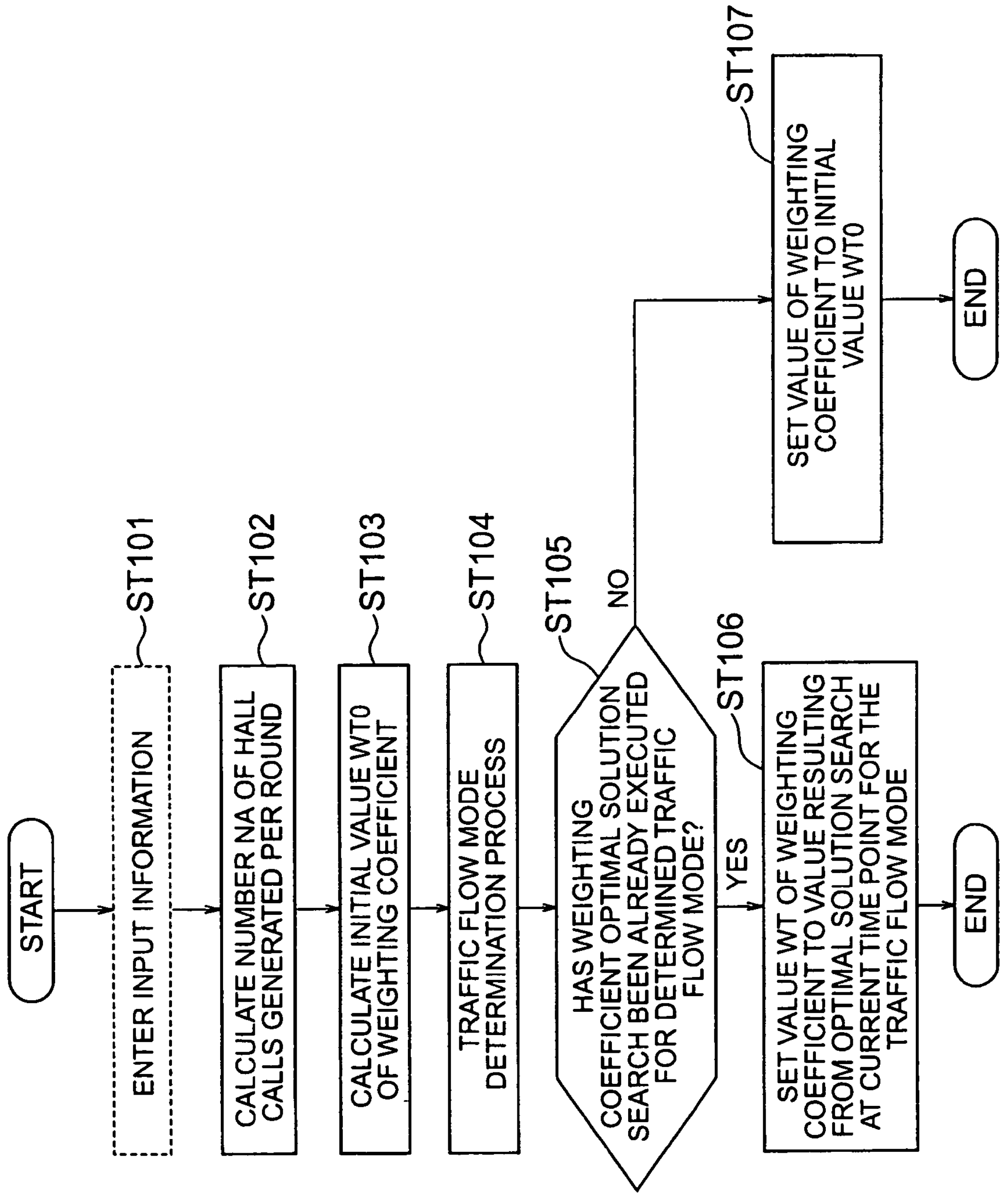

START
ENTER INPUT INFORMATION
ST101
CALCULATE NUMBER NA OF HALL CALLS GENERATED PER ROUND
ST102
CALCULATE INITIAL VALUE WT0 OF WEIGHTING COEFFICIENT
ST103
TRAFFIC FLOW MODE DETERMINATION PROCESS
ST104
HAS WEIGHTING COEFFICIENT OPTIMAL SOLUTION SEARCH BEEN ALREADY EXECUTED FOR DETERMINED TRAFFIC FLOW MODE?
ST105
YES
NO
SET VALUE WT OF WEIGHTING COEFFICIENT TO VALUE RESULTING FROM OPTIMAL SOLUTION SEARCH AT CURRENT TIME POINT FOR THE TRAFFIC FLOW MODE
ST106
END
SET VALUE OF WEIGHTING COEFFICIENT TO INITIAL VALUE WT0
ST107
END

FIG. 10

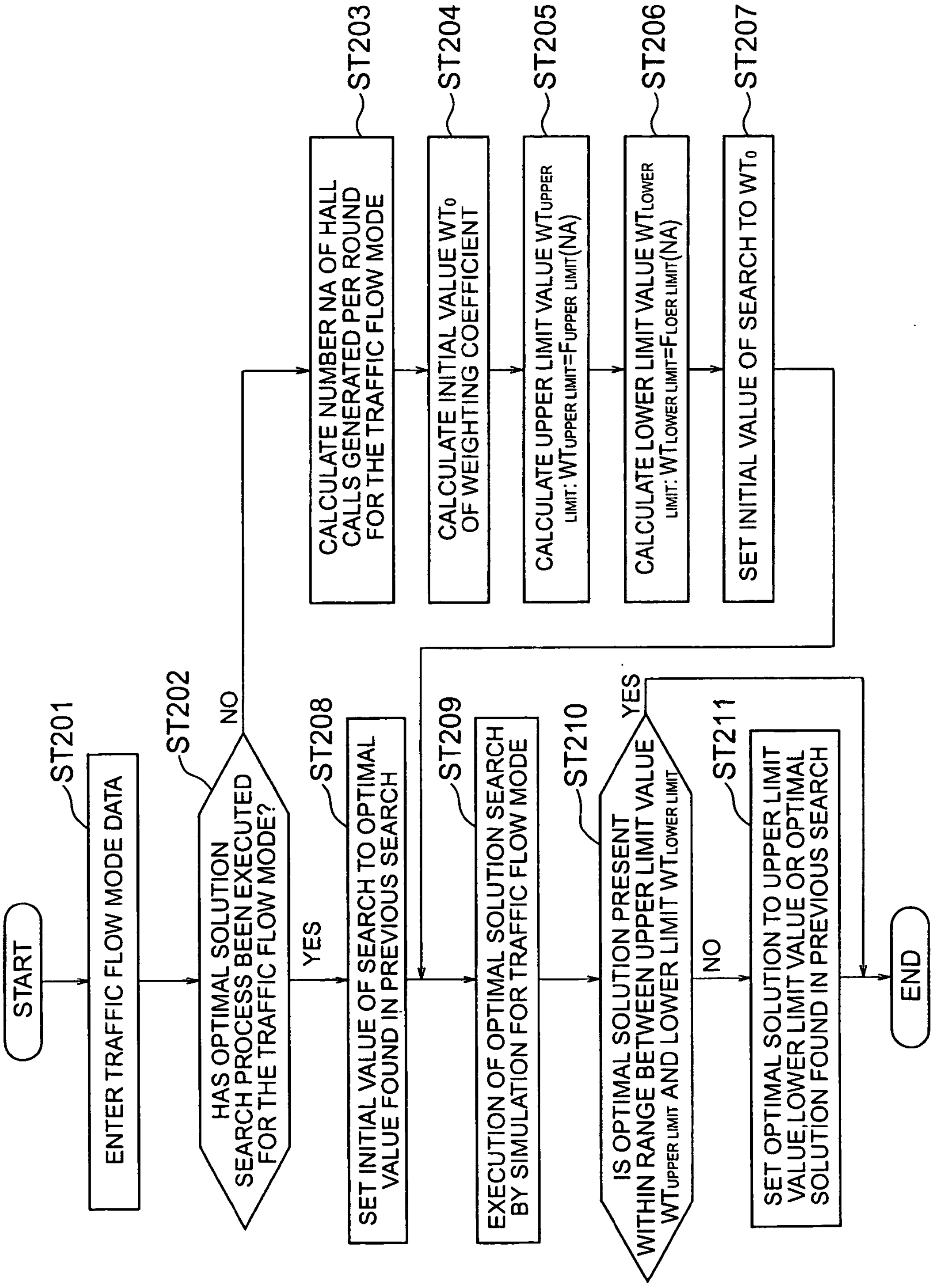

START
ST201
ENTER TRAFFIC FLOW MODE DATA
ST202
HAS OPTIMAL SOLUTION SEARCH PROCESS BEEN EXECUTED FOR THE TRAFFIC FLOW MODE?
YES
NO
ST203
CALCULATE NUMBER NA OF HALL CALLS GENERATED PER ROUND FOR THE TRAFFIC FLOW MODE
ST204
CALCULATE INITIAL VALUE WT_0 OF WEIGHTING COEFFICIENT
ST205
CALCULATE UPPER LIMIT VALUE $WT_{UPPER\ LIMIT}$: $WT_{UPPER\ LIMIT}=F_{UPPER\ LIMIT}(NA)$
ST206
CALCULATE LOWER LIMIT VALUE $WT_{LOWER\ LIMIT}$: $WT_{LOWER\ LIMIT}=F_{LOER\ LIMIT}(NA)$
ST207
SET INITIAL VALUE OF SEARCH TO WT_0
ST208
SET INITIAL VALUE OF SEARCH TO OPTIMAL VALUE FOUND IN PREVIOUS SEARCH
ST209
EXECUTION OF OPTIMAL SOLUTION SEARCH BY SIMULATION FOR TRAFFIC FLOW MODE
ST210
IS OPTIMAL SOLUTION PRESENT WITHIN RANGE BETWEEN UPPER LIMIT VALUE $WT_{UPPER\ LIMIT}$ AND LOWER LIMIT $WT_{LOWER\ LIMIT}$
YES
NO
ST211
SET OPTIMAL SOLUTION TO UPPER LIMIT VALUE,LOWER LIMIT VALUE OR OPTIMAL SOLUTION FOUND IN PREVIOUS SEARCH
END

FIG. 11

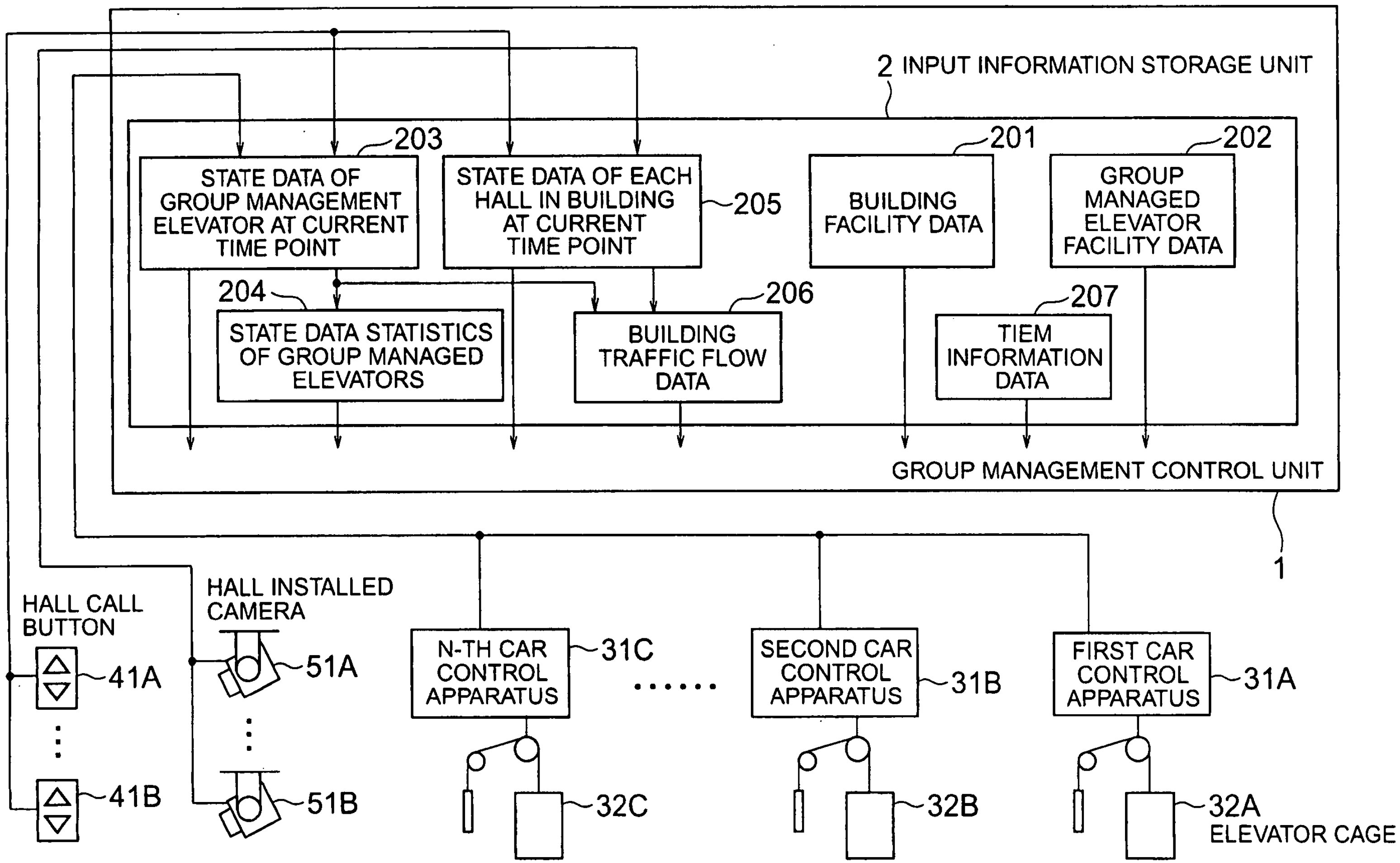

2 INPUT INFORMATION STORAGE UNIT
203
STATE DATA OF GROUP MANAGEMENT ELEVATOR AT CURRENT TIME POINT
STATE DATA OF EACH HALL IN BUILDING AT CURRENT TIME POINT
205
201
BUILDING FACILITY DATA
202
GROUP MANAGED ELEVATOR FACILITY DATA
204
STATE DATA STATISTICS OF GROUP MANAGED ELEVATORS
206
BUILDING TRAFFIC FLOW DATA
207
TIEM INFORMATION DATA
GROUP MANAGEMENT CONTROL UNIT
1
HALL CALL BUTTON
41A
41B
HALL INSTALLED CAMERA
51A
51B
N-TH CAR CONTROL APPARATUS
31C
SECOND CAR CONTROL APPARATUS
31B
FIRST CAR CONTROL APPARATUS
31A
32C
32B
32A
ELEVATOR CAGE

FIG. 12

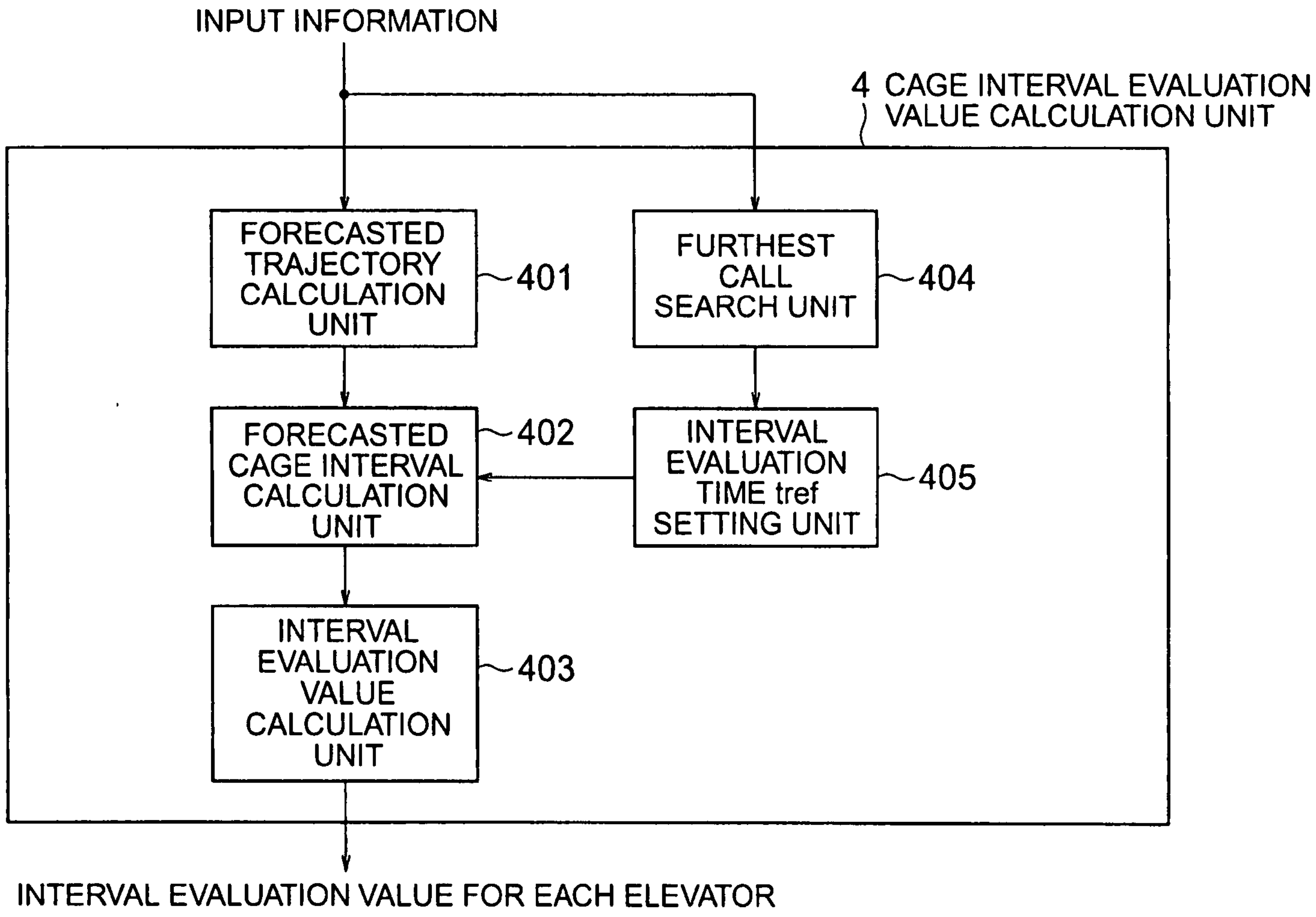

INPUT INFORMATION
4 CAGE INTERVAL EVALUATION VALUE CALCULATION UNIT
FORECASTED TRAJECTORY CALCULATION UNIT
401
FURTHEST CALL SEARCH UNIT
404
FORECASTED CAGE INTERVAL CALCULATION UNIT
402
INTERVAL EVALUATION TIME tref SETTING UNIT
405
INTERVAL EVALUATION VALUE CALCULATION UNIT
403
INTERVAL EVALUATION VALUE FOR EACH ELEVATOR

FIG. 13

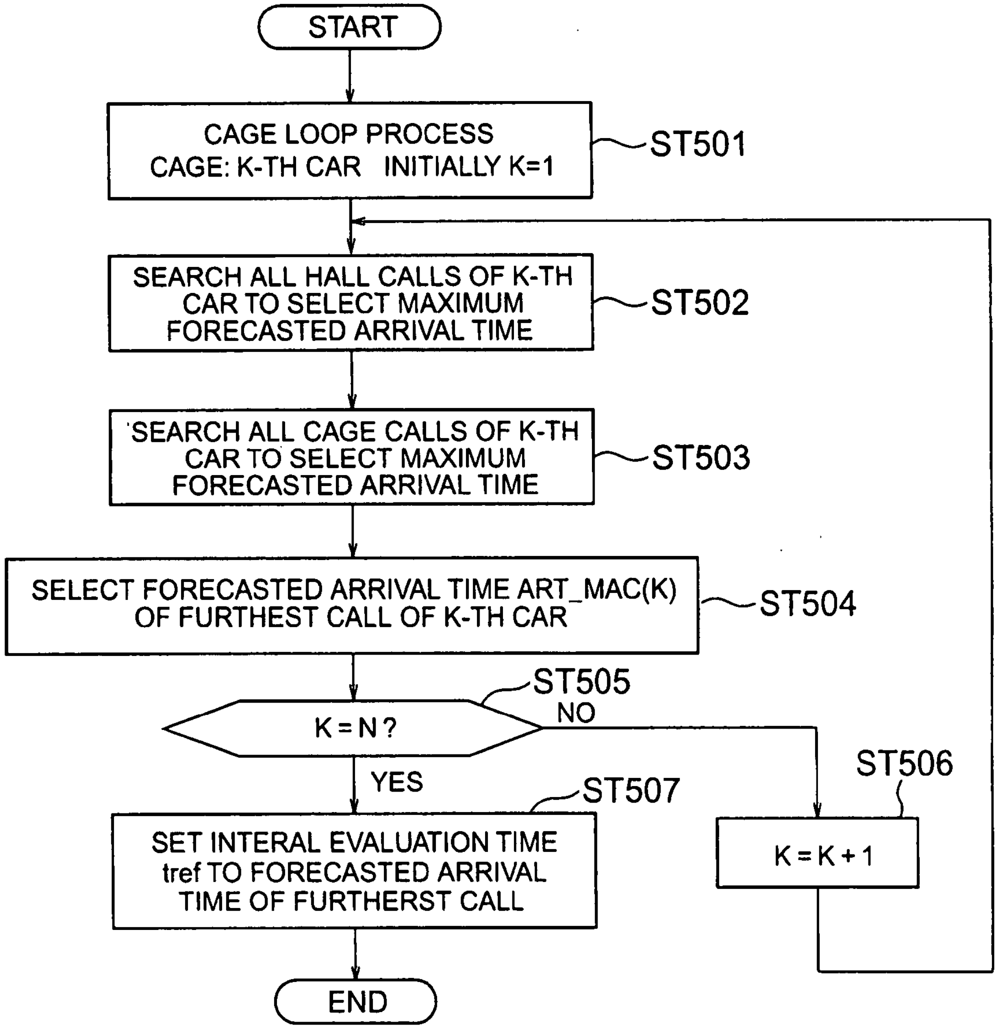

START
CAGE LOOP PROCESS
CAGE: K-TH CAR INITIALLY K=1
ST501
SEARCH ALL HALL CALLS OF K-TH CAR TO SELECT MAXIMUM FORECASTED ARRIVAL TIME
ST502
SEARCH ALL CAGE CALLS OF K-TH CAR TO SELECT MAXIMUM FORECASTED ARRIVAL TIME
ST503
SELECT FORECASTED ARRIVAL TIME ART_MAC(K) OF FURTHEST CALL OF K-TH CAR
ST504
ST505
K = N ?
NO
YES
ST506
K = K + 1
ST507
SET INTERAL EVALUATION TIME tref TO FORECASTED ARRIVAL TIME OF FURTHERST CALL
END

FIG. 14

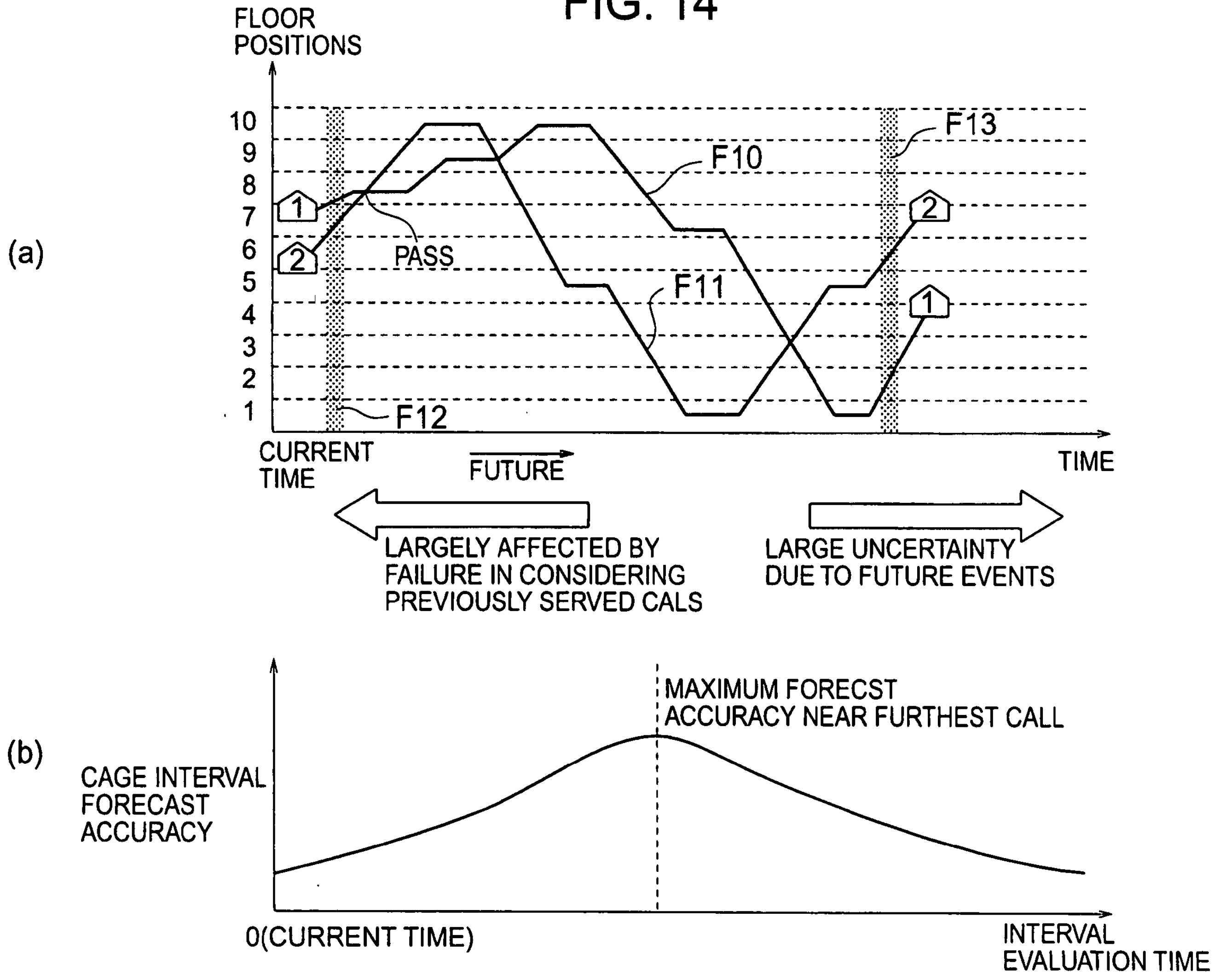
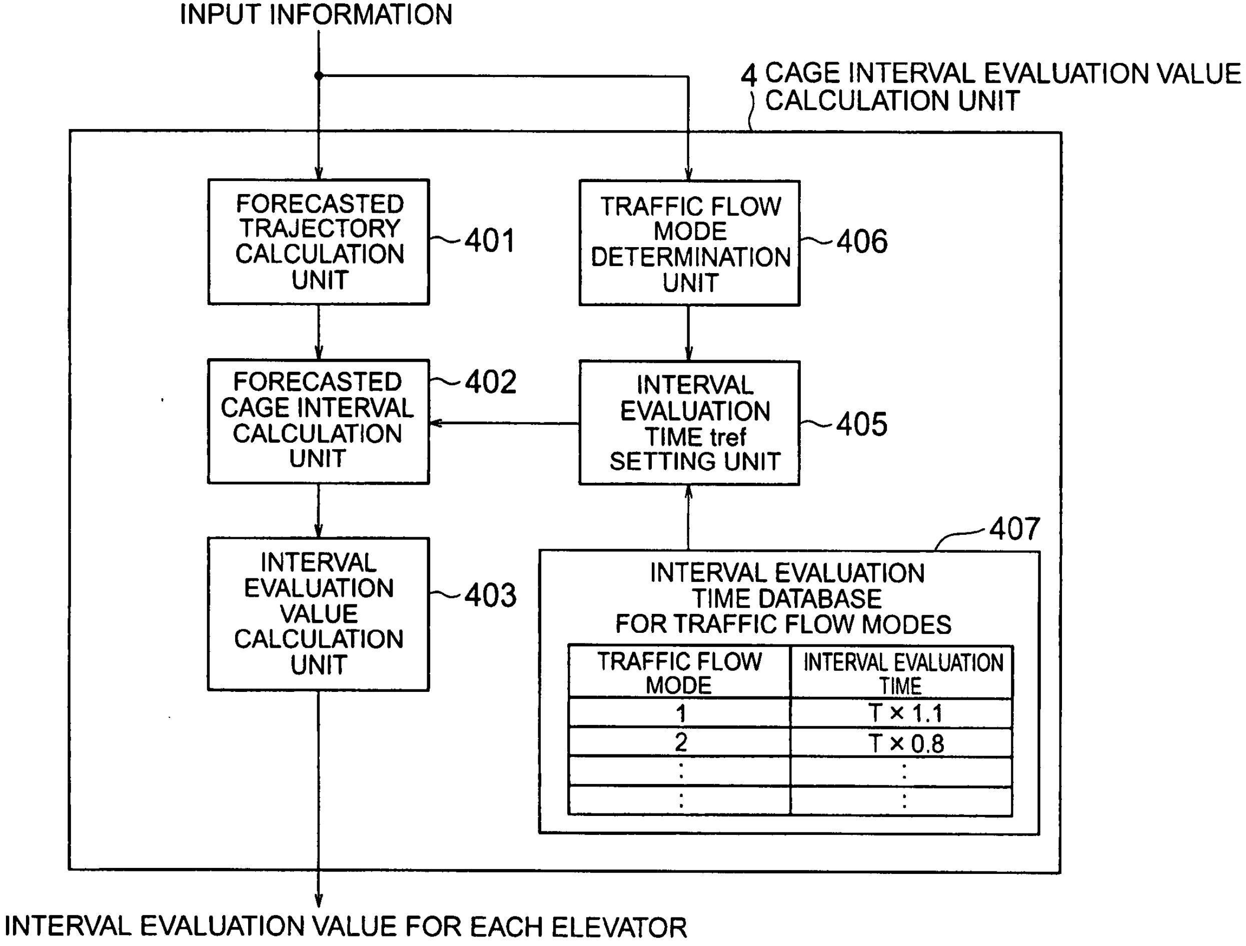

(a)
FLOOR POSITIONS
10
9
8
7
6
5
4
3
2
1
1
2
PASS
F10
F11
F12
F13
2
1
CURRENT TIME
FUTURE
TIME
LARGELY AFFECTED BY FAILURE IN CONSIDERING PREVIOUSLY SERVED CALS
LARGE UNCERTAINTY DUE TO FUTURE EVENTS
(b)
CAGE INTERVAL FORECAST ACCURACY
MAXIMUM FORECST ACCURACY NEAR FURTHEST CALL
0(CURRENT TIME)
INTERVAL EVALUATION TIME

FIG. 15



TRAFFIC FLOW MODE	INTERVAL EVALUATION TIME
1	T × 1.1
2	T × 0.8
:	:
:	:

FIG. 16

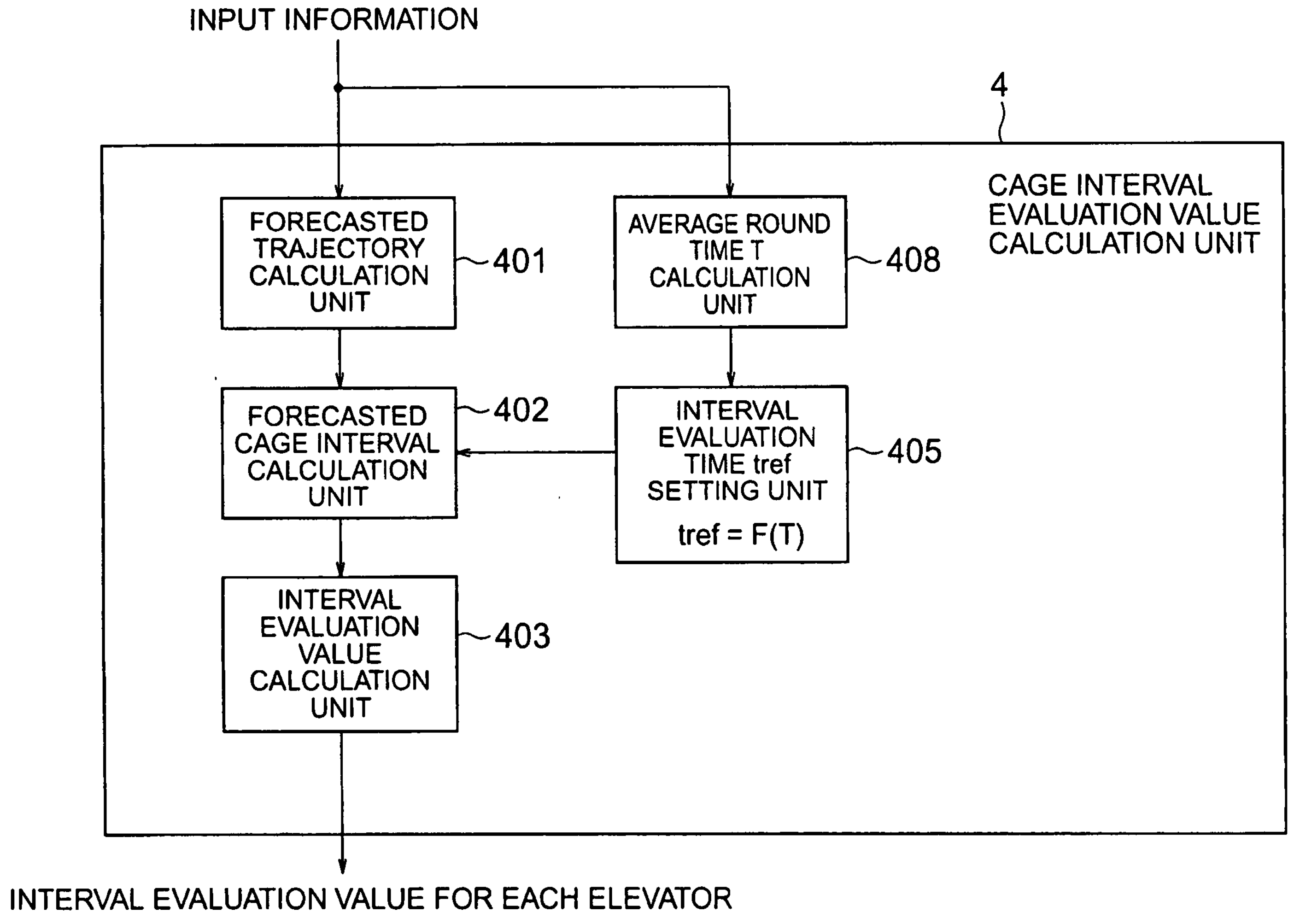

INPUT INFORMATION
4
CAGE INTERVAL EVALUATION VALUE CALCULATION UNIT
FORECASTED TRAJECTORY CALCULATION UNIT
401
AVERAGE ROUND TIME T CALCULATION UNIT
408
FORECASTED CAGE INTERVAL CALCULATION UNIT
402
INTERVAL EVALUATION TIME tref SETTING UNIT
tref = F(T)
405
INTERVAL EVALUATION VALUE CALCULATION UNIT
403
INTERVAL EVALUATION VALUE FOR EACH ELEVATOR

FIG. 17

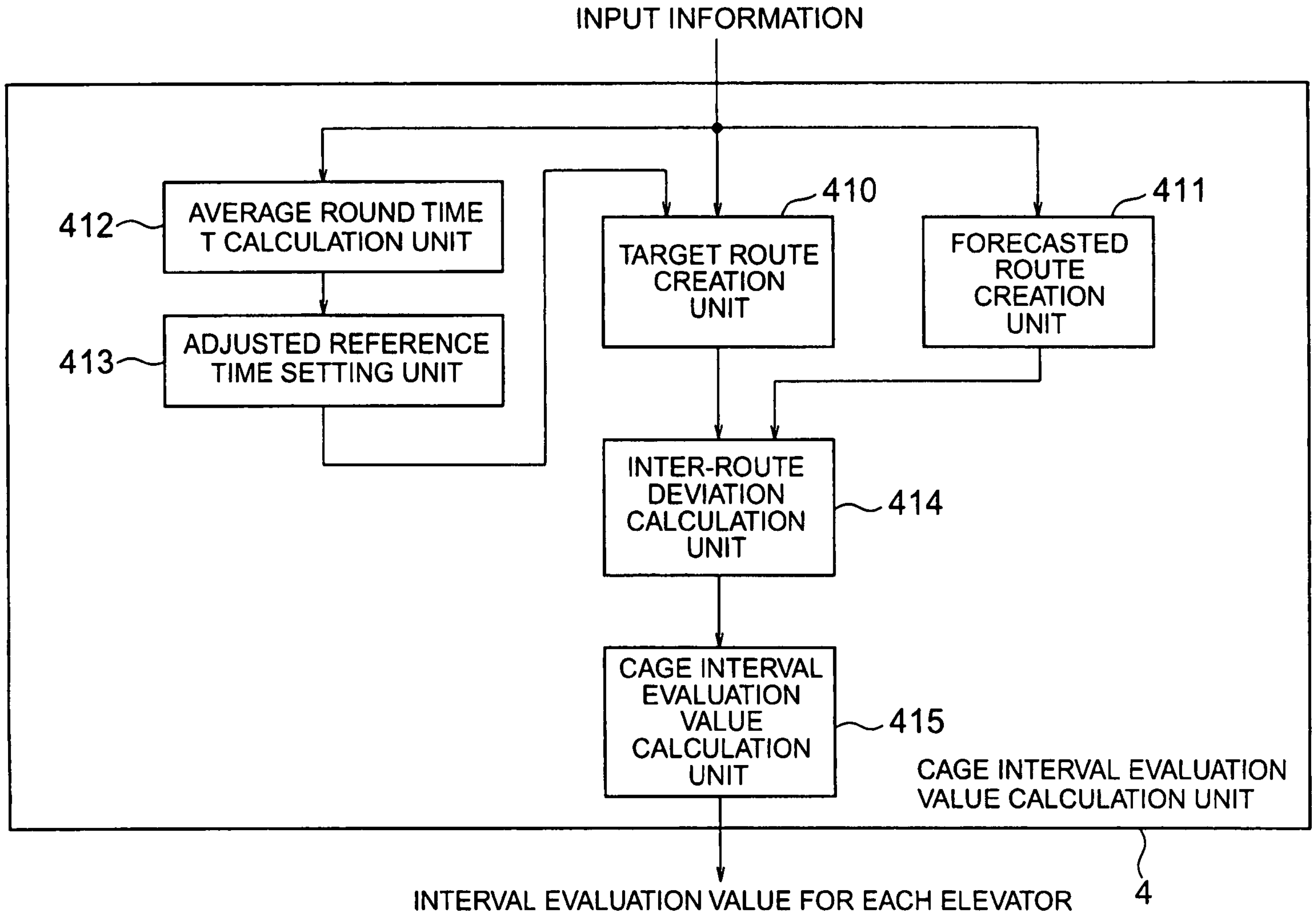

INPUT INFORMATION
412
AVERAGE ROUND TIME T CALCULATION UNIT
413
ADJUSTED REFERENCE TIME SETTING UNIT
410
TARGET ROUTE CREATION UNIT
411
FORECASTED ROUTE CREATION UNIT
INTER-ROUTE DEVIATION CALCULATION UNIT
414
CAGE INTERVAL EVALUATION VALUE CALCULATION UNIT
415
CAGE INTERVAL EVALUATION VALUE CALCULATION UNIT
4
INTERVAL EVALUATION VALUE FOR EACH ELEVATOR

FIG. 18

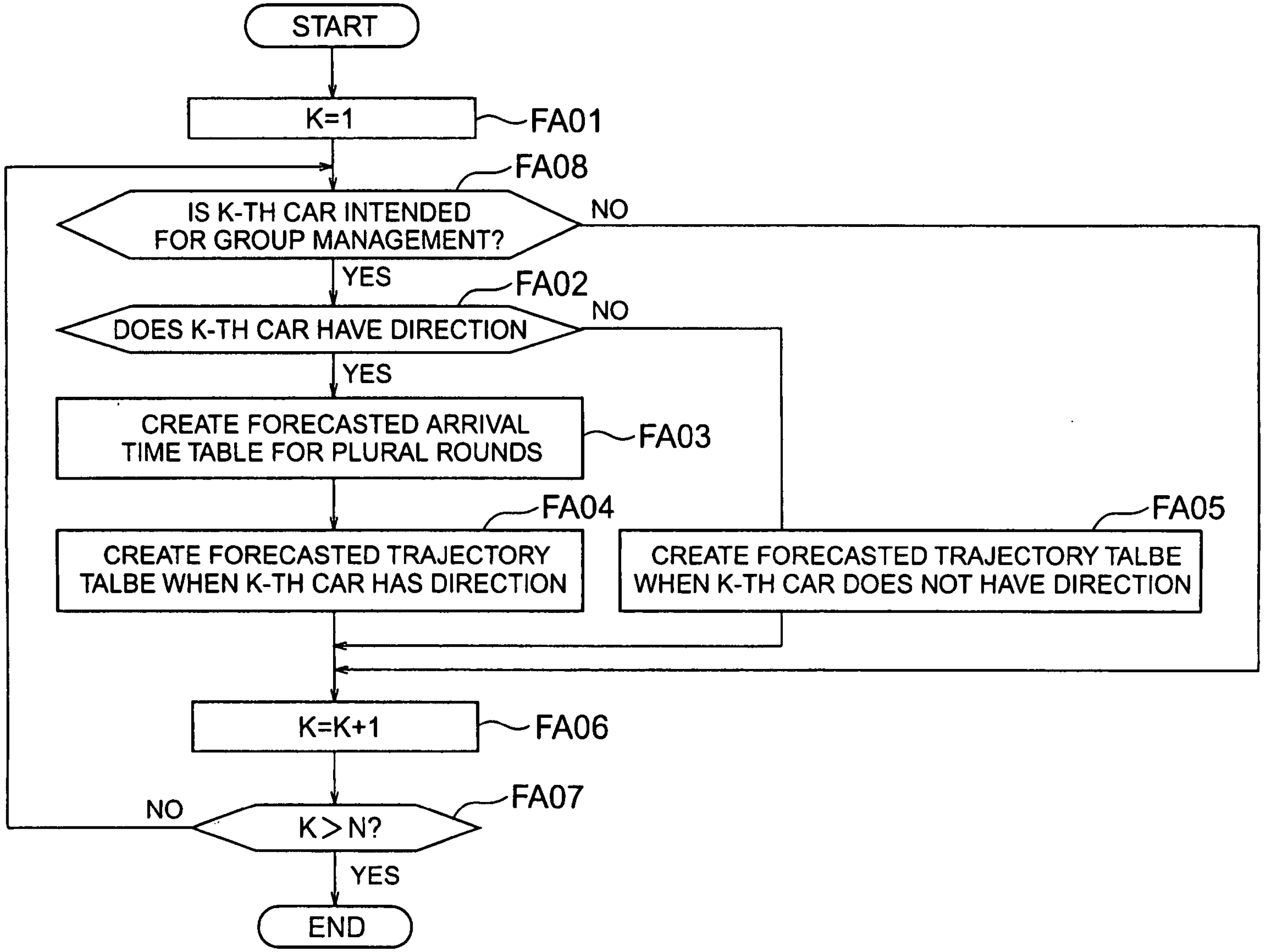

START
K=1
FA01
FA08
IS K-TH CAR INTENDED FOR GROUP MANAGEMENT?
NO
YES
FA02
DOES K-TH CAR HAVE DIRECTION
NO
YES
CREATE FORECASTED ARRIVAL TIME TABLE FOR PLURAL ROUNDS
FA03
FA04
CREATE FORECASTED TRAJECTORY TALBE WHEN K-TH CAR HAS DIRECTION
FA05
CREATE FORECASTED TRAJECTORY TALBE WHEN K-TH CAR DOES NOT HAVE DIRECTION
K=K+1
FA06
FA07
NO
K>N?
YES
END

FIG. 19

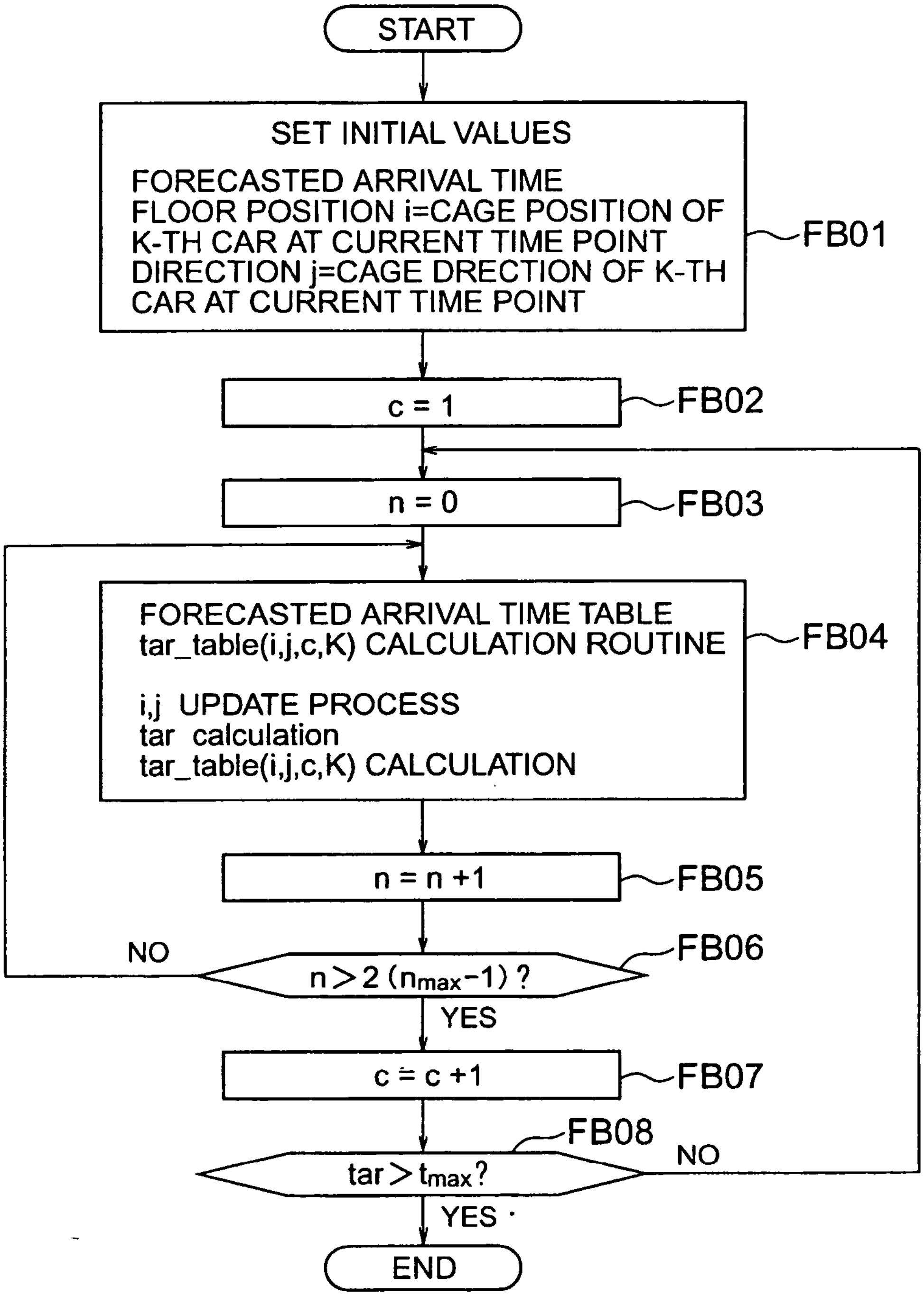

START
SET INITIAL VALUES
FORECASTED ARRIVAL TIME
FLOOR POSITION i=CAGE POSITION OF K-TH CAR AT CURRENT TIME POINT
DIRECTION j=CAGE DRECTION OF K-TH CAR AT CURRENT TIME POINT
FB01
c = 1
FB02
n = 0
FB03
FORECASTED ARRIVAL TIME TABLE tar_table(i,j,c,K) CALCULATION ROUTINE
i,j UPDATE PROCESS
tar calculation
tar_table(i,j,c,K) CALCULATION
FB04
n = n +1
FB05
NO
n > 2 (nmax-1) ?
FB06
YES
c = c +1
FB07
FB08
tar > tmax?
NO
YES
END

FIG. 20

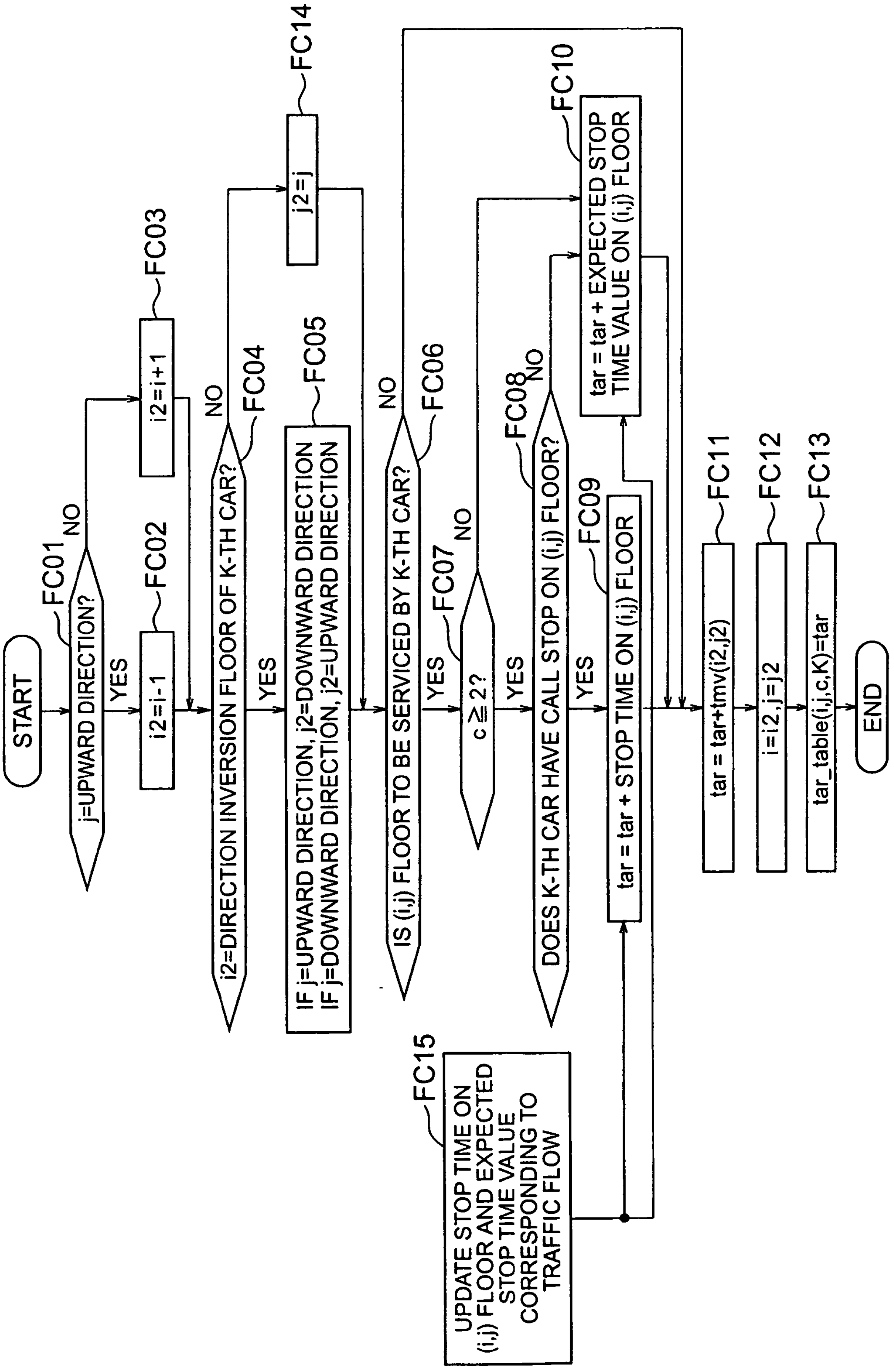

START
FC01
j=UPWARD DIRECTION?
YES
NO
FC02
i2=i-1
FC03
i2=i+1
FC04
i2=DIRECTION INVERSION FLOOR OF K-TH CAR?
YES
NO
FC05
IF j=UPWARD DIRECTION, j2=DOWNWARD DIRECTION
IF j=DOWNWARD DIRECTION, j2=UPWARD DIRECTION
FC14
j2=j
FC06
IS (i,j) FLOOR TO BE SERVICED BY K-TH CAR?
YES
NO
FC07
c ≧ 2?
YES
NO
FC08
DOES K-TH CAR HAVE CALL STOP ON (i,j) FLOOR?
YES
NO
FC09
tar = tar + STOP TIME ON (i,j) FLOOR
FC10
tar = tar + EXPECTED STOP TIME VALUE ON (i,j) FLOOR
FC15
UPDATE STOP TIME ON (i,j) FLOOR AND EXPECTED STOP TIME VALUE CORRESPONDING TO TRAFFIC FLOW
FC11
tar = tar+tmv(i2,j2)
FC12
i=i2,j=j2
FC13
tar_table(i,j,c,K)=tar
END

FIG. 21

(a)

STOP TIME TABLE

j i	UPWARD DIRECTION	DOWNWARD DIRECTION
FIFTH FLOOR		8
FOURTH FLOOR	8	8
THIRD FLOOR	8	8
SECOND FLOOR	8	8
FIRST FLOOR	8	8
GROUND FLOOR	8	

UNITS ARE SECONDS

(b)

STOP PROBABILITY TABLE

j i	UPWARD DIRECTION	DOWNWARD DIRECTION
FIFTH FLOOR		0.2
FOURTH FLOOR	0.6	0.2
THIRD FLOOR	0.6	0.2
SECOND FLOOR	0.6	0.2
FIRST FLOOR	0.6	0.2
GROUND FLOOR	0.6	

UNITS ARE SECONDS

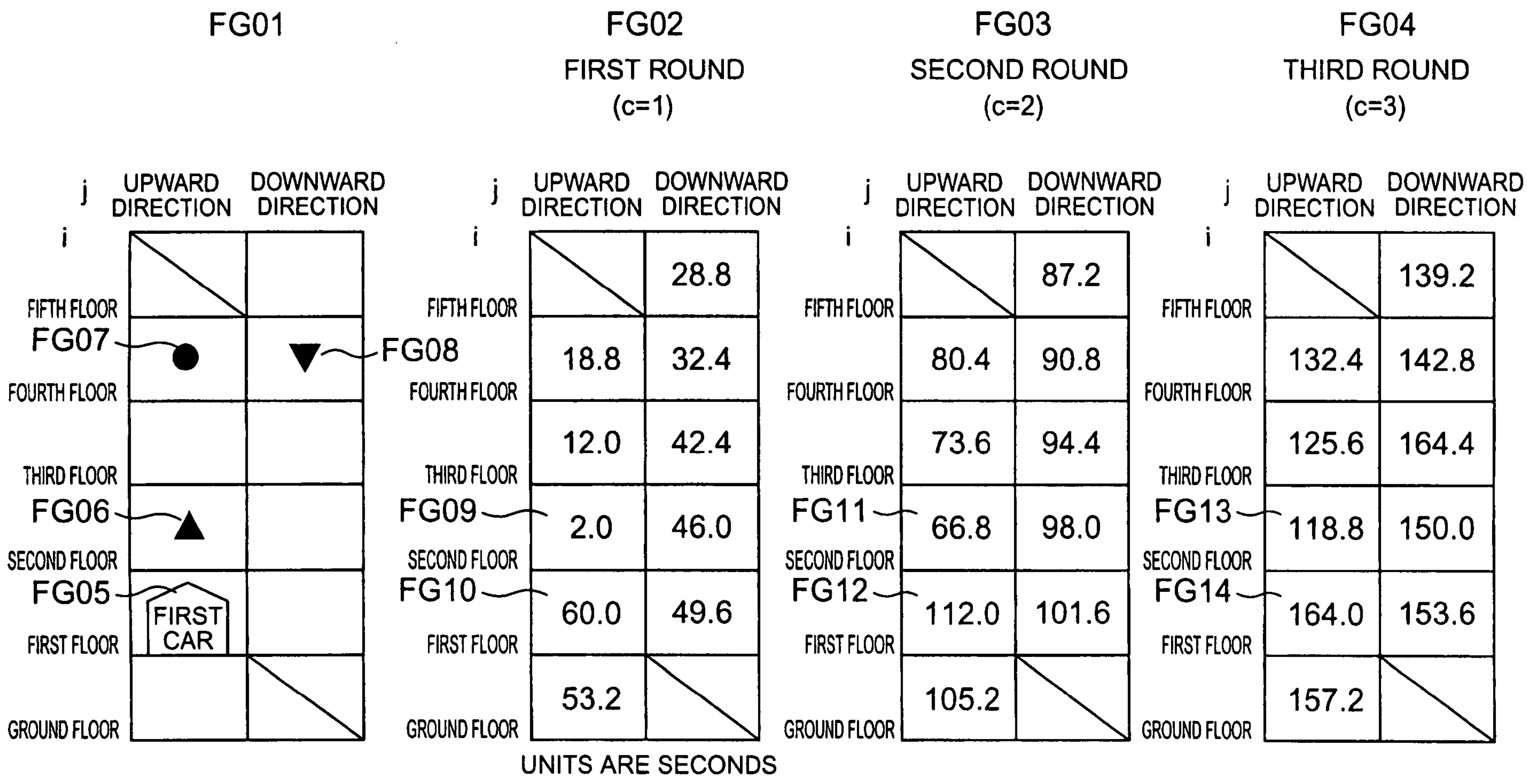
(c)

EXPECTED STOP TIME VALUE TABLE

j i	UPWARD DIRECTION	DOWNWARD DIRECTION
FIFTH FLOOR		1.6
FOURTH FLOOR	4.8	1.6
THIRD FLOOR	4.8	1.6
SECOND FLOOR	4.8	1.6
FIRST FLOOR	4.8	1.6
GROUND FLOOR	4.8	

UNITS ARE SECONDS

FIG. 22



FG02
FIRST ROUND
(c=1)

i \ j	UPWARD DIRECTION	DOWNWARD DIRECTION
FIFTH FLOOR		28.8
FOURTH FLOOR	18.8	32.4
THIRD FLOOR	12.0	42.4
SECOND FLOOR	2.0	46.0
FIRST FLOOR	60.0	49.6
GROUND FLOOR	53.2	

FG03
SECOND ROUND
(c=2)

i \ j	UPWARD DIRECTION	DOWNWARD DIRECTION
FIFTH FLOOR		87.2
FOURTH FLOOR	80.4	90.8
THIRD FLOOR	73.6	94.4
SECOND FLOOR	66.8	98.0
FIRST FLOOR	112.0	101.6
GROUND FLOOR	105.2	

FG04
THIRD ROUND
(c=3)

i \ j	UPWARD DIRECTION	DOWNWARD DIRECTION
FIFTH FLOOR		139.2
FOURTH FLOOR	132.4	142.8
THIRD FLOOR	125.6	164.4
SECOND FLOOR	118.8	150.0
FIRST FLOOR	164.0	153.6
GROUND FLOOR	157.2	

UNITS ARE SECONDS

MOVING TIME TO EACH FLOOR/DIRECTION IS UNIFORMLY TWO SECONDS/FLOOR.

FIG. 23

FH02
FH05
FH03
FH01
FH04

CAR NAME	FIRST CAR		SECOND CAR	
TIME (SECONDS)	POSITION (FLOOR)	DIRECTION	POSITION (FLOOR)	DIRECTION
0	2.0	UP	6.0	DN
1	2.5	UP	5.5	DN
2	3.0	UP	5.0	DN
3	3.1	UP	4.7	DN
4	3.2	UP	4.4	DN
5	3.3	UP	4.2	DN
6	3.4	UP	4.0	DN
7	3.5	UP	3.9	DN
8	3.6	UP	3.8	DN
9	3.7	UP	3.7	DN
10	3.8	UP	3.6	DN
11	3.9	UP	3.5	DN
12	4.0	UP	3.4	DN
13	4.1	UP	3.3	DN
14	4.3	UP	3.2	DN
15	4.4	UP	3.1	DN
16	4.6	UP	3.0	DN
17	4.7	UP	2.9	DN
18	4.9	UP	2.8	DN
19	5.0	UP	2.7	DN
20	5.1	UP	2.6	DN
21	5.2	UP	2.5	DN
22	5.3	UP	2.4	DN
23	5.4	UP	2.3	DN
24	5.5	UP	2.2	DN
25	5.6	UP	2.1	DN
26	5.7	UP	2.0	DN
27	5.8	UP	1.9	DN
28	5.9	UP	1.8	DN
29	6.0	DN	1.7	DN
30	5.7	DN	1.6	DN

FIG. 24

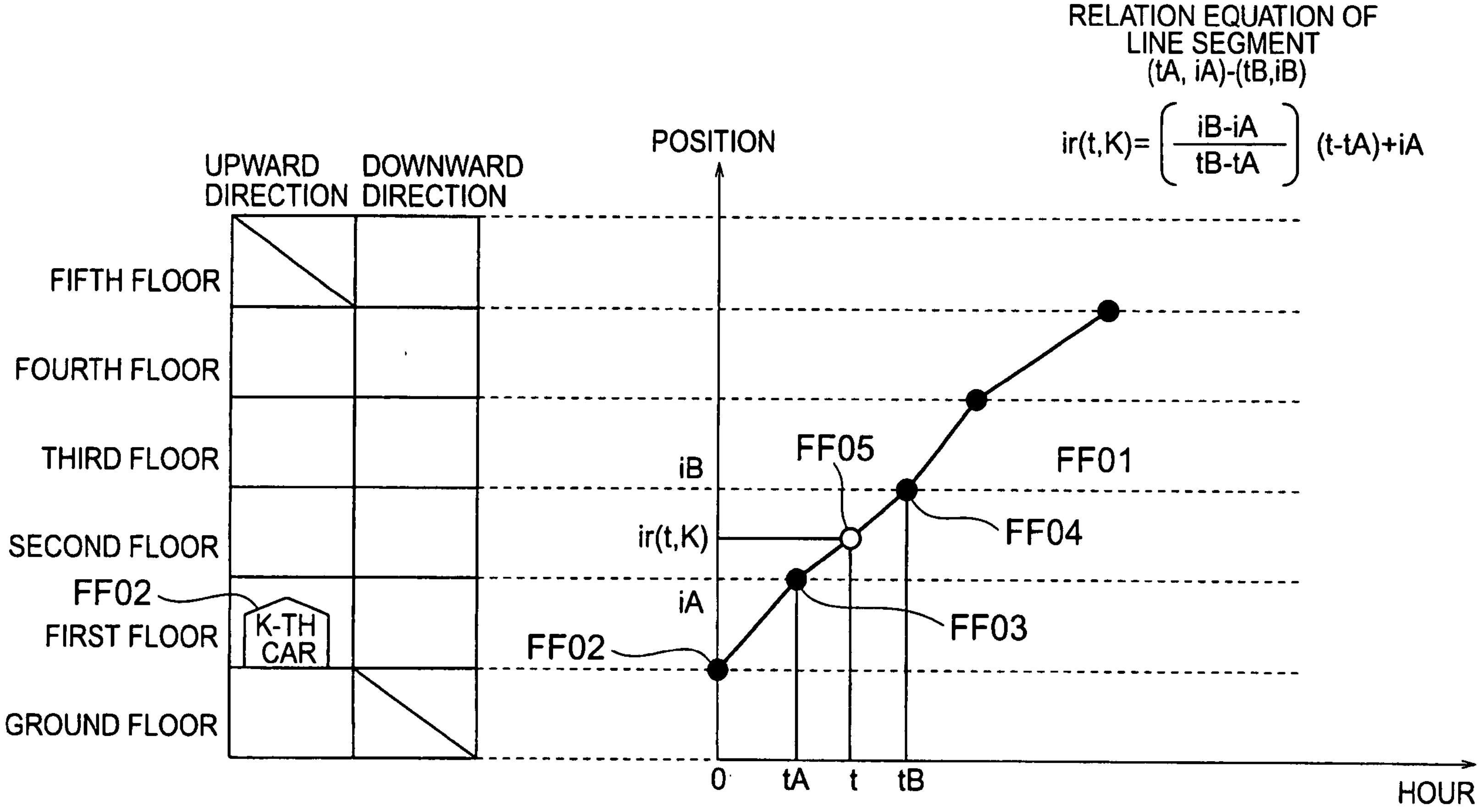

RELATION EQUATION OF LINE SEGMENT (tA, iA)-(tB,iB)
$ir(t,K)=\left(\frac{iB-iA}{tB-tA}\right)(t-tA)+iA$
UPWARD DIRECTION
DOWNWARD DIRECTION
FIFTH FLOOR
FOURTH FLOOR
THIRD FLOOR
SECOND FLOOR
FF02
FIRST FLOOR
K-TH CAR
GROUND FLOOR
POSITION
iB
ir(t,K)
iA
FF02
FF05
FF01
FF04
FF03
0
tA
t
tB
HOUR

FIG. 25

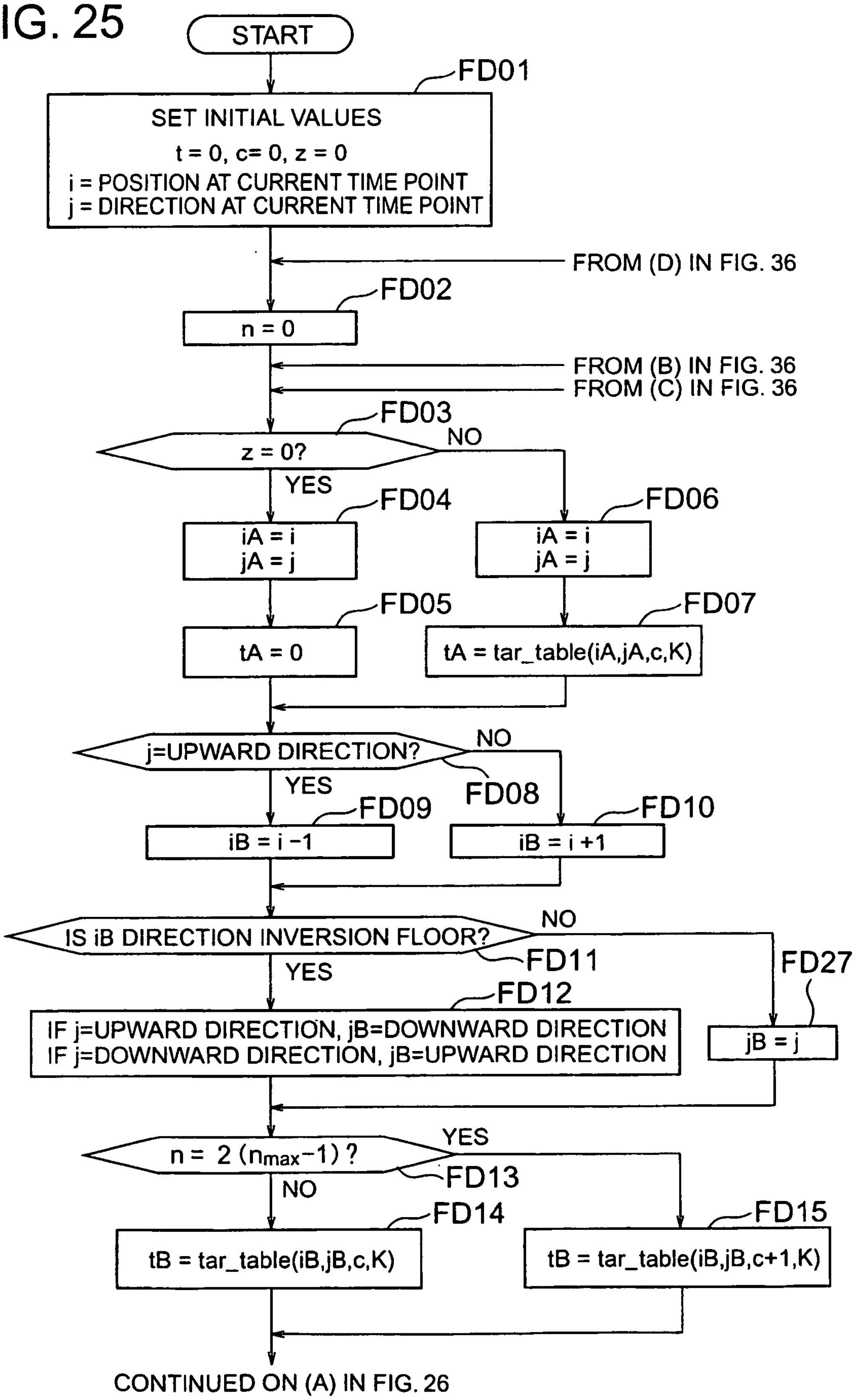

START
FD01
SET INITIAL VALUES
t = 0, c= 0, z = 0
i = POSITION AT CURRENT TIME POINT
j = DIRECTION AT CURRENT TIME POINT
FROM (D) IN FIG. 36
FD02
n = 0
FROM (B) IN FIG. 36
FROM (C) IN FIG. 36
FD03
z = 0?
NO
YES
FD04
iA = i
jA = j
FD06
iA = i
jA = j
FD05
tA = 0
FD07
tA = tar_table(iA,jA,c,K)
j=UPWARD DIRECTION?
NO
YES
FD08
FD09
iB = i -1
FD10
iB = i +1
IS iB DIRECTION INVERSION FLOOR?
NO
FD11
YES
FD27
FD12
IF j=UPWARD DIRECTION, jB=DOWNWARD DIRECTION
IF j=DOWNWARD DIRECTION, jB=UPWARD DIRECTION
jB = j
YES
n = 2 (nmax−1) ?
FD13
NO
FD14
tB = tar_table(iB,jB,c,K)
FD15
tB = tar_table(iB,jB,c+1,K)
CONTINUED ON (A) IN FIG. 26

FIG. 26

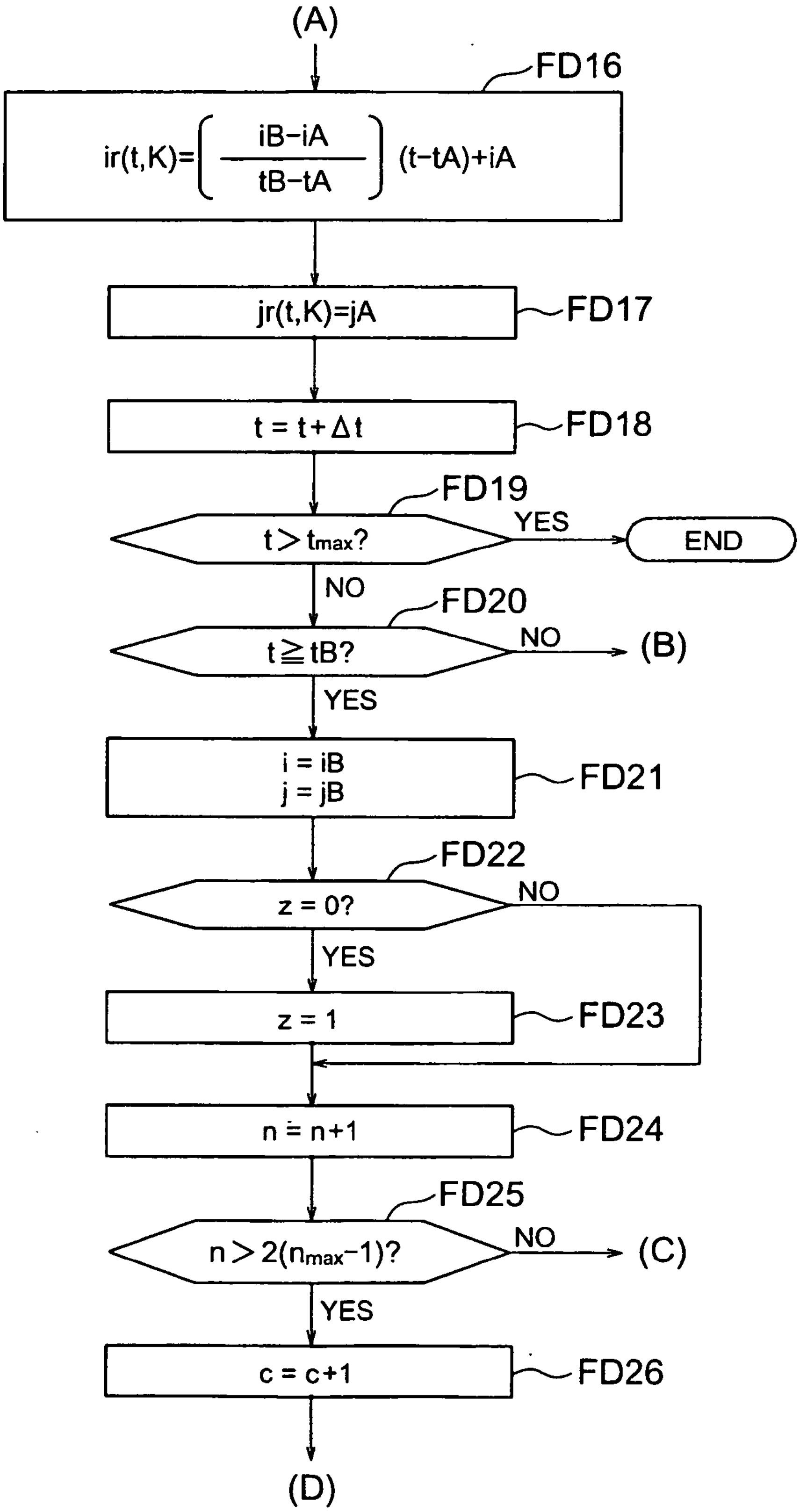

(A)
FD16
ir(t,K)=((iB−iA)/(tB−tA))(t−tA)+iA
jr(t,K)=jA
FD17
t = t+Δt
FD18
FD19
t > tmax?
YES
END
NO
FD20
t ≧ tB?
NO
(B)
YES
i = iB
j = jB
FD21
FD22
z = 0?
NO
YES
z = 1
FD23
n = n+1
FD24
FD25
n > 2(nmax−1)?
NO
(C)
YES
c = c+1
FD26
(D)

FIG. 27

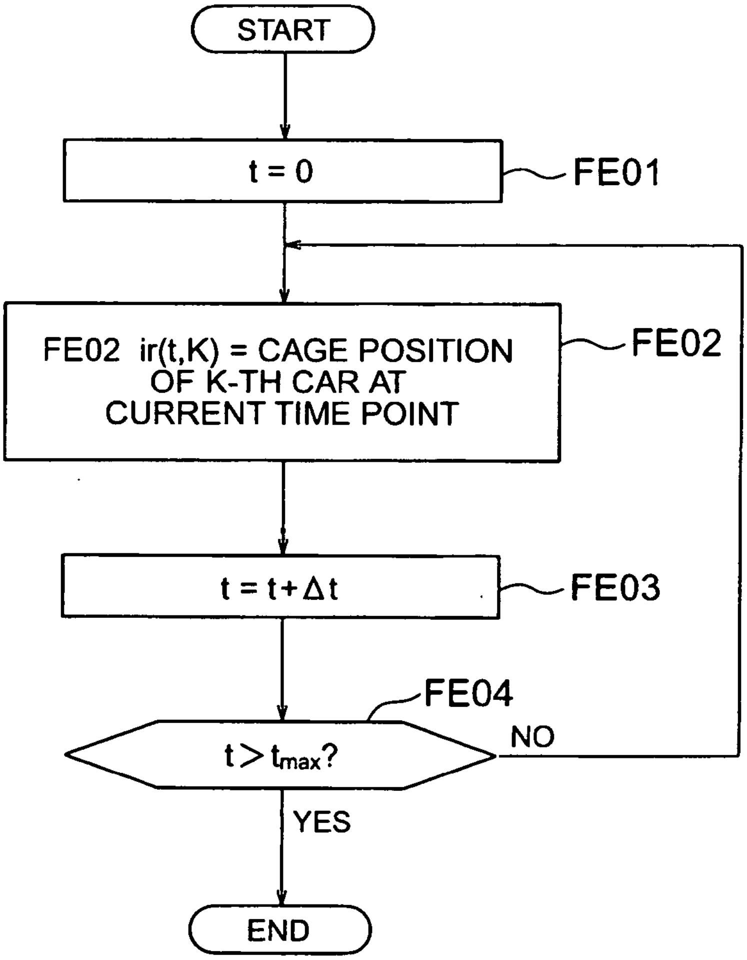

START
t = 0
FE01
FE02 ir(t,K) = CAGE POSITION OF K-TH CAR AT CURRENT TIME POINT
FE02
t = t+Δt
FE03
FE04
t > tmax?
NO
YES
END

FIG. 28

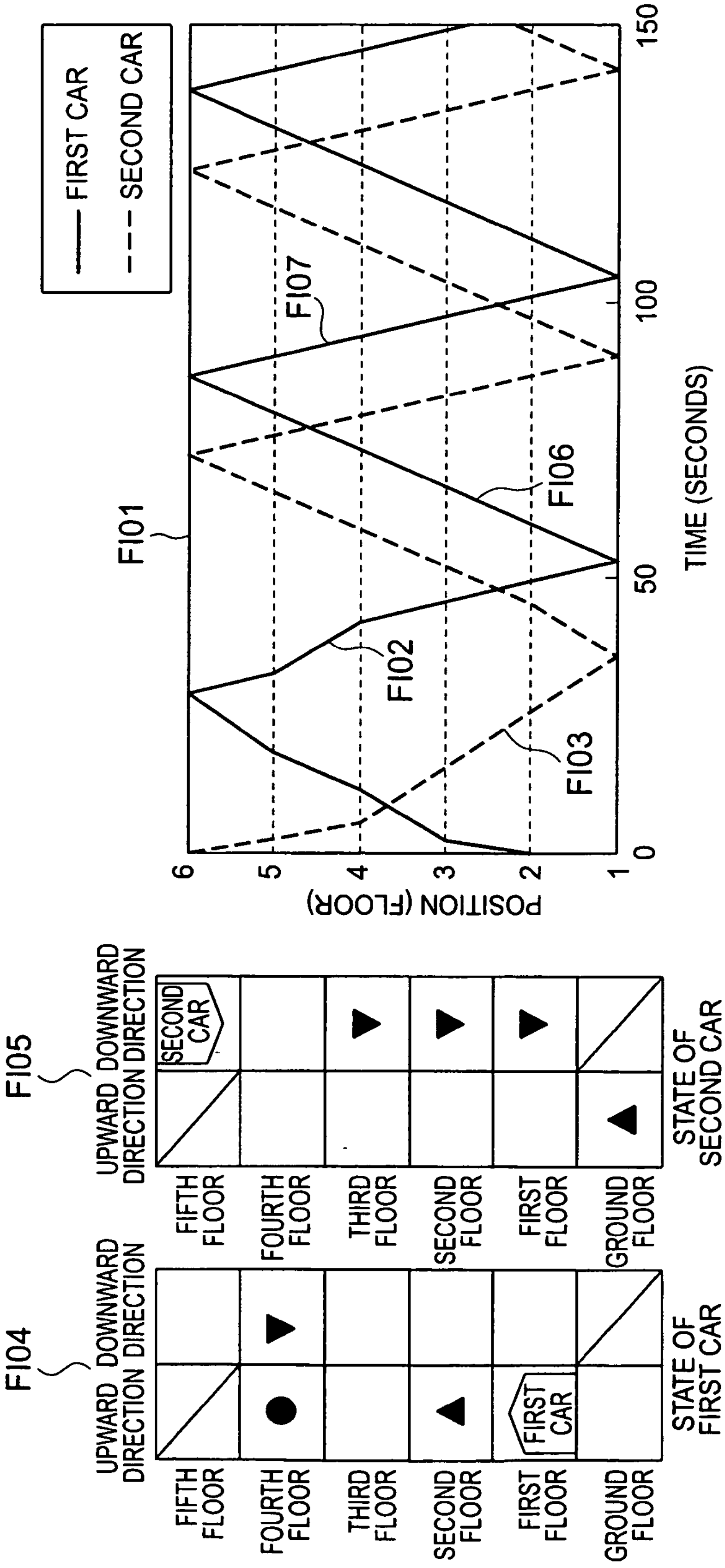

FIRST CAR
SECOND CAR
F101
F102
F103
F106
F107
POSITION (FLOOR)
1
2
3
4
5
6
TIME (SECONDS)
0
50
100
150
F104
UPWARD DIRECTION
DOWNWARD DIRECTION
FIFTH FLOOR
FOURTH FLOOR
THIRD FLOOR
SECOND FLOOR
FIRST FLOOR
GROUND FLOOR
FIRST CAR
STATE OF FIRST CAR
F105
UPWARD DIRECTION
DOWNWARD DIRECTION
FIFTH FLOOR
FOURTH FLOOR
THIRD FLOOR
SECOND FLOOR
FIRST FLOOR
GROUND FLOOR
SECOND CAR
STATE OF SECOND CAR

FIG. 29

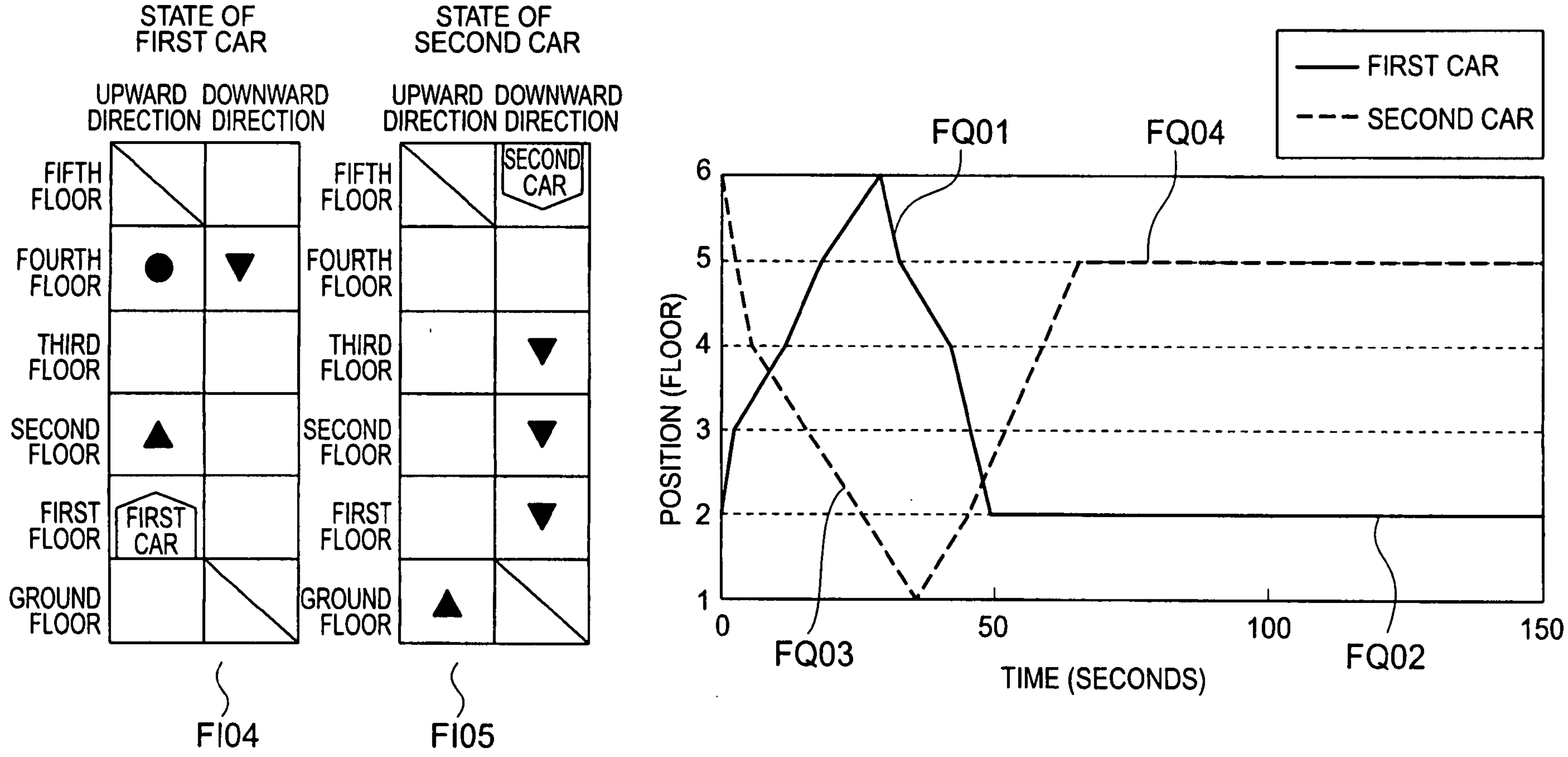

STATE OF FIRST CAR
UPWARD DIRECTION
DOWNWARD DIRECTION
FIFTH FLOOR
FOURTH FLOOR
THIRD FLOOR
SECOND FLOOR
FIRST FLOOR
GROUND FLOOR
FIRST CAR
FI04
STATE OF SECOND CAR
UPWARD DIRECTION
DOWNWARD DIRECTION
FIFTH FLOOR
FOURTH FLOOR
THIRD FLOOR
SECOND FLOOR
FIRST FLOOR
GROUND FLOOR
SECOND CAR
FI05
FIRST CAR
SECOND CAR
FQ01
FQ04
FQ03
FQ02
POSITION (FLOOR)
1
2
3
4
5
6
TIME (SECONDS)
0
50
100
150

FIG. 30

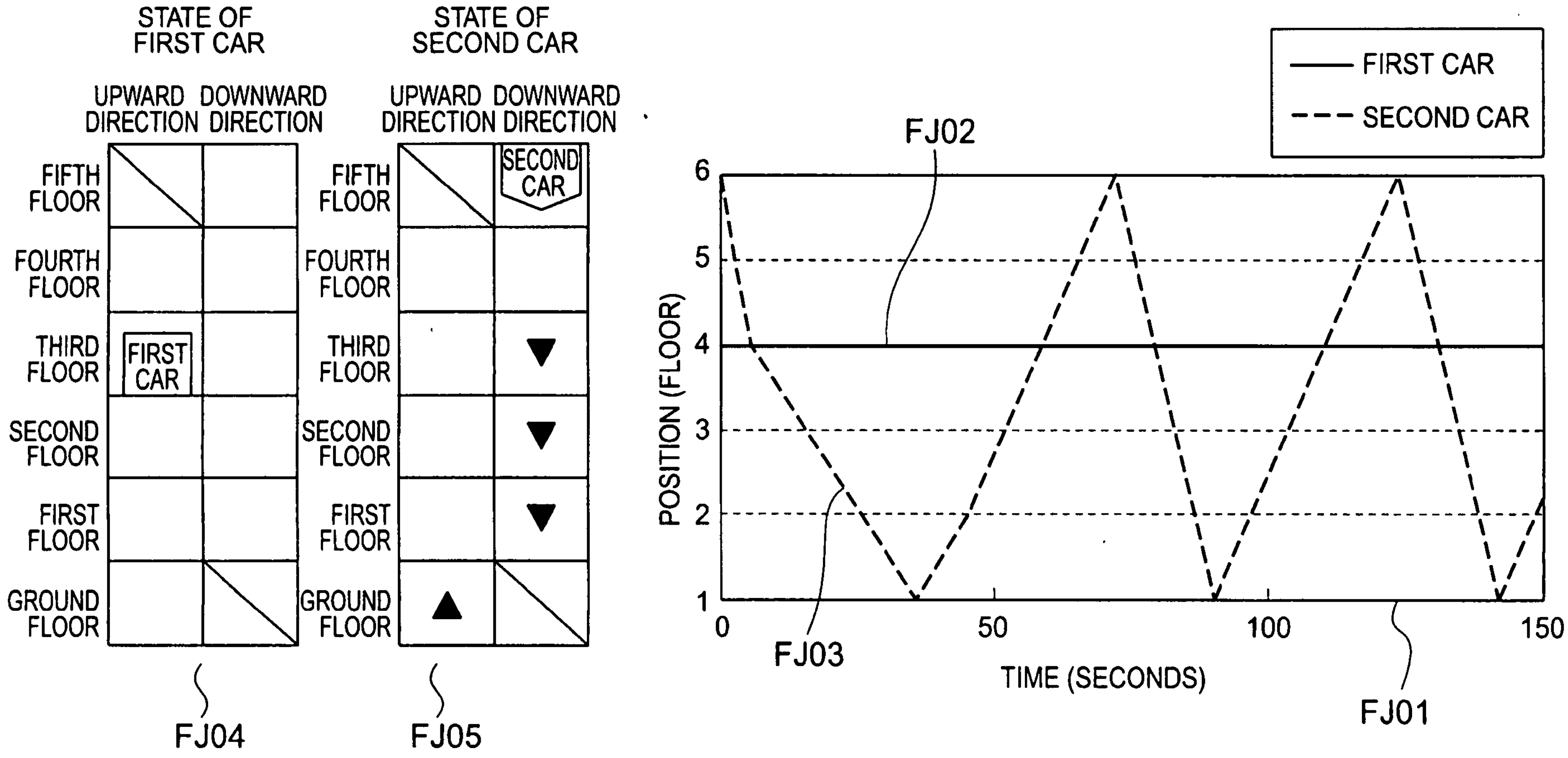

STATE OF FIRST CAR
UPWARD DIRECTION
DOWNWARD DIRECTION
FIFTH FLOOR
FOURTH FLOOR
THIRD FLOOR
SECOND FLOOR
FIRST FLOOR
GROUND FLOOR
FIRST CAR
FJ04
STATE OF SECOND CAR
UPWARD DIRECTION
DOWNWARD DIRECTION
FIFTH FLOOR
FOURTH FLOOR
THIRD FLOOR
SECOND FLOOR
FIRST FLOOR
GROUND FLOOR
SECOND CAR
▼
▼
▼
▲
FJ05
FIRST CAR
SECOND CAR
FJ02
FJ03
FJ01
POSITION (FLOOR)
1
2
3
4
5
6
TIME (SECONDS)
0
50
100
150

FIG. 31

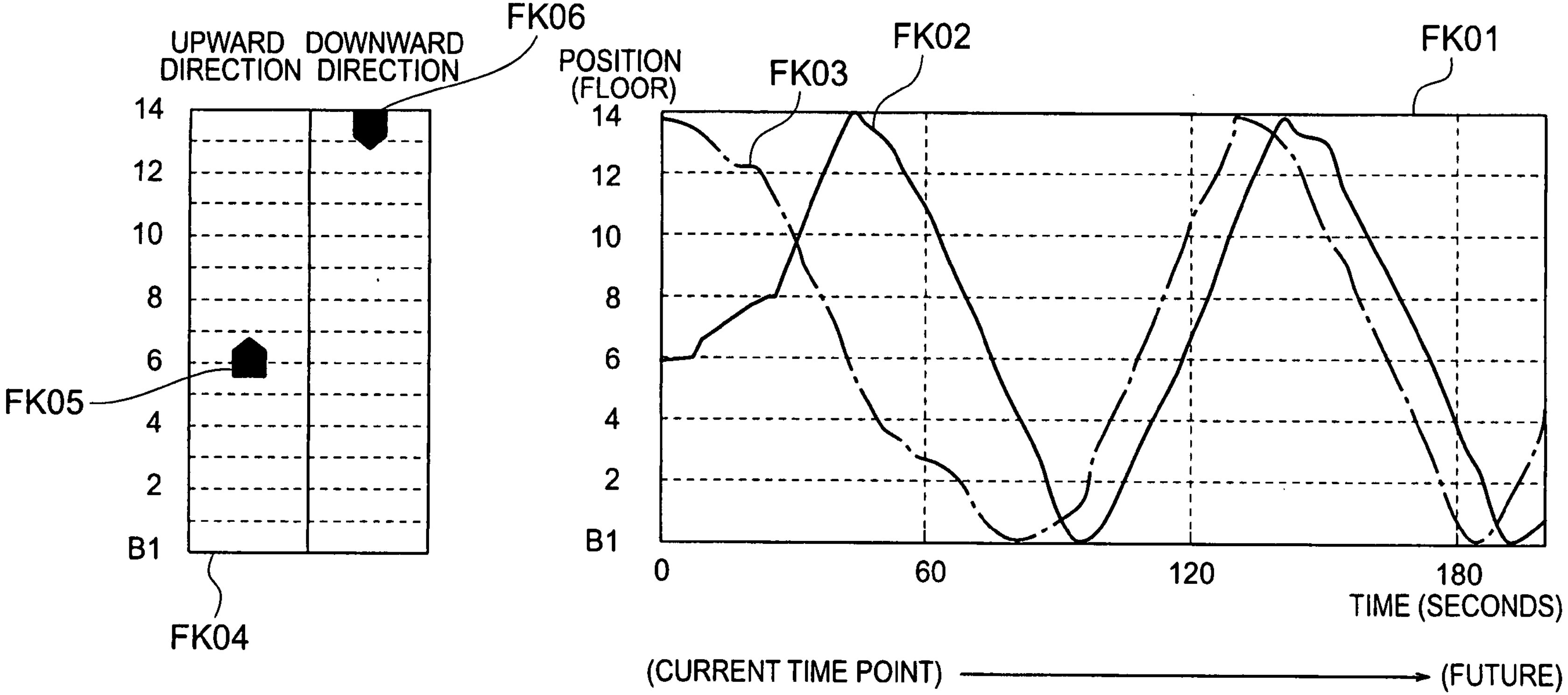

UPWARD DIRECTION
DOWNWARD DIRECTION
FK06
FK05
FK04
14
12
10
8
6
4
2
B1
POSITION (FLOOR)
FK03
FK02
FK01
0
60
120
180
TIME (SECONDS)
(CURRENT TIME POINT)
(FUTURE)

FIG. 32

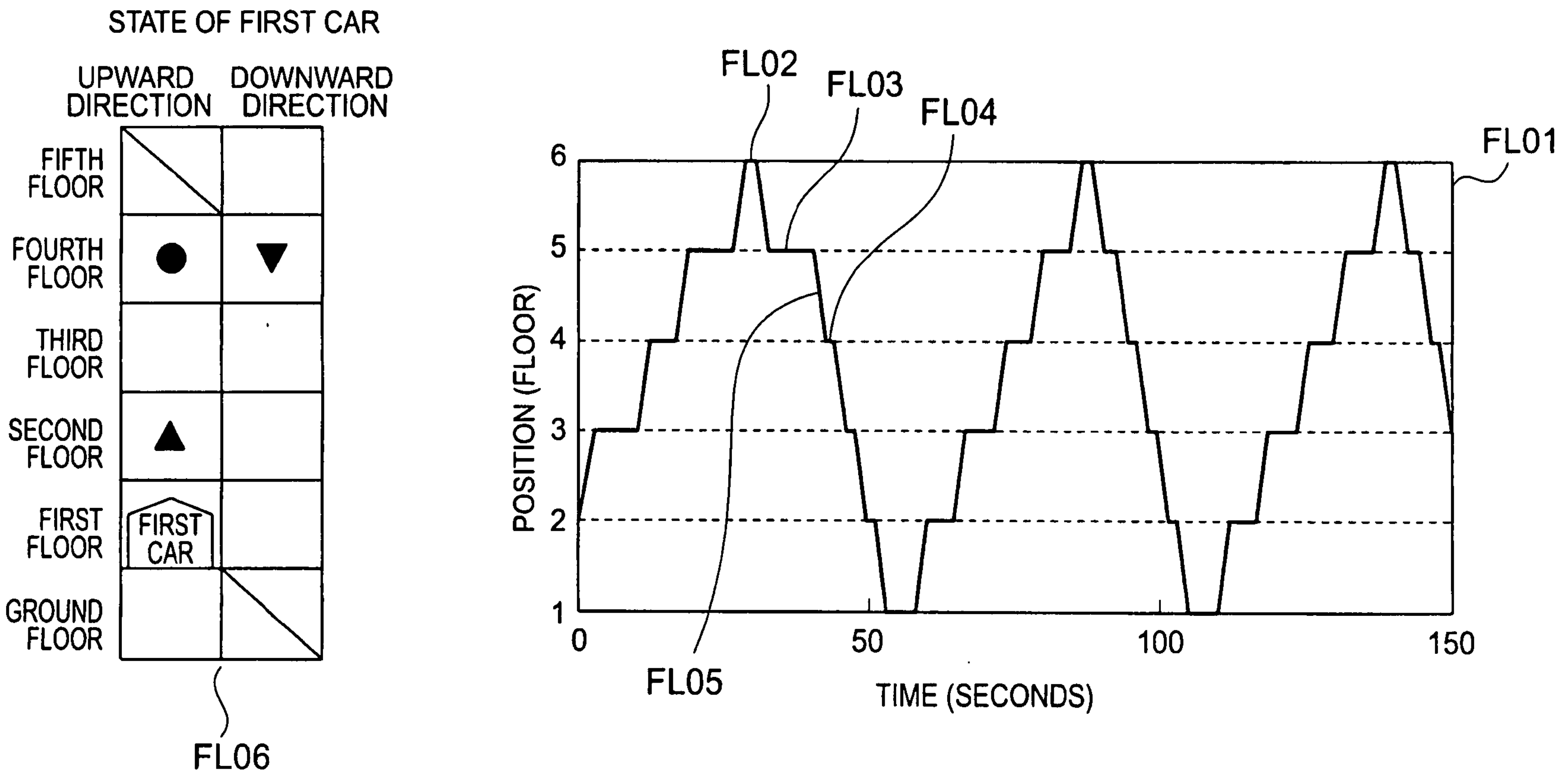

STATE OF FIRST CAR
UPWARD DIRECTION
DOWNWARD DIRECTION
FIFTH FLOOR
FOURTH FLOOR
THIRD FLOOR
SECOND FLOOR
FIRST FLOOR
GROUND FLOOR
●
▼
▲
FIRST CAR
FL06
FL02
FL03
FL04
FL01
FL05
POSITION (FLOOR)
1
2
3
4
5
6
0
50
100
150
TIME (SECONDS)

FIG. 33

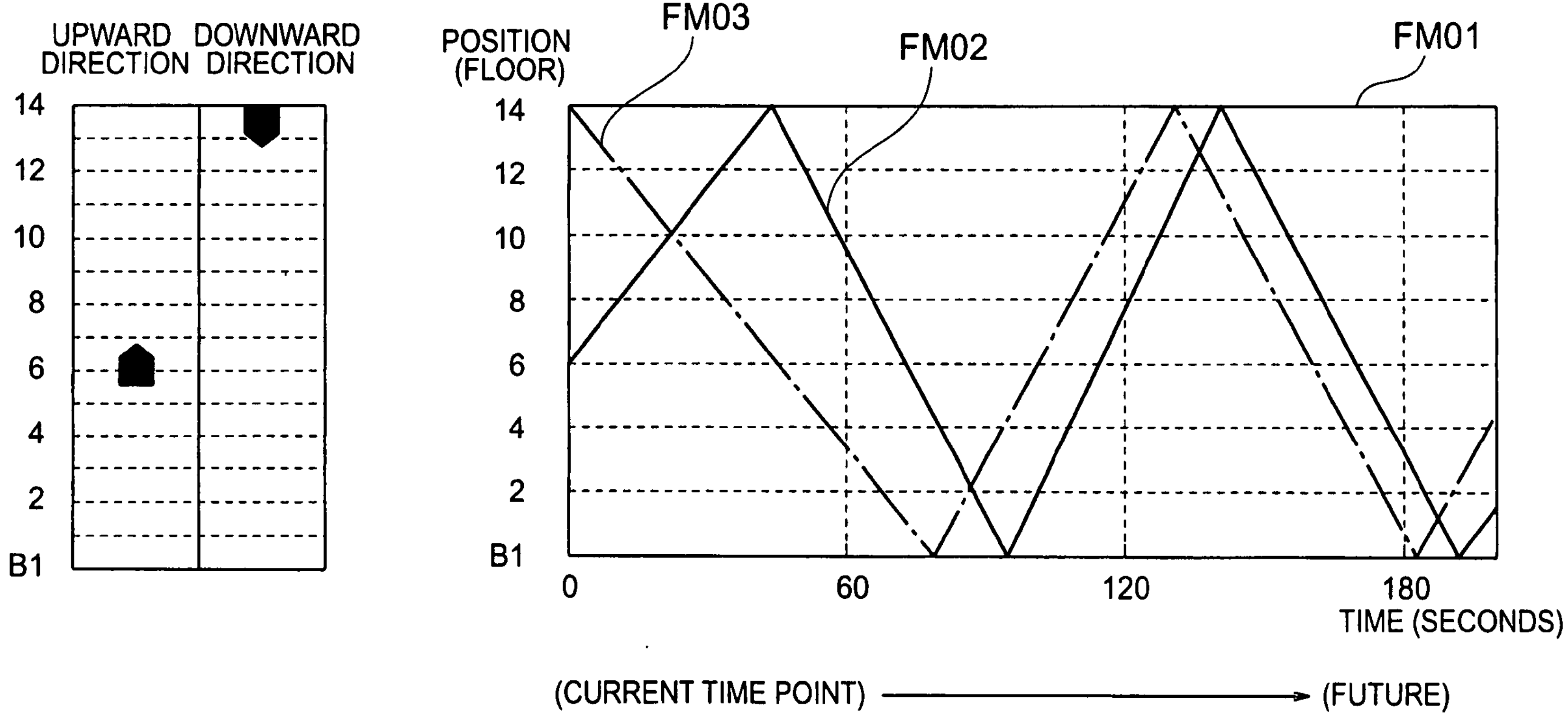
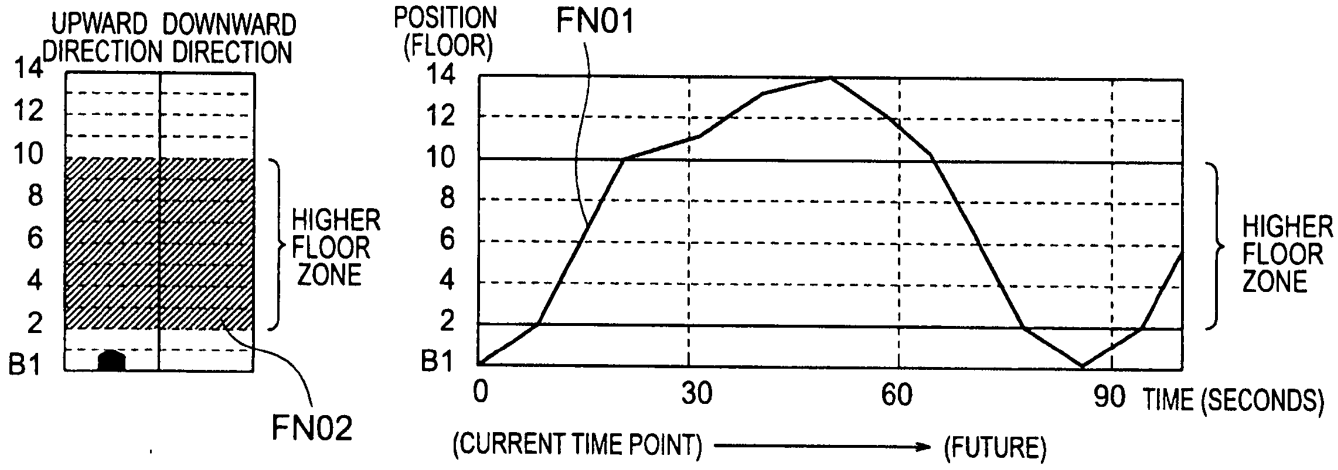

UPWARD DIRECTION
DOWNWARD DIRECTION
14
12
10
8
6
4
2
B1
POSITION (FLOOR)
FM03
FM02
FM01
14
12
10
8
6
4
2
B1
0
60
120
180
TIME (SECONDS)
(CURRENT TIME POINT)
(FUTURE)

FIG. 34

(a) FORECASTED TRAJECTORY OF ALL FLOOR DISPLAY



(b) FORECASTED TRAJECTORY WHEN HIGHER FLOOR ZONE (NON-STOP FLOOR ZONE) IS REPRESENTED BY ONE FLOOR

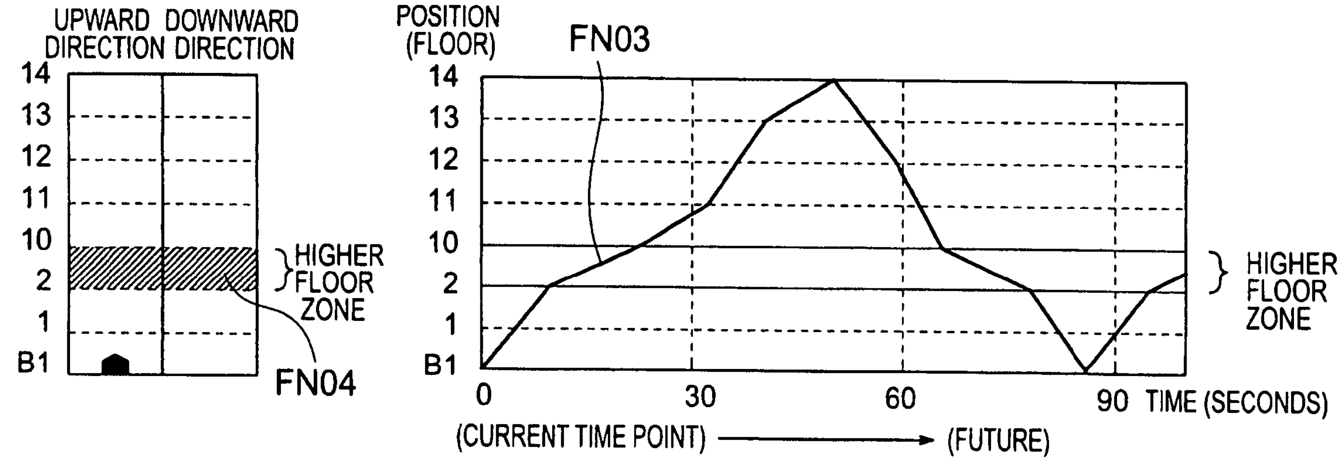


FIG. 35

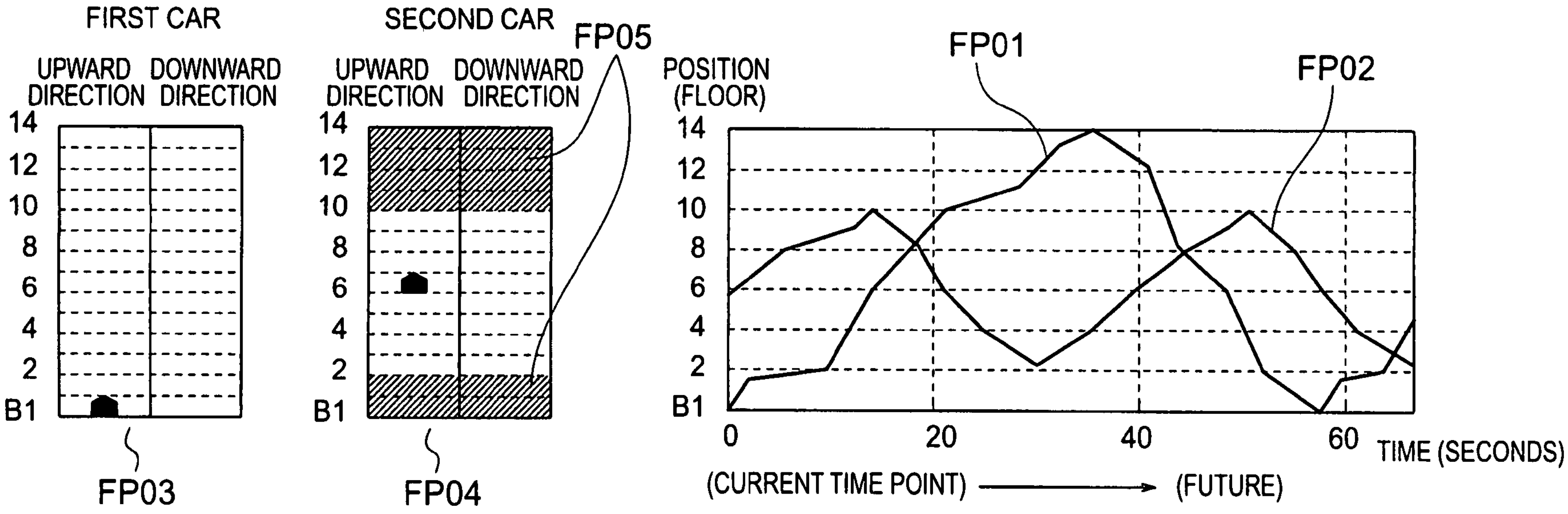

FIRST CAR
UPWARD DIRECTION
DOWNWARD DIRECTION
14
12
10
8
6
4
2
B1
FP03
SECOND CAR
UPWARD DIRECTION
DOWNWARD DIRECTION
14
12
10
8
6
4
2
B1
FP04
FP05
POSITION (FLOOR)
14
12
10
8
6
4
2
B1
FP01
FP02
0
20
40
60
TIME (SECONDS)
(CURRENT TIME POINT)
(FUTURE)

FIG. 36

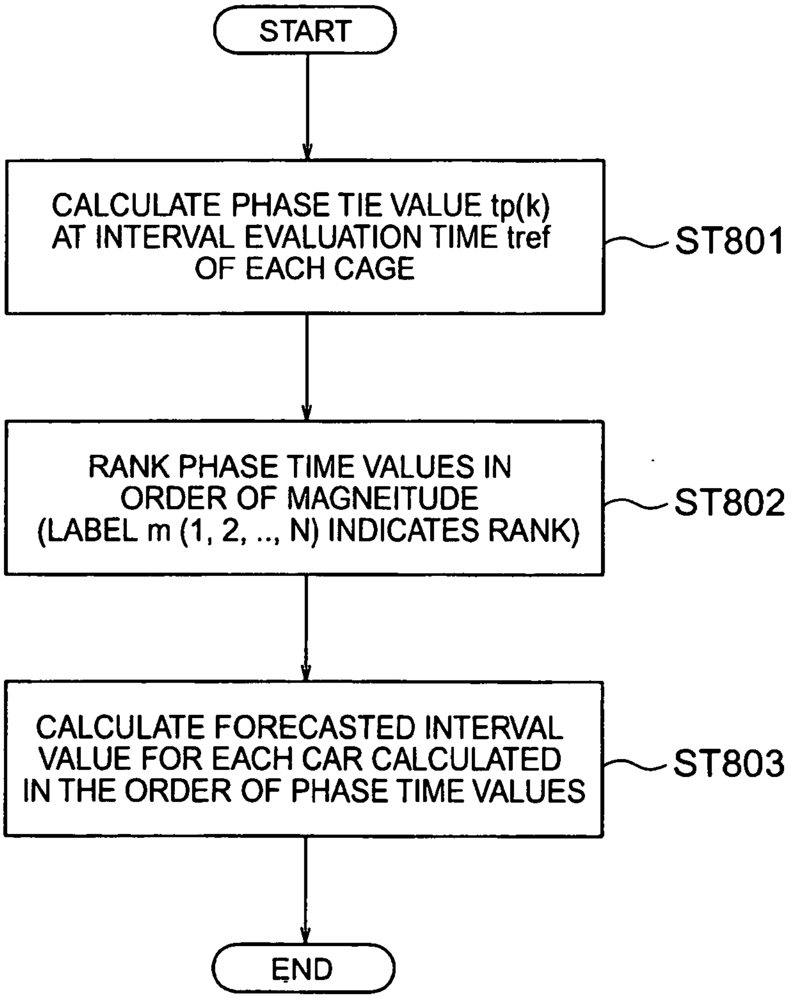

START
CALCULATE PHASE TIE VALUE tp(k) AT INTERVAL EVALUATION TIME tref OF EACH CAGE
ST801
RANK PHASE TIME VALUES IN ORDER OF MAGNEITUDE (LABEL m (1, 2, .., N) INDICATES RANK)
ST802
CALCULATE FORECASTED INTERVAL VALUE FOR EACH CAR CALCULATED IN THE ORDER OF PHASE TIME VALUES
ST803
END

FIG. 37

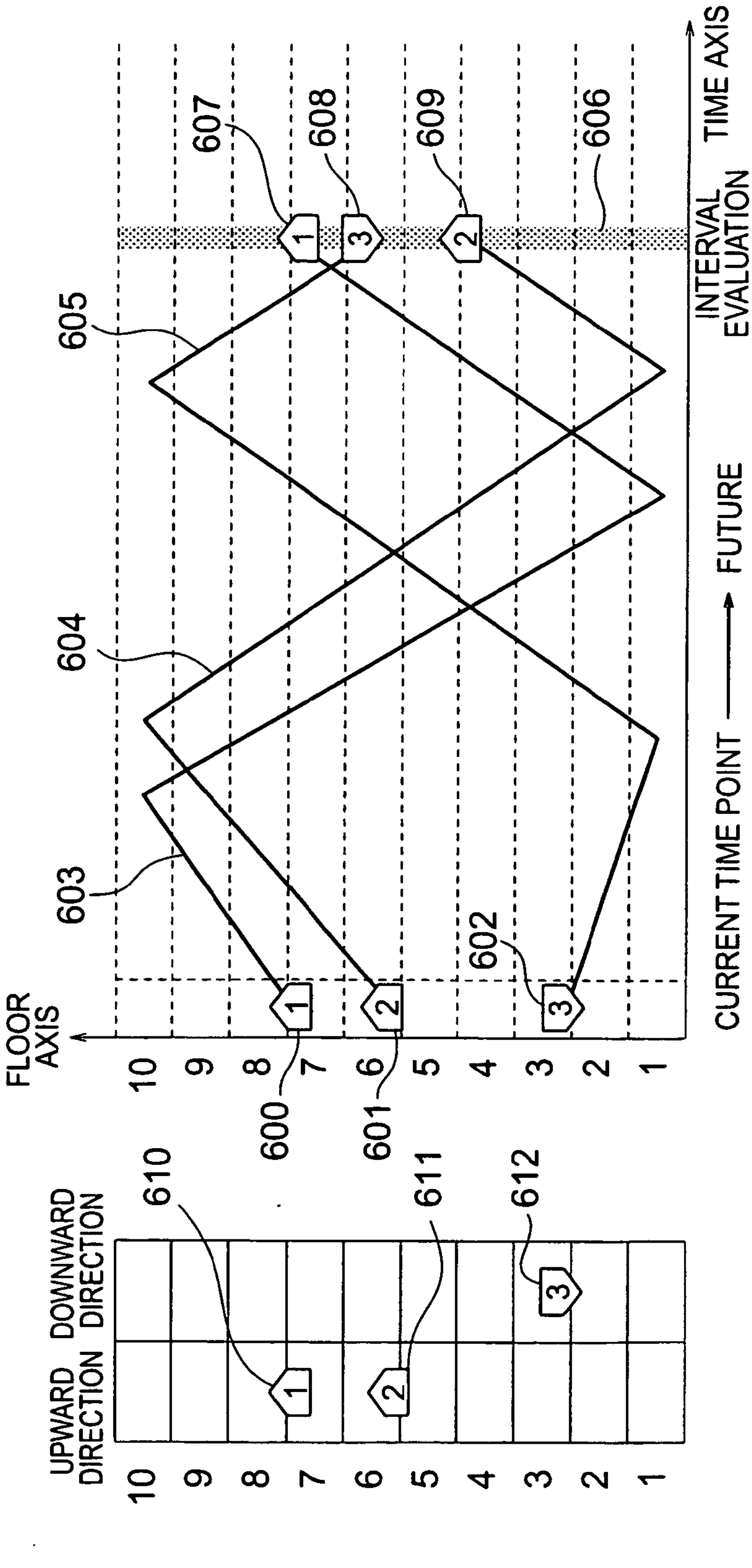

FLOOR AXIS
10
9
8
7
6
5
4
3
2
1
600
601
602
603
604
605
606
607
608
609
1
2
3
TIME AXIS
CURRENT TIME POINT ——→ FUTURE
INTERVAL EVALUATION TIME tref
UPWARD DIRECTION
DOWNWARD DIRECTION
610
611
612

FIG. 38

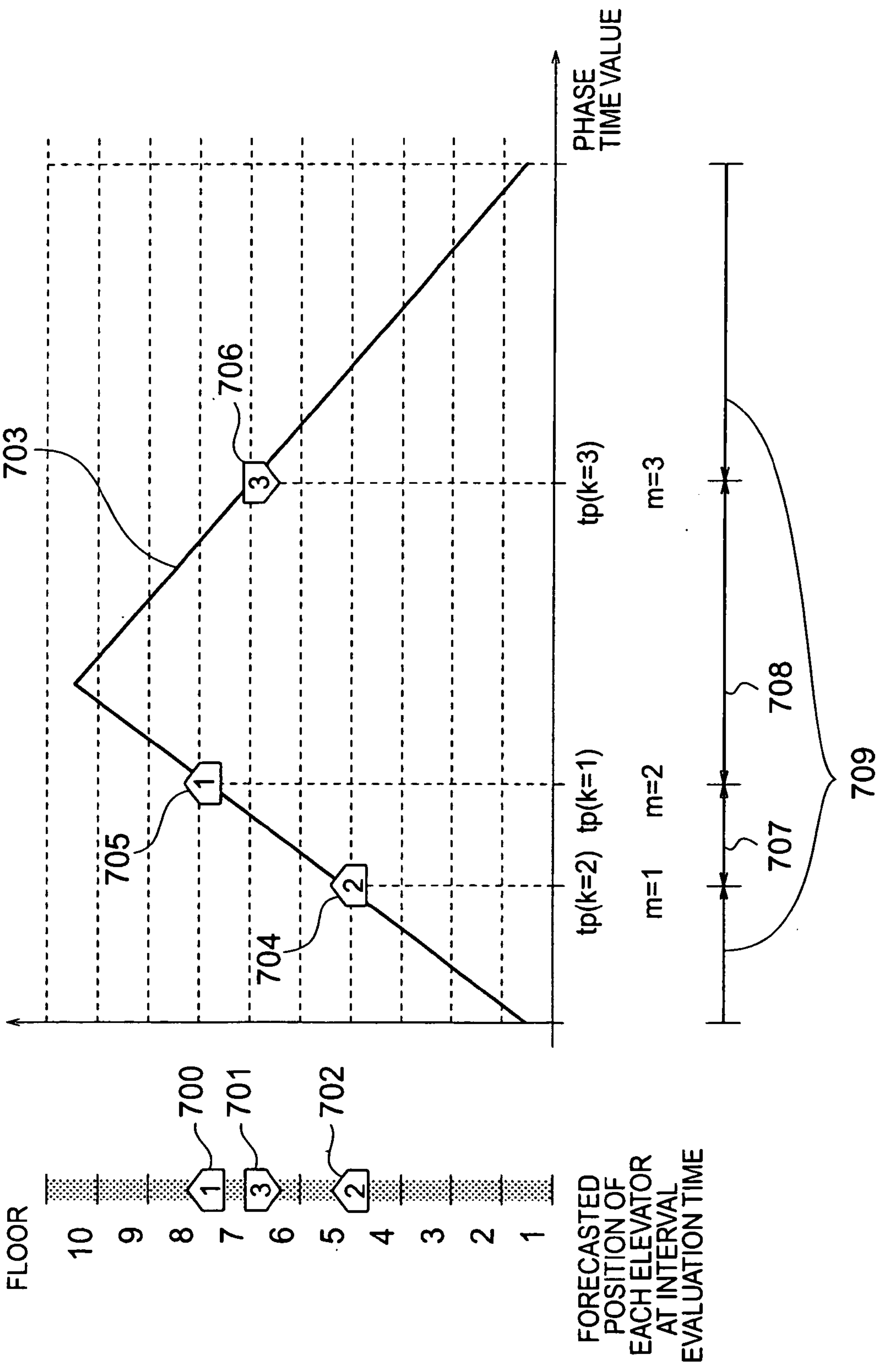
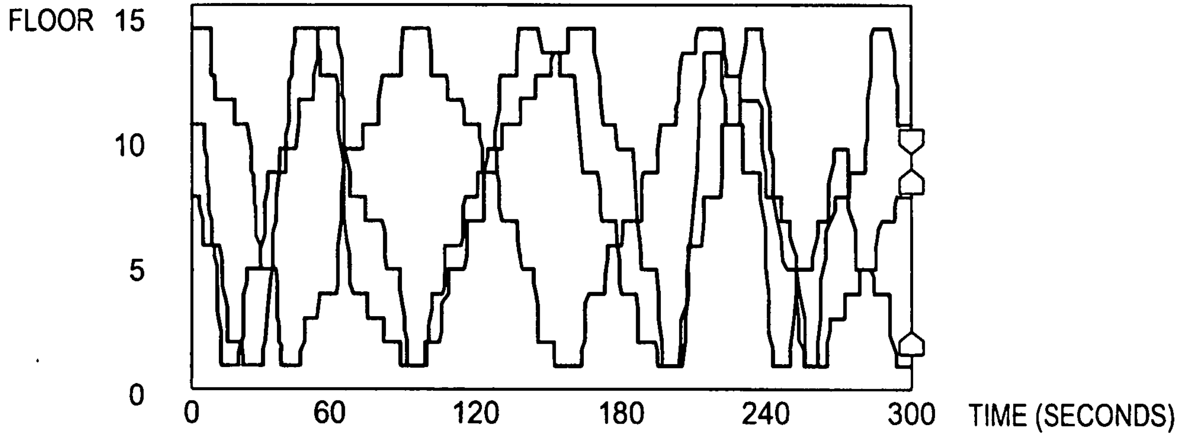

FLOOR
10
9
8
7
6
5
4
3
2
1
FORECASTED POSITION OF EACH ELEVATOR AT INTERVAL EVALUATION TIME
700
701
702
1
3
2
FLOOR AXIS
704
705
703
706
tp(k=2)
tp(k=1)
tp(k=3)
PHASE TIME VALUE
m=1
m=2
m=3
707
708
709

FIG. 39

(a) BEFORE EXECUTION OF CONTROL ACCORDING TO THE PRESENT INVENTION

NUMBER OF ELEVATORS: THREE
NUMBER OF FLOORS: 15 FLOORS (B1 - 14TH FLOOR)



(b) AFTER EXECUTION OF CONTROL ACCORDING TO THE PRESENT INVENTION

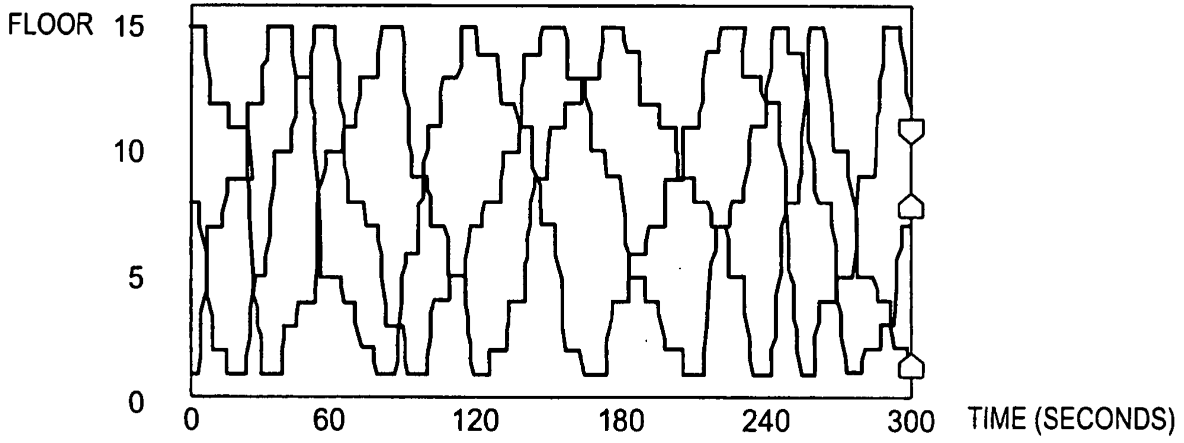


FIG. 40

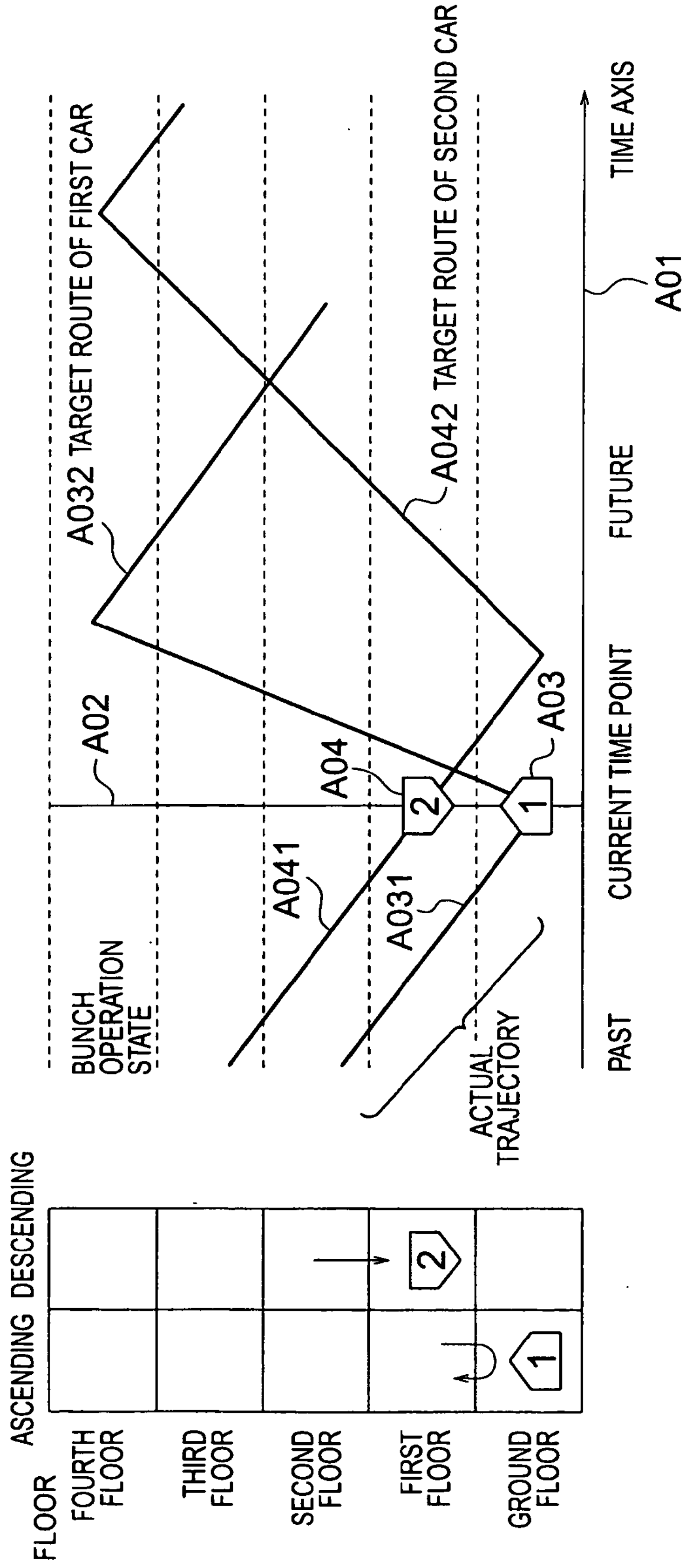

FLOOR
FOURTH FLOOR
THIRD FLOOR
SECOND FLOOR
FIRST FLOOR
GROUND FLOOR
ASCENDING
DESCENDING
1
2
ACTUAL TRAJECTORY
BUNCH OPERATION STATE
A041
A031
A02
A04
A03
1
2
A032 TARGET ROUTE OF FIRST CAR
A042 TARGET ROUTE OF SECOND CAR
PAST
CURRENT TIME POINT
FUTURE
TIME AXIS
A01

FIG. 41

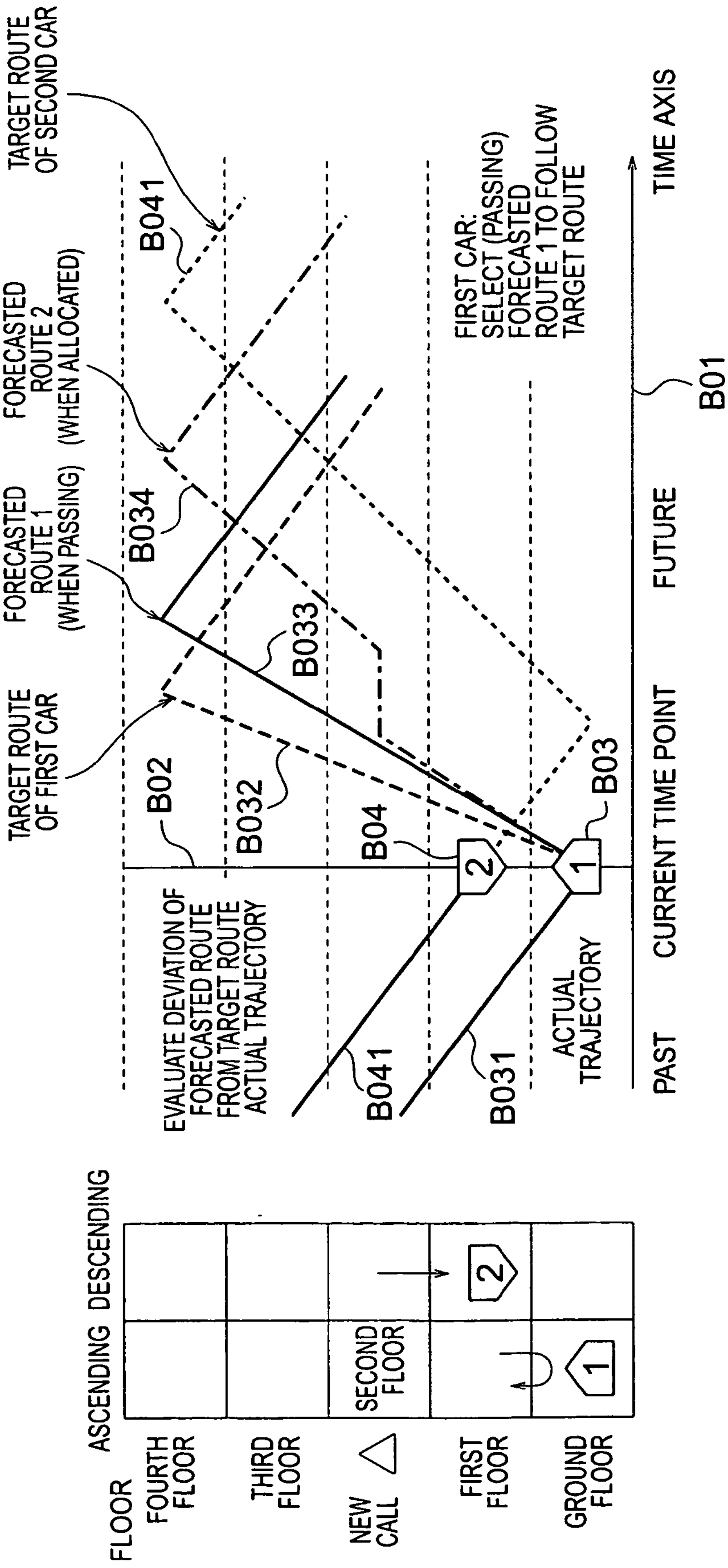

TARGET ROUTE OF SECOND CAR
B041
FORECASTED ROUTE 2 (WHEN ALLOCATED)
B034
FORECASTED ROUTE 1 (WHEN PASSING)
B033
TARGET ROUTE OF FIRST CAR
B02
B032
B04
B03
EVALUATE DEVIATION OF FORECASTED ROUTE FROM TARGET ROUTE ACTUAL TRAJECTORY
B041
B031
ACTUAL TRAJECTORY
FIRST CAR: SELECT (PASSING) FORECASTED ROUTE 1 TO FOLLOW TARGET ROUTE
B01
PAST
CURRENT TIME POINT
FUTURE
TIME AXIS
2
1
FLOOR
ASCENDING
DESCENDING
FOURTH FLOOR
THIRD FLOOR
NEW CALL
SECOND FLOOR
FIRST FLOOR
GROUND FLOOR
2
1

FIG. 42

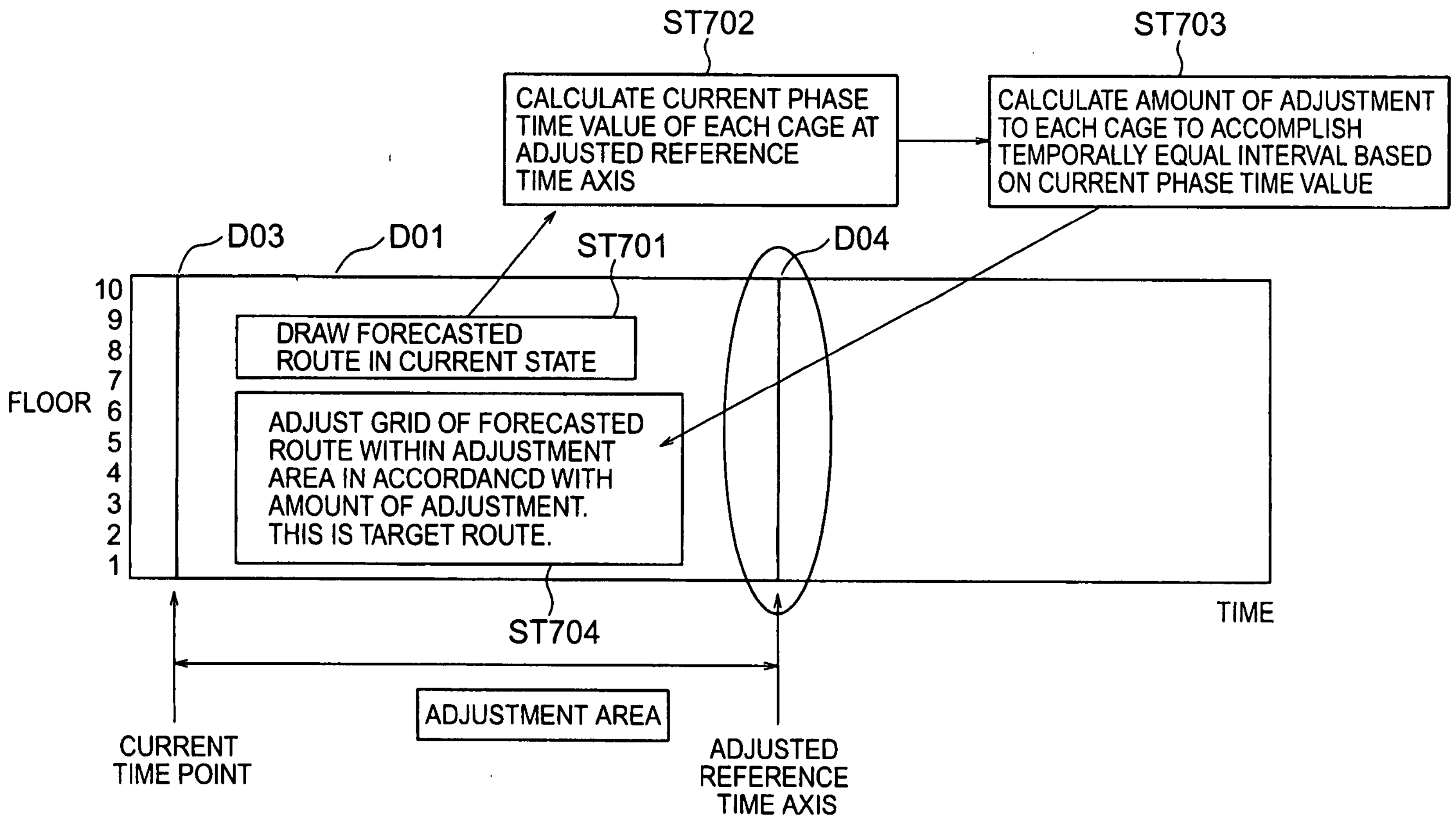

ST702
CALCULATE CURRENT PHASE TIME VALUE OF EACH CAGE AT ADJUSTED REFERENCE TIME AXIS
ST703
CALCULATE AMOUNT OF ADJUSTMENT TO EACH CAGE TO ACCOMPLISH TEMPORALLY EQUAL INTERVAL BASED ON CURRENT PHASE TIME VALUE
D03
D01
ST701
D04
10
9
8
7
6
5
4
3
2
1
FLOOR
DRAW FORECASTED ROUTE IN CURRENT STATE
ADJUST GRID OF FORECASTED ROUTE WITHIN ADJUSTMENT AREA IN ACCORDANCD WITH AMOUNT OF ADJUSTMENT. THIS IS TARGET ROUTE.
ST704
TIME
ADJUSTMENT AREA
CURRENT TIME POINT
ADJUSTED REFERENCE TIME AXIS

FIG. 43

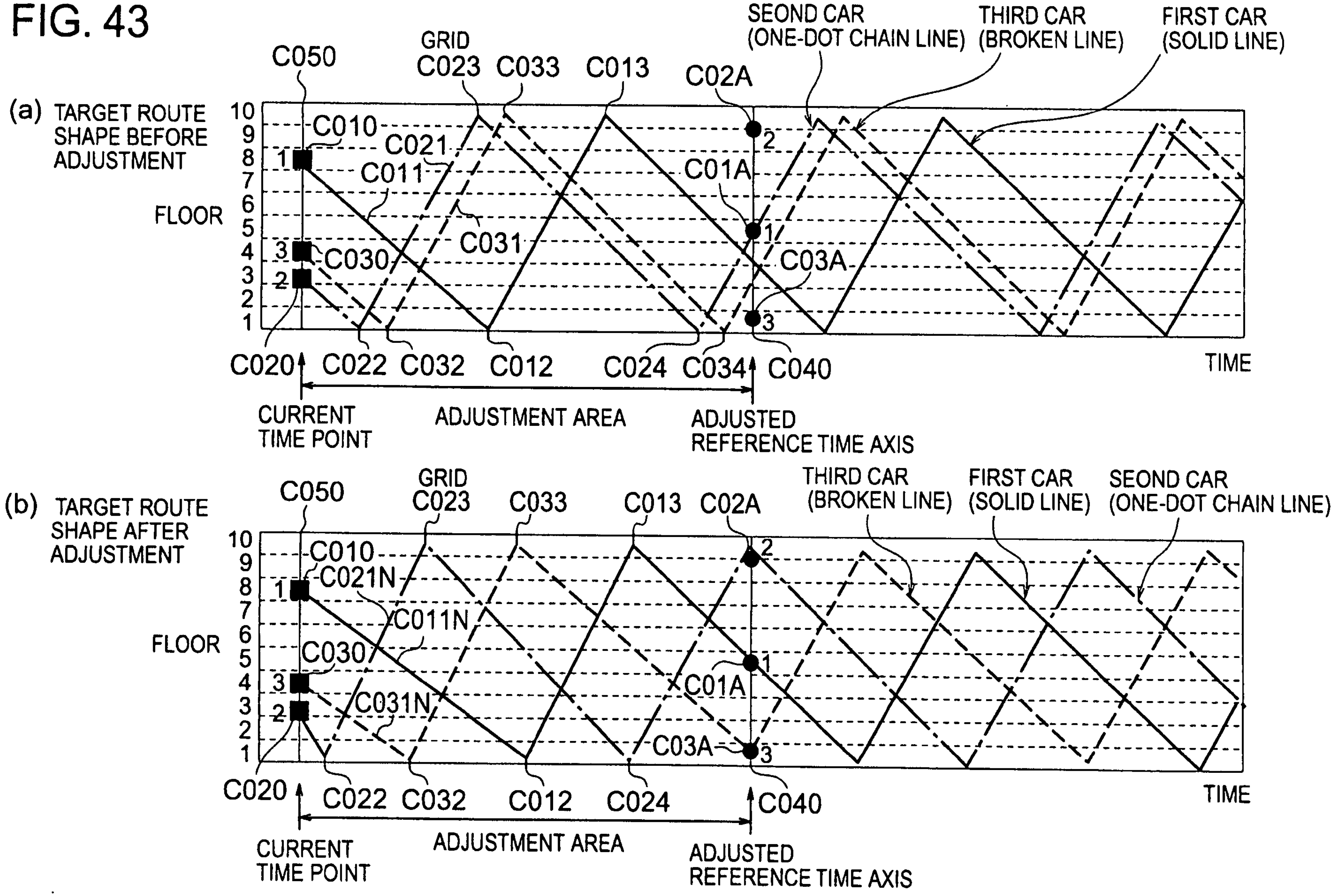

(a) TARGET ROUTE SHAPE BEFORE ADJUSTMENT
FLOOR
10
9
8
7
6
5
4
3
2
1
C050
GRID
C023
C033
C013
C02A
SEOND CAR (ONE-DOT CHAIN LINE)
THIRD CAR (BROKEN LINE)
FIRST CAR (SOLID LINE)
C010
C021
C011
C031
C030
C01A
C03A
1
2
3
C020
C022
C032
C012
C024
C034
C040
TIME
CURRENT TIME POINT
ADJUSTMENT AREA
ADJUSTED REFERENCE TIME AXIS
(b) TARGET ROUTE SHAPE AFTER ADJUSTMENT
FLOOR
10
9
8
7
6
5
4
3
2
1
C050
GRID
C023
C033
C013
C02A
THIRD CAR (BROKEN LINE)
FIRST CAR (SOLID LINE)
SEOND CAR (ONE-DOT CHAIN LINE)
C010
C021N
C011N
C030
C031N
C01A
C03A
1
2
3
C020
C022
C032
C012
C024
C040
TIME
CURRENT TIME POINT
ADJUSTMENT AREA
ADJUSTED REFERENCE TIME AXIS

FIG. 44

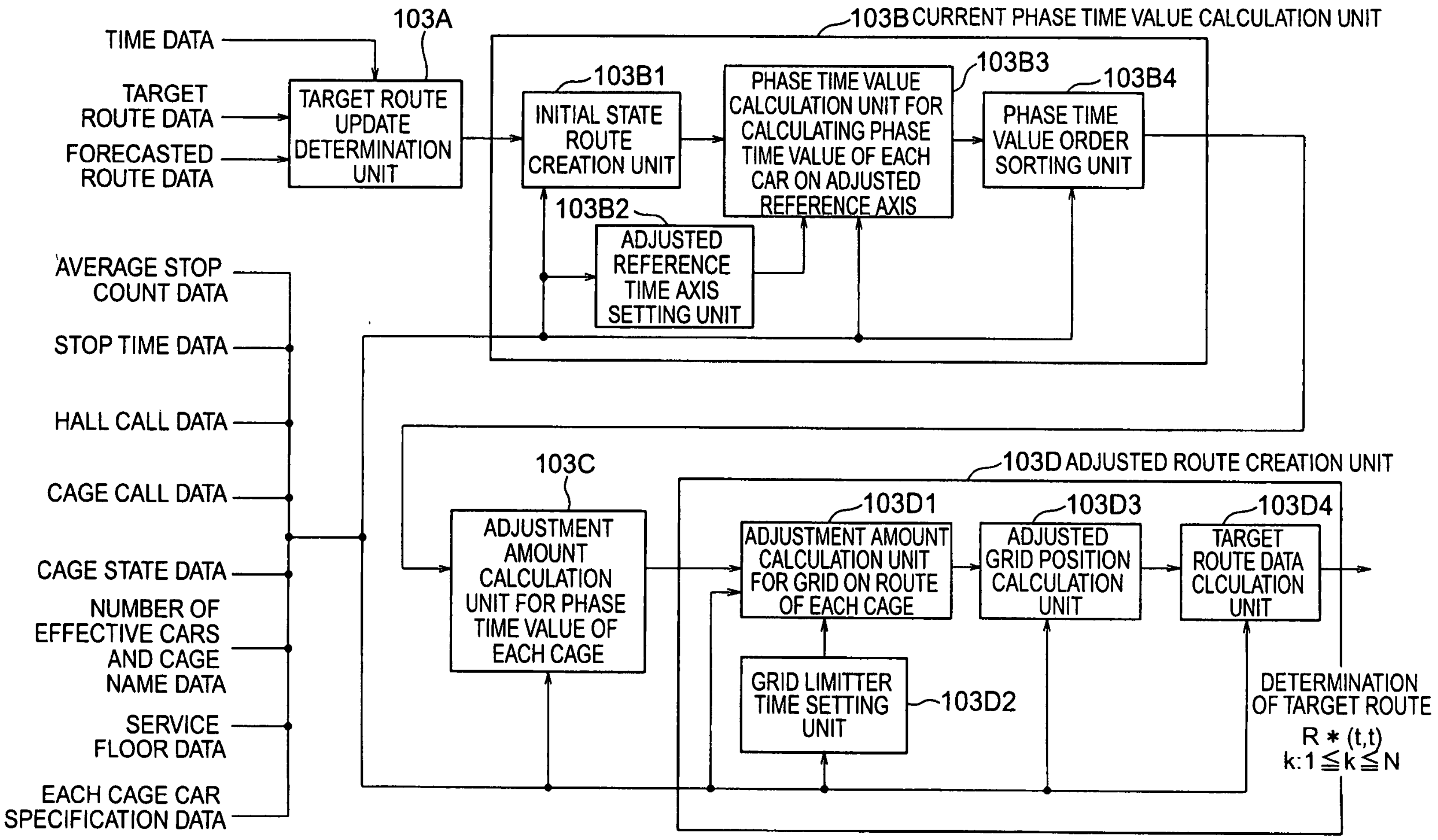

TIME DATA
TARGET ROUTE DATA
FORECASTED ROUTE DATA
103A
TARGET ROUTE UPDATE DETERMINATION UNIT
103B CURRENT PHASE TIME VALUE CALCULATION UNIT
103B1
INITIAL STATE ROUTE CREATION UNIT
103B2
ADJUSTED REFERENCE TIME AXIS SETTING UNIT
103B3
PHASE TIME VALUE CALCULATION UNIT FOR CALCULATING PHASE TIME VALUE OF EACH CAR ON ADJUSTED REFERENCE AXIS
103B4
PHASE TIME VALUE ORDER SORTING UNIT
AVERAGE STOP COUNT DATA
STOP TIME DATA
HALL CALL DATA
CAGE CALL DATA
CAGE STATE DATA
NUMBER OF EFFECTIVE CARS AND CAGE NAME DATA
SERVICE FLOOR DATA
EACH CAGE CAR SPECIFICATION DATA
103C
ADJUSTMENT AMOUNT CALCULATION UNIT FOR PHASE TIME VALUE OF EACH CAGE
103D ADJUSTED ROUTE CREATION UNIT
103D1
ADJUSTMENT AMOUNT CALCULATION UNIT FOR GRID ON ROUTE OF EACH CAGE
103D2
GRID LIMITTER TIME SETTING UNIT
103D3
ADJUSTED GRID POSITION CALCULATION UNIT
103D4
TARGET ROUTE DATA CLCULATION UNIT
DETERMINATION OF TARGET ROUTE
R * (t,t)
k:1≦k≦N

FIG. 45

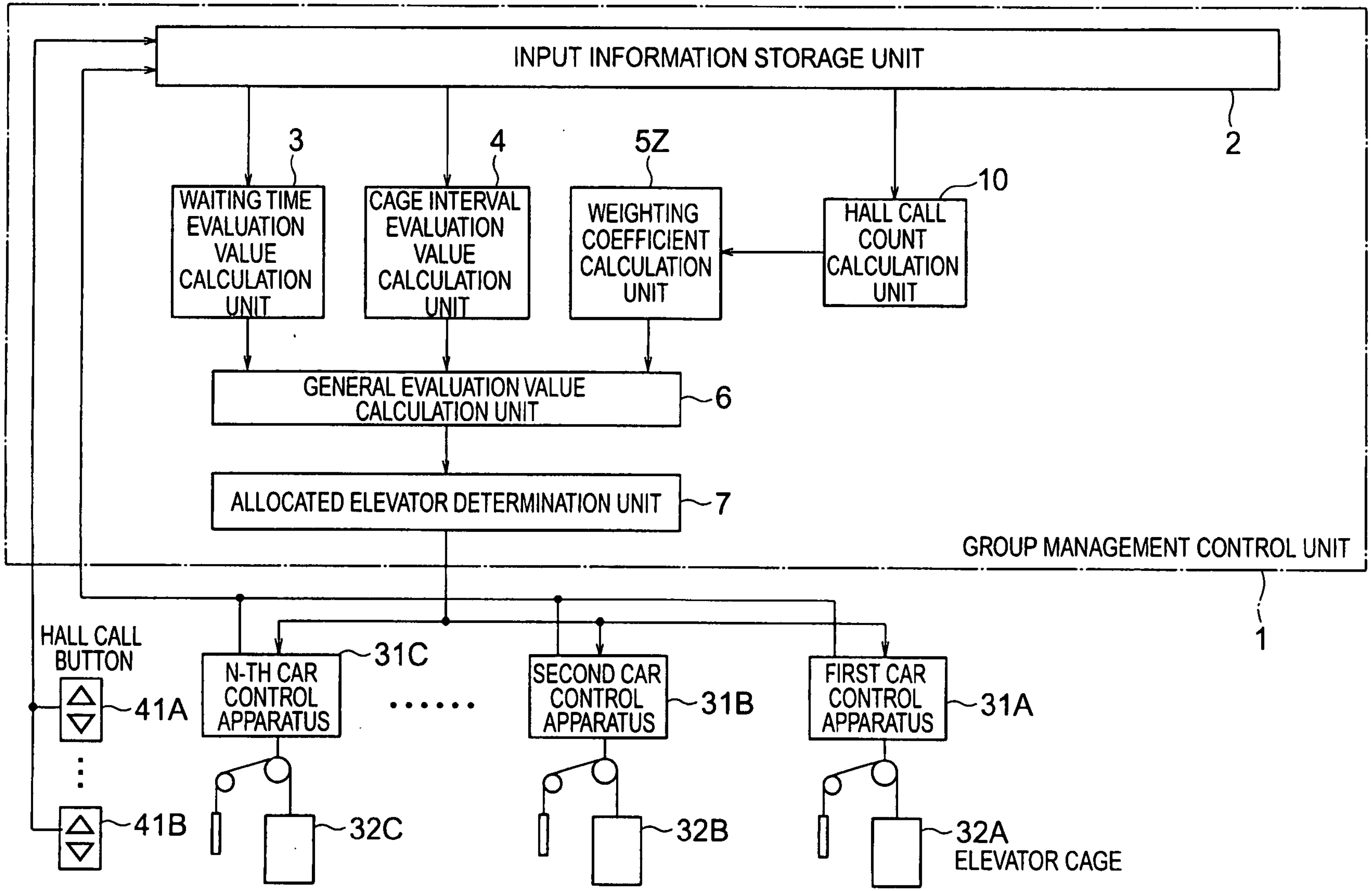

INPUT INFORMATION STORAGE UNIT
2
3
WAITING TIME EVALUATION VALUE CALCULATION UNIT
4
CAGE INTERVAL EVALUATION VALUE CALCULATION UNIT
5Z
WEIGHTING COEFFICIENT CALCULATION UNIT
10
HALL CALL COUNT CALCULATION UNIT
GENERAL EVALUATION VALUE CALCULATION UNIT
6
ALLOCATED ELEVATOR DETERMINATION UNIT
7
GROUP MANAGEMENT CONTROL UNIT
1
HALL CALL BUTTON
41A
41B
N-TH CAR CONTROL APPARATUS
31C
SECOND CAR CONTROL APPARATUS
31B
FIRST CAR CONTROL APPARATUS
31A
32C
32B
32A
ELEVATOR CAGE

FIG. 46

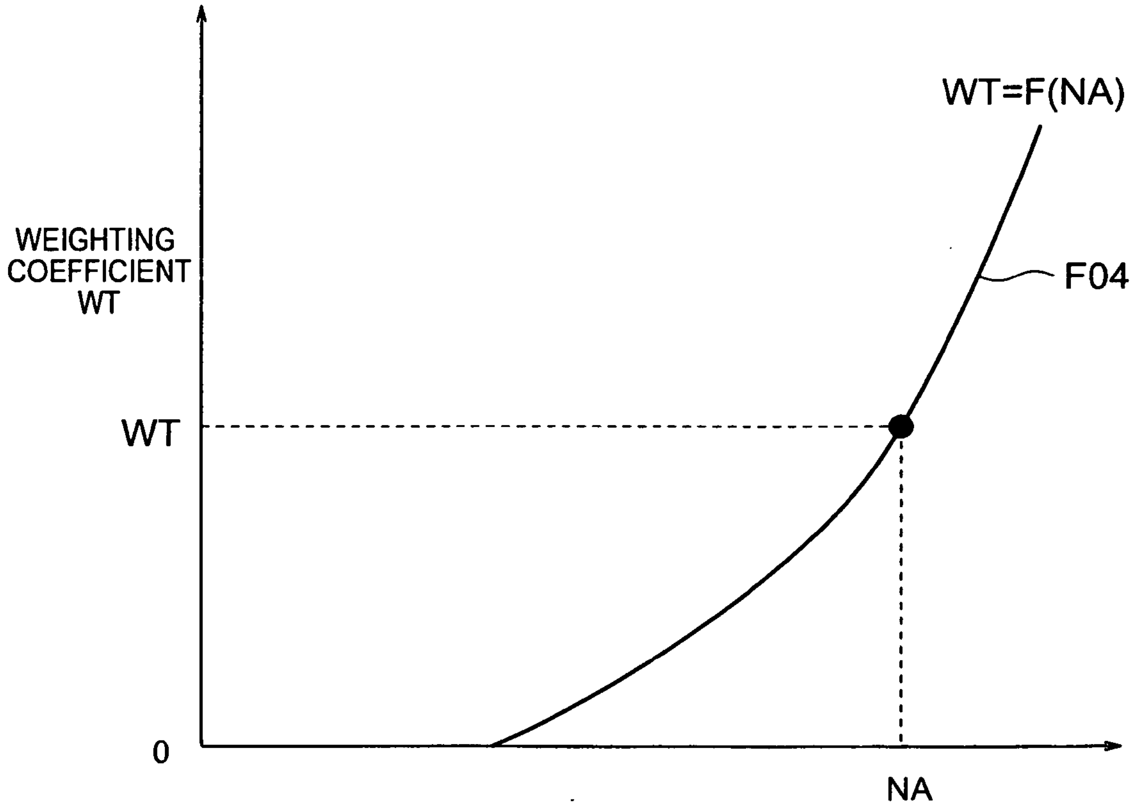


FIG. 47

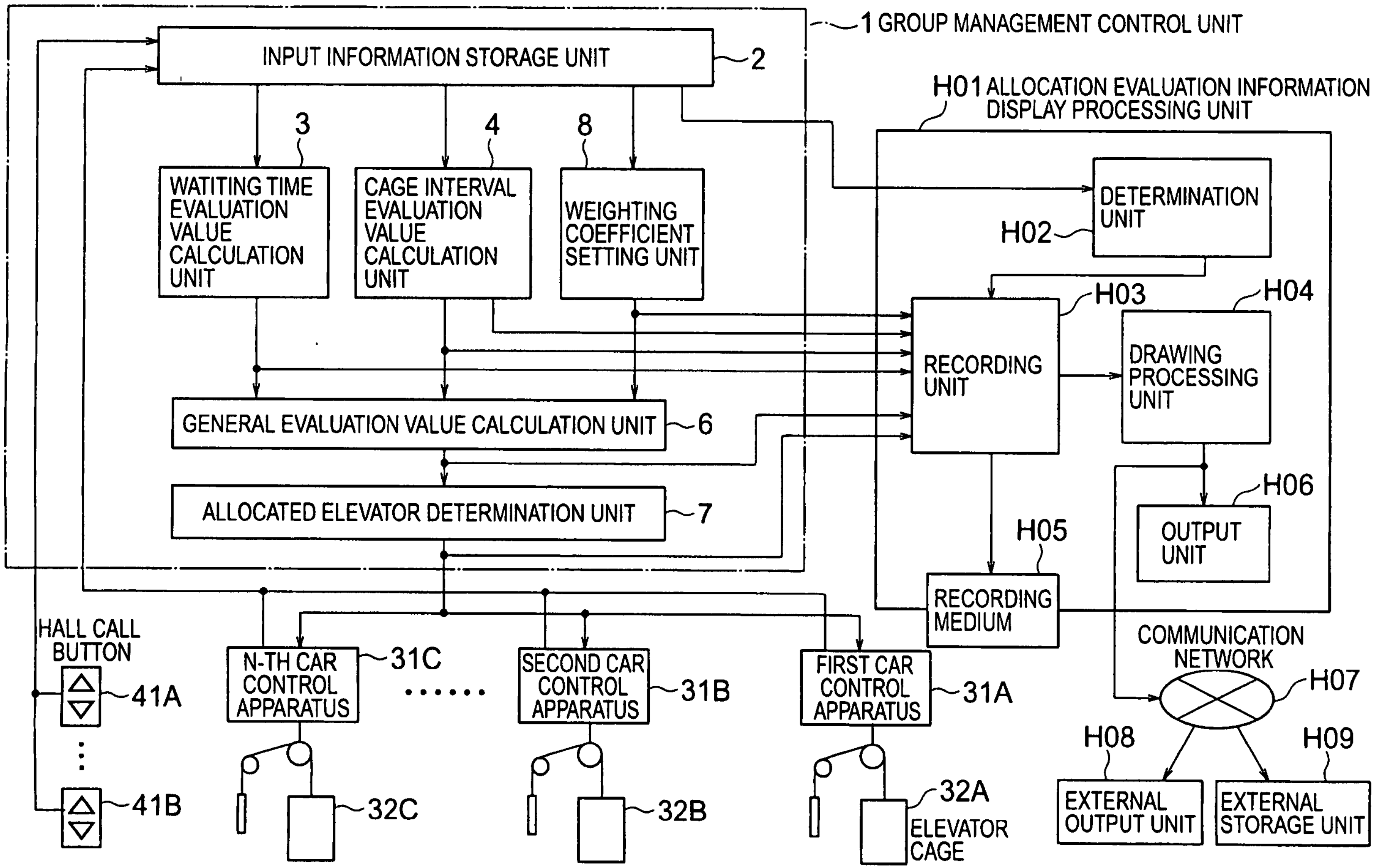

1 GROUP MANAGEMENT CONTROL UNIT
INPUT INFORMATION STORAGE UNIT
2
3
4
8
WATITING TIME EVALUATION VALUE CALCULATION UNIT
CAGE INTERVAL EVALUATION VALUE CALCULATION UNIT
WEIGHTING COEFFICIENT SETTING UNIT
GENERAL EVALUATION VALUE CALCULATION UNIT
6
ALLOCATED ELEVATOR DETERMINATION UNIT
7
H01 ALLOCATION EVALUATION INFORMATION DISPLAY PROCESSING UNIT
DETERMINATION UNIT
H02
RECORDING UNIT
H03
DRAWING PROCESSING UNIT
H04
OUTPUT UNIT
H06
RECORDING MEDIUM
H05
COMMUNICATION NETWORK
H07
H08
EXTERNAL OUTPUT UNIT
H09
EXTERNAL STORAGE UNIT
HALL CALL BUTTON
41A
41B
N-TH CAR CONTROL APPARATUS
31C
SECOND CAR CONTROL APPARATUS
31B
FIRST CAR CONTROL APPARATUS
31A
32C
32B
32A
ELEVATOR CAGE

FIG. 48

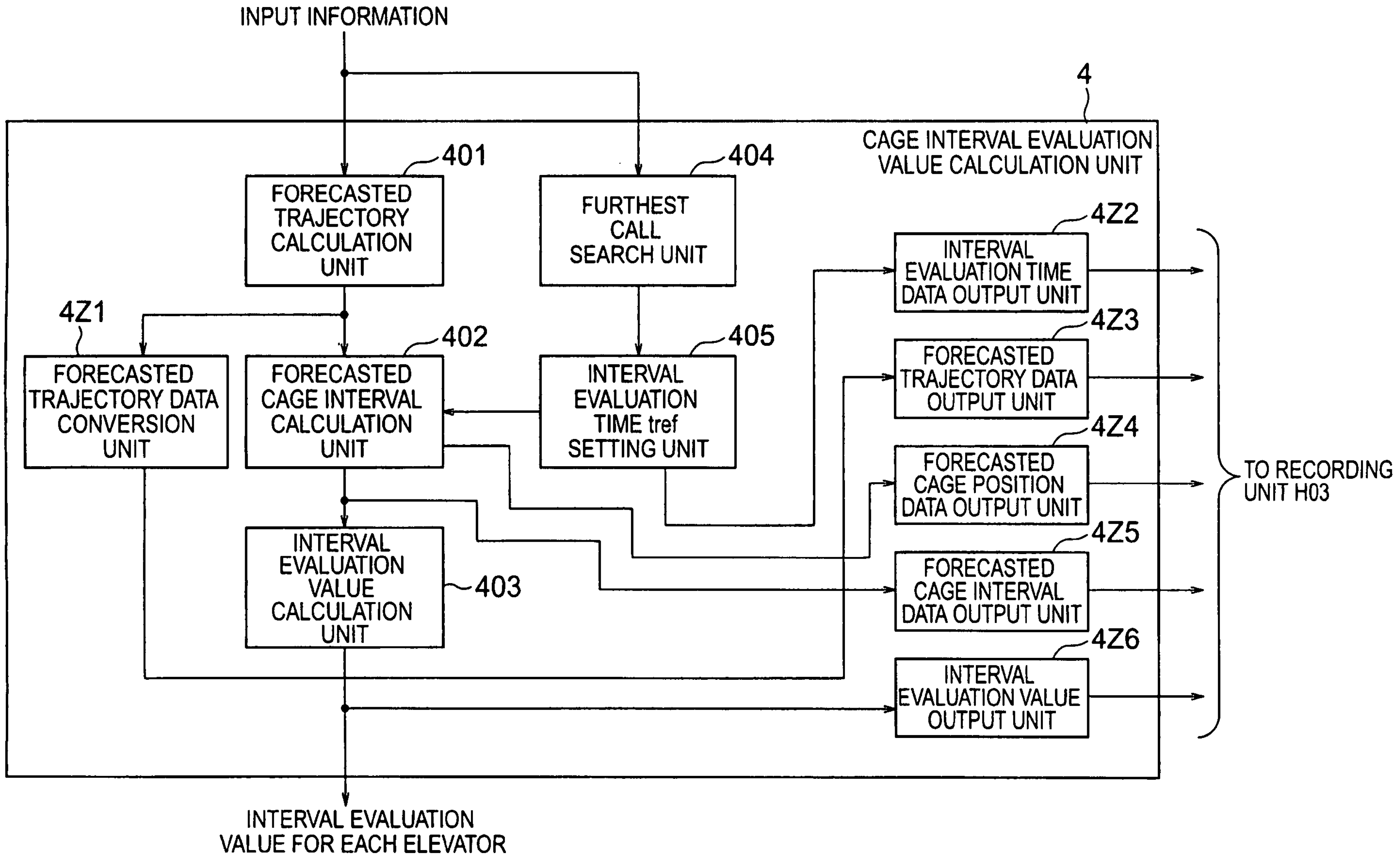

INPUT INFORMATION
4
CAGE INTERVAL EVALUATION VALUE CALCULATION UNIT
401
FORECASTED TRAJECTORY CALCULATION UNIT
404
FURTHEST CALL SEARCH UNIT
4Z1
FORECASTED TRAJECTORY DATA CONVERSION UNIT
402
FORECASTED CAGE INTERVAL CALCULATION UNIT
405
INTERVAL EVALUATION TIME tref SETTING UNIT
403
INTERVAL EVALUATION VALUE CALCULATION UNIT
4Z2
INTERVAL EVALUATION TIME DATA OUTPUT UNIT
4Z3
FORECASTED TRAJECTORY DATA OUTPUT UNIT
4Z4
FORECASTED CAGE POSITION DATA OUTPUT UNIT
4Z5
FORECASTED CAGE INTERVAL DATA OUTPUT UNIT
4Z6
INTERVAL EVALUATION VALUE OUTPUT UNIT
TO RECORDING UNIT H03
INTERVAL EVALUATION VALUE FOR EACH ELEVATOR

FIG. 49

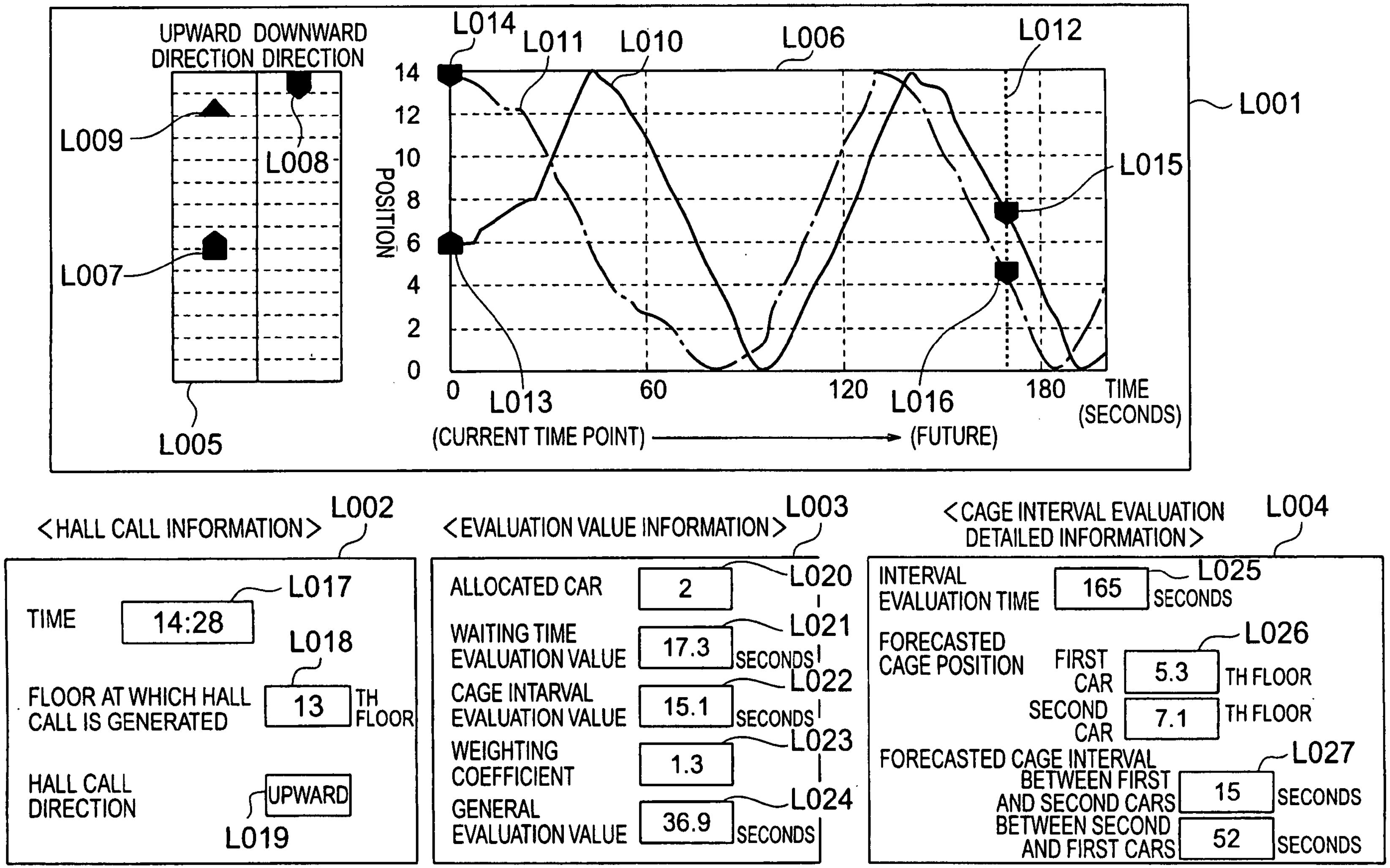

UPWARD DIRECTION
DOWNWARD DIRECTION
L014
L011
L010
L006
L012
L001
L009
L008
L015
L007
L005
L013
L016
14
12
10
8
6
4
2
0
POSITION
0
60
120
180
TIME (SECONDS)
(CURRENT TIME POINT)
(FUTURE)
<HALL CALL INFORMATION>
L002
TIME
14:28
L017
L018
FLOOR AT WHICH HALL CALL IS GENERATED
13
TH FLOOR
HALL CALL DIRECTION
UPWARD
L019
<EVALUATION VALUE INFORMATION>
L003
ALLOCATED CAR
2
L020
WAITING TIME EVALUATION VALUE
17.3
SECONDS
L021
CAGE INTARVAL EVALUATION VALUE
15.1
SECONDS
L022
WEIGHTING COEFFICIENT
1.3
L023
GENERAL EVALUATION VALUE
36.9
SECONDS
L024
<CAGE INTERVAL EVALUATION DETAILED INFORMATION>
L004
INTERVAL EVALUATION TIME
165
SECONDS
L025
FORECASTED CAGE POSITION
FIRST CAR
5.3
TH FLOOR
L026
SECOND CAR
7.1
TH FLOOR
FORECASTED CAGE INTERVAL
BETWEEN FIRST AND SECOND CARS
15
SECONDS
L027
BETWEEN SECOND AND FIRST CARS
52
SECONDS

FIG. 50

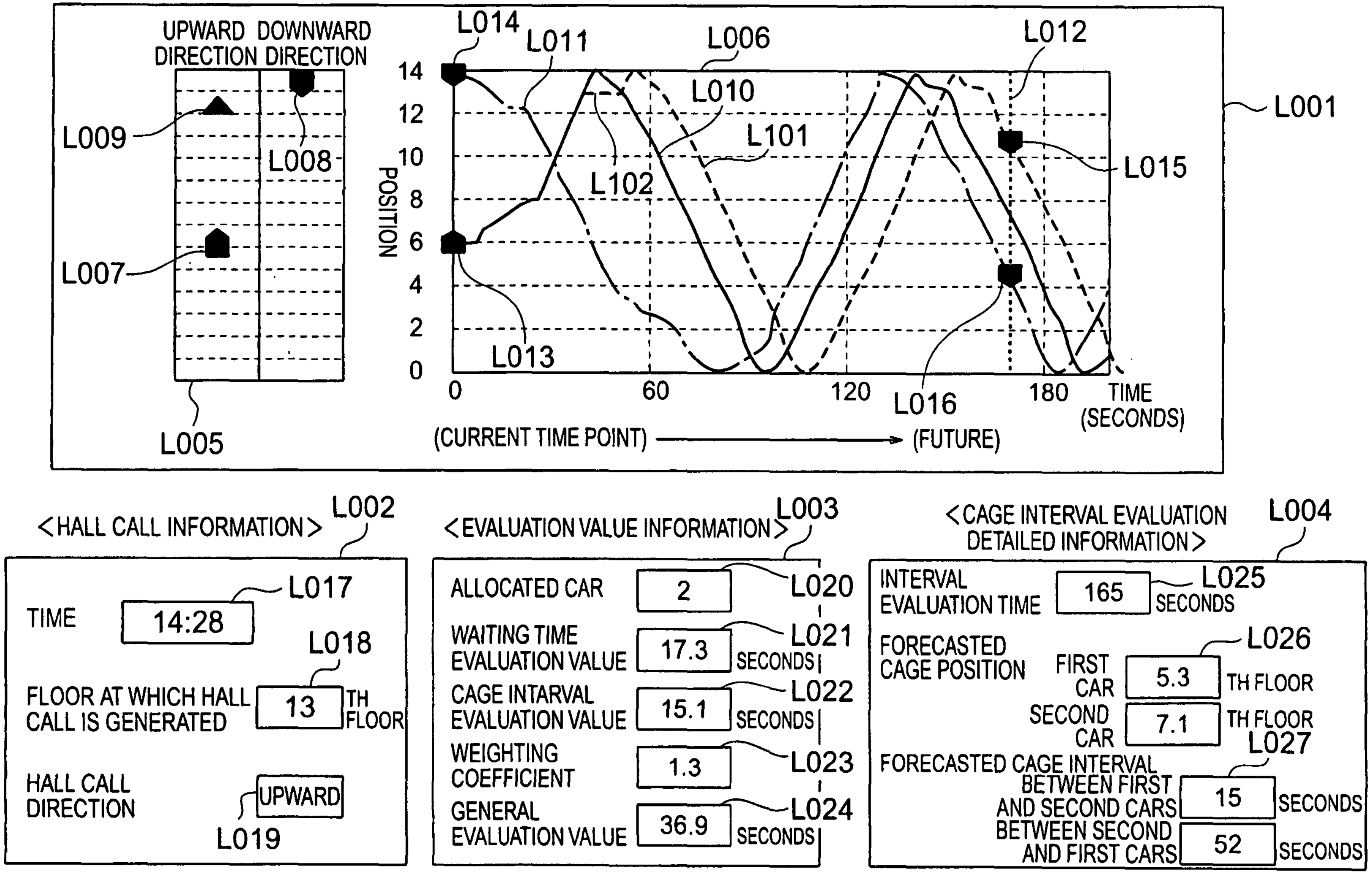
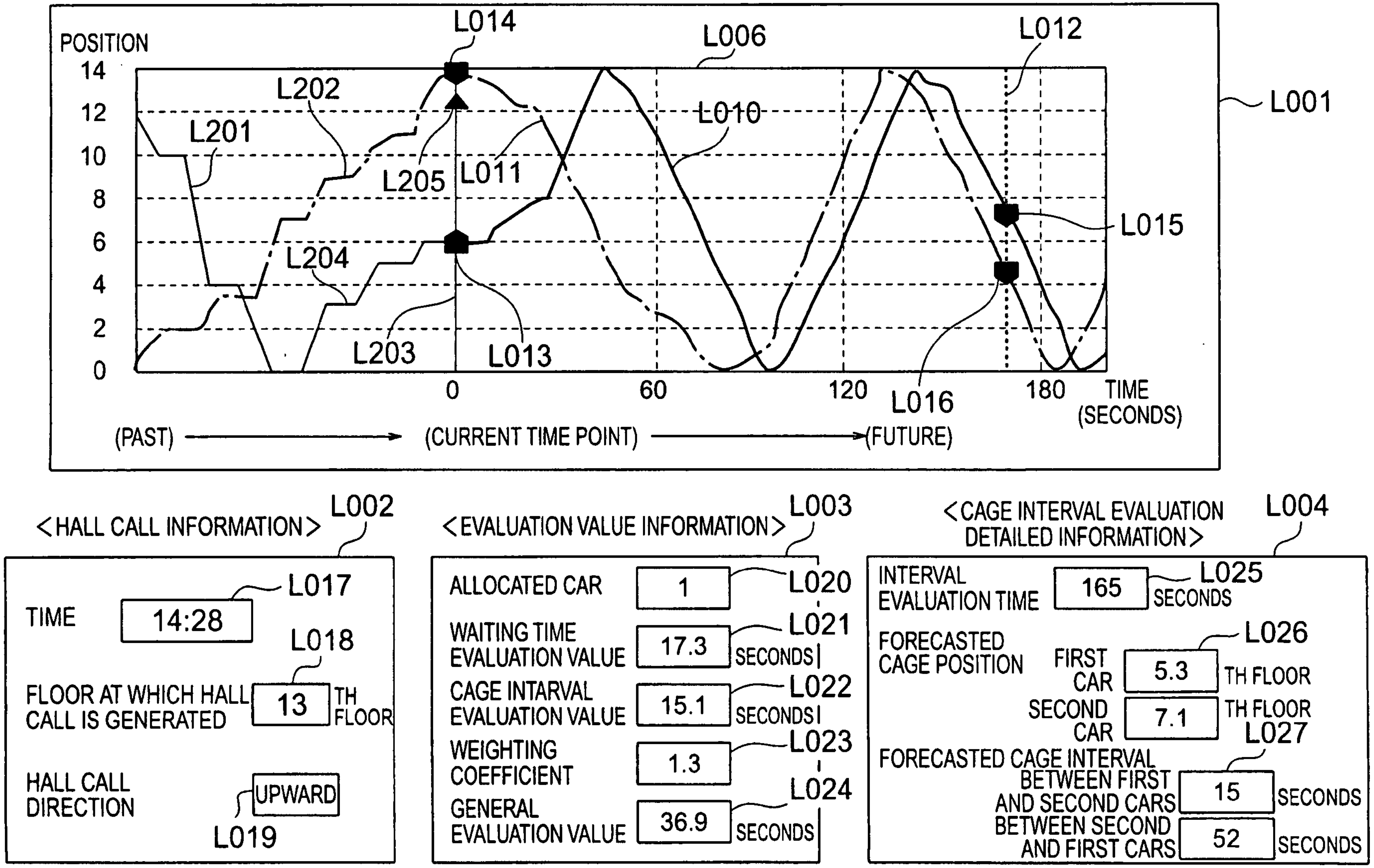

L001
UPWARD DIRECTION
DOWNWARD DIRECTION
L009
L008
L007
L005
POSITION
14
12
10
8
6
4
2
0
L014
L011
L006
L010
L101
L102
L012
L015
L013
L016
0
60
120
180
TIME (SECONDS)
(CURRENT TIME POINT)
(FUTURE)
<HALL CALL INFORMATION>
L002
TIME
14:28
L017
FLOOR AT WHICH HALL CALL IS GENERATED
13
TH FLOOR
L018
HALL CALL DIRECTION
UPWARD
L019
<EVALUATION VALUE INFORMATION>
L003
ALLOCATED CAR
2
L020
WAITING TIME EVALUATION VALUE
17.3
SECONDS
L021
CAGE INTARVAL EVALUATION VALUE
15.1
SECONDS
L022
WEIGHTING COEFFICIENT
1.3
L023
GENERAL EVALUATION VALUE
36.9
SECONDS
L024
<CAGE INTERVAL EVALUATION DETAILED INFORMATION>
L004
INTERVAL EVALUATION TIME
165
SECONDS
L025
FORECASTED CAGE POSITION
FIRST CAR
5.3
TH FLOOR
L026
SECOND CAR
7.1
TH FLOOR
L027
FORECASTED CAGE INTERVAL
BETWEEN FIRST AND SECOND CARS
15
SECONDS
BETWEEN SECOND AND FIRST CARS
52
SECONDS

FIG. 51



<HALL CALL INFORMATION>

TIME 14:28

FLOOR AT WHICH HALL CALL IS GENERATED 13 TH FLOOR

HALL CALL DIRECTION UPWARD

<EVALUATION VALUE INFORMATION>

ALLOCATED CAR 1

WAITING TIME EVALUATION VALUE 17.3 SECONDS

CAGE INTARVAL EVALUATION VALUE 15.1 SECONDS

WEIGHTING COEFFICIENT 1.3

GENERAL EVALUATION VALUE 36.9 SECONDS

<CAGE INTERVAL EVALUATION DETAILED INFORMATION>

INTERVAL EVALUATION TIME 165 SECONDS

FORECASTED CAGE POSITION FIRST CAR 5.3 TH FLOOR

SECOND CAR 7.1 TH FLOOR

FORECASTED CAGE INTERVAL BETWEEN FIRST AND SECOND CARS 15 SECONDS

BETWEEN SECOND AND FIRST CARS 52 SECONDS

FIG. 52

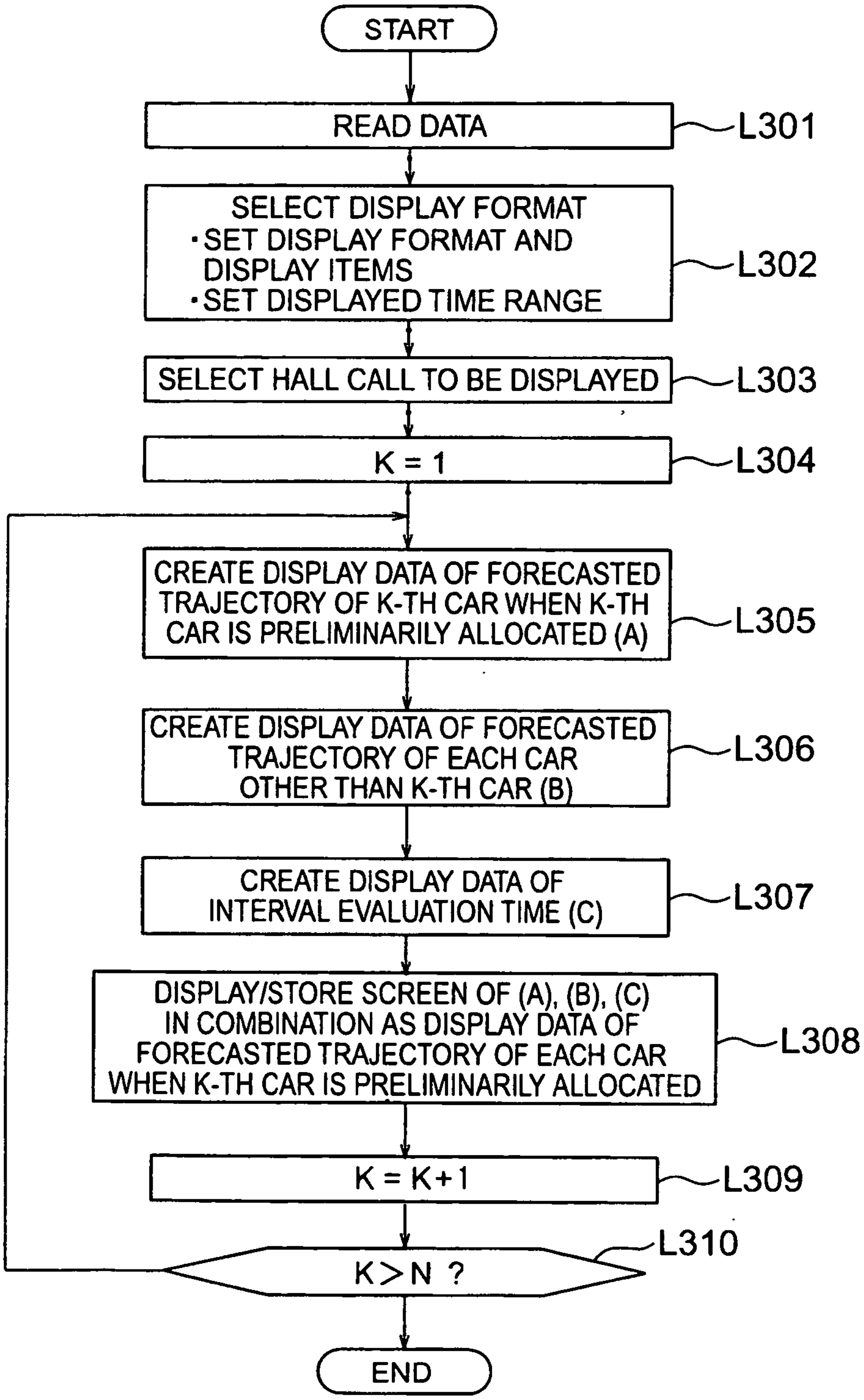
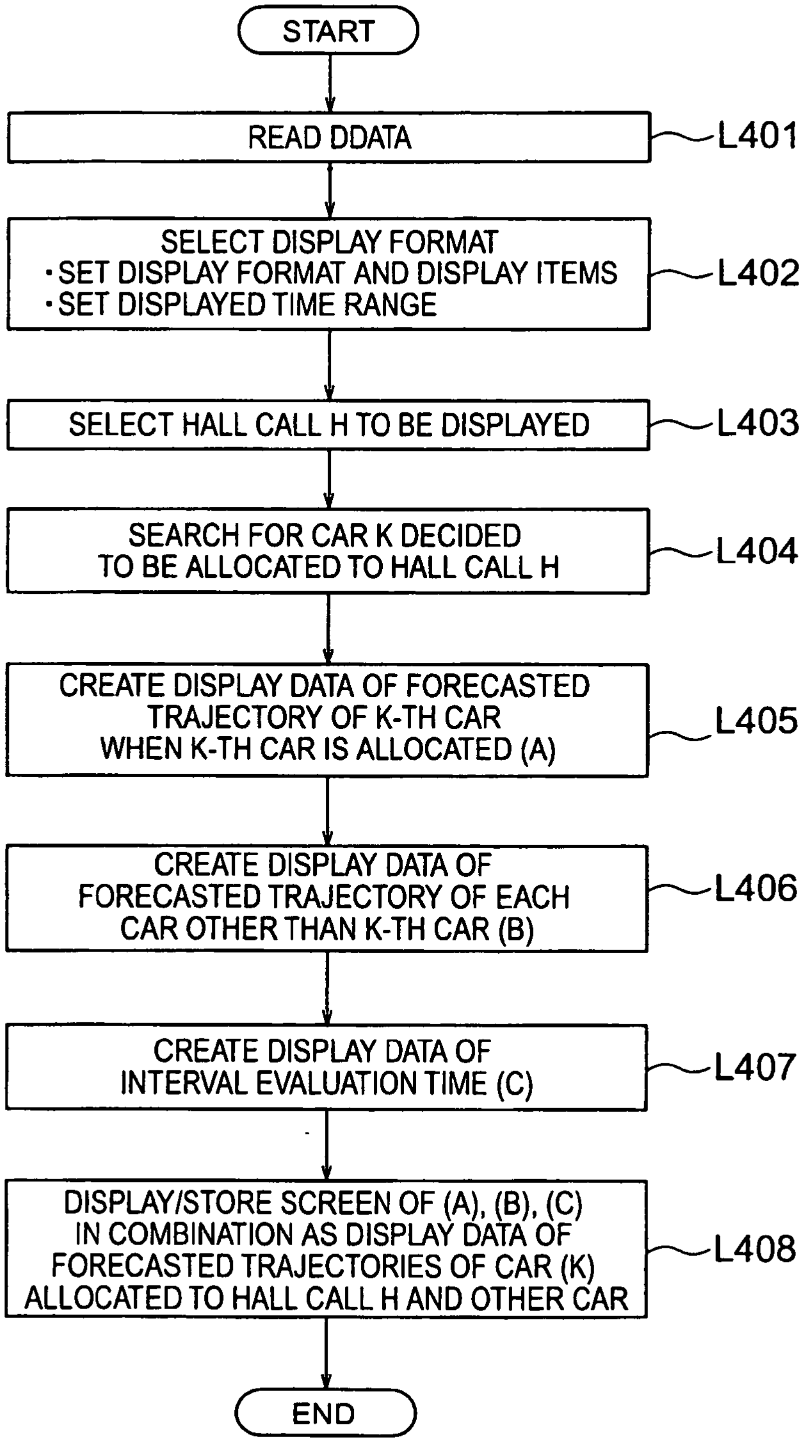

START
READ DATA
L301
SELECT DISPLAY FORMAT
•SET DISPLAY FORMAT AND DISPLAY ITEMS
•SET DISPLAYED TIME RANGE
L302
SELECT HALL CALL TO BE DISPLAYED
L303
K = 1
L304
CREATE DISPLAY DATA OF FORECASTED TRAJECTORY OF K-TH CAR WHEN K-TH CAR IS PRELIMINARILY ALLOCATED (A)
L305
CREATE DISPLAY DATA OF FORECASTED TRAJECTORY OF EACH CAR OTHER THAN K-TH CAR (B)
L306
CREATE DISPLAY DATA OF INTERVAL EVALUATION TIME (C)
L307
DISPLAY/STORE SCREEN OF (A), (B), (C) IN COMBINATION AS DISPLAY DATA OF FORECASTED TRAJECTORY OF EACH CAR WHEN K-TH CAR IS PRELIMINARILY ALLOCATED
L308
K = K+1
L309
K>N ?
L310
END

FIG. 53


START
READ DDATA
L401
SELECT DISPLAY FORMAT
•SET DISPLAY FORMAT AND DISPLAY ITEMS
•SET DISPLAYED TIME RANGE
L402
SELECT HALL CALL H TO BE DISPLAYED
L403
SEARCH FOR CAR K DECIDED TO BE ALLOCATED TO HALL CALL H
L404
CREATE DISPLAY DATA OF FORECASTED TRAJECTORY OF K-TH CAR WHEN K-TH CAR IS ALLOCATED (A)
L405
CREATE DISPLAY DATA OF FORECASTED TRAJECTORY OF EACH CAR OTHER THAN K-TH CAR (B)
L406
CREATE DISPLAY DATA OF INTERVAL EVALUATION TIME (C)
L407
DISPLAY/STORE SCREEN OF (A), (B), (C) IN COMBINATION AS DISPLAY DATA OF FORECASTED TRAJECTORIES OF CAR (K) ALLOCATED TO HALL CALL H AND OTHER CAR
L408
END

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 7012890 B **[0004] [0006]**
- JP 7072059 B **[0004]**
- JP 1226676 A **[0004] [0006] [0073]**
- US 4947965 A **[0004]**
- JP 7061722 A **[0004] [0006]**
- JP 2000118890 A **[0004] [0006]**
- JP 8175769 A **[0004]**
- WO 2005042389 A1 **[0007]**
- EP 1719727 A2 **[0008]**
- US 4982817 A **[0009]**

Non-patent literature cited in the description

- Method of Calculating Forecasted Time of Arrival Using Dynamic Planning Method. Institute of Electrical Engineers of Japan, Electronics, Information and Systems Society Conference, 2003, 1099-1102 **[0004] [0005]**