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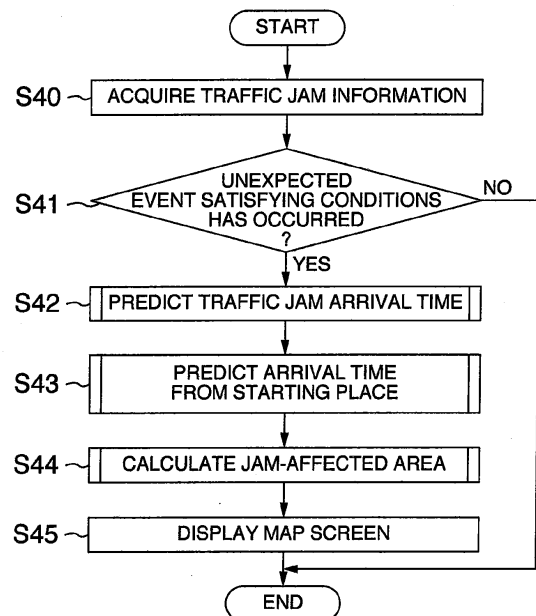
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(54) **Method and apparatus for predicting traffic jam area**

(57) A method and an apparatus are disclosed to predict a traffic jam area and indicate a route for positively avoiding a jam-affected area without repeating the route search upon occurrence of a traffic jam due to an unexpected event. A route is determined to avoid the jam-affected area by executing a step (S40) of acquiring the traffic information including the information on the unexpected event, a traffic jam arrival time prediction step (S42) for predicting, for each mesh, at least one of the starting time and the ending time of the traffic jam caused by the unexpected event, a step (S43) of predicting the time of arrival from the starting place for each mesh around the starting position based on the starting position and the starting time, and a step (S44) of calculating the area affected by the traffic jam before the end of the traffic jam caused by the unexpected event. The traffic jam can thus be avoided positively in the future by setting a route avoiding the jam-affected area thus determined, while at the same time reducing the number of times a route is searched for.

FIG.3



Description**BACKGROUND OF THE INVENTION**

5 **[0001]** This invention relates to a navigation system, or in particular, to a system for calculating a traffic jam area and providing a route avoiding the traffic jam area.

[0002] In recent years, the technique to lead and guide an automotive vehicle along a route from the present place to a destination using a navigation system has extended, in which the user searches for an optimum route by setting the conditions such as the shortest time, the shortest distance and the priority of an ordinary road. In the case where the user selects a route of the shortest time, the car navigation system searches for a route of the shortest time required to the destination using the real-time traffic information and the statistical traffic information.

10 **[0003]** It is difficult, however, to predict and avoid an unexpected traffic jam due to an unexpected event in advance using the real-time and statistical traffic information. The problem is posed, therefore, that in the case where an unexpected traffic jam occurs, the vehicle is involved in the traffic jam and it may take a longer time than predicted to reach the destination. In view of this, a technique has been developed by which in the case where a traffic jam occurs, a route search is made again, and by thus avoiding the traffic jam, the time loss due to the traffic jam is minimized.

15 **[0004]** As described in JP-A-2007-285998, for example, the range of a traffic jam area expected to prevail on the route of the shortest time at about the time when the vehicle is scheduled to arrive at the traffic jam area is predicted, and at an intersection before the predicted traffic jam area, the vehicle begins to follow a detour route meeting the conditions desired by the user thereby to avoid the predicted traffic jam area.

20 **[0005]** Also, JP-A-2008-268149 discloses a technique whereby the size of an area to be avoided is calculated in accordance with the time elapsed from the occurrence of an accident and a route to avoid the particular area is searched for.

25 **[0006]** In applying the technique described in JP-A-2007-285998 to an unexpected traffic jam, though capable of predicting and avoiding the extension or shrinkage of the unexpected traffic jam on the predicted route of the shortest time along which the vehicle is being led and guided, it is impossible to predict a traffic jam which may occur on a detour route. In order to avoid an unexpected traffic jam positively, a traffic jam which may occur unexpectedly on the detour route is also required to be predicted, and the vehicle, if liable to be involved in it, is required to find another detour route.

30 **[0007]** In the application of the technique described in JP-A-2008-268149 to an unexpected traffic jam, on the other hand, though capable of searching for a route to avoid the present unexpected traffic jam area, it is impossible to predict whether a detour route is included in the unexpected traffic jam area which may have been enlarged. In order to avoid an unexpected traffic jam positively, therefore, the search process is required to be repeated.

35 **[0008]** Specifically, according to the conventional techniques described above, the search process is required to be repeated to avoid an unexpected traffic jam positively. This increases both the number of times the route search is made and the calculation amount. In such a case, a recommended route is liable to change frequently very inconveniently for the user. Further, in view of the fact that a route is set without taking the future situation into consideration, the probability is high that no traffic jam can be avoided.

SUMMARY OF THE INVENTION

40 **[0009]** Accordingly, it is an object of this invention to provide a method and apparatus for predicting a traffic jam area, wherein a route avoiding the traffic jam area is positively proposed without repeating the route search, by positively predicting an area affected by the traffic jam (hereinafter referred to as the jam-affected area) taking into consideration the possibility that the area affected by an unexpected event may undergo a change with time during the traffic jam due to the unexpected event.

45 **[0010]** In order to solve the problem described above, according to this invention, according to one aspect of the invention, there are provided a method of predicting a traffic jam area, comprising a step of acquiring the traffic information including the information on an unexpected event, a traffic jam arrival time prediction step for predicting, for each mesh, at least one of the starting time and the ending time of the traffic jam due to the unexpected event, a step of predicting the arrival time from the starting place for each mesh around a starting position based on the starting position and the starting time, and a jam-affected area calculation step for calculating the area expected to be affected by the traffic jam in the future, and an apparatus for executing the method.

50 **[0011]** According to another aspect of the invention, there is provided a method of predicting a traffic jam area, preferably further comprising a display step for displaying a plurality of jam-affected areas in superposed relation to each other on a map, and/or a step of searching for a route by resetting the jam-affected areas in such a manner as to increase a link cost of the link contained in the jam-affected areas thus determined.

55 **[0012]** According to this invention, a jam-affected area is set as an area where a traffic jam is liable to be encountered in the future. By determining a route in such a manner as to avoid the jam-affected area, therefore, the area where the

traffic jam is expected to extend in the future can be positively avoided, thereby reducing the number of times the route is repeatedly searched for.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 is a diagram showing the configuration of a traffic information system according to this invention.

Fig. 2 is a diagram showing an example of the configuration of the map information.

Fig. 3 is a flowchart indicating the process executed in the traffic information system according to the invention.

Fig. 4 is a flowchart of the process executed to predict the traffic jam arrival time.

Fig. 5 is a diagram for explaining a traffic jam propagation model.

Fig. 6 is a diagram showing the traffic jam starting time and the traffic jam ending time in the traffic jam propagation model.

Fig. 7 is a flowchart of the process for predicting the arrival time from the starting place.

Fig. 8 is a diagram for explaining the Dijkstra's algorithm for each mesh in the arrival time prediction process.

Fig. 9 is a diagram showing an example of the structure of the data stored in a prediction information storage unit.

Fig. 10 is a flowchart of the process to calculate the jam-affected area.

Figs. 11A and 11B are diagrams showing an example of displaying the jam-affected area on a screen.

Fig. 12 is a diagram showing another configuration of the traffic information system according to this invention.

Fig. 13 is another flowchart of the process executed by the traffic information system according to this invention.

Fig. 14 is a diagram showing an example of the structure of the data stored in the prediction information storage unit.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Embodiments of the invention are explained below with reference to the accompanying drawings.

[First embodiment]

[0015]

Fig. 1 is a diagram showing the configuration of a traffic information system 110 according to this invention. The traffic information system 110 is configured of a basic map information DB 120, a prediction unit 130, a jam-affected area calculation unit 140, a display map information DB 150 and a display unit 160.

Fig. 2 shows the data structure of the basic map information DB 120. The basic map information DB 120 includes a mesh data 210 indicating the information on a mesh and a link data 220 for each link making up the roads included in the mesh area. Both data are stored for each mesh. The mesh indicates a rectangular area (for example, an area having a latitude difference of 40 minutes and a longitude difference of one degree) on the map set based on the latitude and longitude. The size of a mesh can be set appropriately in accordance with the resolution of the traffic jam area determined by the user and the configuration of the roads. The link is an element making up a road and expressed as a vector connecting the nodes designated by an intersection or a diverging point (fork). In the process, the up and down directions of the same road are managed as different links.

[0016] The mesh data 210 includes a mesh ID 211 and an in-mesh average speed 212. The mesh ID 211 indicates the identification code of each mesh and is assigned regularly in accordance with the position of the mesh on the map. A mesh ID of a mesh adjacent to a given mesh can be determined from the mesh ID 211 of the given mesh. The in-mesh average speed 212 is stored as the average value of a travel speed 224 described later for the link included in a mesh.

[0017] The link data 220 is configured of a link ID 221 indicating the identification code of each link, a road category 222 classified into a toll road and an ordinary national road, a link length 223 indicating the length of each link, a travel speed 224 indicating the average speed to pass through the link and a travel time 225 indicating the time required for passing through the link.

[0018] The restricted speed for each link is stored as the travel speed 224. The travel speed 224 may alternatively be the statistical traffic information generated in accordance with the day type (day of the week, weekday/Saturday/holiday, "gotohbi"-days in which loads are apt to be crowded due to a certain old Japanese custom, weather, etc.) of the days for prediction. Assuming that a plurality of past days correspond to the day type of the prediction day, the statistical value such as the central value or the average value of the travel speed on a link for the same time zone of the plurality of the days corresponds to the statistical travel time of the link. In the case where the statistical traffic information is used, the traffic information for each time zone of each day type is stored for each one of the links. The travel time 225 may

alternatively be a value obtained by dividing the link length 223 by the travel speed 224.

[0019] The prediction unit 130 is configured of a traffic information receiver 131, a present position acquisition unit 132, a traffic jam determining unit 133, a traffic jam arrival time prediction unit 134, an arrival time prediction unit 135 and a prediction information storage unit 136.

[0020] The traffic information receiver 131 receives the real-time traffic information and the unexpected event information from a FM multiplex broadcast receiver, a beacon receiver, a portable phone or a radio, and sends them to the traffic jam determining unit 133. The real-time traffic information includes the travel time and the traffic level for each link. The unexpected event information includes the restrictions (closed road, one-way traffic control, etc.), a causative event (accident, construction work, etc.), the road type of the restricted link, the restricted position, the restriction starting time, etc. The FM multiplex broadcast receiver receives the general traffic information (figure, etc.) and the text information transmitted as a FM multiplex broadcast signal by a FM broadcast station. The general traffic information and the text information are generated based on the real-time traffic information transmitted from a traffic information center to the FM broadcast station. The beacon receiver receives the detailed real-time traffic information transmitted by a traffic control center through a beacon providing an on-road communication unit. This real-time traffic information is the one that has been transmitted to the traffic control center of each area from the traffic information center. The FM multiplex broadcast receiver and the beacon receiver may receive, as the real-time information, the vehicle information (time, running speed, running position, etc.) sent from a floating car and related to the link corresponding to the running position.

[0021] The present position acquisition unit 132 calculates the position of the starting place and acquires the present time. In the process, the position is calculated based on the information acquired from at least one of the vehicle speed sensor, the gyro sensor and the GPS receiver. The vehicle speed sensor measures the running distance based on the product of the circumference of a wheel and the r.p.m. of the wheel on the one hand and the angle of a curve followed by the vehicle based on the r.p.m. difference between a pair of the wheels on the other hand. The gyro sensor is configured of an optical fiber gyro or a vibration gyro and detects the angle of rotation of the vehicle on which the sensor is mounted. Incidentally, the starting place is defined as the position of the user's vehicle having the traffic information system 110 as an on-vehicle device. In the case where the traffic information system 110 is installed in the traffic information center, for example, instead of on the vehicle, on the other hand, the starting point is defined as a point designated by the user or the user's vehicle position notified from an on-vehicle terminal.

[0022] The traffic jam determining unit 133, by taking the position information acquired from the present position acquisition unit 132 into consideration, determines whether a traffic jam liable to have the starting place on the vehicle has occurred or may occur in the future, based on the real-time traffic information and the unexpected event information received by the traffic information receiver 131. Specifically, in the case where at least one of the conditions is met that an unexpected event has occurred within a predetermined distance (for example, in 50 km or less) from the starting place, that the time of occurrence of the unexpected event is in a predetermined time range (for example, between the present time and one hour before the present time) or that the real-time traffic information is undergoing a sudden change beyond a predetermined threshold (for example, the travel speed is sharply reduced), then the traffic jam determining unit 133 determines that a traffic jam liable to have an effect on the starting place has occurred or will occur in the future. Upon determination that a traffic jam liable to have an effect on the starting place has occurred or will occur in the future, the real-time traffic information and the unexpected event information are sent to the traffic jam arrival time prediction unit 134.

[0023] The traffic jam arrival time prediction unit 134 calculates the traffic jam starting time and the traffic jam ending time for each mesh around the unexpected event occurrence position based on the real-time traffic information and the unexpected event information acquired from the traffic jam determining unit 133 and the basic map information acquired from the basic map information DB 120. The traffic jam starting time and the traffic jam ending time calculated for each mesh are sent to the prediction information storage unit 136.

[0024] The arrival time prediction unit 135 calculates the arrival time from the starting place for each mesh around the starting place based on the starting place position information acquired from the present position acquisition unit 132 and the basic map information acquired from the basic map information DB 120. The arrival time from the starting place calculated for each mesh is sent to the prediction information storage unit 136.

[0025] The prediction information storage unit 136 stores therein the arrival time, the traffic jam starting time and the traffic jam ending time for each mesh which have been sent from the traffic jam arrival time prediction unit 134 and the arrival time prediction unit 135. An example of the configuration of the prediction information stored in the prediction information storage unit 136 is shown in Fig. 9. The arrival time, the traffic jam starting time and the traffic jam ending time are recorded one by one for each mesh ID.

[0026] The jam-affected area calculation unit 140 reads the arrival time for each mesh, the traffic jam starting time and the traffic jam ending time from the prediction information storage unit 136, and determines whether each mesh is included in the jam-affected area or not. The result of this determination is sent to the display unit 160.

[0027] The display map information DB 150 contains the information on the roads and other structures required for displaying a map. Examples of the information thus contained include the position coordinate of the complementary

point of the link, the water system data such as the shape of shorelines, lakes and rivers, the data on administrative boundary positions, the data on railway positions, the data on the position/shape of facilities and the display position data such as place names.

[0028] The display unit 160 is configured of a map display unit 161 and a display 162. The map display unit 161 acquires the map information from the display map information DB 150, and sends a plot command to the display 162 to plot marks indicating the roads or other structures in the map and the starting place according to a designated plotting method (plan view, bird's-eye view, etc.) on a designated scale. Also, a plot command is sent to the display 162 to display the mesh appearance in a manner different from the normal mesh appearance (for example, by changing the color) to permit the user watching the display 162 to recognize the mesh determined as existent in the jam-affected area by the jam-affected area calculation unit 140. In the case where the mesh determined as existent in the jam-affected area is included in a sea, a lake or a mountain and no link or very few links exist in the mesh, then the map display unit 161 may send a plot command to display the particular mesh in the ordinary color. In this case, a predetermined threshold value is determined, and in the case where the number of links included in a mesh determined existent in the jam-affected area by the jam-affected area calculation unit 140 is not less than the threshold value, then the particular mesh is displayed as existent in the jam-affected area, while in the case where the number of links included in the mesh is less than the threshold value, on the other hand, the particular mesh is displayed as existent outside the jam-affected area.

[0029] The display 162 is configured of a CRT or a liquid crystal display, and displays the map screen based on the plot command transmitted thereto from the map display unit 161.

[0030] Fig. 11 shows an example of the screen displayed on the display 162. The display 162 displays the jam-affected area together with the starting place, roads and facilities on the map, and thus can indicate the traffic jam area affecting the starting place into the future. As a result, the user can change the route by himself.

[0031] The configuration of the traffic information system 110 described above makes it possible to predict the future situation and determine the traffic jam area having an effect on the starting place. By avoiding this area, therefore, the traffic jam can be positively avoided into the future.

[0032] Fig. 3 is a flowchart showing all the processing steps executed in the traffic information system 110 according to an embodiment of the invention. In the flowchart of Fig. 3, the traffic information system 110 first acquires the real-time traffic information and the unexpected event information from the FM multiplex broadcast receiver or the beacon receiver, and fetches it into the traffic information receiver 131 (step S40). This step is executed at regular time intervals of, say, 5 minutes.

[0033] Next, based on the position information acquired by the present position acquisition unit 132 and the real-time traffic information and the unexpected event information received by the traffic information receiver 131, the traffic jam determining unit 133 determines whether a traffic jam which may have an effect on the starting place has occurred or may occur or not in the future (step S41). Specifically, in the case where at least one of the conditions is met that an unexpected event has occurred within a predetermined distance (for example, in 50 km or less) to the present position from the starting place, that the time of occurrence of the unexpected event is in a predetermined time range (for example, between the present time and one hour before the present time) or that the real-time traffic information is undergoing a sudden change beyond a predetermined threshold (for example, the travel speed is sharply reduced), then the traffic jam determining unit 133 determines that a traffic jam liable to have an effect on the starting place has occurred or will occur in the future. In this case, the real-time traffic information and the unexpected event information are sent to the traffic jam arrival time prediction unit 134 (YES in step S41).

[0034] In the case where the traffic jam determining unit 133 determines that a traffic jam liable to have an effect on the starting place has not occurred and will not occur in the future, in contrast, the process in the traffic information system 110 is finished (NO in step S41).

[0035] Incidentally, the traffic jam determining unit 133 also determines whether the information on the unexpected event received by the traffic information receiver 131 is the same as the previously received information on an unexpected event, and upon determination that it is the same as the previously received information, the process in the traffic information system 110 may be finished. The determination as to whether both information are on the same unexpected event is made by determining, for example, whether both the position and time of occurrence of the two seemingly different unexpected events are the same or not. By doing so, the prediction process is not required to be executed a plurality of times for one unexpected event, and the calculation amount reduced.

[0036] In the case where the traffic jam determining unit 133 determines that an unexpected event meeting the aforementioned conditions has occurred, the traffic jam arrival time prediction unit 134 calculates the traffic jam starting time and the traffic jam ending time for each mesh based on the real-time traffic information and the unexpected event information sent thereto from the traffic jam determining unit 133 (step S42). The traffic jam starting time and the traffic jam ending time thus calculated are stored in the prediction information storage unit 136. Also, the arrival time prediction unit 135 calculates the arrival time from the starting place for each mesh, and the arrival time from the starting place thus calculated is stored in the prediction information storage unit 136 (step S43). Next, the jam-affected area calculation unit 140 reads the arrival time from the starting place, the traffic jam starting time and the traffic jam ending time for each

mesh from the prediction information storage unit 136 and determines whether each mesh is included in the jam-affected area or not. Then, a plot command is sent from the map display unit 161 to the display 162 to acquire the map information for the neighborhood of the starting place from the display map information DB 150 and display the map screen (step S44). The map display unit 161 receives the mesh ID determined as included in the jam-affected area from the jam-affected area calculation unit 140, and sends a command to the display 162 to change the display color of the particular mesh to a designated color. The display 162, upon reception of the command, displays the jam-affected area on the map together with the starting place, roads and facilities (step S45).

[0037] Figs. 11A and 11B show examples of display on the display 162. In Fig. 11A, the starting place is indicated by a triangle on the map, the unexpected event occurrence position by a star and the main roads by black lines. Further, each mesh is indicated by a square grid defined by dotted line and each mesh determined as included in the jam-affected area by hatching.

[0038] In the process, the jam-affected area may be displayed taking the areas such as a sea or a lake free of roads and the areas such as a mountain having few roads into consideration. Fig. 11B shows an example of display on the display 162 taking the areas having no or few roads into consideration. By obtaining the data on the position and shape of a lake from the display map information DB, as shown in Fig. 11B, the display color is not changed for the areas determined as a jam-affected area on the lake. This determination as to whether the display color should be changed or not may alternatively be made based on the number and density of links in a mesh. The determination as to whether the display color should be changed or not may be made for each of small equal division areas of a mesh.

[0039] By executing the process described above, the future traffic level can be predicted and the traffic jam area having the starting place can be determined. Thus, by avoiding the traffic jam area, the traffic jam can be positively avoided in the future.

[0040] Fig. 4 is a flowchart for explaining the detailed process of step S42 in the traffic jam arrival time prediction unit 134. In step S50, the real-time traffic information and the unexpected event information are acquired from the traffic jam determining unit 133. Next, in step S51, various parameters for determining a traffic jam propagation model are set using the real-time traffic information and the unexpected event information thus acquired. By setting the various parameters in the traffic jam propagation model, the future traffic level can be predicted.

[0041] An example of the traffic jam propagation model is explained with reference to Figs. 5 and 6. In this traffic jam propagation model, the traffic jam area is assumed to expand and shrink while maintaining the shape of a donut having the center at the place of occurrence of an unexpected event, and the positions of the outer and inner edges of the traffic jam area undergo a change. A graph indicating the change, with time, in the distance of the outer and inner edges of the traffic jam area from the position of occurrence of the unexpected event is shown in (a) of Fig. 6. In (a) of Fig. 6, the abscissa represents the time and the ordinate the distance from the position of occurrence of the unexpected event. Also, a graph indicating the change, with time, in the displacement rate of the outer and inner edges of the traffic jam area is shown in (b) of Fig. 6. In (b) of Fig. 6, the abscissa represents the time, and the ordinate the displacement rate of the outer and inner edges of the traffic jam area. In this case, the direction outward of the position of occurrence of the unexpected event is taken as a positive value.

[0042] In the traffic jam propagation models shown in (a) and (b) of Fig. 6, the traffic jam occurs at time T1 and ends at time T5. The outer edge of the traffic jam area expands outward at a predetermined rate $V_{j1} (\geq 0)$ between time points T1 and T2, remains unchanged between time points T2 and T4, and shrinks inward at a predetermined rate $V_{j3} (\leq 0)$ between time points T4 and T5. The inner edge of the traffic jam area, on the other hand, has yet to exist between time points T1 and T3, and expands outward at a predetermined rate $V_{j2} (\geq 0)$ between time points T3 and T5.

[0043] In step S51, the various parameters designated by T1, T2, T3, T4, T5, V_{j1} , V_{j2} , V_{j3} shown in (a) of Fig. 6 are set using the real-time traffic information and the unexpected event information. For this purpose, the values of the various parameters are determined in advance for all the situations indicated by the specifics of restriction (closed road, one-way traffic control), the causative event (accident, construction, etc.), the road category of the link to be restricted, the position restricted and the restriction starting time. In the process, the values determined statistically from the information on the past unexpected traffic jams which have occurred in a similar situation may be used as the values of the various parameters. Also, the various parameters may be set either uniformly for the whole of a single unexpected traffic jam or for each of the areas defined at a predetermined angle around the position of occurrence of the unexpected event.

[0044] In step S52, the traffic jam starting time and the traffic jam ending time are calculated for each mesh using the traffic jam propagation model based on the various parameters set in step S51 and the basic map information acquired from the basic map information DB 120. In the process, a mesh for which the traffic jam starting time and the traffic jam ending time are calculated is selected on condition that the distance between the position of occurrence of the unexpected event and the representative point of the mesh (for example, the center of the mesh) is in a predetermined range (for example, not more than 100 km). The traffic jam starting time and the traffic jam ending time thus calculated are stored in the prediction information storage unit 136.

[0045] A specific process for calculating the traffic jam starting time and the traffic jam ending time for a mesh is explained. A mesh on the map is expressed as a square grid in (c) of Fig. 6. First, the distance between the unexpected

event occurrence position 601 and the representative point of each mesh (for example, the center of the mesh) is calculated. In (c) of Fig. 6, the distance between the unexpected event occurrence position 601 and the mesh m1 is given as d1, and the distance between the unexpected event occurrence position 601 and the mesh m2 is given as d2.

[0046] Next, the position changes of the inner and outer edges of the traffic jam area in (a) of Fig. 6 are expressed by Equation 1 and Equation 2, respectively.

$$d = f(t) \dots\dots\dots(1)$$

$$d = g(t) \dots\dots\dots(2)$$

where d is the distance from the unexpected event occurrence position and t the time. From these equations, the traffic jam area at time t is considered to satisfy Equation 3.

$$g(t) \leq d \leq f(t) \dots\dots\dots(3)$$

[0047] Also, a positive micro time Δt is set. For example, assume that $\Delta t = 5$ min. Then, the traffic jam starting time for a mesh at the distance d from the unexpected event occurrence position 601 is determined as time t satisfying the conditions 1 and 2 described below Condition 1: The relation holds that $g(t) = d$ or $f(t) = d$

[0048] Condition 2: The relation holds that $g(t + \Delta t) \leq d \leq f(t + \Delta t)$.

[0049] The traffic jam ending time for the mesh, on the other hand, is determined as time t satisfying the conditions 3 and 4 described below.

[0050] Condition 3: The relation holds that $g(t) = d$ or $f(t) = d$

[0051] Condition 4: The relation holds that $g(t - \Delta t) \leq d \leq f(t - \Delta t)$.

[0052] In the example shown in (c) of Fig. 6, the traffic jam starting time can be determined as t1 and the traffic jam ending time as t2 for the mesh m1 by substituting $d = d1$ into the conditions 1 to 4. As for the mesh m2, on the other hand, neither the traffic jam starting time nor the traffic jam ending time can be calculated for lack of the time 1 even in the case where $d = d2$ is substituted into the conditions 1 to 4. In the case where neither the traffic jam starting time nor the traffic jam ending time can be calculated as described above, it indicates that the traffic jam area fails to propagate to the particular mesh, and "no data" is stored in the corresponding section of the prediction information storage unit 136.

[0053] The traffic jam starting time and the traffic jam ending time for each mesh are calculated by the process described above.

[0054] Next, the process of step S43 executed by the arrival time prediction unit 135 is explained in detail with reference to Figs. 7 and 8. Fig. 7 is a flowchart for the process executed by the arrival time prediction unit 135. In step S80 in Fig. 7, the present position acquisition unit 132 acquires the present position calculated based on the information received from a vehicle speed sensor, a gyro sensor, a GPS receiver, etc. Next, the moving speed between meshes is set (S81). The in-mesh average speed 212 contained in the mesh data of the basic map information DB 120 is used as the moving speed. In the absence of the in-mesh average speed 212, the moving speed between meshes may be calculated by determining the average value for the meshes after changing the travel speed of the link included in the traffic jam area based on the traffic level predicted in advance by the traffic jam arrival time prediction unit 134. Then, the arrival time from the starting place for each mesh is calculated using the set moving speed between meshes and the basic map information acquired from the basic map information DB 120 (step S82).

[0055] The specific process of calculating the arrival time for each mesh is explained with reference to Fig. 8. One representative point (for example, the center of the mesh) is set for each mesh, the distance between the representative points of the meshes is defined as the inter-mesh distance. The inter-mesh distance is divided by the in-mesh average speed 212 to determine the average moving time between the meshes. In Fig 8, each mesh is expressed as a square grid, and the representative point of each mesh by a black circle, on which the moving time between the meshes is noted. With the starting place as a start node and the representative point of each mesh as a node, the minimum time required to arrive at the representative point of each mesh from the starting point can be determined by applying the Dijkstra's algorithm on the assumption that a link having the inter-mesh average moving time as a link cost exists between the representative points of the meshes. By adding the required minimum time determined for each mesh to the present time, the time to arrive at each mesh can be calculated. In the process, the mesh for which the arrival time is calculated is selected, for example, on condition that the distance between the starting place and the representative point of the mesh (for example, the center of the mesh) is within a predetermined range (for example, not more than 100 km).

[0056] In Fig. 8, the arrival time at each mesh is noted on the particular mesh with the upper left mesh as the starting place and the starting time as 9:00.

[0057] As the result of this process, the time to arrive at each mesh from the starting place is calculated.

[0058] Next, the process of step S44 executed by the jam-affected area calculation unit 140 is explained in detail with reference to Fig. 10. This process is executed for each mesh included in a given area. Each area is selected, for example, as a mesh satisfying the condition that the distance between the starting place and the representative point of the particular mesh (for example, the center of the mesh) is within a predetermined range (for example, not more than 100 km).

[0059] First, the jam-affected area calculation unit 140 reads the arrival time from the starting place, the traffic jam starting time and the traffic jam ending time for a given mesh from the prediction information storage unit 136 (S 110). Let T_s be the arrival time, $T_j 1$ the traffic jam starting time and $T_j 2$ the traffic jam ending time for each mesh. Fig. 9 shows an example of the format of the arrival time from the starting place, the traffic jam starting time and the traffic jam ending time stored for each mesh in the prediction information storage unit 136. Assume that the prediction information storage unit 136 stores therein the data on the format shown in Fig. 9 for each mesh within a predetermined area from the mesh corresponding to the starting place.

[0060] Step S111 determines whether the data on the arrival time T_s is contained in the data read from the prediction information storage unit 136 for the mesh to be processed. In the absence of such data ("no data" in S111), the particular mesh is determined not included in the jam-affected area (S117). This is the situation indicated by the data example having the mesh ID of "45678901" in Fig. 9.

[0061] In the presence of the data on T_s ("data available" in step S111), on the other hand, step S 112 determines whether the data on the traffic jam starting time $T_j 1$ for the particular mesh is available or not. In the case where no such data is available ("no data" in step S112), step S 117 determines that the particular mesh is not included in the jam-affected area. This is the situation indicated by the data example having the mesh ID of "34567890" in Fig. 9.

[0062] In the case where the data on $T_j 1$ is available ("data available" in step S 112), step S113 determines whether the data on the traffic jam starting time $T_j 2$ for the particular mesh is existent or not. In the absence of such data ("no data" in step S 113). Step S116 determines whether Equation 4 below is satisfied or not. In the case where Equation 4 is satisfied (YES in step S 116), the particular mesh is determined as included in the jam-affected area, while in the case where Equation 4 is not satisfied (NO in step 116), on the other hand, step S117 determines that the particular mesh is not included in the jam-affected area.

$$T_j 1 \leq T_s \quad \dots\dots\dots(4)$$

[0063] This is the situation indicated by the data example having the mesh ID of "23456789" in Fig. 9. In this example, Equation 1 is satisfied by $T_s = 9: 10$ and $T_j 1 = 9: 05$, and therefore, the particular mesh is determined as included in the traffic jam area (S115).

[0064] Finally, in the case where $T_j 2$ is available ("data available" in step S113), step S 115 determines whether Equation 5 shown below is satisfied or not. In the case where Equation 5 is satisfied (YES in step S115), the particular mesh is determined as included in the jam-affected area (S 115). In the case where Equation 5 is not satisfied (NO in step S 116), on the other hand, the particular mesh is determined as not included in the jam-affected area (S 117).

$$T_j 1 \leq T_s \leq T_j 2 \quad \dots\dots\dots(5)$$

[0065] This is the situation indicated by the example having the mesh ID of "12345678". In this example, $T_s = 9:00$, $T_j 1 = 9:10$ and $T_j 2 = 9:30$, and Equation 2 fails to be satisfied. Therefore, the particular mesh is determine as not included in the jam-affected area.

[0066] The process described above is executed for each mesh in a predetermined area.

[0067] This process determines for each mesh whether it is included the am-affected area or not. This determination for each mesh by the jam-affected area calculation unit 140 whether the particular mesh is included in the jam-affected area or not reduces the calculation amount and shortens the processing time.

[0068] As an alternative, the jam-affected area may be determined not for each mesh but for each link. In such a case, the arrival time is calculated for each link by at least one of the traffic jam arrival time prediction unit 134 and the arrival time prediction unit 135. In the case where the traffic jam arrival time prediction unit 134 calculates the traffic jam starting time and the traffic jam ending time for each link in the process of step S42, unlike in the process explained with reference to Fig. 6, the distance between the unexpected event occurrence position and the representative point of the link (for example, the intermediate point of the link) without using the distance between the unexpected event occurrence position

and the representative point of the mesh. In the case where the arrival time is calculated for each link in the process of step S43, on the other hand, the time required to reach each link is calculated using the normal Dijkstra's algorithm is used for each link instead of the process of calculating the arrival time for each mesh explained with reference to Fig. 8. In determining whether each link is included in the jam-affected area or not, the link ID is stored in place of the mesh ID in the prediction information storage unit 136, and the arrival time from the starting place, the traffic jam starting time and the traffic jam ending time are recorded one by one for each link ID.

[0069] As described above, by determining whether each link is included in the jam-affected area or not, the jam-affected area can be calculated more accurately than in the prediction for each mesh.

[0070] Also, the prediction process may be executed a plurality of times for one unexpected event. By doing so, the prediction accuracy is further increased, and the proper jam-affected area can be calculated. In this case, the vehicle arrival time, the traffic jam starting time and the traffic jam ending time previously calculated are stored in the process of steps S42 and S43. In the case where the difference of the result of calculation of the vehicle arrival time from the starting place, the traffic jam starting time and the traffic jam ending time for each mesh in steps S42 and S43 as compared with the previous calculation result exceeds a threshold value, then the process of step S44 may be executed. Thus, the calculation of the jam-affected area is repeated only in the case where the difference between the previous prediction result and the present traffic level increases for the same unsuspected event. As compared with a case in which all the steps are repeated each time the traffic information is received, therefore, the calculation amount can be reduced.

[Second embodiment]

[0071] Fig. 12 is a diagram showing the configuration of a traffic information system 1410 in which a route search unit 1420 having the function of searching for a route connecting the starting place and the destination is added to the traffic information system 110 shown in Fig. 1.

[0072] Fig. 13 is a flowchart showing the processing steps for the traffic information system 1410. The steps to execute the same process as those of the flowchart shown in Fig. 3 are designated by the same reference numerals, respectively. As compared with the processing steps according to the first embodiment shown in Fig. 3, the second embodiment has added thereto a route search process (S150) in the route search unit 1420. Step S150 searches for the route of the shortest time from the starting place to the destination using the Dijkstra's algorithm or the like. In the process, the link cost is set using the travel time 225 contained for each link in the basic map information DB 120. Alternatively, the link cost may be set using the statistical traffic information contained in the basic map information DB 120. As another alternative, the link cost may be set using the real-time traffic information acquired from the traffic information receiver 131.

[0073] The route search unit 1420 acquires, from the jam-affected area calculation unit 140, the ID of the mesh determined in step S44 as included in the jam-affected area, and resets the link cost for the link included in the mesh determined as included in the jam-affected area. In resetting the link cost, the average speed in the jam-affected area, for example, is uniformly set (for example, at 5 km/h), and the link length 223 of each link is divided by the average speed in the jam-affected area to produce a link cost. Alternatively, the link cost may be set at a smaller value, the nearer to an end of the traffic jam area, and at a larger value, the nearer to the center of the traffic jam area. This is by reason of the fact that the reliability of the traffic jam prediction result is low at an end, and high at the center of the traffic jam area.

[0074] A specific example of the method of calculating the link cost is described below. Let d be the distance from the unexpected event occurrence position, d_i the distance from the unexpected event occurrence position to the inner edge of the traffic jam area, and d_o the distance from the unexpected event occurrence position to the outer edge of the traffic jam area. Then, the center of the traffic jam area is considered at the distance of $d_m = (d_i + d_o)/2$ from the unexpected event occurrence position. Further, the link cost under the normal condition and the link cost determined by uniformly setting the average speed in the jam-affected area are expressed as functions $C1(d)$ and $C2(d)$, respectively, using the character d designating the distance. At the same time, the link cost $C(d)$ for the distance d from the unexpected event occurrence position is determined according to Equation 6 below, where $N(\mu, \sigma^2)$ indicates the normal distribution of the mean μ and the variance σ^2 .

$$C(d) = [1 + N(C2(d_m)/C1(d_m), (d_o - d_i)/2)] \times C1(d), (d_i \leq d \leq d_o)$$

$$C(d) = C1(d), (d \leq d_i \text{ or } d \geq d_o) \dots\dots\dots(6)$$

[0075] As a result, the center of the traffic jam area having a high prediction reliability is positively avoided on the one hand, while a route passing through an end of the traffic jam area low in prediction reliability may be selected depending

on the traffic situation and the relative positions of the starting place and the destination on the other hand. Specifically, a route can be searched for properly in keeping with the traffic situation.

[0076] In the succeeding step S45, like in the first embodiment, the map display unit 161 sends a command to the display 162 to display the map with a different color of the mesh determined as included in the jam-affected area. At the same time, the display 162 may display a recommended route after a repeated search based on the route information acquired from the route search unit 1420.

[0077] Incidentally, the mesh for which the traffic jam arrival time is calculated may be determined in step S52 shown in Fig. 4 on condition that the representative point of the mesh is located in a predetermined area including the destination and the starting place. This predetermined area may be included in an ellipse with the two focal points at the starting place and the destination. Thus, with regard to the mesh for which the arrival time from the starting place is calculated in step S82 of Fig. 7 and the mesh for which the jam-affected area is determined in step S44 of Fig. 3, a similar process may also be executed in the case where the representative point of the mesh is located in the predetermined area including the destination and the starting place.

[0078] In the case where the process is executed only for the mesh located in the predetermined area including the starting place and the destination as described above, each process is executed subsequently only for the mesh highly liable to be passed through, thereby making possible the process of a high efficiency.

[Third embodiment]

[0079] According to the first and second embodiments, the jam-affected area is calculated without taking the road category into consideration. In the third embodiment, on the other hand, the calculation of the jam-affected area taking the road category into consideration is explained. The difference of the configuration of the third embodiment from those of the first and second embodiments lies in the process executed in the basic map information DB 120, the traffic jam arrival time prediction unit 134, the arrival time prediction unit 135, the prediction information storage unit 136 and the map display unit 161.

[0080] Each of these processes constituting the difference from the first and second embodiments is explained below. First, in the calculation of the jam-affected area for each mesh, the basic map information DB 120 stores therein the in-mesh average speed 212 calculated for each road category.

[0081] In step S172, the various parameters (Fig. 5) for the traffic jam propagation model required for calculation of the traffic jam arrival time are determined for each road category.

[0082] After that, the traffic jam starting time and the traffic jam ending time are calculated for each road category in step S42. Similarly, the vehicle arrival time is calculated for each road category in step S43. The vehicle arrival time, the traffic jam starting time and the traffic jam ending time calculated in steps S42 and S43 are stored in the prediction information storage unit 136. Fig. 14 shows a format of the vehicle arrival time from the starting place, the traffic jam starting time and the traffic jam ending time for each mesh stored in the prediction information storage unit 136 according to this embodiment. In this way, the vehicle arrival time, the traffic jam starting time and the traffic jam ending time are stored for each mesh according to the road category.

[0083] Upon occurrence of an unexpected event, the traffic jam starting time and the traffic jam ending time are calculated on the assumption that the traffic jam propagates along the links of the same road category as that of the link at the original occurrence point. The traffic jam caused by an unexpected event occurring on a toll road, for example, is considered not to propagate to an ordinary road which is located nearer on the map but different in road category. In view of the fact that the area of an unexpected traffic jam caused by an unexpected event occurring on a toll road does not propagate to an ordinary road directly, the manner in which the unexpected traffic jam propagates is indicated by coloring the traffic jam area on the toll road on the map in step S45.

[0084] As an alternative, a traffic jam may be considered to propagate also between different road categories. In such a case, the traffic jam propagation is predicted by regarding that an unexpected event has newly occurred at the connecting point of the roads of different categories. For example, it may be that the traffic jam due to an unexpected event occurring on a toll road propagates to an ordinary road from an interchange. Thus, the traffic jam propagation on an ordinary road is predicted by regarding the interchange as the point of occurrence of a new unexpected event. In such a case, although the unexpected traffic jam is assumed to be caused by an unexpected event that has occurred on a toll road, the manner in which the unexpected traffic jam propagates on the ordinary road is indicated on the map in step S45 in the same way as if the unexpected event has occurred at the interchange.

[0085] In step S44, the jam-affected area calculation unit 140 executed the process to calculate the jam-affected area for each road category by reading, from the prediction information storage unit 136, the arrival time from the starting place, the traffic jam starting time and the traffic jam ending time for each mesh according to the road category. In the example shown in Fig. 14, as far as a toll road is concerned, a mesh having the mesh ID of "12345678" satisfies Equation 1, and therefore, is determined as included in the jam-affected area. With regard to an ordinary road, on the other hand, the data on both the traffic jam starting time and the traffic jam ending time are lacking, and therefore, the ordinary road

is determined as not included in the jam-affected area.

[0086] The map display unit 161A sends a plot command to the display 162 to indicate the jam-affected area in such a manner as to permit the user to grasp the jam-affected area according to the road category. In the case where the links of a toll road and an ordinary road exist in the same mesh and a traffic jam occurs only on the toll road, for example, a plot command is sent to indicate the toll road in a different color and the ordinary road in normal color.

[0087] Features, components and specific details of the structures of the above-described embodiments may be exchanged or combined to form further embodiments optimized for the respective application. As far as those modifications are readily apparent for an expert skilled in the art they shall be disclosed implicitly by the above description without specifying explicitly every possible combination, for the sake of conciseness of the present description.

Claims

1. A traffic jam area prediction method comprising:

a step (S40) of acquiring the traffic information including the information on an unexpected event;
 a traffic jam arrival time prediction step (S42) for predicting at least one of the starting time and the ending time of a traffic jam caused by the unexpected event, for each of meshes constituting rectangular division areas based on the latitude and the longitude;
 a position information acquisition step (S80) for acquiring the starting position and the starting time;
 a step (S43) of predicting the time of arrival from the starting place for each mesh around the starting position based on the starting position and the starting time; and
 a jam-affected area calculation step (S44) for calculating, for each mesh, the area affected by the traffic jam during the time from the occurrence to the end of the traffic jam caused by the unexpected event, using at least one of the traffic jam starting time and the traffic jam ending time and the arrival time from the starting place.

2. The traffic jam area prediction method according to Claim 1, wherein the jam-affected area calculation step calculates the jam-affected area for each road category.

3. The traffic jam area prediction method according to Claim 1 or 2, further comprising a step (S 150) of searching for a route from the starting place to the destination after resetting the link cost different from that of other than the jam-affected area for the link included in the jam-affected area.

4. A traffic jam area prediction apparatus comprising:

a traffic information acquisition unit (131) for acquiring the traffic information including the information on an unexpected event;
 a present position acquisition unit (132) for acquiring the present position of a user's vehicle;
 a traffic jam arrival time prediction unit (134) for predicting, for each mesh providing one of a plurality of rectangular sections as divisions based on latitude and longitude, at least one of the starting time and the ending time of a traffic jam caused by the unexpected event;
 a vehicle arrival time prediction unit (135) for predicting the vehicle arrival time from the present position for each mesh around the present position based on the present position and the present time; and
 a jam-affected area calculation unit (140) for calculating, for each mesh, the area in which the vehicle is affected by the traffic jam caused by the unexpected event, using at least one of the traffic jam starting time and the traffic jam ending time and the vehicle arrival time from the present position.

5. The traffic jam area prediction apparatus according to Claim 4, wherein the jam-affected area calculation unit (140) calculates the jam-affected area for each road category.

6. The traffic jam area prediction apparatus according to Claim 4 or 5, further comprising a route search unit (1420) to search for a route from the present position to the destination after resetting the link cost different from that of other than the jam-affected area for the link included in the jam-affected area.

Fig. 1

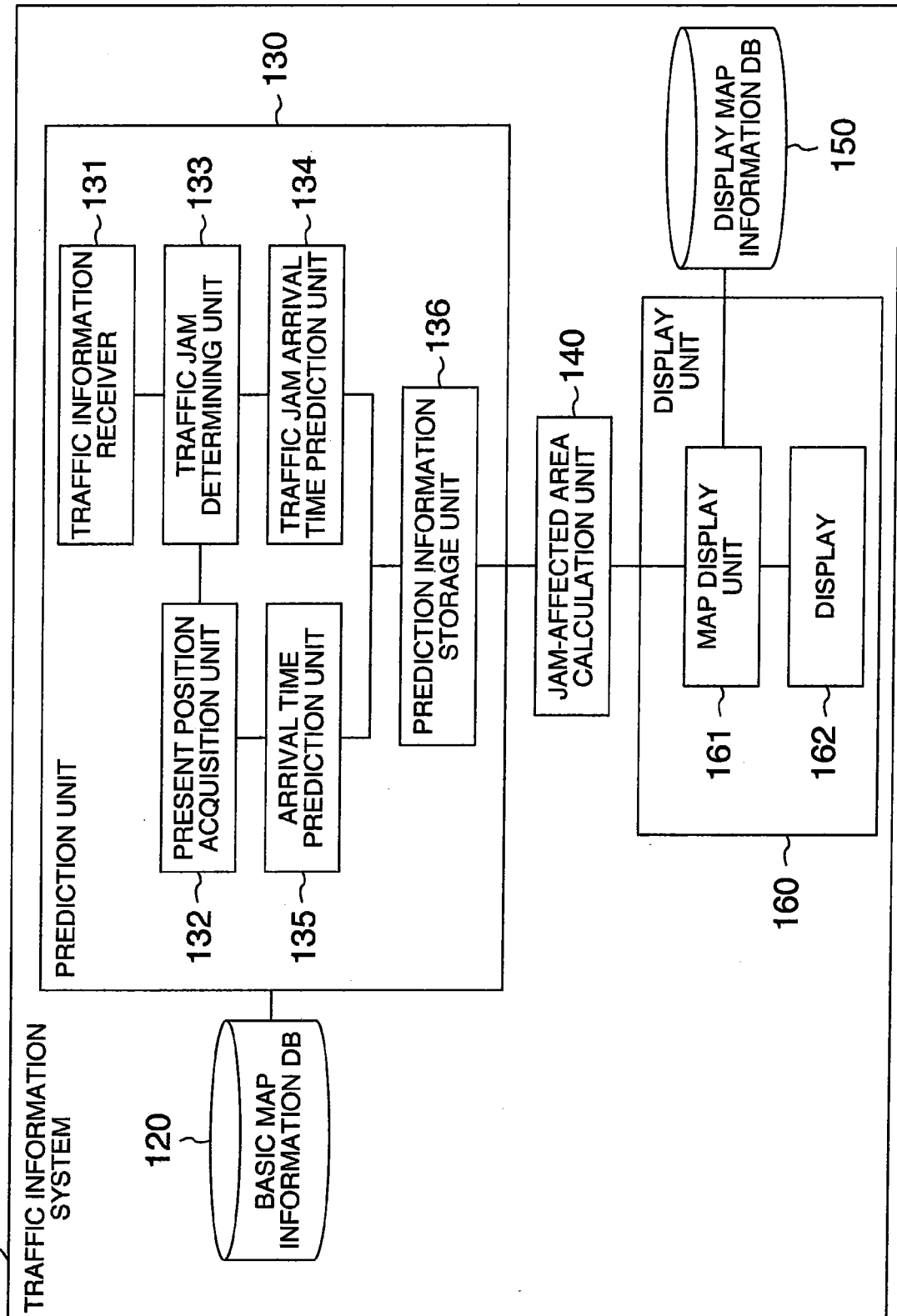


FIG.2

210 MESH DATA	MESH ID	12345678			~ 211
	IN-MESH AVERAGE SPEED	50			~ 212
220 LINK DATA	LINK ID	12345	23456		56789 ~ 221
	ROAD CATEGORY	TOLL ROAD	ORDINARY ROAD		ORDINARY ROAD ~ 222
	LINK LENGTH	6000	1000		2000 ~ 223
	TRAVEL SPEED	90	40		60 ~ 224
	TRAVEL TIME	4	1.5		2 ~ 225

FIG.3

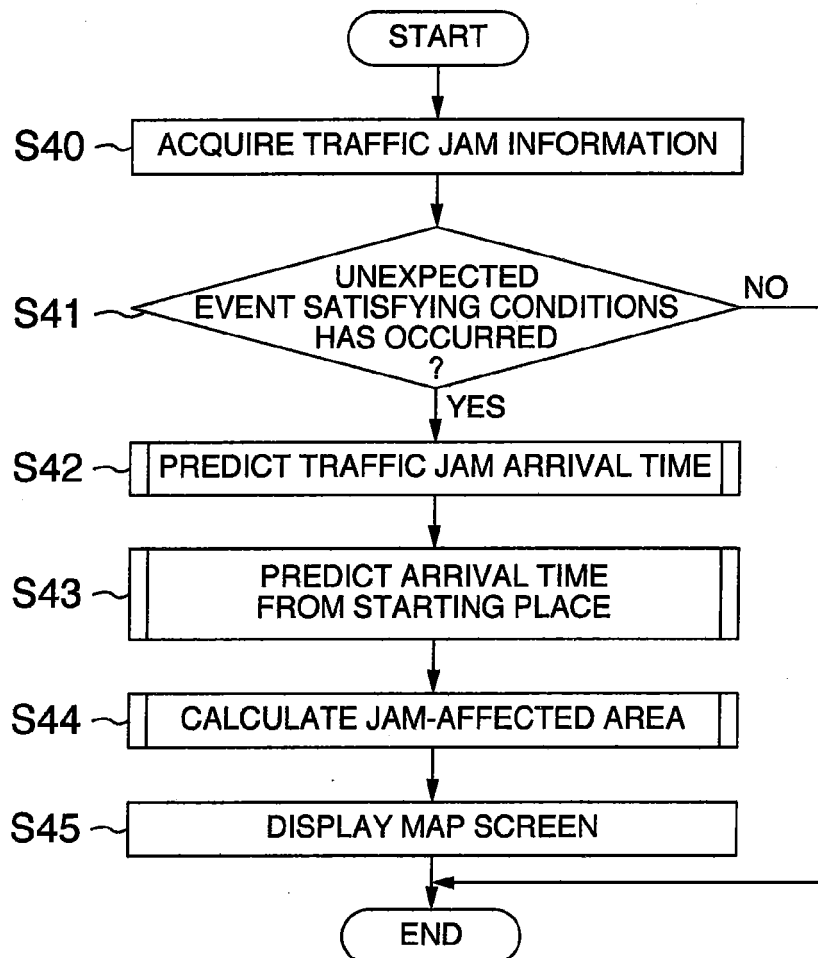


FIG.4

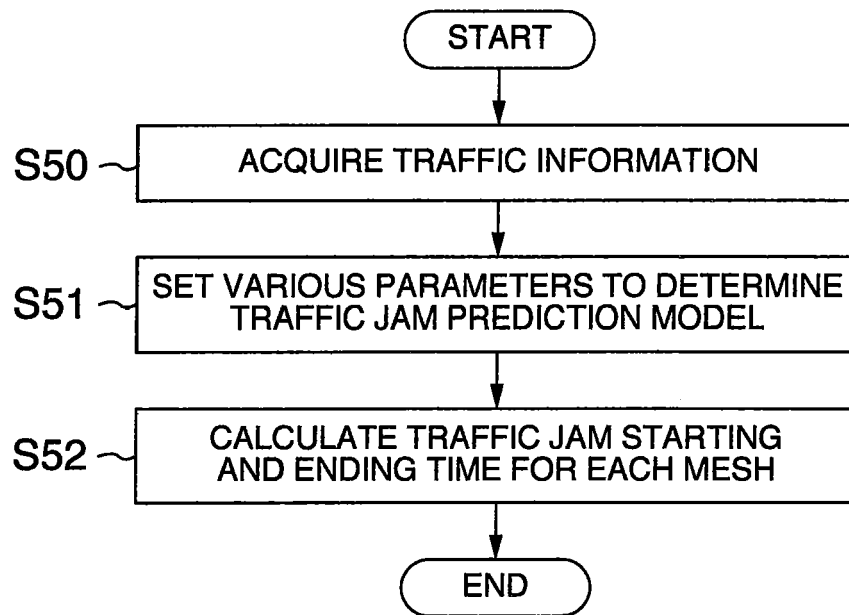


FIG.5

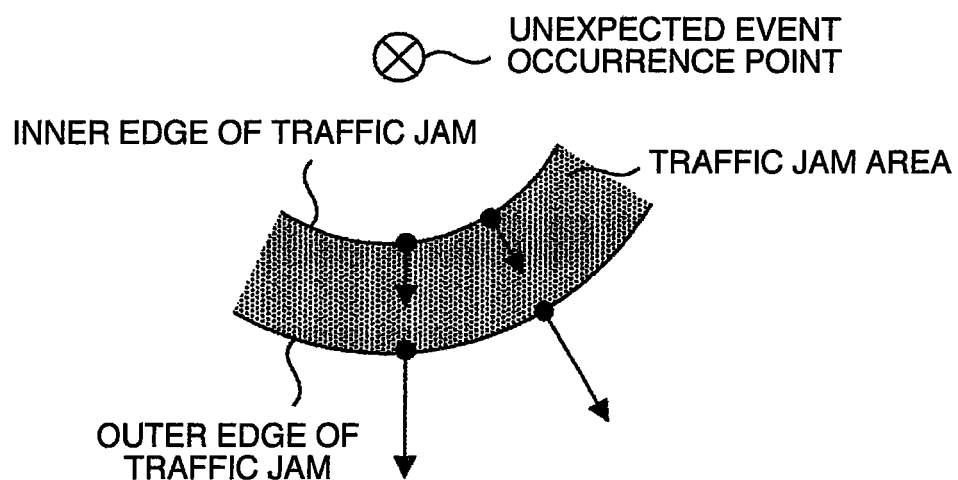


FIG.6

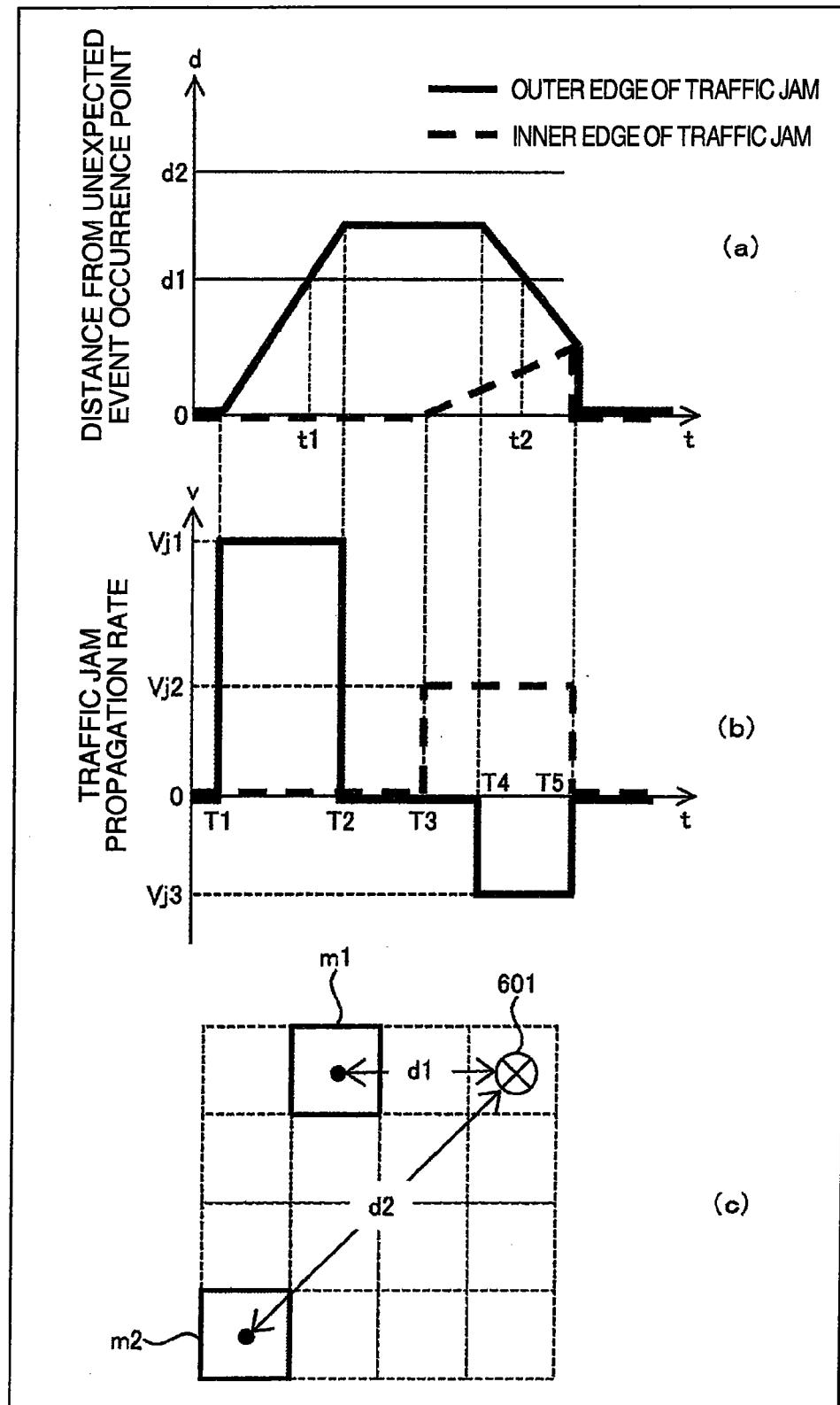


FIG.7

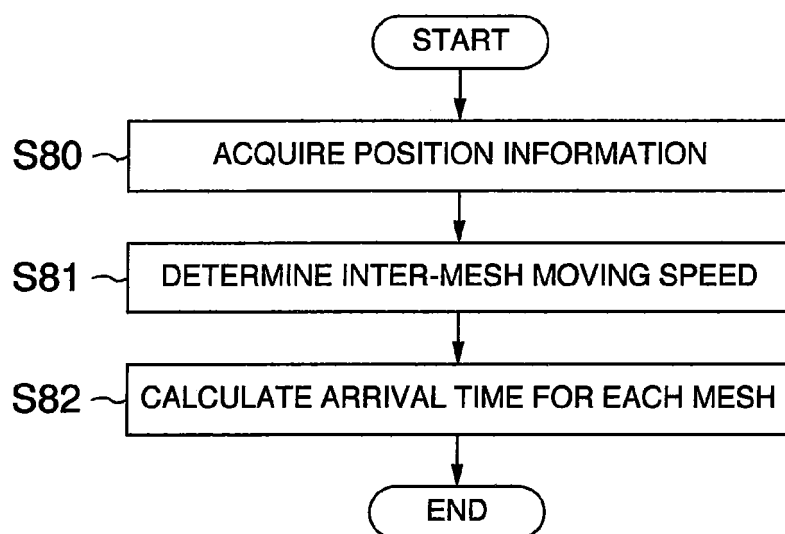


FIG.8

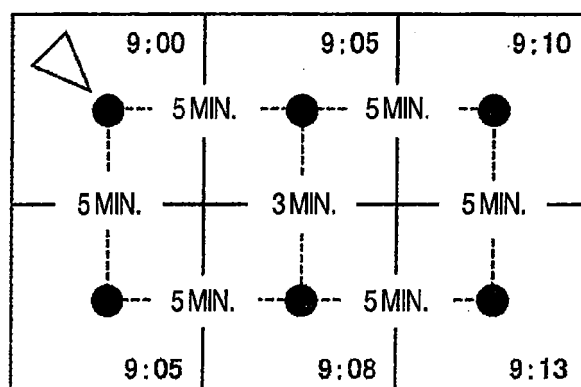


FIG.9

MESH ID	ARRIVAL TIME	TRAFFIC JAM STARTING TIME	TRAFFIC JAM ENDING TIME
12345678	9:00	9:10	9:30
23456789	9:10	9:05	—
34567890	9:20	—	—
45678901	—	9:15	9:40
⋮	⋮	⋮	⋮

FIG.10

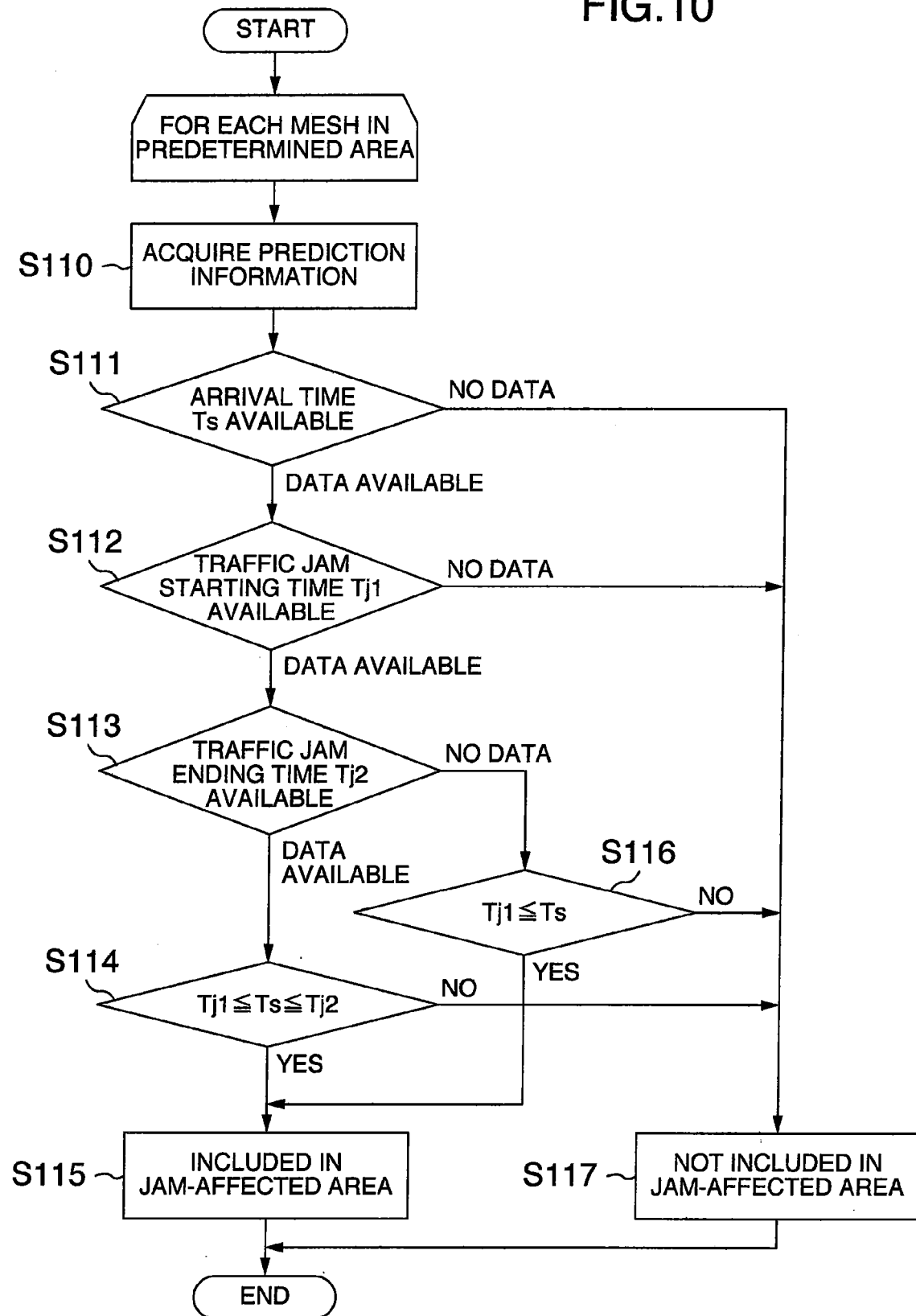


FIG.11A

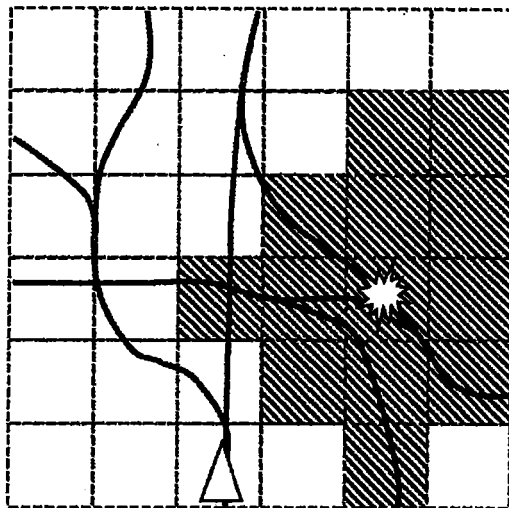


FIG.11B

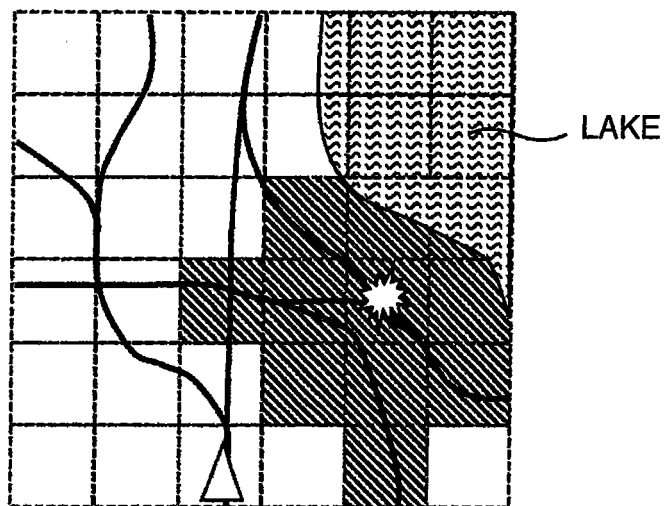


FIG.12

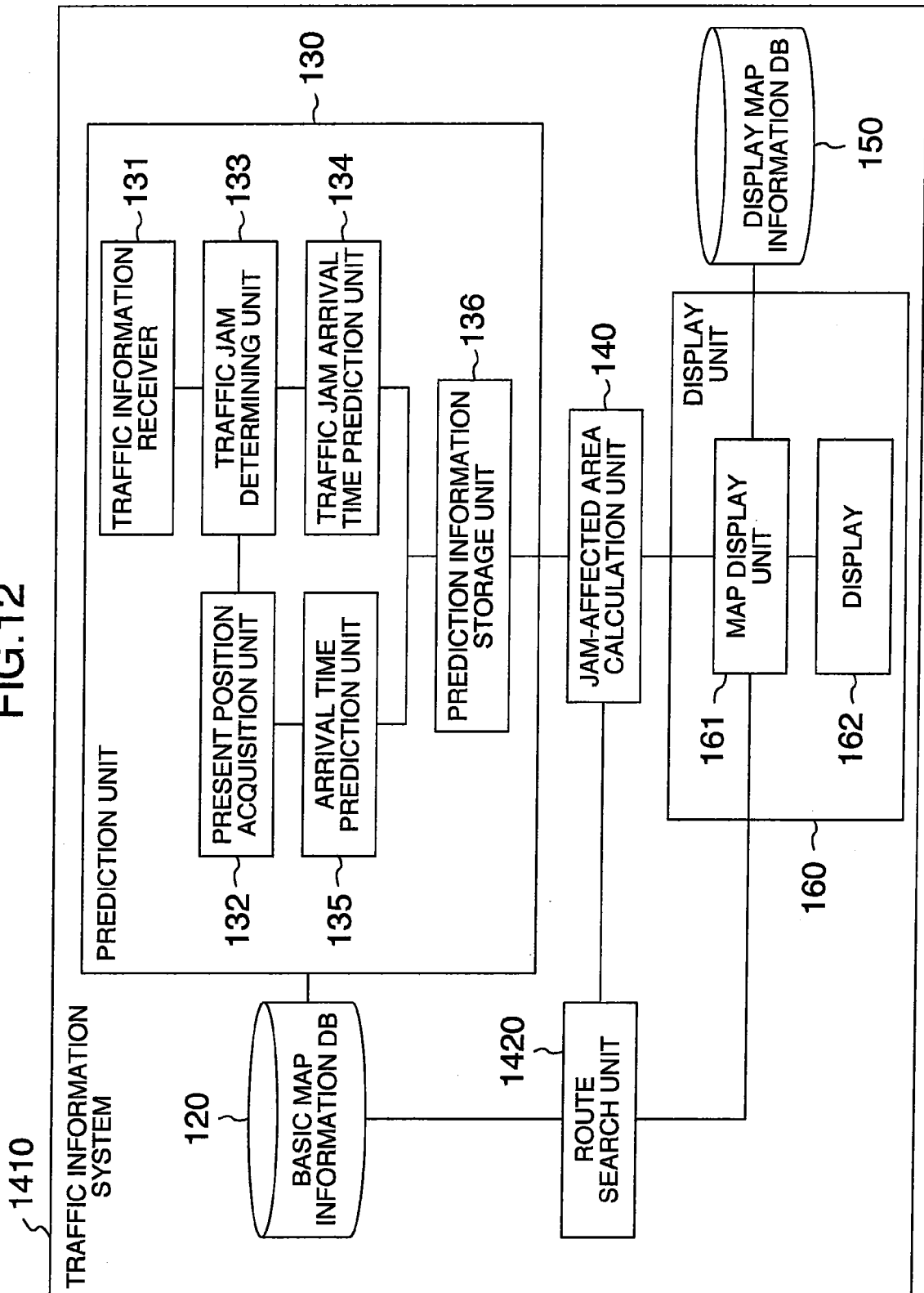


FIG.13

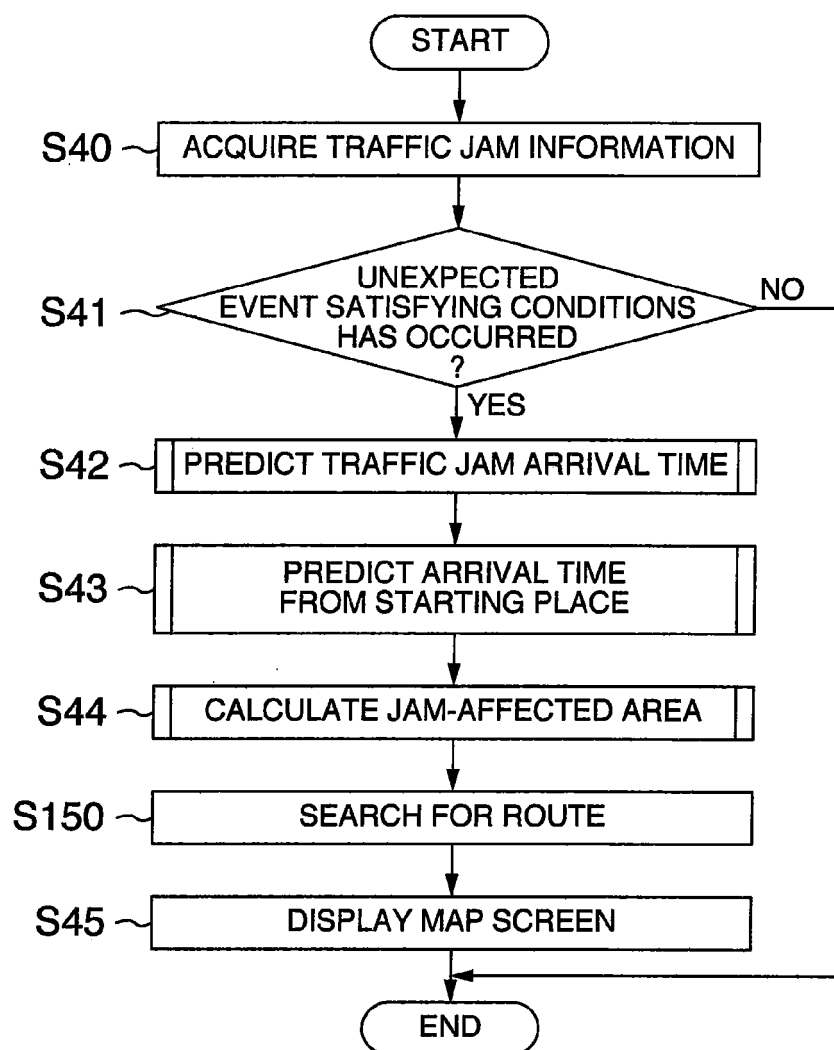


FIG.14

MESH ID	ROAD CATEGORY	ARRIVAL TIME FROM STARTING PLACE	TRAFFIC JAM STARTING TIME	TRAFFIC JAM ENDING TIME
12345678	TOLL ROAD	9:20	9:10	9:30
	ORDINARY ROAD	9:15	—	—
23456789	TOLL ROAD	9:10	9:05	9:30
	ORDINARY ROAD	9:30	9:20	9:30
	⋮	⋮	⋮	⋮

Application Number
EP 10 19 0190

DOCUMENTS CONSIDERED TO BE RELEVANT					
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)		
X	US 2007/013551 A1 (GUEZIEC ANDRE [US] GUEZIEC ANDRE [US] ET AL) 18 January 2007 (2007-01-18) * abstract * * figures 1,13,14 * * page 5, paragraphs 69,71,72,78 * * page 7, paragraph 84 * * page 10, paragraphs 139,146-149 * -----	1-6	INV. G08G1/01		
			TECHNICAL FIELDS SEARCHED (IPC)		
			G08G		
		The present search has been drawn up for all claims			
Place of search Munich		Date of completion of the search 17 February 2011	Examiner Coffa, Andrew		
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			
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		US 2008109153 A1	08-05-2008

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