

METHOD OF BOUNDARY FLOW LIMITING CONTROL OF ROAD NETWORK BASED ON MFD AND QUEUE LENGTH UNDER TELEMATICS

TECHNICAL FIELD

The present invention relates to the technical field of control method, and more specifically, relates to a method of boundary flow limiting control strategy of a road network based on MFD and a queue length under telematics.

BACKGROUND

With the rapid development of social economy, the number of car ownership has increased rapidly. The problem of urban traffic congestion has deteriorated and become one of the bottlenecks of urban development. In order to reduce vehicle delay time and queue length and to alleviate traffic congestion, most large cities adopt advanced traffic control technology and implement intelligent traffic signal control system. However, with the continuous increase of traffic flow, some urban traffic has experienced over-saturated traffic phenomenon, and the effect of the original traffic control system is affected. Recently, Daganzo and Geroliminis studied a large amount of practical traffic data and found that there is a certain objective regularity in the urban traffic network, that is, the connection between the traffic operation state of the road network and the number of moving vehicles. It is called as Macroscopic Fundamental Diagrams (MFD). Multiple scholars also confirmed the generality of the Macroscopic Fundamental Diagrams with a large number of practical data. Some scholars have proposed to use theories related to Macroscopic Fundamental Diagrams to control the traffic in over-saturated traffic areas, thus improving the congestion of the over-saturated traffic areas. For example, Yingying MA proposed using MFD to control the traffic signal for the road network from macroscopic perspective; Yiman DU proposed a dynamic control technology of the total amount of regional traffic based on Macroscopic Fundamental Diagrams; Mehdi et al. studied a control method of feedback gate based on network MFD; Yosh et al. proposed a regional measuring control method based on Macroscopic Fundamental Diagrams for an over-saturated road network, and verified the

effectiveness of the proposed method; and the applicant proposed a simple boundary flow limiting control strategy for a road network based on MFD and verified its effectiveness. With further research, the applicant believes that when flow limiting strategy of surrounding traffic of the road network is implemented, it should avoid the situation that an upstream intersection is congested due to the queuing overflow of the surrounding traffic restriction intersection. However, the key of the problem becomes how to judge whether the boundary section has overflow phenomenon in real time. Recently, various countries vigorously develop the technology of telematics. Telematics is the development direction of intelligent transportation systems. In the context of telematics, information such as vehicle position and speed can be uploaded to a command center in real time through a vehicle terminal and a roadside unit, Reliable means are provided for determining the number of vehicles in the road network and the queue length in real time, and opportunities and conditions are provided for improving traffic signal control.

SUMMARY OF THE INVENTION

An object of the present invention is to overcome the drawbacks of the prior art, and to provide a method of boundary flow limiting control strategy of a road network based on MFD and a queue length under telematics. In the environment of telematics, the present invention determines the number of vehicles in the road network and a maximum queue length of a road section in real time. Based on Macroscopic Fundamental Diagrams and when flow limiting control strategy of surrounding traffic of the road network is implemented, the maximum queue length of the road section of each boundary is determined in real time whether it exceeds a safety queue length of the road section, and an inflow rate of the road network is instantly adjusted and an overflow situation on boundary road sections is avoided.

In order to solve the abovementioned technical problems, the technical solution adopted by the present invention is as follows.

A method of boundary flow limiting control of a road network based on MFD and a queue length under telematics is provided, and specific steps are as follows:

- (a) firstly, obtaining traffic parameters; installing all GPS vehicle equipment to vehicles,

and sending information in real time, such as latitude, longitude and speed;

(b) secondly, delimiting satisfying conditions of the vehicles in a road network area, and determining whether moving vehicles belong to the road network area based on the conditions; leading a line from a latitude and longitude point of the vehicle to be judged towards a certain direction, calculating the number of intersections with the boundary of the road network; if the number is an even number or 0, the point is outside the road network area; if the number is an odd number, the point is inside the road network area; converting the number of vehicles falling within the road network area into an equivalent traffic volume, determining the number N of road network vehicles and a flow rate q_i of each road section (i indicates an i -th road section);

(c) thirdly, calculating a distance of each vehicle on each road section arriving at each entry stop line, and finally obtaining a maximum queue length $q_{Lmax(i)}$; setting a safety queue length of the road section L_{si} to be 95% of a length of the road section L_i , comparing $q_{Lmax(i)}$ with L_{si} to determine whether the vehicles cause a traffic congestion at an upstream intersection or not; if $q_{Lmax(i)} \geq L_{si}$, it will cause that a queue of the vehicle overflows to an upstream of the upstream intersection, resulting in the traffic congestion at the upstream intersection; and

(d) finally, performing the flow limiting control on a boundary traffic; when the road network tends to be congested, carrying out a simple boundary flow limiting control on the road network.

The present invention discloses the method of boundary flow limiting control strategy of the road network based on MFD and the queue length under telematics. In the environment of telematics, the present invention determines the number of the vehicles in the road network and the maximum queue length of the road section in real time. Based on Macroscopic Fundamental Diagrams and when flow limiting control strategy of surrounding traffic of the road network is implemented, the maximum queue length of the road section of each boundary is determined in real time whether it exceeds the safety queue length of the road section, and the inflow rate of the road network is instantly adjusted and the overflow situation on the boundary road sections is avoided.

Preferably, in the step (c), a step to obtain the maximum queue length $q_{L\max(i)}$ is as follows:

(A) firstly, calculating the distance of each vehicle on each road section arriving at each entry stop line, and a calculation formula is as follows:

$$d_{ij} = \sqrt{(AW_{ij} - BW_i)^2 \times 115.789^2 + (AJ_{ij} - BJ_i)^2 \times 86.667^2}$$

wherein d_{ij} is a distance of a j -th vehicle on the i -th road section arriving at the entry stop line of the road section;

AJ_{ij} and AW_{ij} are longitude and latitude of the j -th vehicle on the i -th road section;

BJ_{ij} and BW_{ij} are longitude and latitude of the entry stop line on the i -th road section;

(B) after the step (A), marking a set of distance of the vehicles on each road section arriving at the stop line as D , which is expressed as:

$$D = \{d_{ij} | i \in L, j \in N\}$$

marking a set of instantaneous speed of the vehicles as V , which is expressed as:

$$V = \{v_{ij} | i \in L, j \in N\}$$

wherein v_{ij} is the instantaneous speed of the j -th vehicle on the i -th road section;

(C) after the step (B), defining vehicles with instantaneous speed $v \leq 5\text{km/h}$ as stopped and queuing vehicles, and thus a set of queue length of all stopped and queuing vehicles on the road section is obtained and marked as Q_L , which is expressed as:

$$Q_L = \{d_{ij}, v_{ij} | i \in L, j \in N, \text{ and } v_{ij} \leq 5\}$$

thus the maximum queue length $q_{L\max(i)}$ of the vehicles on the i -th road section is obtained and can be expressed as:

$$q_{L\max(i)} = \max(Q_{Li})$$

thus the maximum queue length $q_{L\max(i)}$ is finally obtained.

Preferably, in the step (d), when the road network tends to be congested, the simple boundary flow limiting control is implemented on the road network, and specific steps utilize

an equation as follows:

$$\begin{cases} q_G(t + \Delta t) + N(t) - O(t) = N_c \\ R_{in} = q_G(t + \Delta t)/I(t) \\ I_i(t + \Delta t) = R_{in} \cdot I_i(t) \end{cases}$$

wherein t is a certain moment (h);

Δt is a time step (h);

q_G is an inflow amount (pcu/h) of a vehicle flow at a controlled boundary of the road network;

I is an inflow amount (pcu/h) of the vehicle flow of the road network at the moment t ,

$I_i(t)$ is an inflow amount (pcu/h) of the vehicle flow of an i -th entry at the moment t ;

$$I(t) = \sum I_i(t)$$

$O(t)$ is an outflow amount (pcu/h) of the road network at a certain moment;

R_{in} is an inflow rate (an inflow ratio of allowable vehicle flow);

according to an inflow amount of allowable vehicle flow $I_i(t + \Delta t)$, re-calculating a best signal cycle of intersections at each boundary after flow limiting with a Webster timing method.

Preferably, specific steps are as follows:

(1) when $N(t) \geq N_c$, the road network enters a congestion status;

(2) when entering the congestion status, a maximum queueing vehicle amount $q_{Lmax(i)}(t)$ of each entry at all boundary intersections at the moment t is calculated; if $q_{Lmax(i)} \geq L_{si}$, surrounding flow limiting strategy is not implemented for this entry of intersection, and according to a practical traffic demand, timing design is carried out with the Webster method; a variable $q_m(t)$ is defined for counting flow limiting value of all boundary intersections which are not suitable for implementing surrounding flow limiting strategy, and the variable $q_m(t)$ can be expressed as:

$$q_m(t) = (1 - R_{in}) \sum_s I_s(t)$$

wherein s represents an entry road section number of a boundary intersection which is not suitable for flow limiting;

if $q_m(t) = 0$, surrounding flow limiting strategy is implemented with an inflow rate R_{in} ; if $q_m(t) > 0$, $q_m(t)$ will be equally transferred to other boundary intersections, and an inflow rate R'_{in} is readjusted.

Preferably, specific steps to obtain R'_{in} are as follows:

$$(1) \text{ firstly, according to } \Delta q_m = \frac{q_m(t)}{n-x} = \frac{(1-R_{in})\sum_s I_s(t)}{n-x}$$

wherein n is the total number of entry road section of boundary intersections in road network;

x is the number of the entry road section of the boundary intersection not suitable for flow limiting in the road network, $n - x$ is the number of entry road section of the boundary intersection suitable for flow limiting in the road network;

Δq_m is an average flow limiting value that should be added by other boundary road section when there is an overflow phenomenon in an individual boundary road section;

(2) secondly, a flow limiting value of entry of the boundary intersection suitable for flow limiting in the road network is obtained:

$$q_{my}(t + \Delta t) = (1 - R_{in})I_y(t) + \Delta q_m$$

wherein, y represents an entry road section number of the boundary intersection suitable for flow limiting;

(3) thirdly, a new inflow amount of each entry of the boundary intersection suitable for flow limiting in the road network is obtained:

$$\begin{aligned} q_{Gy}(t + \Delta t) &= I_y(t) - q_{my}(t + \Delta t) \\ &= I_y(t) - [(1 - R_{in})I_y(t) + \Delta q_m] \\ &= R_{in}I_y(t) - \Delta q_m \end{aligned}$$

thus, the new inflow amount of all entries of the boundary intersections suitable for flow limiting in the road network is obtained:

$$q'_G(t + \Delta t) = \sum_y q_{Gy}$$

$$= R_{in}I(t) - \sum_s I_s(t)$$

an actual inflow amount $I'(t)$ of the boundary intersection suitable for flow limiting has an equation shown as follows:

$$I'(t) = I(t) - \sum_s I_s(t)$$

(4) finally, a new inflow rate R'_{in} after readjusted is obtained:

$$R'_{in} = \frac{q'_G(t+\Delta t)}{I'(t)} = \frac{R_{in}I(t) - \sum_s I_s(t)}{I(t) - \sum_s I_s(t)} = \frac{(1-R_{in})R_{in}I(t) - q_m}{(1-R_{in})I(t) - q_m}.$$

In comparison with the prior art, beneficial effects of the present invention are described in the following.

The present invention discloses a method of boundary flow limiting control strategy of a road network based on MFD and a queue length under telematics. In the environment of telematics, the present invention determines the number of vehicles in the road network and a maximum queue length of a road section in real time. Based on Macroscopic Fundamental Diagrams and when flow limiting control strategy of surrounding traffic of the road network is implemented, the maximum queue length of the road section of each boundary is determined in real time whether it exceeds a safety queue length of the road section, and an inflow rate of the road network is instantly adjusted and an overflow situation on boundary road sections is avoided.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flow diagram of a method of boundary flow limiting control strategy of a road network based on MFD and a queue length under telematics according to an embodiment.

FIG. 2 is a schematic diagram of Sports Center business zone of Tianhe District according to an embodiment.

FIG. 3 is a schematic diagram of simulation model of a road network of Tianhe business zone according to an embodiment.

FIG. 4 is a MFD graph of road network of simulation according to an embodiment.

FIG. 5 is a schematic diagram of average queue length of each intersection of over-saturated road network according to an embodiment.

FIG. 6 is a schematic diagram of average delay time of each intersection of over-saturated road network in the embodiment.

FIG. 7 is a schematic diagram of average number of times of vehicle stopping at each intersection of over-saturated road network.

FIG. 8 is a comparison table of each traffic signal control index of over-saturated road network under three strategies.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will be further described below with reference to the accompanying drawings and specific embodiments. The accompanying drawings are merely used for exemplary illustration and only represents schematic diagram rather than diagram of an actual product, thus it cannot be interpreted as a limit to the present application. In order to better illustrate the embodiment of the present invention, certain components in the accompanying drawings will be omitted, zoomed in or zoomed out, and do not represent the size of the actual product. To those skilled in the art, it can be understood that certain commonly known structure and its explanation in the accompanying drawings can be omitted.

The same or similar reference numbers in the accompanying drawings of the embodiment in the present invention correspond to the same or similar components. In the description of present invention, it needs to be understood that if the position indicated by terms such as “up”, “down”, “left” and “right” is based on the position or location relationship showed in the accompanying drawings. It is merely for describing the present invention and simplifies the description rather than indicating or implying that the referred device or parts must possess certain position and construct and operation with certain position. Therefore, terms describing position relationship in the accompanying drawings are merely used for exemplary description, and cannot be understood as a limit to the present invention. One with ordinary skills in the art can understand the specific meaning of above terms based on specific situation.

Embodiment

The embodiment of a method of boundary flow limiting control strategy of a road network based on MFD and a queue length under telematics is as shown in FIGs. 1 to 8. Specific steps are as follows:

(a) firstly, obtaining traffic parameters; installing all GPS vehicle equipment to vehicles, and sending information in real time, such as latitude, longitude and speed;

(b) secondly, delimiting satisfying conditions of the vehicles in a road network area, and determining whether moving vehicles belong to the road network area based on the conditions; leading a line from a latitude and longitude point of the vehicle to be judged towards a certain direction, calculating the number of intersections with the boundary of the road network; if the number is an even number or 0, the point is outside the road network area; if the number is an odd number, the point is inside the road network area; converting the number of vehicles falling within the road network area into an equivalent traffic volume, determining the number N of road network vehicles and a flow rate q_i of each road section (i indicates an i -th road section);

(c) thirdly, calculating a distance of each vehicle on each road section arriving at each entry stop line, and finally obtaining a maximum queue length $q_{Lmax(i)}$; setting a safety queue length of the road section L_{si} to be 95% of a length of the road section L_i , comparing $q_{Lmax(i)}$ with L_{si} to determine whether the vehicles cause a traffic congestion at an upstream intersection or not; if $q_{Lmax(i)} \geq L_{si}$, it will cause that a queue of the vehicle overflows to an upstream of the upstream intersection, resulting in the traffic congestion at the upstream intersection; and

(d) finally, performing the flow limiting control on a boundary traffic; when the road network tends to be congested, carrying out a simple boundary flow limiting control on the road network.

In particular, in the step (c), a step to obtain the maximum queue length $q_{Lmax(i)}$ is as follows:

(A) firstly, calculating the distance of each vehicle on each road section arriving at each

entry stop line, and a calculation formula is as follows:

$$d_{ij} = \sqrt{(AW_{ij} - BW_i)^2 \times 115.789^2 + (AJ_{ij} - BJ_i)^2 \times 86.667^2}$$

wherein d_{ij} is a distance of a j -th vehicle on the i -th road section arriving at the entry stop line of the road section;

AJ_{ij} and AW_{ij} are longitude and latitude of the j -th vehicle on the i -th road section;

BJ_i and BW_i are longitude and latitude of the entry stop line on the i -th road section;

(B) after the step (A), marking a set of distance of the vehicles on each road section arriving at the stop line as D , which is expressed as:

$$D = \{d_{ij} | i \in L, j \in N\}$$

marking a set of instantaneous speed of the vehicles as V , which is expressed as:

$$V = \{v_{ij} | i \in L, j \in N\}$$

wherein v_{ij} is the instantaneous speed of the j -th vehicle on the i -th road section;

(C) after the step (B), defining vehicles with instantaneous speed $v \leq 5\text{km/h}$ as stopped and queuing vehicles, and thus a set of queue length of all stopped and queuing vehicles on the road section is obtained and marked as Q_L , which is expressed as:

$$Q_L = \{d_{ij}, v_{ij} | i \in L, j \in N, \text{ and } v_{ij} \leq 5\}$$

thus the maximum queue length $q_{L\max(i)}$ of the vehicles on the i -th road section is obtained and can be expressed as:

$$q_{L\max(i)} = \max(Q_{Li})$$

thus the maximum queue length $q_{L\max(i)}$ is finally obtained.

In addition, in the step (d), when the road network tends to be congested, the simple boundary flow limiting control is implemented on the road network, and specific steps utilize an equation as follows:

$$\begin{cases} q_G(t + \Delta t) + N(t) - O(t) = N_e \\ R_{in} = q_G(t + \Delta t) / I(t) \\ I_i(t + \Delta t) = R_{in} \cdot I_i(t) \end{cases}$$

wherein t is a certain moment (h);

Δt is a time step (h);

q_G is an inflow amount (pcu/h) of a vehicle flow at a controlled boundary of the road network;

I is an inflow amount (pcu/h) of the vehicle flow of the road network at the moment t ,

$I_i(t)$ is an inflow amount (pcu/h) of the vehicle flow of an i -th entry at the moment t ;

$$I(t) = \sum I_i(t)$$

$O(t)$ is an outflow amount (pcu/h) of the road network at a certain moment;

R_{in} is an inflow rate (an inflow ratio of allowable vehicle flow);

according to an inflow amount of allowable vehicle flow $I_i(t + \Delta t)$, re-calculating a best signal cycle of intersections at each boundary after flow limiting with a Webster timing method.

In particular, specific steps are as follows:

(1) when $N(t) \geq N_C$, the road network enters a congestion status;

(2) when entering the congestion status, a maximum queueing vehicle amount $q_{Lmax(i)}(t)$ of each entry at all boundary intersections at the moment t is calculated; if $q_{Lmax(i)} \geq L_{si}$, surrounding flow limiting strategy is not implemented for this entry of intersection, and according to a practical traffic demand, timing design is carried out with the Webster method; a variable $q_m(t)$ is defined for counting flow limiting value of all boundary intersections which are not suitable for implementing surrounding flow limiting strategy, and the variable $q_m(t)$ can be expressed as:

$$q_m(t) = (1 - R_{in}) \sum_s I_s(t)$$

wherein s represents an entry road section number of a boundary intersection which is not suitable for flow limiting;

if $q_m(t) = 0$, surrounding flow limiting strategy is implemented with an inflow rate R_{in} ; if $q_m(t) > 0$, $q_m(t)$ will be equally transferred to other boundary intersections, and an inflow rate R'_{in} is readjusted.

In addition, specific steps to obtain R'_{in} are as follows:

(1) firstly, according to $\Delta q_m = \frac{q_m(t)}{n-x} = \frac{(1-R_{in}) \sum_s I_s(t)}{n-x}$

wherein n is the total number of entry road sections of boundary intersections in the road network;

x is the number of the entry road section of the boundary intersection not suitable for flow limiting in the road network, $n - x$ is the number of entry road section of the boundary intersection suitable for flow limiting in the road network;

Δq_m is an average flow limiting value that should be added by other boundary road section when there is an overflow phenomenon in an individual boundary road section;

(2) secondly, a flow limiting value of entry of the boundary intersection suitable for flow limiting in the road network is obtained:

$$q_{my}(t + \Delta t) = (1 - R_{in})I_y(t) + \Delta q_m$$

wherein, y represents an entry road section number of the boundary intersection suitable for flow limiting;

(3) thirdly, a new inflow amount of each entry of the boundary intersection suitable for flow limiting in the road network is obtained:

$$\begin{aligned} q_{Gy}(t + \Delta t) &= I_y(t) - q_{my}(t + \Delta t) \\ &= I_y(t) - [(1 - R_{in})I_y(t) + \Delta q_m] \\ &= R_{in}I_y(t) - \Delta q_m \end{aligned}$$

thus, the new inflow amount of all entries of the boundary intersections suitable for flow limiting in the road network is obtained:

$$\begin{aligned} q'_G(t + \Delta t) &= \sum_y q_{Gy} \\ &= R_{in}I(t) - \sum_s I_s(t) \end{aligned}$$

an actual inflow amount $I'(t)$ of the boundary intersection suitable for flow limiting has an equation shown as follows:

$$I'(t) = I(t) - \sum_s I_s(t)$$

(4) finally, a new inflow rate R'_{in} after readjusted is obtained:

$$R'_{in} = \frac{q'_G(t + \Delta t)}{I'(t)} = \frac{R_{in}I(t) - \sum_s I_s(t)}{I(t) - \sum_s I_s(t)} = \frac{(1 - R_{in})R_{in}I(t) - q_m}{(1 - R_{in})I(t) - q_m}$$

A specific application embodiment is as follows.

The Sports Center business zone of Tianhe District in the embodiment is used as a research subject. As shown in FIG. 2, Tianhe West Road, Tianhe Road and Tianhe East Road are the main passage of this zone.

(1) Determining Macroscopic Fundamental Diagrams of the road network

A traffic simulation model of road network is built within Vissim traffic simulation software. It can effectively simulate the environment of telematics as shown in FIG. 3. In this simulation model of the road network, a traffic flow is simulated by starting from low peak, increasing 100pcu/h every 900s for the driving in traffic amount of each road section of the road network boundaries until the over-saturated status of the peak. The simulation lasts for 27000s, data is collected 1 time every 120s, and a total of 225 times of data collection is performed. Finally, statistics is performed for the number of moving vehicles in the road network (obtained by calculating the density of the road section k_i multiply by the length of road section L_i), an inflow amount of the vehicle flow of boundary intersections, an outflow amount of the vehicle flow and a flow amount of the road section. These data is then processed and the base MFD of this road network is obtained as shown in FIG. 3.

From a fitting curve shown in FIG. 4, a maximum weighting flow of this area q_c^w and the critical number of vehicle N_c are calculated: $q_c^w = 15978pcu/h$, $N_c = 1090pcu$. Clearly, when the number of vehicle $N > 1090pcu$, the road network is in a state of over-saturation and congestion.

(2) Simulation of control strategy of boundary flow limiting

C# language is used to conduct subsequent development on the com programming interface provided by Vissim, and boundary flow limiting control strategy with consideration of road section queue space of boundary is implemented for the road network. In order to

obtain the maximum queue length of the boundary road section, a queue detector is arranged at the safety queue position of the road section. When the road section is simulated to 133 cycles (simulation time is about 15960s), the road network enters a state of congestion. According to the boundary flow limiting control strategy, an initial inflow rate of the road network is 92% and a flow rate of 8% is required to conduct flow limiting. Therefore, in order to simplify the calculation, the green signal duration of driving in direction of the boundary road section is reduced by 8%, and a simulation analysis is re-conducted. After running approximately 156 cycles, due to the limiting queue space of the road section CR, ED and FG, a situation of insufficient queue space occurs. The queue overflows to the upstream intersection, and the overflow rate of road network needs to be readjusted. According to the boundary flow limiting control algorithm with consideration of road section queue space, the recalculated overflow rate is 90 %, and that is, no flow limiting is made to road section CR, ED and FG. Flow limiting with an inflow rate of 90% is implemented to other boundary road section, and simulation analysis is re-conducted.

Analysis is performed to the strategy of not implementing surrounding flow limiting, the simple surrounding flow limiting strategy and the boundary flow limiting control strategy with consideration of queue space. Under the analysis of these three strategies, the simulation data of over-saturated road network (15960~27000s is the over-saturated simulation period), and the traffic signal control index of over-saturated road network is obtained as shown in FIGs. 5-7.

As can be seen from FIG. 8, an average delay time of simple surrounding flow limiting strategy and an algorithm of the present invention are reduced by 12.6% and 17.1% respectively compared to the strategy of not implementing surrounding flow limiting. An average stopping times of simple surrounding flow limiting strategy and the algorithm of the present invention are reduced by 6.7% and 4.2% respectively compared to the strategy of not implementing surrounding flow limiting. An average queue length of simple surrounding flow limiting strategy and the algorithm of the present invention are reduced by 17.7% and 18.6% respectively compared to the strategy of not implementing surrounding flow limiting. Various traffic signal control indexes of simple surrounding flow limiting strategy and the algorithm of the present invention are improved compared to the strategy of not

implementing surrounding flow limiting.

Obviously, the above embodiments are merely examples made for clearly illustrating the present invention rather than limiting the embodiments of the present invention. To one with ordinary skills in the art, other forms of modifications or variants can be made based on the above description. There is no need and also impossible to put forward an exhaustive list of all embodiments. Any modifications, substitutions and improvements made within the spirit and principle of the present invention should all be included in the scope of protection claimed in the present invention.

What is claimed:

1. A method of boundary flow limiting control of a road network based on MFD and queue length under telematics, characterized in that, the method comprises specific steps as follows:

(a) firstly, obtaining traffic parameters; installing all GPS vehicle equipment to vehicles, and sending information in real time, such as latitude, longitude and speed;

(b) secondly, delimiting satisfying conditions of the vehicles in a road network area, and determining whether moving vehicles belong to the road network area based on the conditions; leading a line from a latitude and longitude point of the vehicle to be judged towards a certain direction, calculating the number of intersections with the boundary of the road network; if the number is an even number or 0, the point is outside the road network area; if the number is an odd number, the point is inside the road network area; converting the number of vehicles falling within the road network area into an equivalent traffic volume, determining the number N of road network vehicles and a flow rate q_i of each road section (i indicates an i -th road section);

(c) thirdly, calculating a distance of each vehicle on each road section arriving at each entry stop line, and finally obtaining a maximum queue length $q_{Lmax(i)}$; setting a safety queue length of the road section L_{si} to be 95% of a length of the road section L_i , comparing $q_{Lmax(i)}$ with L_{si} to determine whether the vehicles cause a traffic congestion at an upstream intersection or not; if $q_{Lmax(i)} \geq L_{si}$, it will cause that a queue of the vehicle overflows to an upstream of the upstream intersection, resulting in the traffic congestion at the upstream intersection; and

(d) finally, performing the flow limiting control on a boundary traffic; when the road network tends to be congested, carrying out a simple boundary flow limiting control on the road network

, wherein in the step (c), a step to obtain the maximum queue length $q_{Lmax(i)}$ is as follows:

(A) firstly, calculating the distance of each vehicle on each road section arriving at each entry stop line, and a calculation formula is as follows:

$$d_{ij} = \sqrt{(AW_{ij} - BW_i)^2 \times 115.789^2 + (AJ_{ij} - BJ_i)^2 \times 86.667^2}$$

wherein d_{ij} is a distance of a j -th vehicle on the i -th road section arriving at the entry stop line of the road section;

AJ_{ij} and AW_{ij} are longitude and latitude of the j -th vehicle on the i -th road section;

BJ_{ij} and BW_{ij} are longitude and latitude of the entry stop line on the i -th road section;

(B) after the step (A), marking a set of distance of the vehicles on each road section arriving at the stop line as D , which is expressed as:

$$D = \{d_{ij} | i \in L, j \in N\}$$

marking a set of instantaneous speed of the vehicles as V , which is expressed as:

$$V = \{v_{ij} | i \in L, j \in N\}$$

wherein v_{ij} is the instantaneous speed of the j -th vehicle on the i -th road section;

(C) after the step (B), defining vehicles with instantaneous speed $v \leq 5\text{km/h}$ as stopped and queuing vehicles, and thus a set of queue length of all stopped and queuing vehicles on the road section is obtained and marked as Q_L , which is expressed as:

$$Q_L = \{d_{ij}, v_{ij} | i \in L, j \in N, \text{ and } v_{ij} \leq 5\}$$

thus the maximum queue length $q_{L\max(i)}$ of the vehicles on the i -th road section is obtained and can be expressed as:

$$q_{L\max(i)} = \max(Q_{Li})$$

thus the maximum queue length $q_{L\max(i)}$ is finally obtained

, wherein in the step (d), when the road network tends to be congested, the simple boundary flow limiting control is implemented on the road network, and specific steps utilize an equation as follows:

$$\begin{cases} q_G(t + \Delta t) + N(t) - O(t) = N_c \\ R_{in} = q_G(t + \Delta t)/I(t) \\ I_i(t + \Delta t) = R_{in} \cdot I_i(t) \end{cases}$$

wherein t is a certain moment (h);

Δt is a time step (h);

q_G is an inflow amount (pcu/h) of a vehicle flow at a controlled boundary of the road network;

I is an inflow amount (pcu/h) of the vehicle flow of the road network at the moment t , $I_i(t)$ is an inflow amount (pcu/h) of the vehicle flow of an i -th entry at the moment t ,

$$I(t) = \sum I_i(t);$$

$O(t)$ is an outflow amount (pcu/h) of the road network at a certain moment;

R_{in} is an inflow rate (an inflow ratio of allowable vehicle flow);

according to an inflow amount of allowable vehicle flow $I_i(t + \Delta t)$, re-calculating a best signal cycle of intersections at each boundary after flow limiting with a Webster timing method.,

And wherein the method comprises specific steps as follows:

(1) when $N(t) \geq N_c$, the road network enters a congestion status;

(2) when entering the congestion status, a maximum queueing vehicle amount $q_{Lmax(i)}(t)$ of each entry at all boundary intersections at the moment t is calculated; if $q_{Lmax(i)} \geq L_{si}$, surrounding flow limiting strategy is not implemented for this entry of intersection, and according to a practical traffic demand, timing design is carried out with the Webster method; a variable $q_m(t)$ is defined for counting flow limiting value of all boundary

intersections which are not suitable for implementing surrounding flow limiting strategy, and the variable $q_m(t)$ can be expressed as:

$$q_m(t) = (1 - R_{in}) \sum_s I_s(t)$$

wherein s represents an entry road section number of a boundary intersection which is not suitable for flow limiting;

if $q_m(t) = 0$, surrounding flow limiting strategy is implemented with an inflow rate R_{in} ; if $q_m(t) > 0$, $q_m(t)$ will be equally transferred to other boundary intersections, and an inflow rate R'_{in} is readjusted.

2. The method of boundary flow limiting control of the road network based on MFD and the queue length under telematics according to Claim 1, wherein specific steps to obtain R'_{in} are as follows:

$$(1) \text{ firstly, according to } \Delta q_m = \frac{q_m(t)}{n-x} = \frac{(1-R_{in}) \sum_s I_s(t)}{n-x}$$

wherein n is the total number of entry road sections of boundary intersections in the road network;

x is the number of the entry road section of the boundary intersection not suitable for flow limiting in the road network, $n - x$ is the number of entry road section of the boundary intersection suitable for flow limiting in the road network;

Δq_m is an average flow limiting value that should be added by other boundary road section when there is an overflow phenomenon in an individual boundary road section;

(2) secondly, a flow limiting value of entry of the boundary intersection suitable for flow limiting in the road network is obtained:

$$q_{my}(t + \Delta t) = (1 - R_{in})I_y(t) + \Delta q_m$$

wherein, y represents an entry road section number of the boundary intersection suitable for

flow limiting;

(3) thirdly, a new inflow amount of each entry of the boundary intersection suitable for flow limiting in the road network is obtained:

$$\begin{aligned}
 q_{Gy}(t + \Delta t) &= I_y(t) - q_{my}(t + \Delta t) \\
 &= I_y(t) - [(1 - R_{in})I_y(t) + \Delta q_m] \\
 &= R_{in}I_y(t) - \Delta q_m
 \end{aligned}$$

thus, the new inflow amount of all entries of the boundary intersections suitable for flow limiting in the road network is obtained:

$$\begin{aligned}
 q'_G(t + \Delta t) &= \sum_y q_{Gy} \\
 &= R_{in}I(t) - \sum_s I_s(t)
 \end{aligned}$$

an actual inflow amount $I'(t)$ of the boundary intersection suitable for flow limiting has an equation shown as follows:

$$I'(t) = I(t) - \sum_s I_s(t)$$

(4) finally, a new inflow rate R'_{in} after readjusted is obtained:

$$R'_{in} = \frac{q'_G(t+\Delta t)}{I'(t)} = \frac{R_{in}I(t) - \sum_s I_s(t)}{I(t) - \sum_s I_s(t)} = \frac{(1-R_{in})R_{in}I(t) - q_m}{(1-R_{in})I(t) - q_m}.$$

Abstract

The present invention discloses a method of boundary flow limiting control strategy of a road network based on MFD and a queue length under telematics; firstly, obtaining traffic parameters, installing all GPS vehicle equipment to vehicles, and sending information in real time, such as latitude, longitude and speed; secondly, delimiting satisfying conditions of the vehicles in a road network area, and determining whether moving vehicles belong to the road network area based on the conditions; thirdly, calculating a distance of each vehicle on each road section arriving at each entry stop line, and finally obtaining a maximum queue length to be compared with a safe queue length to determine whether the vehicles cause a traffic congestion at an upstream intersection or not, the safety queue length is set to be 95% of a length of the road section; finally, performing the flow limiting control on a boundary traffic; when the road network tends to be congested, carrying out a simple boundary flow limiting control on the road network, an inflow rate of the road network is instantly adjusted to avoid an overflow situation on boundary road sections.

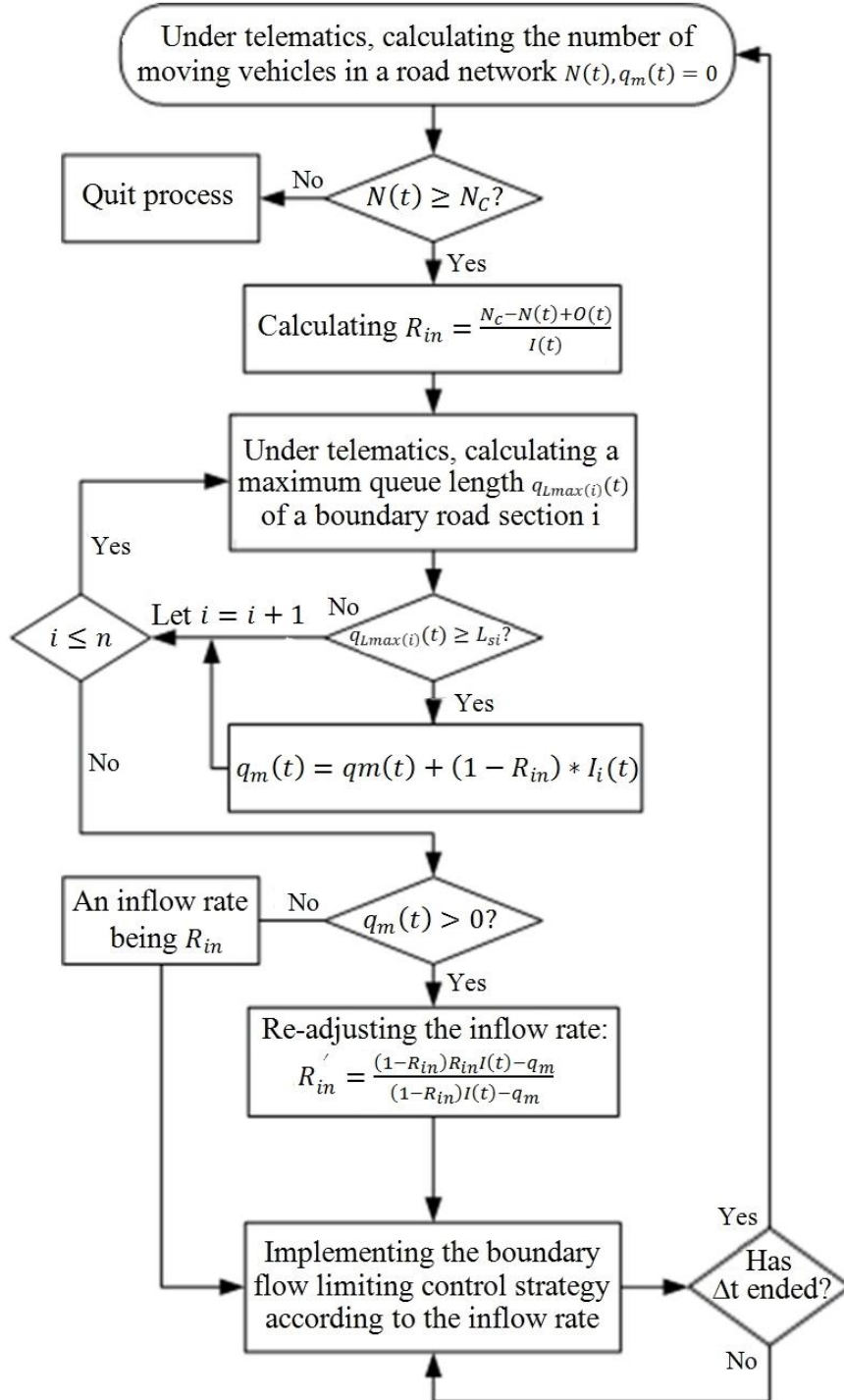
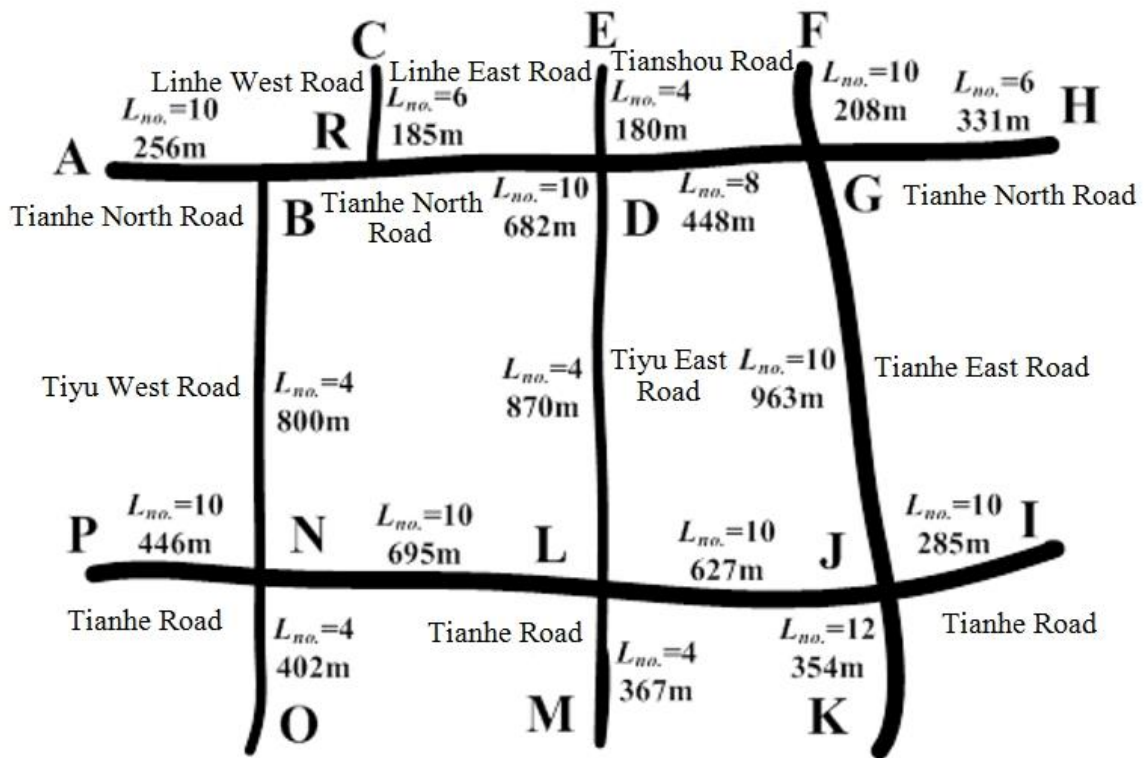


FIG. 1



Note: $L_{no.}$ represents the number of two-way lanes on the road section

FIG. 2

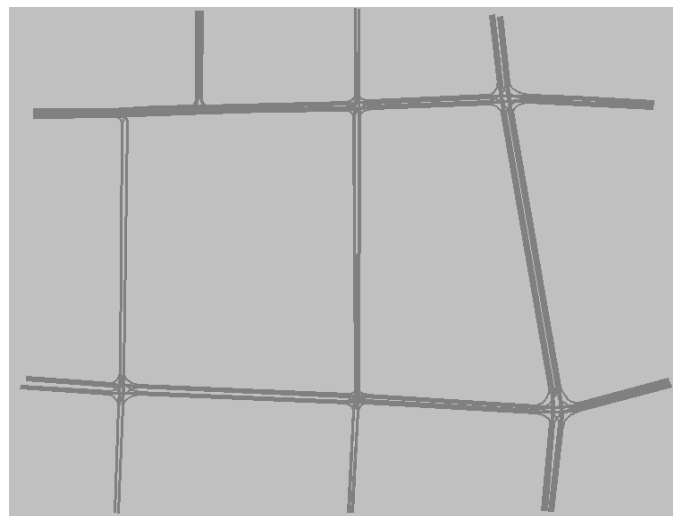


FIG. 3

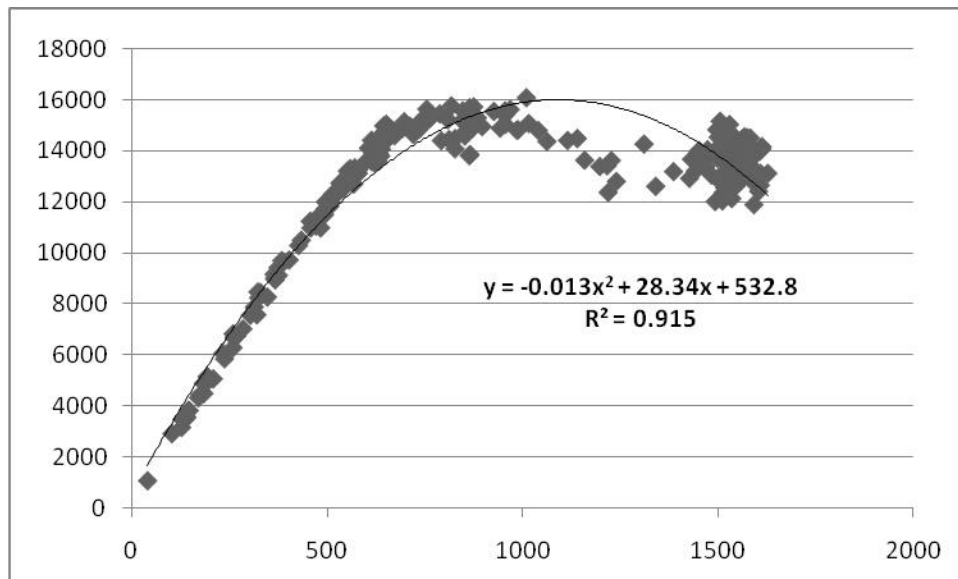


FIG. 4

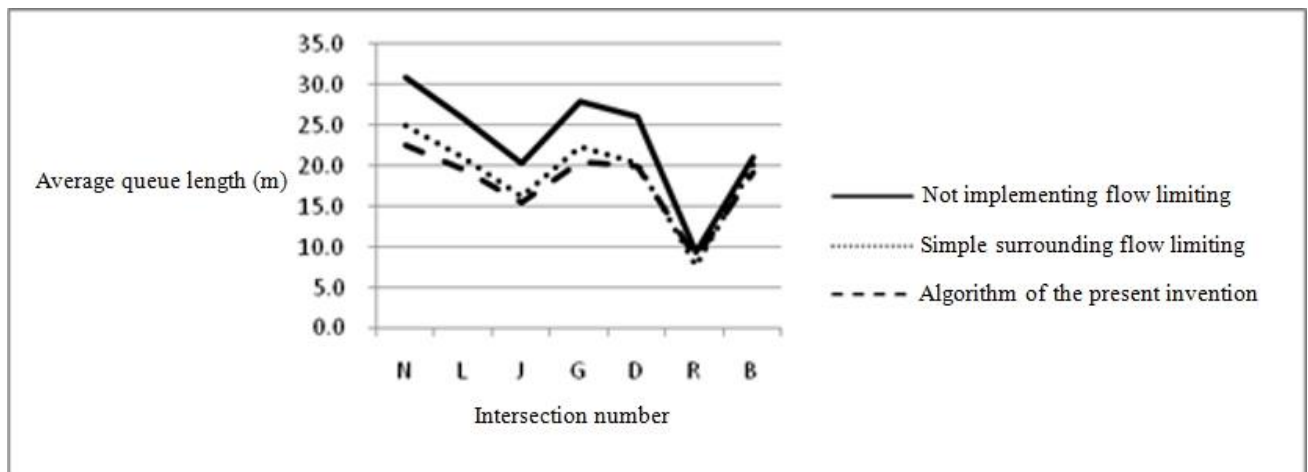


FIG. 5

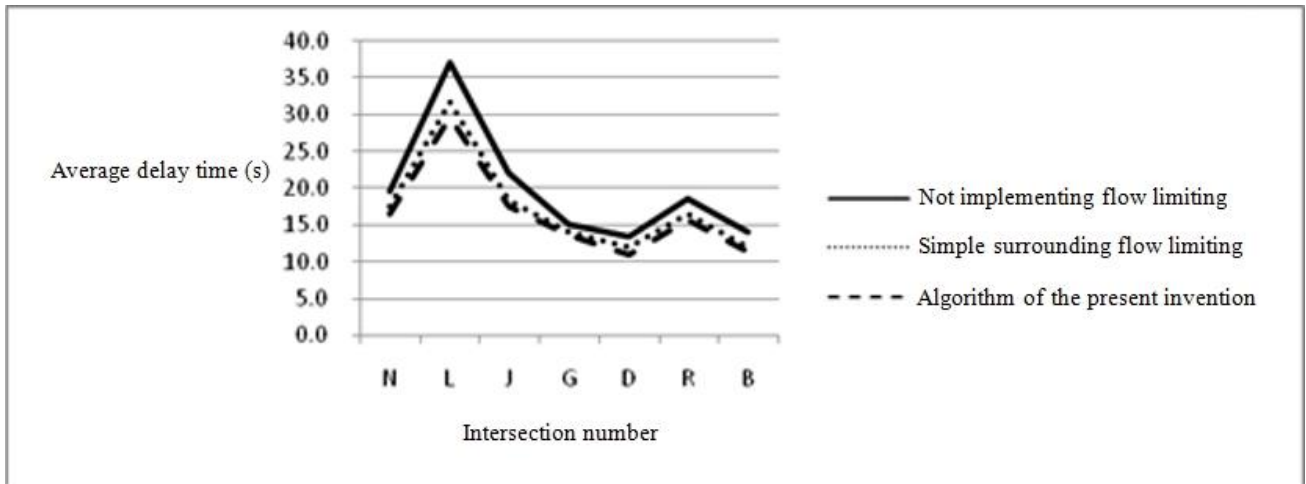


FIG. 6



FIG. 7

	Not implementing flow limiting	Simple surrounding flow limiting	Algorithm of the present invention
Average delay time (s)	19.9	17.4	16.5
Average stopping times (times)	0.45	0.42	0.39
Average queue length (m)	23.1	19.0	18.8

FIG. 8