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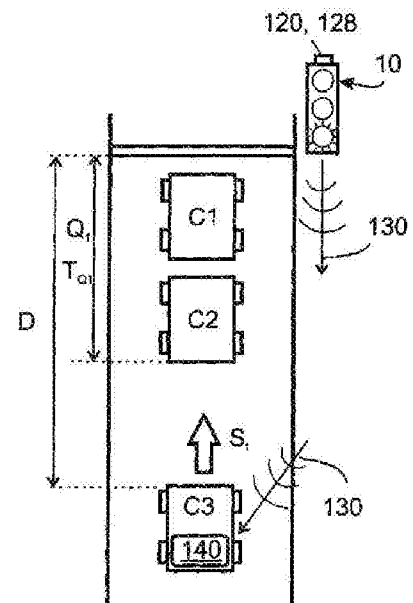
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**METHOD AND SYSTEM FOR ENHANCED TRAFFIC LIGHT SIGNALING AND FOR COMPUTING A TARGET SPEED OF AN AUTOMOTIVE VEHICLE.**

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The invention provides a method and devices for determining a target speed of an automotive vehicle approaching a traffic light. The method uses extended traffic information signalling and allows for the computation of a target speed that allows, for example, the vehicle to pass the traffic light during a green phase and while there is no waiting queue in front of the traffic light. Other targets such as reducing CO2 emissions or overall energy consumption of the vehicle approaching the traffic light may also be taken into account when computing the target speed.



**METHOD AND SYSTEM FOR ENHANCED TRAFFIC LIGHT SIGNALING AND FOR  
COMPUTING A TARGET SPEED OF AN AUTOMOTIVE VEHICLE**

**Technical field**

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The invention generally relates to automotive vehicles and to methods and devices for regulating road traffic. In particular, the invention relates to a method for computing a target speed, at which an automotive vehicle is able to approach a traffic light and pass through it while the traffic light is in a green phase, taking into account the state of the waiting queue in front of the traffic light.

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**Background of the invention**

It is known in the art to use smart traffic management systems, such as Cooperative Intelligent Transport Systems, C-ITS, which are based on local and direct data communication between  
15 entities of the system, such as automotive vehicles and entities implementing the road infrastructure. Accordingly, it has been proposed to exchange information between a traffic light and automotive vehicles approaching the traffic light. The information is generally sent by way of wireless data communication channels such as WiFi™ or Vehicular Ad-Hoc Networks, VANET.

20 An example of such a system is shown in figure 1. A traffic light 10 is equipped with an electronics module 12 configured to generate and transmit data 30 periodically. A vehicle 20 is equipped with receiving means 40 capable of receiving said messages. The vehicle is further capable of interpreting and processing the data comprised in said messages. It is known in the art to transmit Signal Phase and Time, SPaT messages, which provide information about the physical location of  
25 the traffic light, but also information indicating the current phase of the traffic light, i.e., green, orange or red, and information about the timing of upcoming phase changes. Figure 2 illustrates an exemplary known SPaT signal, wherein at time  $t_{g1}$ , a green phase starts. The traffic light changes to orange at time  $t_{o1}$  and further to red at time  $t_{r1}$ , and so on. While the information obtained by the vehicle may be used in several ways, an application of particular interest lies in so-called Green  
30 Light Optimized Speed Advisory, GLOSA, applications. Therein, the information provided by a traffic light is used by an electronics module of the automotive vehicle to compute a speed  $S$ , at which the car should approach the traffic light in order to arrive at the light while it is in a green phase. With reference to figure 2, the corresponding time period at which the vehicle should arrive at the traffic light is indicated by the interval  $[t_{g1}, t_{o1}]$ . The traffic lights along a road traffic axis are  
35 generally linked by a data communication network, allowing for a synchronization among several traffic lights, and allowing a vehicle to obtain information enabling it to pass all the lights along a traffic axis during a green phase. GLOSA systems have been studied in the prior art, see for

example “*Performance study of Green Light Optimized Speed Advisory (GLOSA) application using an integrative cooperative ITS simulation platform*”, Katsaros et al., 2011 IEEE – 978-1-4577-9538-2/11).

5 Patent document WO 2016/055589 suggests to extend the GLOSA framework to include further traffic information that is being sensed by one or more sensing modules on board of an automotive vehicle. The goal is to take into account at least some traffic information that is external to both the vehicle and the traffic light, such as regulatory speed limitations, or the speed of a third-party vehicle driving in front of the vehicle performing the GLOSA computation.

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According to the best knowledge of the inventors, none of the available systems is able to take into account the waiting queues of vehicles forming in front of traffic lights. Even though a known GLOSA computation based on known SPaT signals may be implemented at an automotive vehicle, the vehicle adopting the GLOSA-compliant speed may still find itself stuck in a waiting queue in front of the traffic light, so that the vehicle is unable to pass the traffic light during the targeted green phase.

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#### **Technical problem to be solved**

20 It is an objective of the present invention to provide a method and system which overcomes at least some of the disadvantages of the prior art. The invention aims at providing a method and system that allow to take into account the state of the expected waiting queue in front of a traffic light, when computing a GLOSA-like speed advisory.

#### **25 Summary of the invention**

The invention provides a method for determining a target speed of an automotive vehicle using a speed computing device as the vehicle approaches a traffic light. The method comprises the following steps:

- 30
- providing at the speed computing device an estimate of the distance separating the vehicle and the traffic light, and a signal indicating the traffic light’s phases as a function of time;
  - computing said target speed so that the automotive vehicle driving at the target speed arrives at the traffic light during a green phase thereof.

In accordance with the invention, said signal further comprises information relating to the length of a waiting queue in front of the traffic light, and said target speed is computed as a function of said information.

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Preferably, said information relating to the length of a waiting queue in front of the traffic light may comprise the indication of at least one time period during which the traffic light is in a green phase and the corresponding waiting queue in front of the traffic light is expected to be empty.

- 5 Said information relating to the length of a waiting queue in front of the traffic light may preferably comprise the indication of at least one time instant at which the waiting queue is not empty, together with the corresponding expected queue length.

- 10 Preferably, said information relating to the length of a waiting queue in front of the traffic light may preferably comprise an indication of the distance between the traffic light and the last vehicle in the corresponding waiting queue.

The target speed may preferably be computed so that the automotive vehicle driving at the target speed is able to pass the traffic light without queuing in front of it.

- 15 Preferably, the method may comprise a step of generating said signal using a signal generating device and transmitting the signal using data transmission means to said speed computing device via a data communication channel.

- 20 The data transmission means may preferably comprise a networking interface of the signal generating device.

The data communication channel may preferably comprise a cellular data network or a vehicular ad-hoc network.

- 25 Preferably, the step of generating said signal may comprise:
- obtaining, using sensing means, an estimate of the time required for a waiting queue in front of the traffic light to empty;
  - encoding, using processing means, said estimate into a signal indicating the traffic light's
- 30 phases as a function of time, so that said signal indicates at least one time period during which the traffic light is in a green phase and the waiting queue is expected to be empty.

The step of generating said signal may further preferably comprise:

- 35 - obtaining, using sensing means, a further estimate, said further estimate being of a waiting queue's length, or of a waiting queue's duration being the expected time required for a waiting queue to empty, at at least one time instant wherein said waiting queue is not empty;

- encoding, using processing means, said further estimate of the waiting queue's length/duration into a signal indicating the traffic light's phases as a function of time, so that said signal comprises the indication of at least one time instant at which the corresponding waiting queue is not empty, together with the corresponding expected queue length/duration.

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The signal may preferably be updated or regenerated periodically.

Said waiting queue may preferably comprise a current waiting queue or at least one upcoming waiting queue in front of the traffic light.

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The time required for a queue of automotive vehicles in front of the traffic light to empty may preferably be computed starting from the beginning of an upcoming green phase of the traffic light.

The sensing means may preferably comprise a data processor, a traffic sensor, an image sensor coupled to an image processor, a data receiving device, or a combination of the above.

15

The estimate(s) may preferably be stored in a memory element.

Preferably, said sensing means may estimate the length of a waiting queue in front of the traffic light and compute said estimate(s) on an average draining rate of the queue. The draining rate may be estimated based on observed draining rates of the queue, or it may be a predetermined value stored in a memory element to which the sensing means have read access.

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The sensing means may preferably receive traffic information via a data communication channel, said information being transmitted from at least one traffic information gathering node in a communication network and indicating a waiting queue length/duration or said estimate.

25

Alternatively, the sensing means may preferably receive data from a transmitting device on board of the last automotive vehicle in a waiting queue as it passes the traffic light, said data indicating the time said vehicle spent in the queue, and wherein the sensing means use said waiting time as the estimate of the time required for the next upcoming waiting queue to empty.

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The estimate(s) and/or expected queue lengths/durations may preferably be a function of previously encoded estimates. The function may preferably be a linear function.

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Preferably, said signal may further be received by data reception means of said speed computing device. The data reception means may preferably comprise a networking interface of said speed computing device.

5 According to a preferred embodiment, said distance estimate, representing the distance separating the traffic light from the automotive vehicle, may be received by data reception means of said speed computing device or estimated using distance sensing means of said speed computing device. The distance sensing means may preferably comprise a radar device, or an imaging sensor coupled to an image processor.

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Said speed computing device may preferably be an on-board device of said vehicle. The device may comprise a Global Satellite Positioning, GPS, device. Alternatively, the device may be an electronic module that is part of the vehicles data infrastructure.

15 Alternatively, the speed computing device may comprise a data processor located at a node in a communication network, which is configured to transmitting said target speed to said automotive vehicle.

The signal generating device may preferably be comprised in an electronics module of said traffic  
20 light. Alternatively, the signal generating device may comprise a data processor located at a node in a communication network, which is configured to transmit said signal to said automotive vehicle.

It is a further object of the present invention to provide a speed computing device. The device comprises data reception means configured for receiving, when an automotive vehicle approaches a  
25 traffic light, a signal indicating the phases of said traffic light as a function of time, the signal further indicating at least one time period during which the traffic light is in a green phase and a waiting queue in front of the traffic light is empty. The device further comprises computing means configured for computing a target speed of said automotive vehicle, the target speed being such that the automotive vehicle driving at the target speed arrives at the traffic light during a green phase  
30 thereof, wherein said target speed is computed as a function of an estimate of the distance separating the vehicle and the traffic light, and of said time period.

It is yet another object of the present invention to provide a signal generating device. The signal  
35 generating device comprises signal generating means, the signal generating means being configured to generate a signal indicating a traffic light's phases as a function of time, the signal further comprising information relating to the length of a waiting queue in front of the traffic light.

Said information relating to the length of a waiting queue in front of the traffic light may preferably comprise the indication of at least one time period during which the traffic light is in a green phase and the corresponding waiting queue in front of the traffic light is expected to be empty.

- 5 Preferably, said information relating to the length of a waiting queue in front of the traffic light may comprise the indication of at least one time instant at which the corresponding waiting queue is not empty, together with the corresponding expected queue length.

10 The signal generating device may further preferably comprise data transmission means configured for transmitting said generated signal to a receiving device.

15 Preferably, the signal generating device may further comprise sensing means for obtaining an estimate of the time required for a queue of automotive vehicles in front of said traffic light to empty, and processing means for encoding said estimate into said signal, so that the latter indicates at least one time period during which the traffic light is in a green phase and a waiting queue in front of the traffic light is expected to be empty.

20 The signal generating device may further comprise sensing means for obtaining a further estimate, said further estimate being of a waiting queue length, or of a waiting queue duration being the expected time required for a waiting queue to empty, at at least one time instant wherein said waiting queue is not empty, and processing means for encoding said time instant and the corresponding waiting queue length/duration into said signal, so the latter indicates at least one time instant at which the waiting queue is not empty, together with the corresponding expected waiting queue length/duration.

25 Preferably, said waiting queue comprises a current waiting queue or at least one upcoming waiting queue in front of the traffic light.

30 In accordance with embodiments of the invention, a method and system are provided, which allow to take into account the time expected for a waiting queue in front of a traffic light to become empty, when computing a GLOSA-like speed advisory. By adopting the resulting target speed, an automotive vehicle can approach the traffic light such that when it arrives at the height of the traffic light, the latter is in a green phase and there is no waiting queue. The invention extends the efficiency of GLOSA systems in real-world scenarii. Further, it allows the automotive vehicle to  
35 operate at a higher fuel efficiency, as braking, stopping and restarting actions due to the arrival in a waiting queue in front of a traffic light are avoided. The invention enables smoother traffic flows, improving in particular the overall traffic efficiency around traffic lights. According to further

embodiments of the invention the expected lengths and/or durations of the waiting queue(s) in front of a traffic light are communicated to an automotive vehicle approaching the traffic light. Knowing the lengths and/or durations of the waiting queues, a reduced target speed may be computed so as to arrive at the traffic light in a manner that minimizes or reduces the CO<sub>2</sub> emissions of a thermal engine driven vehicle, or more generally the energy consumption of any vehicle.

### **Brief description of the drawings**

Several embodiments of the present invention are illustrated by way of figures, which do not limit the scope of the invention, wherein:

- figure 1 provides an illustration of a cooperative intelligent transport system known from the prior art;
- figure 2 provide an illustration of the evolution of a SPaT signal in time, as known from the prior art;
- 15 - figure 3 provides a schematic top view of a road with a traffic light in front of which a queue of vehicles as formed, and a third car approaching the traffic light;
- figure 4 provides an illustration of the evolution of an extended SPaT-like signal in time, in accordance with a preferred embodiment of the invention;
- figure 5 provides a schematic illustration of a signal generating device in accordance with a preferred embodiment of the invention;
- 20 - figure 6 provides a schematic illustration of a speed computing device in accordance with a preferred embodiment of the invention.

### **Detailed description of the invention**

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This section describes features of the invention in further detail based on preferred embodiments and on the figures, without limiting the invention to the described embodiments. Unless otherwise stated, features of one described embodiment may be combined with additional features of another described embodiment.

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The relative wording "in front of a traffic light" is to be understood as describing locations from which the light emitted by a traffic light can be seen when looking into the direction of the traffic light. Therefor a queue of waiting automotive vehicles forms "in front" of a traffic light if said traffic light is in a red phase and the vehicles must stop and wait. It is further noted that one traffic light per road lane is assumed. Where there are several lanes and traffic lights on one road, the method according to the invention may be implemented independently for each lane and/or traffic light as adequate.

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Known traffic lights are equipped with electronics and logic modules that enable them to function and to change light phases on a regular predetermined basis or using information obtained using traffic sensors. Such equipment will not be described to any detail, as the present description focusses on features that are relevant to the invention.

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In all embodiments, even if not explicitly mentioned, the length of a waiting queue may be readily exchanged with the duration of the waiting queue, as both measures are deemed equivalent and the skilled person is capable of computing one from the other. Similarly, whenever a duration of a waiting queue, or equivalently the time required for a waiting queue to become empty, is  
10 mentioned, that duration may be readily exchanged with the length of the waiting queue, without departing from the scope of the invention.

Figure 3 offers an illustration of a scenario in which the method in accordance with the invention finds its applications. While the traffic light 10 is in a red phase, automotive vehicles C1, C2 stop at  
15 the light and a queue forms along the road lane whose traffic is regulated by the traffic light 10. Using a signal generating device 120 having data transmission means 128, the traffic light periodically broadcasts a signal 130 indicating its current phase and the timing of forthcoming phase changes. In addition, the signal includes information relating to the length and/or duration of the current waiting queue in front of the traffic light. Optionally, the signal may also comprise  
20 information indicating the length and/or duration of upcoming waiting queues in front of the traffic light. The information relating to the length of the waiting queue in front of the traffic light comprises for example the expected timing of at least one phase during which the traffic light is in a green phase and the queue in front of it is empty. The time period  $T_{Q1}$  corresponding to this additional phase is encoded in the signal 130. The signal 130 may be transmitted in the form of an  
25 analogue signal or preferably in the form of data packets comprising structured data. Knowing the instants  $t_{g1}$ ,  $t_{g2}$ , ... at which green phases of the traffic light start, the signal generating device 120 has to obtain an expected time required for the current queue (and upcoming queues) to become empty. The estimation of the expected time period(s) may be implemented by several mathematical forecast models known as such in the art, without departing from the scope of the present  
30 invention. For example, the last observed draining time for the queue may be used as expected value for all draining times of upcoming waiting queues. Alternatively, a linear extrapolation of several previously measured queue draining times may be used to estimate draining times  $T_{Q1}$ ,  $T_{Q2}$ , ... of upcoming waiting queues. In what follows, the notation  $T_{Q1}$  will denote either a current observation of the queue draining time, or a computed expected queue draining time, which takes  
35 into account, among other data, a current observation of the queue draining time. The use of the notation is clear for each specified embodiment. Estimates of the draining times of upcoming waiting queues, i.e. waiting queues that are expected to form after the next upcoming green phase

of the traffic light,  $T_{Q2}$ , ... are computed similarly based on expected behavior of the traffic flows, and on the observations acquired up until the signal is generated.

5 If the waiting queue is too long to become empty during an upcoming green phase of the traffic light, the signal may comprise only the information indicating the waiting queue's length and/or duration.

10 The information relating to the length of the waiting queue in front of the traffic queue may further comprise indications of the expected length of the waiting queue, at at least one instant in time. The estimation of the queue lengths may be implemented by several mathematical forecast models known in the art, based on current and/or earlier observations of the queue length evolution.

15 To update the signal 130 based on new observations, e.g. newly observed queue draining times, the signal is preferably updated or regenerated periodically. The expected time/times that is/are encoded into signal 130 is/are preferably computed at an electronics module embedded on the traffic light 10, even more preferably being part of the signal generating means 120. Alternatively, the computation may be made at a central computation node in a communication network linked to the signal generating means, or even on board of an automotive vehicle. In the latter cases, the resulting expected draining time is transmitted to the signal generating means using a VANET or  
20 using a cellular data communication channel. The computed values are preferably stored in a memory element.

The signal 130 is preferably transmitted using a SPaT-like protocol by the traffic light. The signal generating means are in that case embedded in an electronics module of the traffic light and  
25 comprise data transmission means for emitting the SPaT-like signal 130.

30 According to a preferred embodiment of the invention, an observation of the current queue draining time  $T_{Q1}$ , or the current length of the queue in front of the traffic light, is obtained by using at least one traffic camera installed at or around the traffic light 10. The traffic camera comprises an image sensor linked to an image data processor for extracting visual information from the sensed image or video data. The image sensor and image data processor provide sensing means for obtaining the queue draining time and/or the queue lengths. By acquiring image data of the queue in front of the traffic light while the traffic light is in a red phase, the length of the current queue  $Q_1$  is obtained. Knowing the length of the queue and assuming a constant draining rate, the queue draining time is  
35 readily obtained. The assumption of a constant average draining rate makes sense as the automotive vehicles start slowly once the light's phase changes from red to green. Alternatively, the draining rate may be modelled according to observed data such as the actual speed of the automotive

vehicles leaving the queue, wherein such data may also be obtained using the image sensor and an appropriately programmed image data processor. Based on previous observations of the queue length, which may be complemented by traffic flow statistics, the expected queue lengths of upcoming waiting queues forming at later times may also be obtained.

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According to a further embodiment of the invention, an observation of the current queue draining time  $T_{Q1}$  or the queue length is obtained by using dedicated traffic sensors that detect the passing of vehicles at the traffic light. Such sensors may for example comprise inductive loops embedded in the road and linked to a data processor.

10

Another alternative for obtaining an observation of the current queue draining time  $T_{Q1}$  or the queue length is provided by way of one or more traffic information gathering nodes located in a communication network to which the signal generating means 120 have read access. The data reception means of the signal generating means 120, through which the queued draining time is obtained, therefore implement sensing means for obtaining the queue draining time and/or queue lengths. Such known traffic information nodes implement services that aggregate publicly available traffic data, and they may be extended to use dedicated processing means to extract measurements of the queue draining times of each traffic lights. The resulting information is then either broadcast to all traffic lights or transmitted to a specific traffic light upon request.

15

According to another implementation of the invention, an observation of the current queue draining time  $T_{Q1}$  is obtained by means of the automotive vehicles waiting in the queue. As a vehicle passes the traffic light, it estimates whether it is the last vehicle of the current queue and sends the time it spent in the queue to a central entity or to the signal generating means 120. The data reception means of the signal generating means 120, through which the queue draining time is obtained, therefore implement sensing means for obtaining the queue draining time. The communication originating at the automotive vehicle may be made using a VANET or a cellular data communication channel. Alternatively, all vehicles passing the traffic light transmit their waiting times, and the central entity or signal generating means detect which vehicle was the last in the queue, for example based on imaging data.

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Figure 4 illustrates an exemplary extended SpaT-like signal 130 in accordance with a preferred embodiment the present invention, wherein at time  $t_{g1}$ , a green phase starts. The traffic light changes to orange at time  $t_{o1}$  and further to red at time  $t_{r1}$ , and so on. In addition, the signal provides an indication of the time  $t_{q1}$  at which the queue in front of the traffic light is expected to be empty. The interval  $[t_{g1}, t_{q1}]$  equates to the expected draining time  $T_{Q1}$  of the queue of vehicles waiting at the traffic light at time  $t_{g1}$ . If a vehicle should arrive at the traffic light during a green phase at

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which the queue is empty, it should therefore arrive during the interval  $T_1=[t_{q1}, t_{o1}]$ . The signal is similarly extended with estimates of the lengths/durations of upcoming waiting queues in front of the traffic lights, which may be greater or equal to zero..

5 With reference to figure 2, a third automotive vehicle C3 approaches the traffic light 10 having queue  $Q_1$  and expected queue draining time  $T_{Q1}$ . A speed computing device 140 obtains an estimate  $D$  of the distance separating the vehicle and the traffic light, and said signal 130 indicating the traffic light's phases  $a$  as a function of time, as well as, for example, the time period  $T_1$  during which the queue is expected to have cleared while the phase of the traffic light is green. Using these data,  
10 the speed computing device computes a target speed  $S_t$ . If the vehicle adopts speed  $S_t$  while approaching the traffic light 10, it will be expected to arrive during period  $T_1$ , thereby being able to pass the light without stopping and without queuing up. The device may also compute the target speed  $S_t$  using a later time period, for example  $T_2$ , if the automotive vehicle C3 would not be able to reach the traffic light within period  $T_1$ . Alternatively, or in conjunction therewith, the knowledge  
15 of expected upcoming queue lengths may be used by the speed computing device to compute a reduced target speed, so as to arrive at the traffic light at a time when the queue is expected to be within a predetermined limit, thereby reducing CO<sub>2</sub> emissions of a thermal engine driven vehicle, or more generally the energy consumption of any vehicle.

20 The resulting target speed is either communicated to the driver of the vehicle using audio or visual display means, or it may be fed to an onboard computing device of the vehicle, that is in charge of regulating the car's speed autonomously. The speed computing device 140 is shown as being onboard of vehicle C2, it may for example be a GPS device, a smartphone or an electronics module that is part of the vehicle's data infrastructure. Alternatively, the speed computing means may be  
25 implemented at a central computing node in a communication network, which has access to data  $D$  and signal 130, and which communicates with the vehicle using a VANET or using a cellular data communication channel.

The distance  $D$  is preferably sensed at the vehicle C3 by appropriate distance sensing means, such  
30 as an onboard radar, for example. Alternatively, the distance may be provided by traffic sensors linked to a central computing entity or by the traffic light having appropriated sensing means. In the latter cases, the distance information  $D$  is transmitted to the vehicle C3 using a VANET or using a cellular data communication channel.

35 While numerous techniques may be used for computing the target speed  $S_t$ , we provide here one preferred example, which is both simple and flexible, without limiting the scope of the invention thereto.

Define:

- $D$ , the distance between the considered vehicle and the traffic light,
- $t_{q1}$  and  $t_{o1}$  for the beginning and end of the first time slot that can be reached by the car (i.e. via driving at the max authorized speed),
- 5 -  $\lambda \in [0,1]$  an aggressiveness parameter, which can be set by the user and/or by the computation entity (e.g. via leveraging some information on the expected accuracy of  $t_{q1}$ ,  $t_{o1}$ ),
- $S_t$  the recommended target speed that a vehicle should drive at, to arrive at the traffic light when it is green and passing,
- 10 -  $S_{max}$  the maximum speed at which the vehicle can drive,

The recommended target speed for a vehicle to reach a traffic light when that light is green and passing (i.e. there are no more cars waiting or going through it) may be one of the three following choices:

- 15 a) Aggressive choice (Seeks to arrive right at the beginning of the passing time slot  $T_1=[t_{q1},t_{o1}]$ ; the duration of  $T_1$  equals  $t_{o1}-t_{q1}$ ):

$$S_t = S_{ta} = \min\left(\frac{D}{t_{q1}}, S_{max}\right)$$

- b) Robust choice (Seeks to arrive right in the middle of the passing time slot  $T_1=[t_{q1},t_{o1}]$ , so as to be more robust with respect to the uncertainties of the passing time slot estimation):

20 
$$S_t = S_{tr} = \min\left(\frac{D}{(t_{o1} - t_{q1})/2}, S_{max}\right)$$

- c) Weighted aggressiveness choice (weighted trade-off between the two choice above of aggressiveness and robustness):

$$S_t = \lambda S_{ta} + (1 - \lambda) S_{tr}$$

- 25 Note also that this computation may be improved so that the recommended speed tries to make the vehicle go through several successive traffic lights. We will not go through the details of that type of scenarii, for which solutions of the literature can be used (cf. for instance M. Seredynski, W. Mazurzyk, D. Khadraoui, "Dynamic Multi-Segment Green Light Optimal Speed Advisory", 27th IDPSW, IEEE, pp. 469-465, ISBN: 978-0-7695-4979-8, Cambridge, MA, USA, May 20-24, 2013).

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If the waiting queue in front of the upcoming traffic light is too long to empty completely during the next upcoming green phase of the traffic light, the target speed may optionally be set to a low value, for which the automotive vehicle adopting the target speed is known to perform efficiently.

Figure 5 provides a schematic illustration of the main building blocks of a signal generating device 120 in accordance with a preferred embodiment of the invention, which is preferably embedded with a traffic light. The device comprises sensing means for obtaining an estimate of the time  $T_{Q1}$  required for the current queue in front of the traffic light to empty, once the light changes to green. The sensing means include for example an imaging sensor, an image processor and a data processor for computing said estimate based on past and current queue observations. Using processing means 122, the information  $T_{Q1}$  is stored in a memory element 126 for later use and encoded into a signal 130 indicating the traffic light's phases as a function of time and indicating at least one period  $T_1$  during which the traffic light is in a green phase and the waiting queue is expected to be empty. Alternatively, or complementary to embedding the information  $T_1$  into the signal, expected queue lengths may also be encoded into the signal 130.

Figure 6 provides a schematic illustration of the main building blocks of a speed computing device 140 in accordance with a preferred embodiment of the invention, which is preferably provided on board of an automotive vehicle. The device comprises data reception means 144 configured for the reception of the signal 130 as transmitted by the signal generating device 130. The data reception means 144 may comprise a networking interface and data processing means configured to extract the time and phase information included in said signal, so that it may be used by processing means 142. The device further comprises distance sensing means 146 for obtaining an estimate of the distance  $D$  separating the vehicle from the traffic light it approaches. The processing means 144 include a processor configured to compute the target speed  $S_t$  of the vehicle as a function of the time interval  $T_1$  comprised in the received signal 130. If the signal 130 comprises information on the evolution of the length of the waiting queue, that information may also be taken into account while computing the target speed  $S_t$  of the vehicle. Using output means 138, the resulting speed information is provided either to a display unit, a speech generating unit, or to an electronics module of the vehicle.

The algorithms outlined here above, for example for the computation of the expected queue draining times or for the computation of the target speed, are implemented using processing means that are by appropriately programmed, or by specific analogue circuitry, as it is known in the art. The skilled person is capable of providing such programming code means or circuitry providing the required functionality based on the description that has been given.

It should be understood that the detailed description of specific preferred embodiments is given by way of illustration only, since various changes and modifications within the scope of the invention will be apparent to the skilled person. The scope of protection is defined by the following set of claims.

**Revendications**

1. Procédé de détermination d'une vitesse cible ( $S_t$ ) d'un véhicule automobile en utilisant un dispositif de calcul de vitesse (140) lorsque le véhicule s'approche d'un feu de circulation, le procédé comprenant les étapes suivantes:
- 5
- fournir au dispositif de calcul de vitesse (140) une estimation (D) de la distance séparant le véhicule et le feu de circulation, et un signal (130) indiquant les phases du feu en fonction du temps;
  - calculer ladite vitesse cible ( $S_t$ ) de sorte que le véhicule automobile qui arrive à la
- 10
- vitesse cible arrive au feu de circulation pendant une phase verte de celui-ci; caractérisé en ce que ledit signal (130) comprend en outre des informations relatives à la longueur d'une file d'attente devant le feu de circulation, et en ce que ladite vitesse cible ( $S_t$ ) est calculée en fonction de ladite information.
- 15
2. Procédé selon la revendication 1, caractérisé en ce que lesdites informations relatives à la longueur d'une file d'attente devant le feu de circulation comprennent l'indication d'au moins une période de temps ( $T_1$ ,  $T_2$ ) pendant laquelle le feu est en phase verte et la file d'attente correspondante devant le feu de circulation devrait être vide.
- 20
3. Procédé selon l'une quelconque des revendications 1 ou 2, dans lequel lesdites informations relatives à la longueur d'une file d'attente devant le feu de circulation comprennent l'indication d'au moins un instant de temps auquel la file d'attente correspondante n'est pas vide, ainsi que la longueur de file d'attente attendue correspondante.
- 25
4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel lesdites informations relatives à la longueur d'une file d'attente devant le feu de circulation comprennent une indication de la distance entre le feu de circulation et le dernier véhicule dans la file d'attente correspondante.
- 30
5. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel le procédé comprend en outre l'étape consistant à générer ledit signal (130) en utilisant un dispositif de génération de signal (120) et à transmettre le signal en utilisant des moyens de transmission de données (128) audit dispositif de calcul de vitesse (140) par l'intermédiaire d'un canal de communication de données.
- 35
6. Procédé selon la revendication 5, dans lequel l'étape de génération dudit signal (130) comprend:

- obtenir, à l'aide d'un moyen de détection (124), une estimation ( $T_{Q1}$ ,  $T_{Q2}$ ) du temps nécessaire pour vider une file d'attente devant le feu de signalisation;
  - encoder, en utilisant des moyens de traitement (122), ladite estimation ( $T_{Q1}$ ,  $T_{Q2}$ ) en un signal (130) indiquant les phases du feu en fonction du temps, de sorte que ledit signal (130) indique au moins une période de temps ( $T_1$ ,  $T_2$ ), pendant laquelle le feu est en phase verte et la file d'attente devrait être vide.
- 5
7. Procédé selon la revendication 6, dans lequel l'étape de génération dudit signal (130) comprend en outre:
- l'obtention, à l'aide d'un moyen de détection (124), d'une autre estimation, de la longueur d'une file d'attente, ou de la durée d'une file d'attente, cette dernière étant le temps estimé pour vider une file d'attente, à un instant où ladite file d'attente n'est pas vide;
  - encoder, en utilisant des moyens de traitement (122), ladite estimation supplémentaire de la longueur/durée de la file d'attente en un signal (130) indiquant les phases du feu en fonction du temps, de sorte que ledit signal (130) comprend l'indication d'au moins un instant auquel la file d'attente correspondante n'est pas vide, ainsi que la longueur/durée attendue correspondante de la file d'attente.
- 10
- 15
- 20
8. Procédé selon l'une quelconque des revendications 1 à 7, dans lequel ladite file d'attente comprend une file d'attente en cours ou au moins une file d'attente à venir devant le feu de circulation.
- 25
9. Procédé selon l'une quelconque des revendications 6 à 8, dans lequel ladite estimation ( $T_{Q1}$ ,  $T_{Q2}$ , ...) et/ou les longueurs/durées de file d'attente attendues sont stockées dans un élément de mémoire (126).
- 30
10. Procédé selon l'une quelconque des revendications 6 à 9, dans lequel lesdits moyens de détection (124) estiment la longueur d'une file d'attente devant le feu et calculent ladite estimation ( $T_{Q1}$ ,  $T_{Q2}$ ) sur la base d'un taux de drainage moyen de la file d'attente.
- 35
11. Procédé selon l'une quelconque des revendications 6 à 9, dans lequel lesdits moyens de détection (124) reçoivent des informations de trafic via un canal de communication de données, lesdites informations étant transmises depuis au moins un nœud de collecte d'informations de trafic dans un réseau de communication et indiquant une longueur/durée de file d'attente, ou ladite estimation ( $T_{Q1}$ ,  $T_{Q2}$ ).

12. Procédé selon l'une quelconque des revendications 6 à 9, dans lequel lesdits moyens de détection (124) reçoivent des données d'un dispositif de transmission à bord du dernier véhicule automobile dans une file d'attente au passage du feu, lesdites données indiquant le temps que ledit véhicule a passé dans la file d'attente, et dans lequel les moyens de détection (124) utilisent ledit temps d'attente en tant qu'estimation ( $T_{Q1}$ ) du temps nécessaire pour que la prochaine file d'attente se vide.
13. Procédé selon l'une quelconque des revendications 6 à 12, dans lequel l'estimation ( $T_{Q1}$ ,  $T_{Q2}$ ) et/ou les longueurs/durées attendues de file d'attente sont une fonction d'estimations précédemment encodées.
14. Procédé selon l'une quelconque des revendications 1 à 13, dans lequel ledit signal (130) est reçu par des moyens de réception de données (144) dudit dispositif de calcul de vitesse (140).
15. Procédé selon l'une quelconque des revendications 1 à 14, dans lequel ladite estimation de distance (D) est reçue par des moyens de réception de données (144) dudit dispositif de calcul de vitesse (140) ou estimée en utilisant des moyens de détection de distance dudit dispositif de calcul de vitesse.
16. Procédé selon l'une quelconque des revendications 1 à 15, dans lequel ledit dispositif de calcul de vitesse (140) est un dispositif embarqué dudit véhicule.
17. Procédé selon l'une quelconque des revendications 5 à 16, dans lequel ledit dispositif de génération de signal (120) est compris dans un module électronique dudit feu de circulation.
18. Dispositif de calcul de vitesse (140), le dispositif comprenant des moyens de réception de données (144) configurés pour recevoir, lorsqu'un véhicule automobile s'approche d'un feu de circulation, un signal (130) indiquant les phases dudit feu de circulation en fonction du temps, le signal indiquant en outre au moins une période de temps ( $T_1$ ,  $T_2$ ) pendant laquelle le feu de circulation est en phase verte et une file d'attente devant le feu de circulation est vide, le dispositif comprenant en outre des moyens de calcul (142) configurés pour calculer une vitesse cible ( $S_t$ ) dudit véhicule automobile, la vitesse cible étant telle que le véhicule automobile qui conduit à la vitesse cible arrive au feu de circulation pendant une phase verte de celui-ci, dans lequel ladite vitesse cible ( $S_t$ ) est calculée en fonction d'une

estimation de la distance (D) séparant le véhicule et le feu de circulation, et de ladite période de temps ( $T_1$ ,  $T_2$ ).

19. Dispositif de génération de signal (120) comprenant un moyen de génération de signal (122), le moyen de génération de signal étant configuré pour générer un signal (130) indiquant les phases d'un feu en fonction du temps, le signal comprenant en outre des informations relatives à la longueur d'une file d'attente devant le feu de signalisation.  
5
20. Dispositif (120) selon la revendication 19, dans lequel lesdites informations relatives à la longueur d'une file d'attente devant le feu de circulation comprennent l'indication d'au moins une période de temps ( $T_1$ ,  $T_2$ ) pendant laquelle le feu de trafic est dans une phase verte et la file d'attente correspondante devant le feu de circulation devrait être vide.  
10
21. Dispositif (120) selon l'une quelconque des revendications 19 ou 20, dans lequel lesdites informations relatives à la longueur d'une file d'attente devant le feu de circulation comprennent l'indication d'au moins un instant auquel la file d'attente correspondante n'est pas vide, ainsi que la longueur/durée attendue de la file d'attente correspondante.  
15
22. Dispositif (120) selon l'une quelconque des revendications 19 à 21, comprenant en outre des moyens de transmission de données (128) configurés pour transmettre ledit signal généré (130) à un dispositif de réception.  
20
23. Dispositif (120) selon l'une quelconque des revendications 19 à 22, comprenant en outre des moyens de détection (124) pour obtenir une estimation du temps ( $T_{Q1}$ ,  $T_{Q2}$ ) requis pour qu'une file d'attente de véhicules automobiles devant ledit feu de circulation se vide, et des moyens de traitement (122) pour encoder ladite estimation ( $T_{Q1}$ ,  $T_{Q2}$ ) dans ledit signal (130), de sorte que ce dernier indique au moins une période de temps pendant laquelle le feu est en phase verte et une file d'attente devant le feu est censée être vide.  
25
24. Dispositif (120) selon l'une quelconque des revendications 19 à 23, comprenant en outre des moyens de détection (124) pour obtenir une estimation supplémentaire, d'une longueur d'une file d'attente, ou d'une durée de file d'attente, cette dernière étant le temps attendu requis pour qu'une file d'attente se vide, à au moins un instant auquel ladite file d'attente n'est pas vide, et des moyens de traitement (122) pour encoder ledit instant et la longueur/durée de file d'attente correspondante en ledit signal (130), de sorte que ce dernier indique au moins un instant auquel la file d'attente n'est pas vide, ainsi que la longueur/durée attendue de la file d'attente correspondante.  
30  
35

25. Dispositif (120) selon l'une quelconque des revendications 19 à 24, dans lequel ladite file d'attente comprend une file d'attente en cours ou au moins une file d'attente à venir devant le feu de circulation.

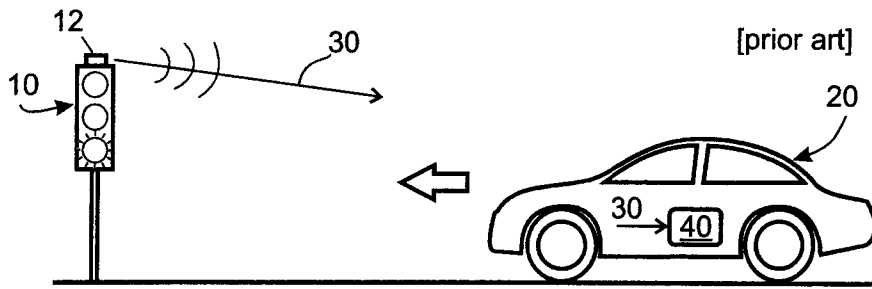


Fig. 1

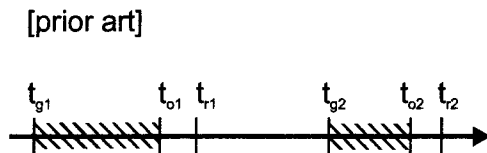


Fig. 2

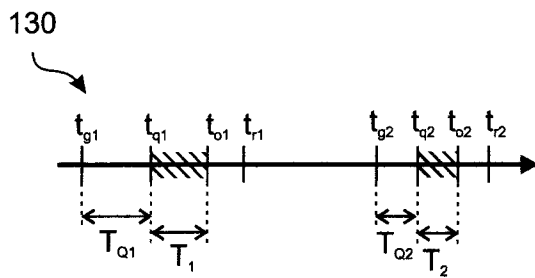


Fig. 4

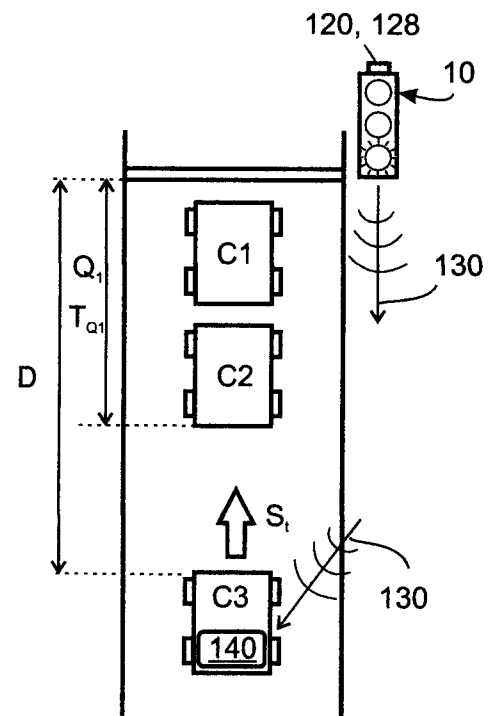


Fig. 3

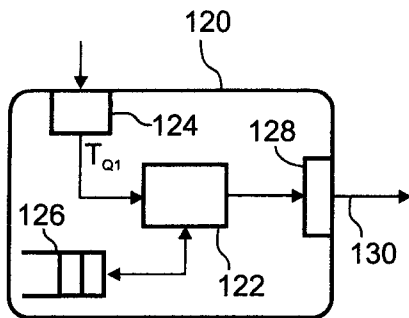


Fig. 5

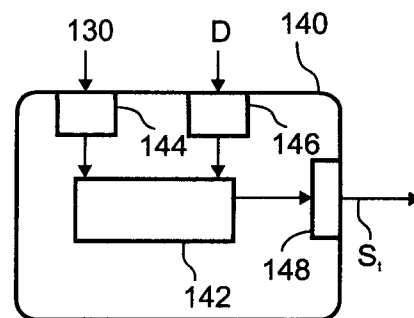


Fig. 6

Abstract

**METHOD AND SYSTEM FOR ENHANCED TRAFFIC LIGHT SIGNALING AND FOR  
COMPUTING A TARGET SPEED OF AN AUTOMOTIVE VEHICLE**

The invention provides a method and devices for determining a target speed of an automotive  
5 vehicle approaching a traffic light. The method uses extended traffic information signalling and  
allows for the computation of a target speed that allows, for example, the vehicle to pass the traffic  
light during a green phase and while there is no waiting queue in front of the traffic light. Other  
targets such as reducing CO<sub>2</sub> emissions or overall energy consumption of the vehicle approaching  
the traffic light may also be taken into account when computing the target speed.  
10 (Fig. 3)



**SEARCH REPORT**  
in accordance with Article 35.1 a)  
of the Luxembourg law on patents  
dated 20 July 1992

LO 1568  
LU 93392

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 2014/046581 A1 (OTA YUKO [JP] ET AL) 13 February 2014 (2014-02-13) * abstract * * column 4, line 28 - line 67 * * column 9, line 16 - line 21 * * column 9, line 29 - line 36 * * column 10, line 38 - column 11, line 4 * * column 16, line 55 - line 62 * * claims 1, 2 * * figure 8 *	1-25	INV. G08G1/04 G08G1/042 G08G1/0967
X	DE 10 2009 042923 A1 (SIEMENS AG [DE]) 4 August 2011 (2011-08-04) * abstract * * paragraph [0033] * * paragraph [0035] - paragraph [0036] * * paragraph [0038] - paragraph [0039] * * paragraph [0051] - paragraph [0052] * * paragraph [0056] - paragraph [0062] * * paragraph [0066] * * claims 1, 2 * * figures 1-3 *	1-25	TECHNICAL FIELDS SEARCHED (IPC)
X	GB 2 452 835 A (BOSCH GMBH ROBERT [DE]) 18 March 2009 (2009-03-18) * abstract * * page 2, line 23 - line 24 * * page 3, line 13 - line 18 * * page 4, line 20 - line 24 * * claims 1, 5, 6 * * figure 1 *	1	G08G
The present search report has been drawn up for all claims			
		Date of completion of the search 5 September 2017	Examiner Renaudie, Cécile
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	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

**ANNEX TO THE SEARCH REPORT  
ON LUXEMBOURG PATENT APPLICATION NO.**

LO 1568  
LU 93392

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

05-09-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014046581 A1	13-02-2014	CN 103503044 A	08-01-2014
		DE 112012001799 T5	16-01-2014
		JP 5518257 B2	11-06-2014
		JP W02012144255 A1	28-07-2014
		US 2014046581 A1	13-02-2014
		WO 2012144255 A1	26-10-2012
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DE 102009042923 A1	04-08-2011	NONE	
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GB 2452835 A	18-03-2009	DE 102007043602 A1	19-03-2009
		FR 2921183 A1	20-03-2009
		GB 2452835 A	18-03-2009
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WRITTEN OPINION

File No. LO1568	Filing date (day/month/year) 22.12.2016	Priority date (day/month/year)	Application No. LU93392
International Patent Classification (IPC) INV. G08G1.04 G08G1.042 G08G1.0967			
Applicant Luxembourg Institute of Science and Technology			

This report contains indications relating to the following items:

- Box No. I Basis of the opinion
- Box No. II Priority
- Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- Box No. IV Lack of unity of invention
- Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- Box No. VI Certain documents cited
- Box No. VII Certain defects in the application
- Box No. VIII Certain observations on the application

Form LU237A (Cover Sheet) (January 2007)	Examiner Renaudie, Cécile
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## WRITTEN OPINION

Application No.

LU93392

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### Box No. I Basis of the opinion

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1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:
  - a. type of material:
    - a sequence listing
    - table(s) related to the sequence listing
  - b. format of material:
    - on paper
    - in electronic form
  - c. time of filing/furnishing:
    - contained in the application as filed.
    - filed together with the application in electronic form.
    - furnished subsequently.
3.  In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

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### Box No. V Reasoned statement with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement

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#### 1. Statement

Novelty	Yes: Claims	3, 7, 10-13, 17, 21, 24
	No: Claims	1, 2, 4-6, 8, 9, 14-16, 18-20, 22, 23, 25
Inventive step	Yes: Claims	
	No: Claims	1-25
Industrial applicability	Yes: Claims	1-25
	No: Claims	

#### 2. Citations and explanations

**see separate sheet**

**WRITTEN OPINION**

Application No.  
LU93392

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**Box No. VII Certain defects in the application**

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The following defects in the form or contents of the application have been noted:

**see separate sheet**

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**Box No. VIII Certain observations on the application**

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**see separate sheet**

Reference is made to the following documents:

- D1 US 2014/046581 A1 (OTA YUKO [JP] ET AL) 13 February 2014  
(2014-02-13)
- D2 DE 10 2009 042923 A1 (SIEMENS AG [DE]) 4 August 2011  
(2011-08-04)
- D3 GB 2 452 835 A (BOSCH GMBH ROBERT [DE]) 18 March 2009  
(2009-03-18)

**Re Item V**

- 1 Reasoned statement with regard to novelty, inventive step or industrial applicability
- 1.1 Notwithstanding the further below-mentioned lack of clarity, the present application does not meet the criteria of patentability, because the subject-matter of claims 1, 2, 4, 5, 6, 8, 9, 14-16, 18-20, 22, 23 and 25 is not new and the subject-matter of claims 3, 7, 10-13, 17, 21 and 24 does not involve an inventive step.
- 1.2 Document D1 discloses a method for determining a target speed of an automotive vehicle using a speed computing device as the vehicle approaches a traffic light, wherein the method comprises the following steps:
  - I. providing at the speed computing device an estimate of the distance separating the vehicle and the traffic light, and a signal indicating the traffic light's phases as a function of time;
  - II. computing said target speed so that the automotive vehicle driving at the target speed arrives at the traffic light during a green phase thereofcharacterized in that
  - III. said signal further comprises information relating to the length of a waiting queue in front of the traffic light, and in that said target speed is computed as a function of said information

(D1: abstract; column 4, lines 28-67; column 9, lines 16-21 and 29-36; column 10, line 38 - column 11, line 4; column 16, lines 55-62; claims 1 and 2; figure 8).

The subject-matter of claim 1 is therefore not new.

- 1.3 The reasoning above also applies, *mutatis mutandis*, to the corresponding independent claim 19. The subject-matter of claim 19 is therefore not new.
- 1.4 Document D1 further discloses the features of claims 2, 4, 5, 6, 8, 9, 14-16 and 22 (D1: see point 1.2). The subject-matter of claims 2, 4, 5, 6, 8, 9, 14-16 and 22 is therefore not new.
- 1.5 The features of claims 3, 7, 10-13 and 17 are considered to be trivial. The subject-matter of claims 3, 7, 10-13 and 17 is therefore not inventive.
- 1.6 Further to points 1.2 and 1.4, claim 18 which combines the features of claims 1 and 2 is not new.
- 1.7 The same reasoning as for dependent claims 2, 3 and 6-8 applies, *mutatis mutandis*, to the subject-matter of dependent claims 20, 21 and 23-25. Therefore, the subject-matter of claims 20, 23 and 25 is not new and the subject-matter of claims 21 and 24 is not inventive.
- 1.8 Furthermore, the subject-matter of claims 1, 2, 4, 5, 6, 8, 9, 14-17 and 22 is also disclosed by document D2 (D2: abstract; paragraphs 33, 35, 36, 38, 39, 51, 52, 56-62 and 66; claims 1 and 2; figures 1-3). Therefore, the subject-matter of claims 1, 2, 4-6, 8, 9, 14-18, 17-20, 22, 23 and 25 is not new over D2 and the subject-matter of claims 3, 7, 10-13, 17, 21 and 24 is not inventive when departing from D2.
- 1.9 Claim 1 is also not inventive when departing from document D3 (D3: abstract; page 2, lines 23 and 24; page 3, lines 13-18; page 4, lines 20-24; claims 1, 5 and 6; figure 1).

### **Re Item VII**

- 2 Certain defects in the international application
  - 2.1 The independent claims are not in the two-part form, which in the present case would be appropriate, with those features known in combination from the prior art D1 being placed in the preamble and the remaining features being included in the characterising part.
  - 2.2 It is suggested to insert in the claims reference signs placed in parentheses relating to the vehicle (20), the traffic light (10), the waiting queue's length (Q1, Q2), waiting queue's duration (TQ1, TQ2), speed computing device (140), distance sensing means (146), electronics module (12), signal (130).

2.3 Documents D1-D3 should be acknowledged in the description.

**Re Item VIII**

3 Certain observations on the international application

- 3.1 In claim 3, when depending on claim 2, the verb "comprises" should be replaced by "further comprises". The dependency of claim 3 should therefore be revised.
- 3.2 In claim 4, when depending on claims 2 or 3, the verb "comprises" should be replaced by "further comprises". The dependency of claim 4 should therefore be revised.
- 3.3 In claim 6, the term "a signal" should be replaced by "said signal" because the signal is already defined in claim 1.
- 3.4 In claim 6, the feature "a signal indicating the traffic light's phases ... empty" is redundant because it is already defined in claim 2.
- 3.5 Claims 9-11 are unclear because when depending on claim 8, claims 9-11 comprise features (TQ1, TQ2) which are defined for the first time in claim 6. The dependency of claims 9-11 should therefore be revised.
- 3.6 Claims 9 and 11 is unclear because when depending on claim 6, claims 9 and 11 comprises features (expected queue lengths/durations) which are defined for the first time in claim 7. The dependency of claims 9 and 11 should therefore be revised.
- 3.7 In claim 18, the terms "the distance" should be replaced by "a distance".
- 3.8 In claim 23, the terms "the time" should be replaced by "a time".