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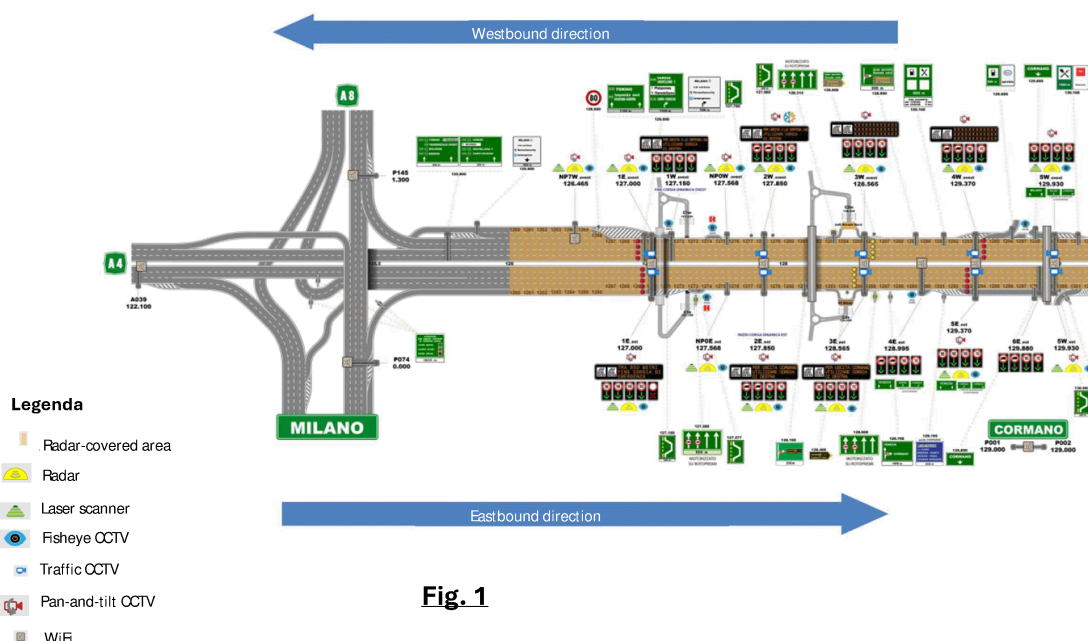
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(54) **DYNAMIC LANE MANAGEMENT SYSTEM**

(57) A dynamic lane management system in a multi-lane road section is disclosed, comprising a plurality of detection sensors to detect transit vehicles, an IT infrastructure that transfers signals from said detection sensors to an area control room manned by operators, where said detection sensor signals are converted into graphical representations on display devices, a plurality of signalling apparatus placed in the vicinity of said road section to display the open/close condition of said dynamic lane, said signalling apparatus being con-

trolled by said area control room on the basis of said graphic representations, wherein said plurality of sensors comprises at least first detection sensors, second verification sensors and third traffic sensors, and further comprising a central reporting system (src), arranged to process said signals of the first, second and third sensors and an area control room and a traffic management information system (sirt) of said graphical representations.



Description

FIELD OF THE INVENTION

5 **[0001]** The present invention relates to the management of a dynamic lane of a high-traffic road, such as a motorway in the vicinity of a large urban centre. In particular, a dynamic lane may be an emergency lane of a motorway that can be used dynamically, depending on traffic conditions, also as a normal traffic lane for a determined time.

OBJECT OF THE INVENTION

10 **[0002]** A dynamic lane management system will be set forth below, sometimes making explicit reference to a Fourth Dynamic Lane of Milan, hereinafter (QCDM), i.e. an emergency lane arranged on the right side of a three-lane motorway, located on the northern ring road of the city of Milan. This reference is to be understood as exemplary and non-limiting only. The management system of the invention, through the use of a certain number of data from a heterogeneous sensor
15 system, allows a series of homogeneous, reliable and useful information to be displayed to the operators of an area control room to allow the dynamic lane to be easily and quickly managed correctly as a traffic lane through appropriate signalling.

BACKGROUND

20 **[0003]** The dynamic use of an emergency lane as an additional traffic lane is already widespread, with various implementations existing today in Italy as well as in Europe and the USA. In the systems currently in use, although some monitoring sensors are provided to verify the state of the emergency lane, it has not yet been proposed to coordinate and integrate these data in order to provide the operators of an area control room (i.e. the control room where the operators who can intervene on the monitoring and control of the road reside) with reliable tools for managing the dynamism of the
25 opening/closing of the lane and monitoring of any dangerous situations, delegating the management to the area control room through standard section management tools.

[0004] For example, documents EP4085443, EP3836116, CN109615863, WO2016/165742, CN104392610, KR10-1101860, KR2002-0092046 and US6177885 disclose some detection sensors and techniques for evaluating vehicular traffic or related abnormal conditions (for example an accident). The document "Case Study, Stopped Vehicle
30 Detection (SVD) Demonstrating Radar Performance on Track Test" (<https://ogierelectronics.com/wp-content/uploads/2024/03/svr-500-case-study-nov-2021-track-day.pdf>) discloses some efficacy tests performed on a radar sensor for traffic detection.

[0005] These examples of prior art do not, however, provide effective decision-making support for the operators of an area control room, which allows the opening/closing of the dynamic lane to be managed quickly, reliably and with minimal
35 effort.

[0006] EP2269180 expressly discloses a supervision infrastructure intended to act as a support for an area control room; however, the video sensors provided here are capable of issuing simple alarms when they detect abnormal conditions, but they must be manually controlled and verified by operators.

[0007] The document AMPOUNTOLAS KONSTANTINOS ET AL: "Motorway Tidal Flow Lane Control", IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, IEEE, PISCATAWAY, NJ, USA, vol. 21, no. 4, 1 April 2020
40 discloses some techniques for managing sensor signals, based on an infrastructure corresponding to the preamble of the main claim here attached .

[0008] Although the operators of an area control room today have at their disposal both control units to open or close a dynamic lane to traffic - for example by means of suitable routing barriers or traffic light apparatus - and real-time traffic
45 information (cameras, passage sensors, ...), they do not have decision-making aids for the management of the dynamic lane that simplify the evaluation process, but rely solely on their own experience or on shared safety protocols to decide whether and when to open or close a dynamic lane to regular traffic on the basis of a certain number of available sensor information.

50 SUMMARY OF THE INVENTION

[0009] The object of the present invention is therefore to provide a management system for a dynamic road lane, which offers the operators of the area control room (or control room) integrated and complete information that facilitates and speeds up the decision-making process on the temporary opening/closing of one or more dynamic lanes to regular traffic,
55 depriving motorists of its availability in emergency conditions.

[0010] To this end, in the system according to the invention, the data coming from a group of sensors, suitably selected and arranged to detect abnormal events and traffic conditions on the road, are transferred to a central processing unit. Through appropriate data processing, a plurality of information is obtained regarding traffic conditions, the operating state

of the sensors and the presence of any obstructive events. The processed information is used to provide the operators of an area control room with supervision and guidance information suitable for supporting actions to be undertaken and automation systems aimed at simplifying the management activities of a dynamic lane, such as the automatic closing of the lane in the presence of stationary vehicles that require an emergency lane.

[0011] In order to allow the use of the emergency lane as an additional traffic lane, a dual-technology Automatic Incident Detection (AID) system has been specifically configured, so as to obtain total coverage of each monitored road section, free of blind spots, with a high detection rate, reliable classification of detected events and a low number of false alarms.

[0012] The solution of the invention is defined and described in its essential characteristics in the main claim attached hereto. The dependent claims describe preferred aspects of the invention.

[0013] According to a first aspect of the invention, a dynamic lane management system is provided in a multi-lane road section, comprising

a plurality of detection sensors to detect passing vehicles, comprising at least first detection sensors, an IT infrastructure that transfers signals from said detection sensors to an area control room manned by operators, where said signals from the detection sensors are converted into graphical representations on display devices, a plurality of signalling apparatus located in the proximity of said multi-lane road section to display the open/close condition of said dynamic lane, said signalling apparatus being controlled by said area control room on the basis of said graphic representations, wherein

said plurality of sensors also comprises second verification sensors and third traffic sensors, and wherein said first detection sensors are radio frequency radar or laser sensors in a fixed position in the vicinity of said road section, arranged to detect a vehicle event and to issue a vehicle event signal with location information of said vehicle event,

said second verification sensors comprise pan-and-tilt video cameras arranged to frame a variable position of said road section on the basis of said location information of the event signal,

said third sensors are radio frequency (RT) sensors arranged to detect a count, a classification and a speed of said passing vehicles,

and further comprising a central reporting system (SRC), arranged to process said signals of the first, second and third sensors and an area control room and traffic management information system (SIRT) for said graphical representations

wherein at least said first and second sensors are connected to and controlled by a first control unit (AID) equipped with processing capabilities and arranged to

- generate a first alarm signal upon detection of said vehicle event signal from said first detection sensors,
- drive said second verification sensors to frame said variable position of said road section on the basis of said event signal,
- acquire video signals from said second verification sensors,

and wherein said central reporting system (SRC) is arranged to forward said first alarm signal and said video signal to said area control room and traffic management information system (SIRT) and to analyse said video signal to identify a confirmation of said vehicle event and to generate a second alarm signal to be forwarded to said area control room and traffic management information system (SIRT),

and wherein said central reporting system (SRC) is arranged to calculate a vehicular flow, average speed and vehicular density on the basis of said counts, classification and speed of passing vehicles detected by said third sensors and to perform a predictive analysis over time to determine an expected traffic level,

on said area control room and traffic management information system (SIRT) a suggestion to open/close said dynamic lane being represented on the basis of a status processing performed by said central reporting system (SRC) of at least said first alarm signal, said second warning alarm and said expected traffic level.

[0014] According to a preferred aspect, a degradation analysis unit is also provided for generating degradation level signals of at least said first, second and third sensors which are used in said status processing of the central reporting system (SRC).

[0015] Preferably, the predictive analysis over time is based on standard profile method or Dyna method and CTM model (Cell Transmission Model).

[0016] According to a further aspect, said second alarm signal prevents triggering a suggestion to open said dynamic lane.

[0017] According to a further aspect, the graphic representations on display devices are comprised of at least a plurality of display panels comprising pictographic images representative of said road section and videos of said video signals.

[0018] Preferably, the display panels also comprise information dashboards having symbology representative of said

signals processed by said central reporting system (SRC).

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Further characteristics and advantages of the invention will in any case become more evident from the following detailed description of preferred embodiments, given by way of non-limiting example and illustrated in the accompanying drawings, wherein

figs. 1 and 2 are pictorial views of an infographic in two different operating conditions of the dynamic lane;
 fig. 3 is a schematic view of a logical interaction diagram between first and second sensors according to the invention;
 figs. 4A and 4B are flowcharts representative of the functionality of the invention;
 fig. 4C is a pictorial view of a synoptic panel according to the invention during the signalling of an alarm;
 fig. 5 is a flowchart similar to that of fig. 4A of the entire system according to the invention;
 fig. 6 shows three different graphs of flowcharts of critical parameters for the operation of the invention;
 fig. 7 is an illustrative view of a synoptic panel in an area control room;
 figs. 8A and 8B are two exemplary flowcharts of the process of generating suggestions for closing/opening the dynamic lane;
 fig. 9A is an exemplary view of an information dashboard in an area control room;
 fig. 9B is an exemplary view of a further version of an information dashboard in an area control room, with some legends in an exploded view;
 fig. 10 is a flowchart of a part of the system according to the invention; and
 fig. 11 is a pictorial exemplary representation of a traffic light signal.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0020] A high-traffic road typically consists of a plurality of lanes for each direction of travel. To cope with emergency situations, these roads are also normally equipped with an emergency lane (arranged on the far right in contexts where faster vehicles travel in the far left lane) which is occupied by vehicles that must stop for reasons of force majeure (fault, accident, driver illness, ...). In the following description, the term dynamic lane means a lane of a multi-lane road, typically the aforementioned emergency lane, which can be used alternatively, in a dynamic way, as an emergency-only lane or as a normal traffic lane.

[0021] Normally the dynamic lane is kept closed and serves only an emergency function (it can be occupied for example by broken-down vehicles or by duly authorised rescue vehicles), but it can be opened dynamically, in specific traffic conditions, to be travelled by standard vehicular traffic so as to advantageously increase the capacity of the road and thus reduce the causes of traffic slowdown. The closing/opening of the dynamic lane can be made by specific indications to the drivers of the vehicles, for example by intervening on traffic light apparatus located on a bridge structure across the road, or by means of mobile barriers or other remotely controllable device that can be made available.

[0022] A centralised dynamic lane management system comprises a plurality of devices and apparatuses that have different functions aimed at providing the services listed below:

- identification of obstructive events which prevent the opening of the lane, such as the presence of broken-down vehicles, queues, etc., by means of appropriate sensors;
- monitoring of the degradation of the available sensors and calculation of the achievable service level;
- traffic analysis and corresponding signalling suitable for suggesting the opening or closing of the dynamic lane;
- visual representation of the data to the operators of an area control room through a synoptic panel.

[0023] To this end, the system comprises a first series of detection sensors, in the form of radar and laser sensors, intended to identify specific stationary vehicles in the dynamic lane, second verification sensors, in the form of pan-and-tilt video cameras, intended to accurately verify the preliminary data acquired by the first sensors, as well as third traffic sensors intended to detect the overall traffic conditions in terms of at least speed and density to complete a cross-check monitoring of the traffic.

[0024] At least the first and second sensors are connected to and controlled by a first control unit having processing capabilities. In the first control unit, at least one automatic incident detection (AID) unit is implemented that performs a series of evaluations on individual road sections of relevance, as will be better illustrated below.

[0025] The third traffic sensors are connected to a second control unit with processing capability, which may also coincide with or be located in the same infrastructure as the first control unit, which receives data from the third traffic sensors and performs a traffic analysis intended to be integrated into the management system to provide adequate support to the operators of the area control room.

[0026] In the first or second control unit, a degradation analysis unit can also be implemented.

[0027] The control units collect the data from the respective sensors and process parameters and alarm levels, based on which an automatic signal suggesting the opening of the dynamic lane can be generated. The latter is shown in the area control room to the operators, who have the final responsibility for the choice and therefore the authorisation of the command to open the dynamic lane. The opening suggestion signal can be displayed, together with a series of other immediately understandable information for the operators, on a synoptic panel - controlled by an area control room and traffic management information system (SIRT) equipped with processing capability - displayed on a display device in the area control room (see figs. 1 and 2) according to methods that will be better explained below.

[0028] Finally, signalling systems are provided suitable for communicating to users driving with their respective vehicles the appropriate information to allow the use or non-use of the dynamic lane.

[0029] The signalling systems can be in the form of the following signalling tools:

- Variable Message Signage (PMV): with which it is possible to display alphanumeric text and pictograms;
- Line Control Signs (LCS): signalling with arrow/cross and pictograms;
- Rotoprisms.

[0030] The purpose of the signalling system is to communicate to drivers in transit, in a clear and immediate way, information relating to the change in use of the lanes available and the speed limits.

[0031] The individual systems for the realisation of the above-mentioned functional aspects are detailed below.

AID System

[0032] An Automatic Incident Detection (AID) unit consists of a dual-technology system aimed at identifying stationary vehicles (for example due to breakdown or emergency) along a road section pertaining to the dynamic lane. The detection of any stationary vehicles along the section is achieved through first detection sensors in the form of a pair of Radar and Laser sensors which, appropriately located along the road section of interest and operating in the radiofrequency spectrum, allow for day/night detection with a range of competence of about 400 meters.

[0033] The range of competence also defines the length of the road section pertaining to a specific AID unit, beyond which a further AID unit must be provided which will have competence on a subsequent or preceding road section of relevance.

[0034] The radar sensors are typically installed on bridge structures over the lane. The Laser sensors are provided for monitoring the dynamic lane also to compensate for the blind spot of the radar sensors (for example of about 25 m radius), so as to detect the presence of vehicles that are stationary in the immediate vicinity of the bridge structure.

[0035] Each station, in addition to the radar sensor, is preferably provided with two laser sensors and a control unit. The laser sensors have the task of performing a tracking of potential vehicles that are within the detection areas, giving rise to a transit. Each transit is communicated to the dedicated control unit, with the aim of aggregating the transits coming from the sensors and managing the alarm activation logic. For the purposes of traffic detection, the sensor can be installed at a distance from the road between 4 and 7 meters, allowing each sensor to perform measurements within a detection area of 25 meters near the bridge structure, thus allowing to cover the entire blind spot area of the radar sensor.

[0036] The Automatic Incident Detection (AID) unit detects the presence of stationary vehicles on the dynamic lane along this road section of relevance and outputs a relative signal towards a first control unit, which has the task of interpreting and integrating the signals of the first Radar and Laser sensors. On the basis of this interpretation and integration, the condition of a stationary vehicle and its position (in terms of absolute coordinates or only in terms of longitudinal distance relative to a certain known reference on the road section) along the section of lane of relevance is determined.

[0037] Once the generic position of the stationary vehicle has been determined, the first control unit provides for sending a command signal to a second verification sensor, which can acquire further data of the vehicle to further qualify its nature.

[0038] In particular, the Automatic Incident Detection (AID) unit is integrated with second verification sensors in the form of appropriately configured pan-and-tilt video cameras. The video cameras are driven by the first control unit so as to frame the coordinates of a potential stationary vehicle as detected by the first detection sensors. In this way, an image (as a static frame or as a video stream) of the scene is automatically associated with the identification of the target vehicle. The association of a scene image with the signals from the first detection sensors makes it possible to obtain, in addition to video support to be provided to the area control room operator, also useful information for allowing the process of a predefined KPI (Key Performance Indicator), which then results into a high detection rate (DR) and low false alarm frequency (FAF).

[0039] The complete monitoring can therefore take place through the use of the following exemplary sensor apparatuses (hardware):

- Radar, for example Navtech CTS 350-X radar;
- Laser Scanner, for example Comark LSR2001;
- pan-and-tilt video camera (PTZ), for example Bosch MIC IP starlight 7000i;
- Wide-angle camera (fisheye), for example AXIS P3807-PVE Network Camera.

5 [0040] Each station (for example a bridge structure across the road, such as a PMV bridge, or similar) equipped with an AID unit provides for first Radar and Laser Scanner detection sensors and second verification sensors in the form of pan-and-tilt (PTZ) and fisheye cameras installed on the bridge. Each alarm generated by the first sensors is managed by a service of a central reporting system (SRC), in order to identify the second sensors, i.e. the cameras, potentially involved in
10 the framing and then to suitably drive their acquisition orientation. The alarms are then associated with the videos of the pre-arranged surveillance cameras and sent to the competent area control room.

[0041] For example, each station with an AID unit covers an area of interest divided into eight sections (each section corresponding to 100 meters). The management of the associated cameras changes depending on the sensor that generates the event. In the event of a radar alarm, the central reporting system (SRC) associates as the primary camera
15 the pan-and-tilt CCTV camera belonging to the same station as the sensor, a camera that is arranged to cover the eight sections. Two further secondary pan-and-tilt cameras are associated with each station, consisting of the cameras at the stations of the adjacent AID units (in turn primary cameras of the respective stations of competence). Fisheye cameras instead cover the role of a possible tertiary camera for framing any vehicles that are stationary in the vicinity of the station itself (for example within 200 meters of the first sensors). In case an event signal is issued by a certain laser sensor, the
20 central reporting system (SRC) associates as the primary camera the fisheye camera belonging to the same station, a camera that is arranged to cover the two sections under the bridge structure. The PTZ pan-and-tilt camera of the station is configured as a secondary camera to support the video of the fisheye camera.

[0042] An exemplary architecture of the monitoring system composed of radar and cameras is illustrated in fig. 3. A plurality of radars are interfaced with respective 'track engines' which are in turn controlled by a management server that
25 controls a plurality of pan-and-tilt cameras. On a user interface, integrated parameters representative of the lane conditions and alarms are provided, together with the significant images captured by the cameras.

[0043] In particular, groups of radar sensors are assigned to a Track Engine server that processes the data generated by the individual sensors and transforms it into logical information (for example unique index and absolute or relative coordinates) representing targets (the vehicles) that are within the analysis scenario, i.e. the emergency lane. In the event
30 that one of the servers on which the online Track Engine is installed should fail, the Radars are automatically taken over by the Backup Track Engine, ensuring continuity of the AID unit's service. The management of the assignments is carried out by the Manager Server, which is responsible for the management and monitoring of all the services that make up the software system.

[0044] The information processed by the Track Engine is sent to the Manager Server service which is responsible for processing and distributing the alarm signals to the SRC, managing the configuration and master data, and performing the periodic backup of the system.
35

[0045] In case of detection of abnormal events through the first radar sensors, the system has the task of verifying which is the closest pan-and-tilt camera and pointing it so as to frame the interested section, to allow the operator who views it a more immediate understanding of the situation. The management of the positioning of the cameras takes place on the
40 basis of absolute positioning data and the timings of permanence of the framing on an certain event are preferably adjustable.

[0046] The alarms associated with the detected events are sent, according to appropriate aggregation logics, to the central reporting system (SRC). The subsequent integration of the data deriving from the central reporting system (SRC) with the area control room and traffic management information system (SIRT) - as will be seen later - allows signals to be
45 sent to the area control room, providing various support data such as: live video and recordings, temporal and spatial data of the event.

[0047] According to a preferred embodiment, the image (static or video stream) associated with the signals of the second sensors in the form of TLC or CCTV, is processed by means of Video Analysis and Artificial Intelligence algorithms aimed at identifying the vehicles in the scene and classifying the type of event detected: for example, Broken-down
50 Vehicle, Queue, Traffic and Queue on Dynamic Lane.

[0048] Following the video analysis, if the AID unit detects some types of events considered unsuitable for opening the dynamic lane, it issues an alarm signal. The alarm can have different severity levels, only some of which constitute a parameter for inhibiting the opening of the dynamic lane. For example, three increasing levels of severity can be defined, green, yellow and red, only the last of which, exceeding a safety threshold, completely inhibits the opening of the dynamic
55 lane.

[0049] The video analysis algorithms that can be used to identify elements in the framed scene that confirm or deny the existence of a risk factor (one or more stationary vehicles in the lane, for example) can be of various types. In the context of the present discussion, no further details will be provided as they are not part of the object of the invention considered in this

application.

[0050] The diagram in fig. 4A shows a flowchart of the data and signal management, as indicated above.

[0051] The first control unit transmits an initial preset to the first detection sensors in the form of radar and laser units, as well as to the second sensors in the form of pan-and-tilt cameras.

5 [0052] As seen above, when the first detection sensors of a respective road section detect the presence of a potentially relevant event, such as a stationary vehicle, a first alarm threshold (alarm-id#A) is generated and the AID unit also activates the second verification sensors, causing them to point towards the coordinates of the target identified by the first sensors; the control section of the AID unit then acquires the output data from the first and second sensors (alarm-id#A, video-id#B) and preferably sends them to an image processor equipped with a scene identification system with Artificial
10 Intelligence AI.

[0053] Thus, each radar alarm (first sensors) is associated with a video analysis of the video signal captured by the second sensors, which allows the abnormal event detection signal to be automatically confirmed/denied.

[0054] The alarm signal (alarm-id#A) generated on the basis of the acquisition of the first sensors is addressed as a first alarm threshold to the central reporting system (SRC) which provides this first information to the area control room (for example as a yellow alarm, in the manner that will be illustrated later). If the automatic analysis on the video signal of the
15 second sensors is consistent with the alarm signal of the first sensors, the system considers the first alarm threshold confirmed and triggers a second alarm threshold (for example as a red alarm, in the manner that will be illustrated later) which is shown in the area control room and issues a command to suggest closing or not opening (which the operators must simply confirm) of the dynamic lane; if the automatic analysis on the video signal of the second sensors is not consistent
20 with the alarm signal of the first sensors (detection = no), the system does not generate the second alarm threshold and transfers the video signal of the second sensors (video-id #B) to the area control room for manual verification by the operators.

[0055] From a functional point of view, the process occurs as schematised in fig. 4B. All alarms generated by the first Radar and Laser sensors are sent to the central reporting system (SRC). The SRC, after associating the videos with the
25 received alarm, labels the received alarm as a "yellow alarm" and it is forwarded to the synoptic panel of the area control room. Simultaneously with the sending of the "yellow alarm" type signal, the SRC sends the video analysis request to the neural network of the same alarm. If the video analysis process actually detects the event signalled by the first sensors, a positive outcome is obtained and the SRC labels the alarm as "red alarm" and proceeds to send the signal to the area control room to the SIRT. The video analysis can give a consistent result (vehicle identified by the AID unit) or un-consistent
30 result (vehicle not identified by the AID unit, possible false alarm); in case of a un-consistent result, a possible false alarm is determined and the alarm continues to be labelled as "yellow alarm"; in case of a consistent result, the alarm is confirmed by the video analysis and is labelled as a red alarm and forwarded to the SIRT and to the area control room to issue a command apt to suggest the closure of the dynamic lane.

[0056] In the case of a "yellow alarm", the signal is forwarded and displayed in the area control room on the synoptic
35 panel of the Video Wall (flashing visual signal in the interested hectometre). In the case of the forwarding of a "red alarm", the dedicated SIRT process in correspondence of the road trunk captures the alarm and shows the signal to the operator in the area control room in the form of a red visual signal to which a sound alarm is associated (Fig. 4C). This "red alarm" signal remains active until managed by the operator: through a link associated with the red icon of the alarm signal, the visualisation of the video recording of the event in deferred time and related information is made available to the operator.
40 Simultaneously with the signalling to the area control room operator, the live videos of all the cameras associated with the alarm are displayed on the Video Wall of the area control room and the alarm is shown on the synoptic panel (flashing visual signal in the interested hectometre).

[0057] The video analysis through artificial vision tools with the use of neural networks is used as confirmation of the alarms produced in the detection of stationary vehicles by the first sensors present, in particular Radar and Laser
45 Scanners. As seen, the confirmation is carried out with two specific methods that make use, in the first case, of the pan-and-tilt CCTV cameras placed on the bridge structures and, in the second case, of the Fisheye CCTV cameras placed in the vicinity of the Laser Scanner sensor.

[0058] In the TLC or pan-and-tilt CCTV cameras, the framings of the road sections covered by the radars where the stationary vehicles are detected are preliminary configured. The video analysis process is mainly composed of four
50 phases:

1. The radar sensor that generated the alarm identifies the section in which the alarm was detected and issues a pan-and-tilt command to the indicated CCTV camera, causing its framing to move, zooming in on the coordinates of the road section in which the event was detected.
2. The video analysis process is invoked on the CCTV camera with the framing zoomed in on the road section where the event occurred. The video processing begins by performing a statistical calculation of the image background.
3. The image obtained from the previous analysis is subjected to processing by the neural network for the identification of the vehicles and the validation of the generated alarm.

4. A response is sent to the central system, which can be a confirmation of the stationary vehicle or that no vehicle has been identified. In the case where more than two vehicles are identified in the same lane, a queue presence message is returned.

5 More in detail:

Phase 1 - Radar

10 **[0059]** Upon a stationary vehicle alarm detected by radar, a command signal is issued to perform the pan-and-tilt of the interested camera on the road section where the alarm occurred. After a time-out of a few seconds (for example 7 sec), the time necessary for the camera to perform the pan-and-tilt and zoom on the interested section, a message is sent to the central reporting system (SRC) which is responsible for signalling the alarm to the video analysis system (neural network, AI) and for starting the Video analysis on the interested CCTV camera.

15 Phase 2 - Start of Video Analysis Process

20 **[0060]** Upon receipt of the alarm start message from the central reporting system (SRC), the video analysis system generates two parallel video analysis processes. The first is specific for the emergency dynamic lane with a background calculation time-out of 1 second. The second analyses all the lanes of the road way with a standard processing time-out (on average from 12 to 18 sec) configurable on a configuration file for each framing according to the different processing needs due to the different perspective framings of the cameras. The background calculation process is a technique that deals with separating moving objects (foreground) from static objects that remain unchanged for a long period of time (background).

25 Phase 3 - Neural Network Image Analysis

[0061] The image deriving from the "Background" calculation is subjected to further processing to identify the stationary objects/vehicles in the scene.

30 Phase 4 - Sending analysis response to the central reporting system (SRC)

[0062] The recognition of the stationary vehicle from the video signals of the cameras produces the sending to the SRC of the confirmation of the stationary vehicle alarm, giving precedence to the process that analyses the dynamic lane. In the stationary vehicle alarm message, the lane and the classification of the detected vehicle are reported.

35 **[0063]** In the case where more than two vehicles are identified on the same lane, a queue presence message is sent to the central reporting system (SRC). In the case where, after a time out (for example of 25 seconds), no vehicle is recognised on both processes, a response of no detection will in any case be sent to the central reporting system (SRC) and will be validated as a false alarm of the radar.

[0064] With reference to fisheye CCTV cameras, there are two scenarios in which to apply the video analysis of the images:

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- 1) Validation of the alarm produced by the radio frequency sensors (Laser or Radar);
- 2) Recognition of "Stationary Vehicle" in "rest/lay-by areas".

45 **[0065]** The main difference between the two types is that the first is requested in response to an alarm produced by another device, the second autonomously produces the alarm by performing a continuous analysis of the video stream.

Degradation analysis system (diagnostics)

50 **[0066]** The diagnostic information relating to all the devices and apparatuses (including the aforesaid sensors, the connection networks, the control unit, the software components that execute the data processing algorithms, ...) located in the vicinity of the area control room (central area of the apparatus network) and on the periphery along the dynamic lane, are monitored in order to be able to provide the operators with information on correct operation or possible failure.

55 **[0067]** Within the first or second control unit, a verification system is implemented in which the operating state of each single apparatus, influenced by its location and in the presence of redundancies, is mapped into a suitable service level matrix divided into degrees of severity of the fault. The service levels range from a level 1, which identifies a perfect functioning of all connected apparatuses, to a series of levels of higher value that progressively indicate increasingly disabling faults.

[0068] In the case where a fault of an apparatus is detected which is at such a level (for example level 3) as to make the

reliability and safety of the management of the dynamic lane uncertain, the system transmits on the synoptic panel in the area control room the service level accompanied by all the information that has determined its increment and, contextually, a signal to inhibit the opening of the dynamic lane or, if this is open, a suggestion for possible closure.

[0069] For example, with reference to the laser sensors, which are configured to send TCP/IP packets on a configurable port to the central reporting system (SRC), containing information on vehicle detection or on monitoring the state of the system, the analysis system considers the following state information:

> Heartbeat: monitoring of the connection state. Through a special packet, the state of the connectivity is monitored every minute. The system is considered offline if it is unreachable for at least 5 minutes.

> Sensor status: packets containing data on the status of the control unit and the two lasers of each station. Each packet is automatically sent to the SRC upon variation of the state of one of the three components of the system.

[0070] On the basis of previously set reference values, the state information is evaluated and then a reliability score of the apparatus can be assigned.

Traffic analysis system

[0071] A traffic analysis unit consists of an apparatus having processing capability arranged to analyse the information coming from a plurality of third traffic sensors placed on the various sections of the dynamic lane. By processing the data coming from these sensors, in terms of number of vehicular transits, speed and travel times, information useful for establishing the existing traffic conditions such as hourly vehicular flow, hourly harmonic mean speed and vehicular density is obtained. The data coming from these third traffic sensors are processed by the second control unit by means of a special algorithm or application software by the central reporting system (SRC), in order to be able to provide the operators of the area control room with suggestion signals for opening or closing the dynamic lane on the basis of the actual need detected on the ground and in a predictive manner, in order to prevent the onset of queues.

[0072] For example, the third sensors are in the form of radar scanners, counting sensors and Bluetooth™ sensors to define travel times. More precisely, for the determination of the traffic characteristic, the data obtained from the following monitoring sensors are analysed:

- Traffic Detection (RT) sensors;
- Radar in Counter & Classify (C&C) configuration;
- WiFi Spotter with Bluetooth™ technology.

[0073] The traffic analysis unit can acquire and aggregate the data from the third sensors every minute, for example, maintaining a data history of up to about 10 minutes in a corresponding storage memory.

[0074] The data acquired from the radar scanner allow for determining an average traffic speed, for example every 100 meters (depending on the coverage of the section with the radar devices, which can also be used as first sensors for the AID unit): therefore aggregated data and an average harmonic speed.

[0075] The counting sensors - for example in the form of radar in C&C configuration - allow for obtaining the count of vehicles divided by type, as they are able to determine the measurement of the wheelbase and the weight of each vehicle, so as to obtain a classification and relative weights of the vehicles that provide a vehicular flow parameter. For example, for each lane the passage of vehicles parameterised as light, medium or heavy is detected based on the length of the detected vehicle. The flow used for the analysis is the equivalent and not the real one, because the vehicles are weighted, for example by assigning weight 1 to light vehicles (less than 5 meters), 2 to medium vehicles (between 5 and 10 meters) and 3 to heavy vehicles (over 10 meters). In the calculation, the overall transit data are used, aggregating them by the minute and using the flow information to derive the density on a single road and 3 lanes, in case of a closed dynamic lane, and 4 lanes in case of an open dynamic lane.

[0076] The RT sensors are for example Raser Comark 4001 sensors, based on microwave radar and laser scanner technologies; by combining the two technologies, it is possible to obtain a system capable of providing counting, classification and speed measurement both in cases of high-speed traffic and in congested traffic conditions. The radar component of the sensor operates at frequencies in the order of 20-25 GHz and uses the Doppler effect for the detection of moving vehicles and measurement of their transit speed. The laser component uses a laser scanner to scan a plan surface, allowing the reconstruction of the profile of the transiting vehicle. By processing the detected profile data, by means of appropriate classification algorithms, it is possible to obtain the classification of the vehicles and their relative weight.

[0077] These sensors are designed to detect multiple lanes simultaneously, by carrying out scans transversely to the direction of travel of the vehicles: for example, on road bridge structures the sensors are installed at a height of about 5 meters, each at the centre of its own detection lane, allowing for a precise count of the vehicles running below.

[0078] To determine the travel time parameter, sensors in the form of WiFi spotters are used, which detect the MAC addresses of Bluetooth™ devices on board vehicles running in the vicinity. A plurality of Bluetooth™ spots is distributed on the sections of the dynamic lane and placed in a network with each other: by uniquely detecting the passage of Bluetooth™ devices by identifying their MAC address, it is possible to derive the passage times of the device from the various Bluetooth™ spot stations and therefore determine the average travel times of the vehicular flow.

[0079] The algorithm installed in the traffic detection unit aggregates the data every minute and calculates the vehicular flow, density and average harmonic speed. On the basis of these parameters and a comparison with respective pre-set thresholds, the system performs a predictive analysis over time and determines expected traffic levels and consequently issues warning signals, which are then displayed in the area control room.

[0080] For example, on the basis of the continuous detection of data, the analysis unit determines that the traffic level is passing, in a determined time frame, from one congestion class to another, for example from class LOS E to class LOS F: on the basis of the derivative of this trend, the system determines that the traffic is congested and issues a corresponding warning signal.

[0081] In particular, a mode of issuing warning signals provides for determining the traffic condition over time, by means of estimation and prediction algorithms (standard profile method, Dyna method) of the traffic variables, in conditions of the sections with the dynamic lane open or closed. These traffic estimates, based on current and past data of the traffic variables, allow the need for opening the dynamic lane to be determined in advance and therefore to generate a suggestion signal for opening. The predictive models act on the individual section portions and the relative results can then be integrated over the entire section - taking into consideration an extension in time and space - using other models suitable for the purpose, for example the CTM (Cell Transmission Model).

[0082] Further details will be specified in the next chapter.

[0083] In order to provide an automated management system and not to delegate to the traffic operators a series of manual checks and controls, the system of the invention determines a signal of suggestion for opening by weighting, in addition to the traffic conditions coming from the traffic analysis system, also a series of parameters of:

- presence of an alarm signal from the AID unit,
- presence of a service level other than 0 or above a preestablished threshold,
- presence of any disruption of service and area control room events that are obstructive to the use of the dynamic lane.

[0084] The alarm signalling for possible accidents or abnormal traffic slowdowns can also derive from the same RT traffic sensors, for example by analysing parameters such as average speed, traffic density and threshold speed in successive sections by means of per se known algorithms (for example DIDX or DUTCH) possibly integrated with each other.

[0085] The combination of these parameters (for example the absence of all obstructive events) with the parameter deriving from the traffic analysis, generates a possible signal of invitation to open the dynamic lane and its forwarding to the area control room for appropriate signalling on the dedicated synoptic panel, leaving the operators of the room only the final choice of whether or not to accept the suggestion signal for opening and to authorise the opening of the dynamic lane. The possible presence of an obstructive event, such as an alarm from the system of the AID units confirmed by the operators of the room and translated into an event, entails the automatic closure of the dynamic lane.

[0086] In particular, a preliminary check is carried out on any alarm signals (indicative, for example, of accidents occupying the lane, existence of construction sites, ...), entered into the system automatically or with manual flags (for example because it is programmed that a certain section of the dynamic lane will be unusable for traffic due to the temporary presence of a construction site).

[0087] Fig. 5 shows a flowchart of the management of the data for the traffic analysis. A plurality of third sensors obtains data relating to traffic, such as average speed, number of transits, travel time, and so on which are provided to the traffic analysis unit for a relative processing. At the end of this processing, parameters relating to the hourly vehicular flow, the hourly harmonic mean speed and the vehicular density are obtained. Downstream of the determination of these parameters, they are combined with the parameters deriving from the AID unit, with the parameters deriving from the diagnostic analysis and with any obstructive events of the area control room, to then determine whether or not a signal of suggestion for opening the dynamic lane can be issued, which is shown in the area control room, for example on the synoptic panel.

Detail of the traffic detection system

[0088] The control logic with which the overall check on traffic is carried out can have at least five objectives which translate into as many functionalities:

- Measure traffic conditions
- Identify any anomalies

- Predict any anomalies in traffic conditions
- Determine and issue suggestions/warnings for opening or closing the dynamic lane (DL);
- Control of vehicle speed.

[0089] The first two are pure monitoring functionalities, while the third, fourth and fifth are prediction and control activities - in the terms mentioned above - which actively allow the burden on the operators in the area control room to be reduced.

[0090] The monitoring functionalities are implemented using the different types of sensors seen above, each of which has specific characteristics in terms of time interval and spatial extension of measurement. In particular, as seen above, the measurement of traffic conditions can be operated with

- RT traffic detection sensors, which measure flow and speed per lane in the detection sections (spaced 1.5-2.5 km apart), every 1 min;
- RADAR (in C&C function), which measures carriageway speed, for example every 100 m over the entire extension of the sections, every 1 min;
- WiFi (with Bluetooth™ spotter) measures the roadway travel time (tdp) on sections of an average of 700 m, for example every 1 min.

[0091] Through RT sensors it is possible to obtain a system capable of providing the counting, classification of transiting vehicles and measurement of speeds, both in case of high-speed traffic and in congested traffic conditions.

[0092] The RT sensors are used to detect the vehicular flow and the average speed, from which the density is derived (calculated value). In particular, the flow values are relevant for being able to know the traffic entering each flow tube (section between two measurement stations without intermediate entrances or exits).

[0093] The radar sensors, used in Counter&Classify configuration, are used for the purpose of monitoring the average speeds of the vehicular flow. The Radar sensors are the same used for the AID system. The radar technology allows for making average speed measurements on time intervals of 1 minute and sections of 100 meters.

[0094] The WiFi spotter sensors are used to measure the travel time (TDP) and derive the average travel speed of the vehicular flow. These devices, through a system detecting mac addresses of transiting bluetooth devices, allow the average value of the TDP to be derived in a time frame not exceeding, for example, 1 minute.

[0095] The data acquired by the sensors are used as a verification and backup system, in order to provide the analysis system with greater robustness to possible faults of the radar sensors.

[0096] For each of a plurality of functional segments into which the analysis is divided, the data obtained from the traffic analysis sensors (Radar, RT, WiFi) are used in order to provide the outflow data in real time. All the data acquired by the sensors are integrated into the central reporting system (SRC) capable of processing the data and providing the area control room with functional services (traffic signals, traffic status, dynamic lane opening proposal, detected speed) and non-functional services (system and second-level peripheral diagnostics).

[0097] With the data obtained from the various sensors it is also possible to carry out predictive analyses and estimates of the outflow curves, obtaining a Fundamental Diagram (FD). This operation is performed periodically with a monthly frequency or whenever a significant modification of the traffic flow occurs.

[0098] For the realisation of the logic to be applied for the decision to send signals for opening/closing the Dynamic Lane, one starts by considering the classification of the Levels of Service (LOS) defined for a road section. These indicators allow the measurement of the performance of the road in delivering the vehicular flow. A possible classification of the LOS is reported in the following table:

Table 1. LOS Level

Level	Description
LOS A	Free-flowing traffic, maximum comfort, stable flow.
LOS B	Free-flowing traffic, modest reduction in speed, acceptable comfort, stable flow.
LOS C	First constraints on circulation, speed reduction, comfort is reduced, stable flow.
LOS D	Constraints on circulation, low comfort, flow that may begin to be unstable.
LOS E	Flow at the limit of capacity, unstable flow.
LOS F	Obstructed flow.

[0099] To calculate the current LOS level, the objective measurements obtained for the road section must be integrated. For example, at each interval of measurements carried out, a LOS level is associated with each variable and tables of this

type are obtained:

Table 2: LOS values based on density (no. of vehicles/km/lane)

LOS	Vehicular density
LOS A	0 - 7
LOS B	7 - 11
LOS C	11 - 16
LOS D	16 - 22
LOS E	22 - 28
LOS F	> 28

Table 3: LOS values based on average speed (km/h).

LOS	speed
LOS A	> 90
LOS B	86 - 90
LOS C	75 - 86
LOS D	60 - 75
LOS E	15-60
LOS F	0 - 15

[0100] The combination of the LOS values associated with the various measurements would allow for obtaining an overall LOS that adequately reflects the traffic conditions.

[0101] Therefore, at least these three variables (flow, speed and density) are calculated on a given road section in a given time frame at regular time intervals and the relative results are compared with respective thresholds provided for the opening/closing of the dynamic lane, thus generating the suggestion signal for the change of state of the dynamic lane (Open/Closed).

[0102] In fig. 6, examples are presented relating to "working points" (Speed, Flow, Density) detected by RT sensors on measurements carried out on an exemplary test site (measurement interval = 5') for an entire day.

[0103] The logic that determines the suggestion for the individual "sections" requires the definition of the thresholds of the control variables to generate the suggestion for opening or closing the dynamic lane. The definition of the thresholds can be obtained using the Fundamental Diagrams of fig. 6, i.e. the diagrams of the working points (flow, speed) relating to traffic with the dynamic lane open or closed in the space-time window used.

[0104] As already mentioned, to ensure maximum flexibility, the calculation logic takes into consideration all three quantities that describe the state of the traffic: V, F, D; for the calculation of the suggestion, reference is made to the fundamental diagram of the lane relating to the considered spatial element (section).

[0105] Referring to the graphs of fig. 6, it is noted that the critical speed V_{crit} is the speed at which the maximum flow rate (capacity) is achieved and is also the speed below which the traffic becomes unstable and inefficient since lower flows correspond to increasing densities. The critical Density D_{crit} , similarly, is the density at which the critical speed and the maximum capacity are reached.

[0106] The traffic situation is such as to require an additional lane if the capacity of the road is exceeded or if the traffic is "unstable", i.e. if conditions of density higher than D_{crit} and speed lower than V_{crit} are reached. It is evident that intervening when the indicated thresholds have been exceeded is risky because, if compression waves with slowdowns and/or queues are already present that must be absorbed, this transitory for the recovery of a situation of instability is generally complicated and certainly requires a lot of time; therefore, it is appropriate to work in advance and intervene with the additional lane when one is "sufficiently" far from the conditions of "instability".

[0107] For example, if the working point of the traffic at a certain time is characterised by the values V' , F' , D' then the dynamic lane must be open when the flow F' is "close" to the capacity Cap , or the density D' is "close" to D_{crit} . The term "close" can be quantified with a proximity parameter expressed as a percentage. Considering the DFs in fig. 6 the values are:

$$V_{crit}=60 \text{ km/h}$$

Dcrit'=30 veh/km/lane

Cap= 1800 veh/h

[0108] Using a proximity factor of 0.9 for D and F, the following threshold values will be had for the opening of the dynamic lane:

SA3_V= 61 km/h

SA3_D= 27 veh/km/lane

SA3_F= 1650 veh/h/lane

[0109] The point and predictive analysis - for example constructed with the 'Cell Transmission' (CTM) model as indicated above - must also ensure that the possible change of "state" of the dynamic lane is such as to last for a suitable time; in particular, should a change of state of the dynamic lane be suggested, the new state must be kept stable for a certain time, in such a way as to not have sudden oscillations of the state in the presence of borderline traffic situations (anti-flickering).

[0110] The traffic situation once the dynamic lane is open can be estimated provided that the Fundamental Diagram DF of the lane relative to the situation with the dynamic lane open is known or by making approximation hypotheses, i.e. estimating that the DF remains the same.

[0111] As can be understood, the efficiency of the opening/closing of the dynamic lane depends on the shapes of the DFs relating to traffic in the two conditions of a closed and open dynamic lane.

[0112] As mentioned above, for the prediction and control functionalities, the implementation of specific algorithms is provided which process the parameters collected by the control and analysis units and provide:

- Prediction of traffic conditions,
- use of RT flow data, historical profiles and prediction models based on the analysis of time series and propagation models in time and space (Cell Transmission Model),
- suggestion for opening/closing the dynamic lane,
- use of the measurements and predictions of the traffic conditions to decide which is the "right" suggestion,
- speed control.

Signalling system

[0113] The signalling to vehicle drivers takes place by means of devices located within the interested road section or in the vicinity of the access points to it. As mentioned above, it can be composed of the following apparatuses:

- PMV: Alphanumeric panels and pictogram with pre-coded message;
- LCS (Line Control Signs): arrow/cross type lane signals and pictogram to signal to transiting vehicles which lanes can be used and the speed limits;
- Rotoprisms: variable message signs reporting the lane use signal provided for by the rules corresponding to the active asset.

[0114] In an exemplary operation with four or three lanes, in the absence of other events, the indications on the use of the lanes provide, on the section equipped with a Dynamic Lane:

- arrow/cross lane signals,
- pictograms with maximum speed limit,
- alphanumeric variable message panels and relative pictogram with pre-coded messages;

on the approach sections towards the area equipped with a dynamic lane:

- alphanumeric variable message panels and relative pictogram with pre-coded messages,
- rotoprisms.

[0115] The switching of these signalling apparatuses, for the passage from an open dynamic lane to a closed dynamic lane, and vice versa, are initiated by the control systems employed by the area control room of that trunk.

[0116] In case of closure/opening of the dynamic lane, the system provides for:

- automatic activation of the specific signalling (arrow/cross) and pictograms with speed limit for the closure/opening of

the section;

- automatic visualisation of the information messages to the users provided in case of a closed/open section by means of PMV and pictograms;
- automatic activation of the rotoprisms to signal the allowed use of the lanes.

Visualisation system

[0117] In order to provide the operators of the area control room with an overall information system on the state of the monitored section, all the information described above is suitably synthesised and displayed on a synoptic panel of the video wall of the room. The traffic information, AID event signals, diagnostics, opening/closing signals and status of the managed dynamic lane are suitably displayed on the synoptic panel in such a way as to be able to provide a rapid feedback and additional information of the signals received through usual section management systems.

[0118] The instances for the visualisation of information on the synoptic panel can be more than one and divided into two types:

- a) Video wall synoptic: subdivision of the synoptic on the various monitors that make up the Video walls of the area control rooms;
- b) Desktop synoptic: version for the fixed station of the area control room operator that can be viewed from a monitor.

[0119] The central management system forwards the signals to all active instances. Preferably, the live videos relating to the cameras (second verification sensors) are displayed exclusively on monitors arranged in the video wall of the area control room.

[0120] As exemplary represented in fig. 7, on a video wall consisting of 3x3 monitors,

- three horizontally aligned monitors in the central part constitute the representation of the synoptic (similar to that of figs. 1 and 2);
- a monitor at the bottom left can act as a monitor for viewing alarms;
- all the other monitors remain freely settable by the operators of the area control room to be able to view the desired parameters.

[0121] The information reported can be subdivided into the following groups

- I. Alarms due to presence of stationary vehicles on the section road and in lay-bys;
- II. Suggestions for opening/closing the fourth lane
- III. Traffic analysis information
- IV. Diagnostic and fault information;
- V. Dynamic section management information.

I. Representation of alarms due to the presence of stationary vehicles

[0122] The signals for the presence of stationary vehicles are divided into two topologies

- 1) Yellow type signal: signal of the presence of a stationary vehicle from a peripheral AID unit coming from the first radio frequency traffic sensors (Radar or Laser);
- 2) Red type signal: signal of a stationary vehicle confirmed by the analysis of the videos coming from the second verification sensors.

[0123] As a hierarchical representation, the red type alarms have priority over the yellow type signals. In fig. 8A a flow for the signalling of a yellow type alarm is represented (the warning signals for identification of stationary vehicles determined only by the first sensors).

[0124] A unit of the peripheral system forming part of the AID system detects the presence of a stationary vehicle. The information of the peripheral system is forwarded to the central dynamic lane management system reporting the information of the signal including:

- a. "alarm-id" to which an identifier is assigned and containing the information relating to the signal of the sensor that detected the vehicle including:
 - i. Type of sensor that identified the vehicle and station

- ii. Position of the vehicle along the motorway section;
- iii. Date and time of alarm start/end

b. "video-id": information relating to the video to be associated with the signal including:

- i. Camera station
- ii. Date and time of the video stream to be used

[0125] The central system, upon receipt of the signal with the alarm start date, assigns the yellow signal label and arranges the signal toward the operator. Being a yellow type alarm, the representation will take place by means of appropriate symbology on the synoptic panel in correspondence with the road section (with sufficient precision, for example of 100 meters) on which the signal occurred, according to the following logics

- i. In the case the section does not contain any type of signal, the yellow signal is represented;
- ii. in the case a non-resolved yellow signal is already present, the new signal is not represented as the section is already alarmed;
- iii. in the case the section presents a red type signal, the yellow type signal is discarded;
- iv. signal times: the signal lasts for the entire start and stop time indicated by the peripheral system. It is possible to set maximum and minimum times as for example:

Minimum representation time: 1 min
Maximum representation time: 5 min

[0126] In fig. 8B, a flow for the signalling of a red type alarm is instead represented, i.e. an alarm deriving from the second management phase of a signal from a peripheral AID unit. Having received the signal from the first sensors and having labelled it as a "yellow signal" and forwarded it to the synoptic for representation, the central control and management system starts the verification phase of the signal through the video signals coming from the second sensors and the relative video analysis. If the detection of a relevant event is confirmed, the signal is labelled as red, otherwise it remains labelled as "yellow signal". In the case of confirmation of the presence of a stationary vehicle:

- 1) The signal is forwarded to the synoptic panel, superimposing the yellow alarm representation with a red alarm (higher priority), terminating the yellow signal.
- 2) The live video streams of the cameras of the peripheral AID unit are forwarded for the pre-arranged cameras:

- a. In order to differentiate the alarm videos from the normal management video streams, the alarm videos have a graphic representation that distinguishes them as a red type alarm video stream (for example by means of a red frame representation and a special flashing danger icon)
- b. It is possible to represent more videos in the same monitor (pertaining to alarms of the other peripheral stations), for example by dividing the monitor into monitor quadrants: 2x2, 4x4;

- 3) The signalling is forwarded to the traffic management system of the operators of the area control room:

- a. The signal occurs through a special pop-up icon and acoustic signal
- b. The icon is clickable so that a confirmation can be input by the operator and/or to obtain active information, for example the site that generated the alarm, positioning, video recording, url address of the web interface of the SRC reporting for the visualisation of the details of the alarm.

[0127] In the case of a red signal and validation by the operator of the event, this is converted into an event that is obstructive to the opening of the dynamic lane.

[0128] The lay-bys are also monitored by means of an AID unit consisting exclusively of cameras and applying a dedicated video analysis system. The lay-bys are divided into two types:

- 1) SOS type lay-bys: lay-bys dedicated to emergency stops for users
- 2) Technical lay-bys: lay-bys for the exclusive use of authorised technical personnel.

[0129] The representation of the signals also occurs in this case by dividing signals of yellow and red type (or, alternatively, first level and second level signals) in the following way. Through video analysis the presence of a stationary vehicle is identified and a yellow type alarm is generated, representing the lay-by on the synoptic panel graphically

coloured yellow. The signal then becomes red if the presence of a stationary vehicle is detected for a maximum configurable time t1 or t2 respectively for SOS or technical type lay-bys. Once this maximum time has been exceeded, the signal becomes red, replacing the yellow type signal on the synoptic panel and the videos and signals are displayed to the traffic management system as described above.

II. Signals suggesting dynamic lane opening/closing

[0130] The representations regarding the suggestions for opening/closing are reported on 'information dashboards' dedicated to the synoptic panel of the dynamic lane and on the station of the area control room operator through integration with the traffic management system.

[0131] Figs. 9A and 9B show exemplary representations of information dashboards. The dashboards have the purpose of synthesising different information for each elementary semi-section that constitutes the entire section of the dynamic lane, differentiating them by roadway. By elementary semi-section is meant that roadway section where between the beginning and the end there are no exit or entry junctions that involve significant variations of the vehicular flow. Furthermore, by sub-segment is meant the minimum logical management section of the dynamic lane. For example, at a certain road position, both in one direction and in the opposite one, there is an exit/entry junction: for this reason, the relative information dashboards are 4, two for one direction and two for the opposite direction. The dashboards show the data visualised in terms of:

- Date/time of last update
- Direction of travel
- Relating position reference

[0132] The dashboards also represent the information on the current state of the dynamic lane and any suggestion for opening/closing (dark box at the bottom right of the arrow in fig. 9A).

1) If the dynamic lane is open: the dashboard relating to the semi-section must report the indication of the condition of the open dynamic lane. If the suggestion to close the dynamic lane is forwarded, this must be represented in the dashboard and is updated every minute.

2) If the dynamic lane is closed: the dashboard relating to the semi-section must report the indication of the condition of the closed dynamic lane. If the suggestion to open the dynamic lane is forwarded this must be represented in the dashboard and is updated every minute.

[0133] The suggestions for opening/closing the dynamic lane, in addition to being represented on the dashboard, are forwarded to the stations of the operators of the area control room and displayed through the traffic management system by means of a dedicated pop-up and acoustic signal.

III. Visualisation of traffic information

[0134] The representations regarding the traffic analyses are reported on the dashboards dedicated to the synoptic of the dynamic lane. For the representations of the traffic information, information summarising parameters must be present (see central part of the dashboards of figs. 9A and 9B) for each elementary semi-section that constitutes the entire section of the dynamic lane differentiating them by roadways. The types of information for the purpose of giving indications to the operators of the area control room are for example

- Equivalent vehicular flow of the last 5 minutes, 15 minutes and hour (the three numerical indications in the central area of the dashboard);
- Transits detected in terms of occupation of the maximum capacity of the semi-section (the value expressed numerically with 79% and with filling bars in fig. 9A);
- Trend of the vehicular flow on the basis of the data aggregated at 15 minutes (for example with symbology < = >);
- Service levels (LOS) of the semi-section (letter D in fig. 9A): since the elementary semi-section is subdivided into the sub-segments of the decision of the algorithm for suggesting opening/closing (a sub-segment: section between two bridge structures with LCS), for the purpose of a precautionary use/opening of the section the worst LOS is represented.

[0135] The traffic information is preferably aggregated and updated every minute for each elementary semi-section using the information from the peripheral sensors:

- RT sensors for counting the equivalent vehicular flow with classification: light, medium and heavy vehicles: aggregated flow and updated every minute of the station pertaining to the semi-section that has detected the highest number of transits (validated by checking the status of the sensors and settable threshold limits);
- Speed: aggregated harmonic mean speed over the sub-segment

[0136] Since the speed information is present for each sub-segment, it is displayed by means of special icons along the section for each sub-segment.

[0137] For the speed information, the following hierarchy is used: Radar sensor speed - Spotter speed - RT speed (depending on the availability of the data).

IV. Poor service signalling

[0138] The information relating to the degradation matrix is also represented in the respective information dashboards of the synoptic panel, for example the first icon on the left in fig. 9B.

[0139] From the degradation matrix, for example, three levels are identified:

Level 1 - System functioning

Level 2 - Degraded system: one or more apparatuses are detected to present malfunction and their poor service is not such as to jeopardise the functioning of the system

Level 3 - Degradation of one or more apparatuses for which the correct functioning of the dynamic lane is no longer guaranteed.

[0140] The degradation level is displayed for the entire time of the disrupted or poor service and updated only upon the solution of the problem.

[0141] In the case of service level 3, the degradation is represented on the synoptic panel and in the relative information dashboard and it is indicated on the synoptic panel which are the faulty apparatuses, for example with a red representation of the icon that depicts the apparatus itself. In this case, the suggestion to close the dynamic lane is also represented on the information dashboard.

[0142] In summary, an exemplary operating mode of the system according to the invention is as follows.

[0143] All the data acquired by the first, second and third sensors are sent to the central reporting system (SRC) capable of providing the area control room with functional services (alarms, traffic signals, traffic status, suggestion for opening the dynamic lane, suggested speed by vehicle category) and non-functional services (system and second-level peripheral diagnostics). All the data collected by the devices located on the road are stored on databases of respective analysis and control applications (Manager Server in fig. 3).

[0144] Before sending the suggestion signal for opening to the area control room and traffic management information system (SIRT) and then to the synoptic panel, the operating software of the central reporting system (SRC) implemented in the system of the invention carries out the analysis of any alarms generated by the AID units to ascertain the absence of blocking alarms (for example red) generated on the basis of the data deriving from the first Radar or Laser traffic sensors and confirmed by the video analysis obtained from the pan-and-tilt cameras of the second verification sensors. In case of absence of blocking alarms, or presence of only low-level alarms (for example yellow), a suggestion signal for opening is issued towards the area control room and traffic management information system (SIRT) (see fig. 10).

[0145] As mentioned, events identified by the AID units that can lead to the generation of blocking alarms (red) which therefore inhibit the opening of the dynamic lane are for example:

- Stationary vehicle;
- Wrong-way vehicle;
- Queue at the exit of a critical junction.

[0146] The events associated with the identification of stationary vehicles in the rest areas and service areas for technical personnel, detected by the sole video analysis of the specially positioned wide-angle cameras (fisheye TLC), are instead always associated with non-blocking type alarms.

[0147] At the same time, the traffic analysis is carried out on the data coming from the section sensors.

[0148] These informations are used by the central reporting system (SRC) to carry out a verification analysis for the presence of blocking type events, such that the use of the dynamic lane is not possible.

[0149] Once the absence of blocking events has been confirmed, the system creates the opening suggestion (CDA) event and displays the event to the area control room operator on the area control room and traffic management information system (SIRT), by means of a corresponding pop-up window with a relative confirmation button for confirming the clearing activity and a button for accepting the opening suggestion. A possible configuration provides, for example, that

the events to be displayed on the operator's console (monitor) are alarms relating to the AID units for the presence of stationary vehicles and/or queues and a suggestion for opening or closing the dynamic lane; while the events to be shown on the general synoptic panel (video wall) of the room may be the information relating to traffic and diagnostics, clustered in the information dashboards (one for each section of the dynamic lane in the two directions).

[0150] If the operator confirms the choice of opening, the system automatically provides for the change of configuration of the signalling apparatuses arranged in the vicinity of the dynamic lane and easily interpretable by the drivers who arrive with their respective vehicles.

[0151] The infographic on the synoptic panel will have an appearance similar to that represented in fig. 1, in which the fourth lane further to the right in each direction of travel - which corresponds to the dynamic lane - is open, as represented by the traffic light signals with a green check mark.

[0152] The signal to close the dynamic lane is forwarded to the area control room operator either in the form of a suggestion, in the case of a change in the conditions of the vehicular outflow detected by the analysis system, or in the form of signals of blocking type events on the area control room and traffic management information system (SIRT), including the blocking (red) type alarms of the AID unit.

[0153] In the case of a reduction in the congestion of the vehicular flow, such that it is no longer necessary to maintain the four-lane configuration, the suggestion signal for closing the dynamic lane is sent univocally. The signal is sent from the SRC system to the SIRT to then display the closing suggestion to the area control room operator through a special event on their display or on the synoptic panel.

[0154] In this situation, no particular checks are provided by the area control room operator and they are limited to a possible supervision via videostream of the traffic cameras. It always remains the faculty of the area control room operator to accept the suggestion to close the lane. Once the closure has been confirmed, the SRC system automatically provides for the change of configuration of the signalling apparatuses.

[0155] In the case of the presence of one or more blocking type events - i.e., events that entail the impossibility of using the dynamic lane - during a phase in which the dynamic lane is open, the system proceeds to re-configure the signalling apparatuses to determine the closure of the dynamic lane and bring the configuration of the road section to its basic configuration, for example three traffic lanes plus an emergency lane.

[0156] The transition phase is preferably managed in a differentiated manner. In the closing phase of the dynamic lane, an open condition is switched to a closed condition through a transitional phase - with a minimum duration (for example of 30 seconds) that depends on the reactivity of the signalling systems and the specific configuration of the road section - to give time to the vehicles that occupy the dynamic lane as a traffic lane to merge into the adjacent lane before the restoration of the use of the same as an emergency lane. The signalling associated with this dynamic lane passes from an opening signal (green check mark) to a closing signal (red cross) through a clearing signal (orange inclined arrow), as schematised in fig. 11. The reverse switch, i.e. from a closed lane to an open dynamic lane, does not instead provide for the use of a transitional phase.

[0157] As can be well understood from the description reported above, the system of the invention allows the requirements set forth in the premises to be satisfied. In particular, through an appropriately defined configuration, it is possible to generate automatic information, useful to the operators of the area control room to enable the opening/closing of the dynamic lane in a fast, simple and reliable way.

[0158] It is understood, however, that the invention should not be considered limited to the particular arrangements illustrated above, which constitute only illustrative embodiments thereof, but that various variants are possible, all within the reach of a person skilled in the art, without thereby departing from the scope of protection of the invention itself, as defined by the following claims.

Claims

1. A dynamic lane management system in a multi-lane road section, comprising

a plurality of detection sensors to detect transit vehicles, comprising at least first detection sensors,
an IT infrastructure that transfers signals from said detection sensors to an area control room manned by operators, wherein said signals from the detection sensors are converted into graphical representations on display devices,

a plurality of signalling apparatus placed in the vicinity of said multi-lane road section to display the open/close condition of said dynamic lane, said signalling apparatus being controlled by said area control room on the basis of said graphic representations, **characterized in that**

said plurality of sensors also comprises second verification sensors and third traffic sensors, and **in that** said first detection sensors are radio frequency radar or laser sensors in a fixed position in the vicinity of said road section, arranged to detect a vehicle event and issuing a vehicle event signal with positional information of said

vehicle event,
 said second verification sensors include pan-and-tilt video cameras capable of framing a variable position of said road section on the basis of said positional information of the vehicle event signal,
 said third sensors are radio frequency (RT) sensors arranged to detect a count, a classification and a speed of said transit vehicles,
 and further comprising a central reporting system (SRC), to process said signals of the first, second and third sensors and an area control room and traffic management information system (SIRT) of said graphical representations
 wherein at least said first and second sensors are connected to and controlled by a first control unit (AID) equipped with processing capabilities and arranged to

- generate a first alarm signal upon detection of said vehicle event signal from said first detection sensors,
- drive said second verification sensors to frame said variable position of said road section on the basis of said vehicle event signal,
- acquire video signals from said second verification sensors,

and wherein said central reporting system (SRC) is arranged to forward said first alarm signal and said video signal to said area control room and traffic management information system (SIRT) and to analyse said video signal to detect a confirmation of said vehicle event and to generate a second alarm signal to be forwarded to said area control room and traffic management information system (SIRT),
 and wherein said central reporting system (SRC) is arranged to calculate a vehicular flow, average speed and vehicular density based on said counts, classification and speed of transit vehicles detected by said third sensors and perform a predictive analysis over time to determine an expected traffic level,
 on said area control room and traffic management information system (SIRT) being represented a suggestion to open/close said dynamic lane on the basis of a status processing performed by said central reporting system (SRC) of at least said first alarm signal, said second alarm signal and said expected traffic level.

2. System as in claim 1, wherein a degradation analysis unit is also provided arranged to generate degradation level signals of at least said first, second and third sensors which are used in said status processing of the central reporting system (SRC).
3. System as in claim 1 or 2, wherein said predictive analysis over time is based on standard profile method or Dyna method and CTM model (Cell Transmission Model).
4. System as in claim 1, 2 or 3, wherein said second alarm signal prevents triggering a suggestion to open said dynamic lane.
5. System as in any one of the preceding claims, wherein said vehicle event is represented by:
 - stationary vehicle;
 - wrong-way vehicle;
 - queue on a critical junction.
6. System as in any one of the preceding claims, wherein said graphic representations on display devices are comprised of at least a plurality of display panels including pictographic images representative of said road section and video stream of said video signals.
7. System as in claim 6, wherein in any one of the preceding claims, said display panels also comprise information dashboards having symbology representative of said signals processed by said central reporting system (SRC).

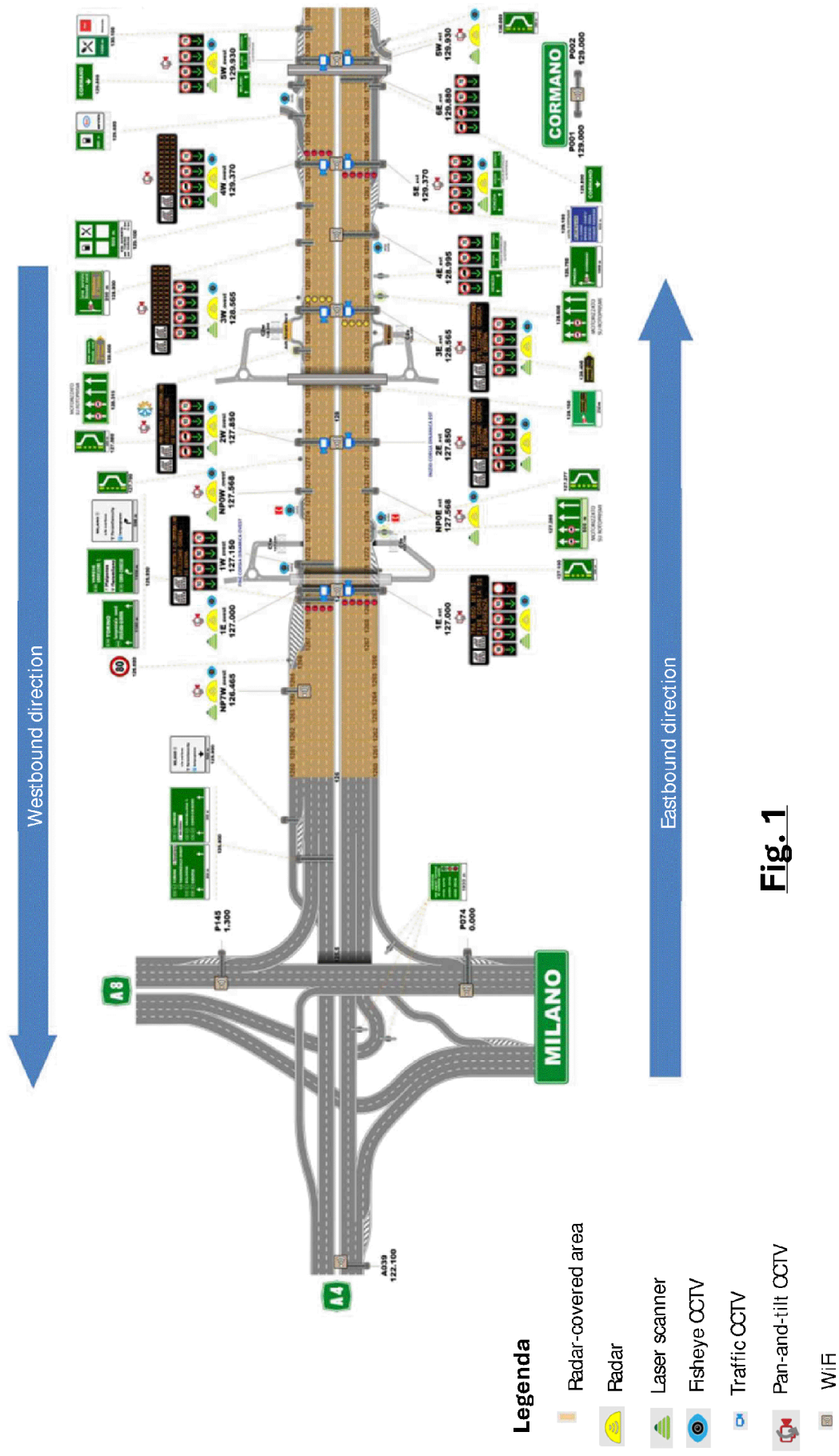


Fig. 1

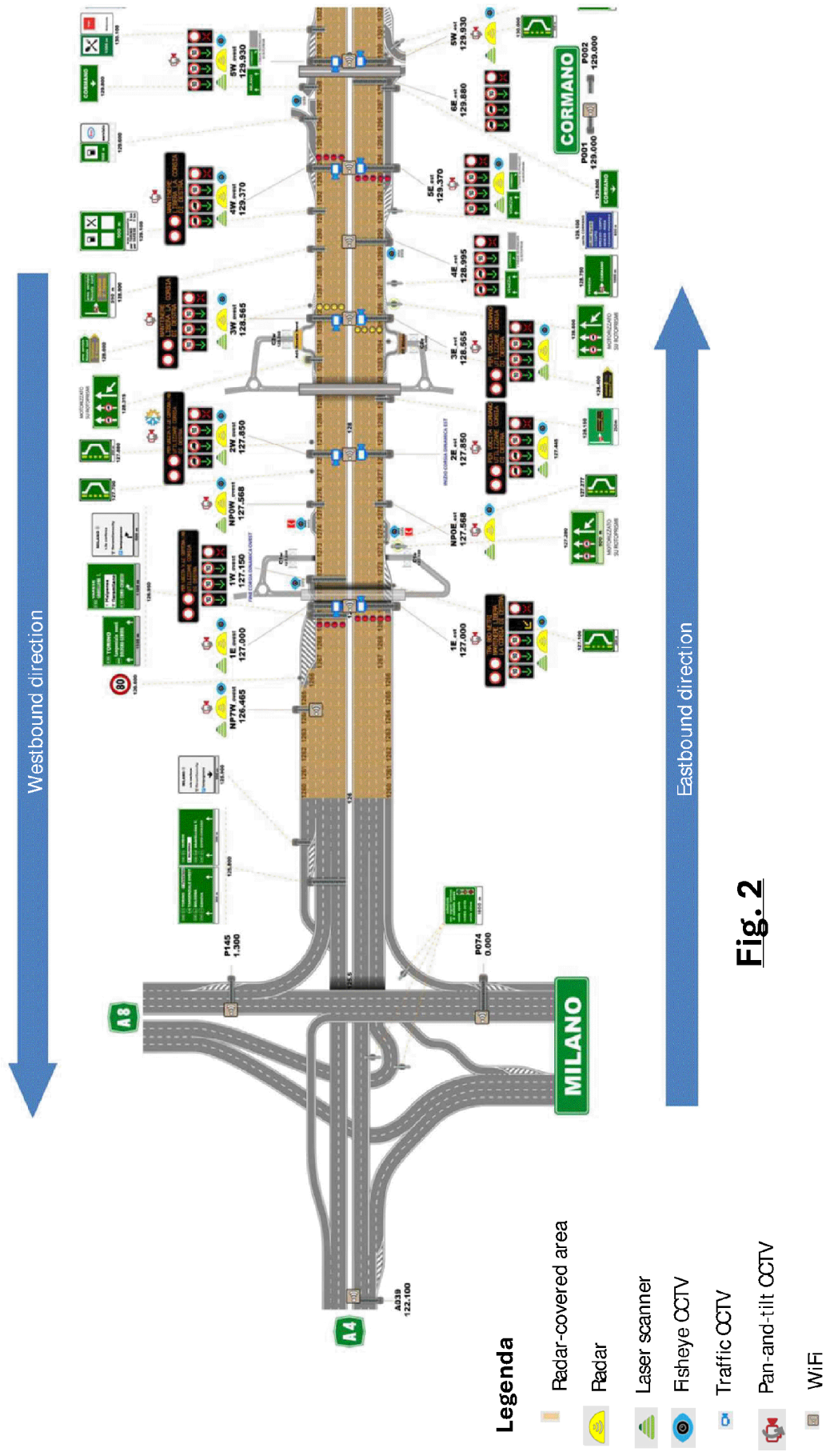


Fig. 2

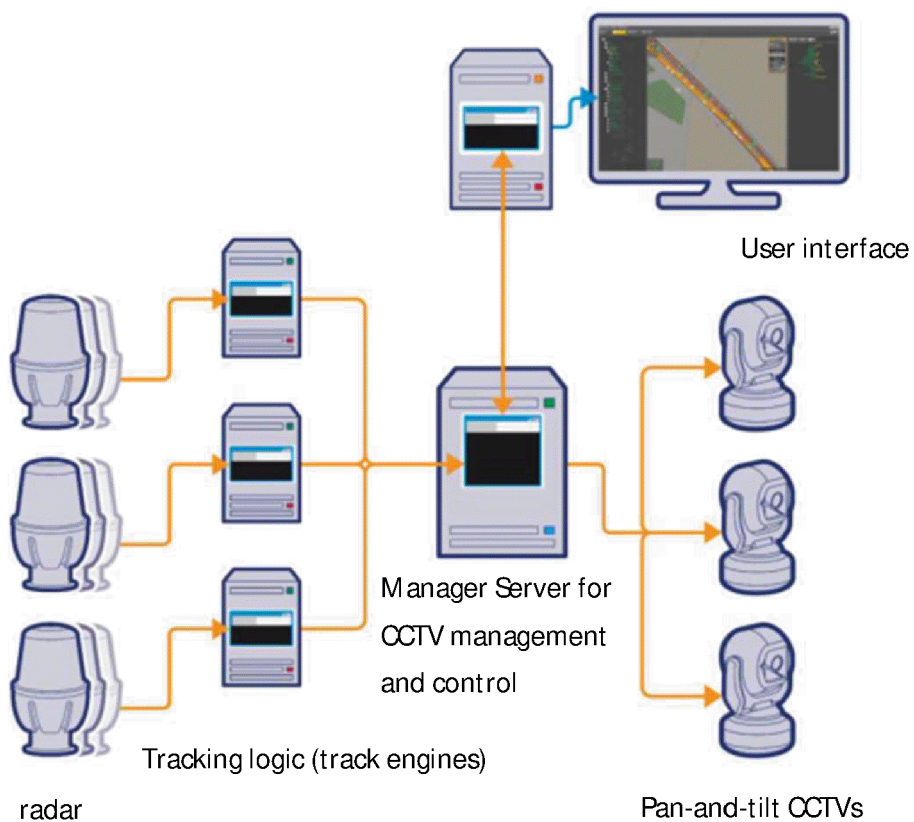


Fig. 3

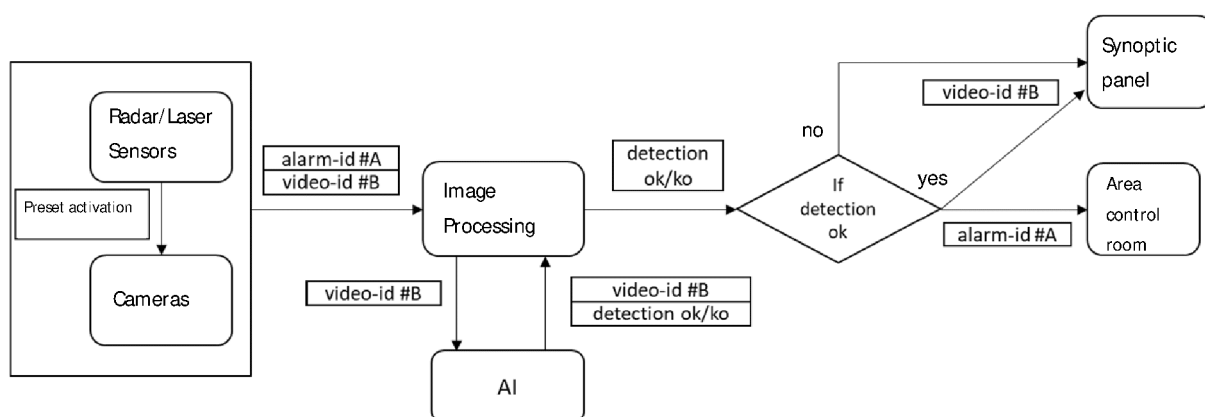


Fig. 4A

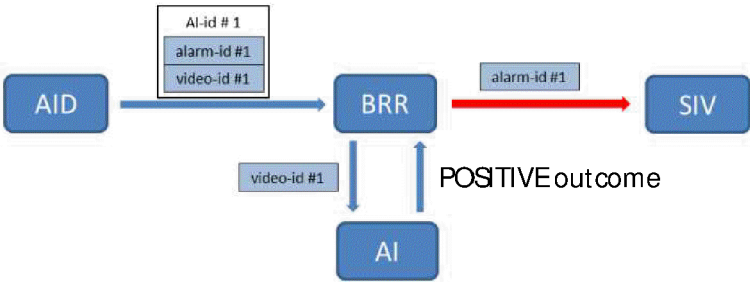


Fig. 4B

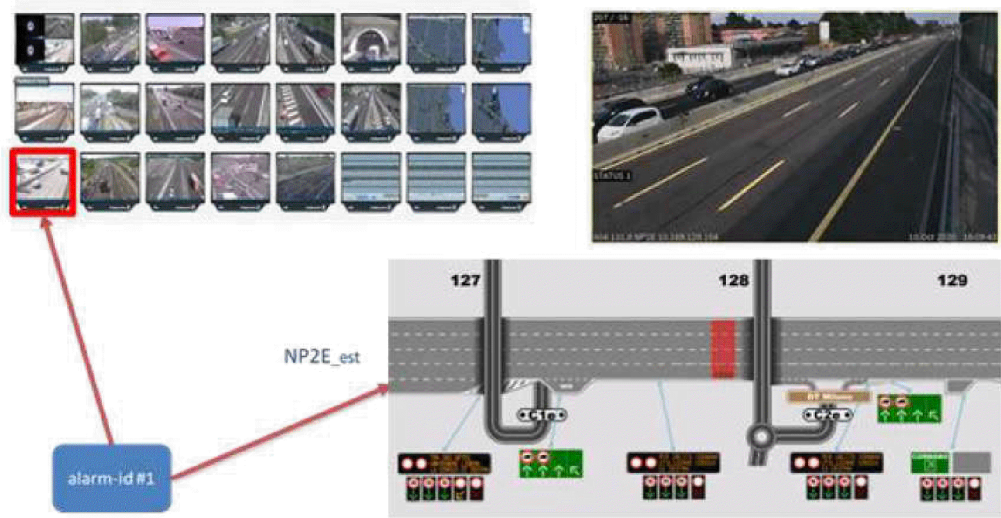
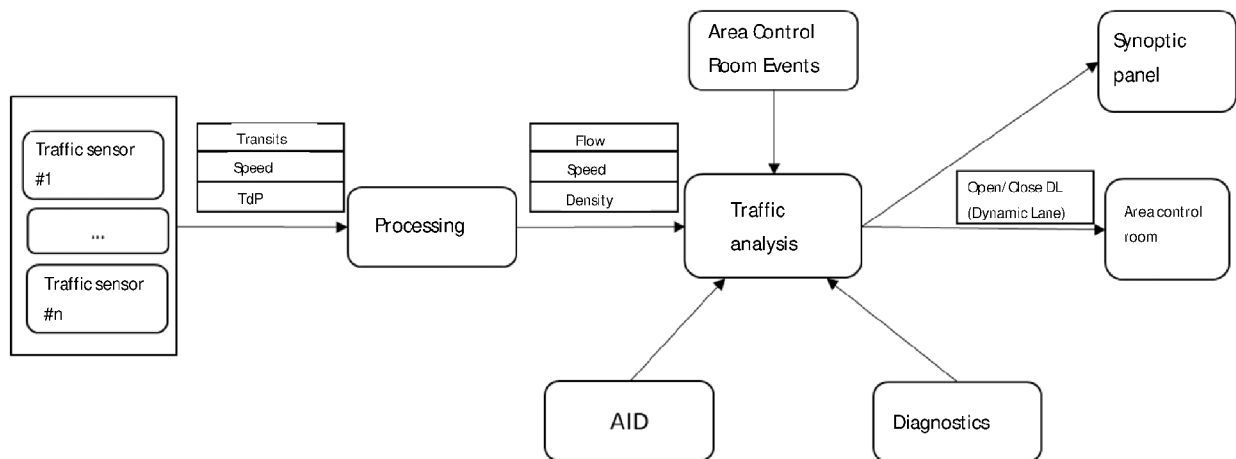
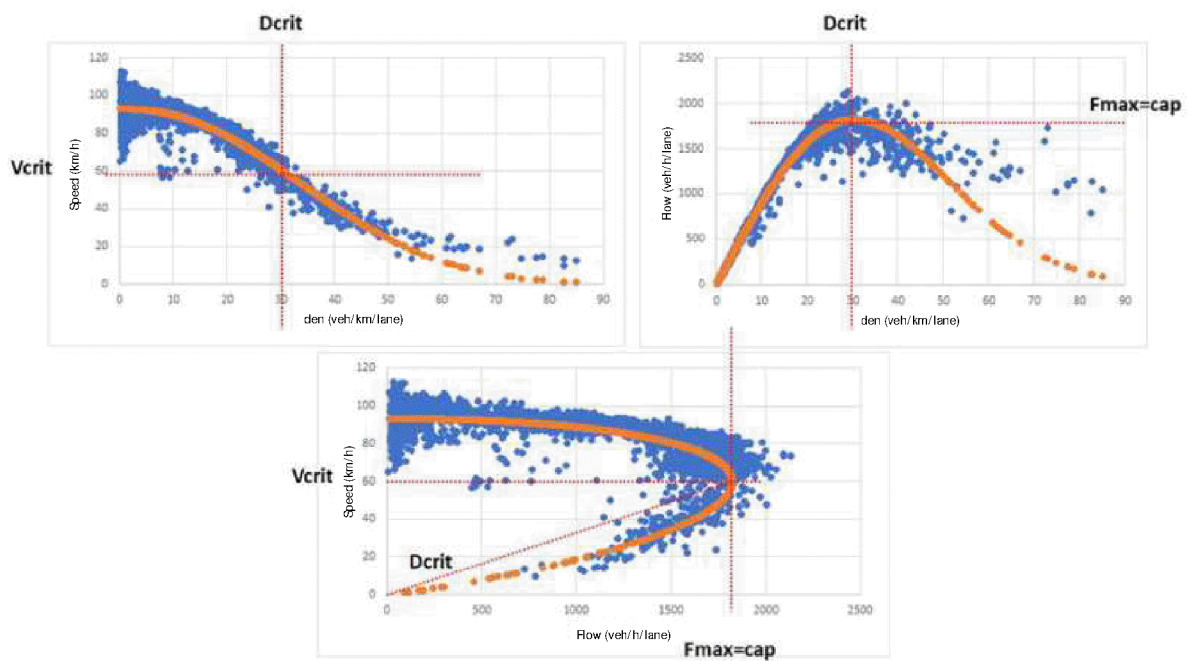


Fig. 4C

**Fig. 5****Fig. 6**

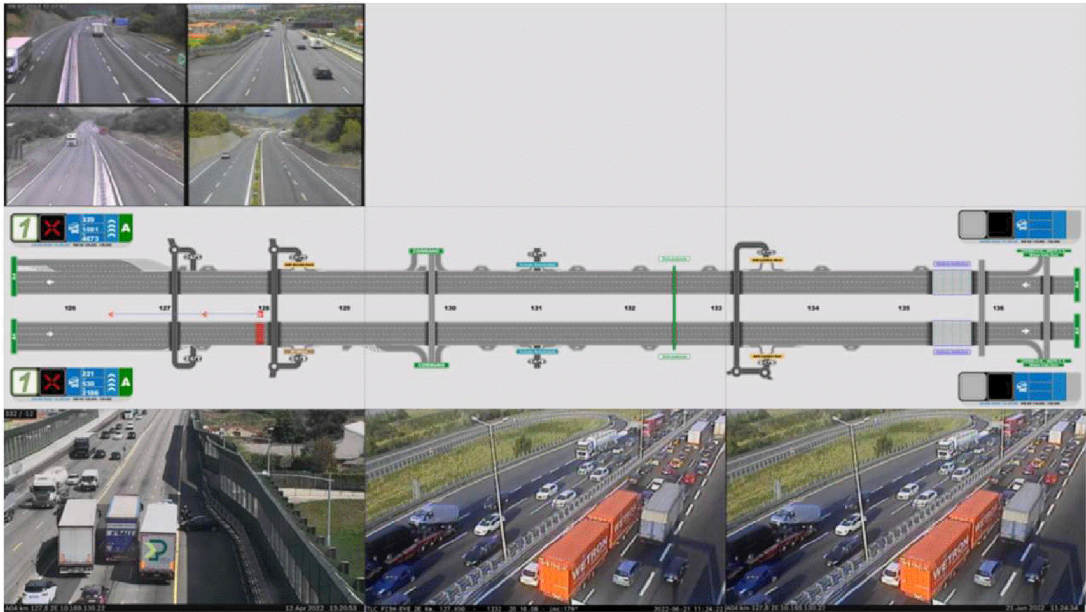


Fig. 7



Fig. 8A

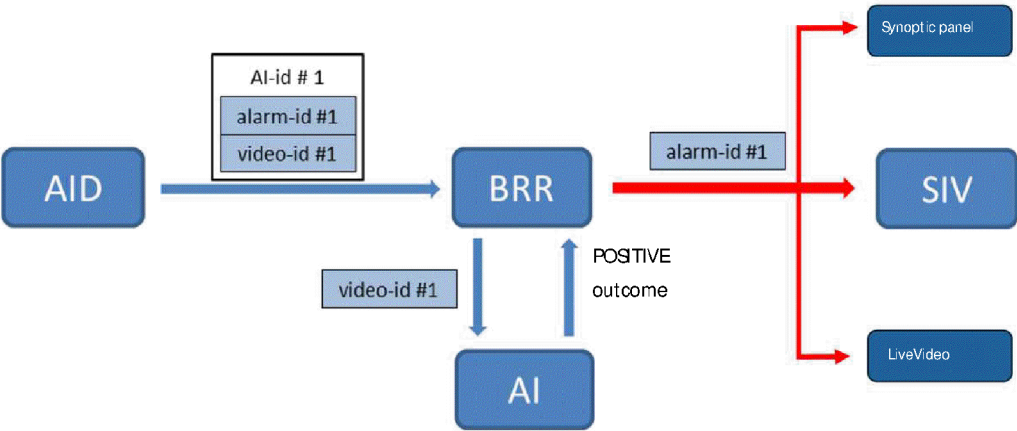


Fig. 8B

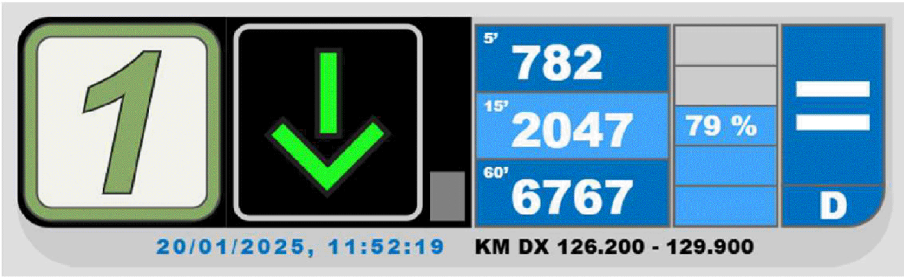


Fig. 9A

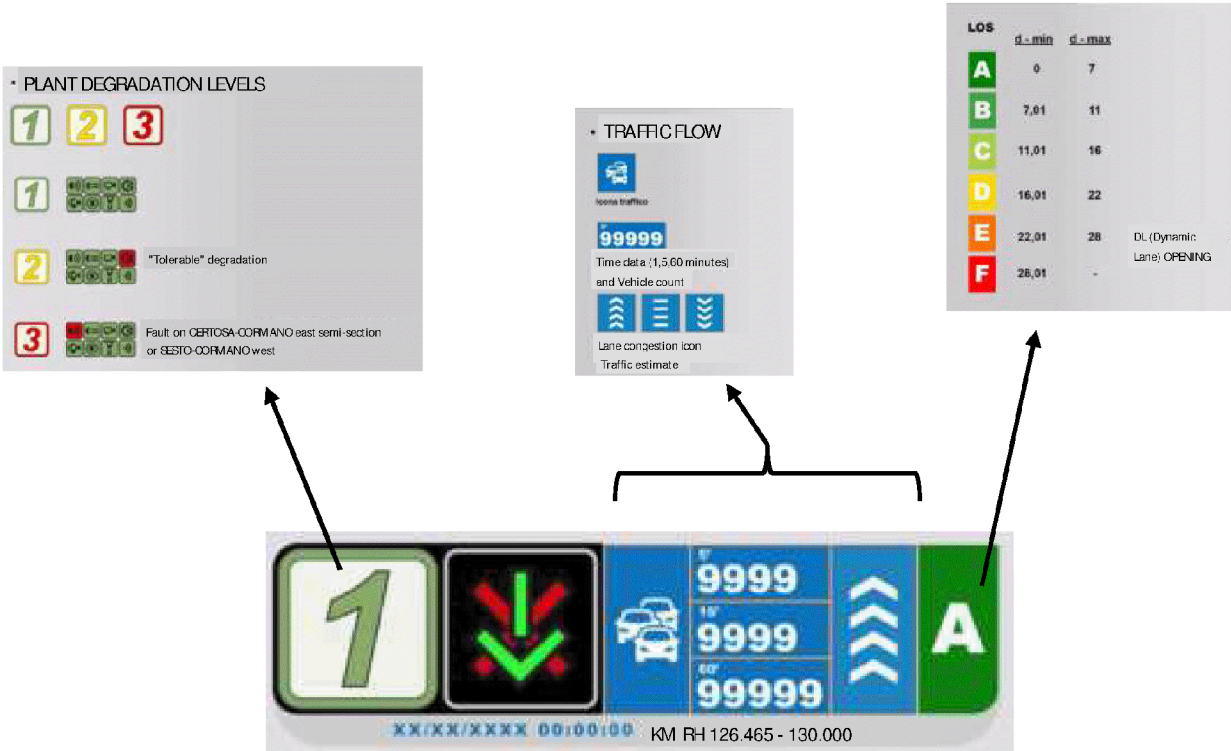


Fig. 9B

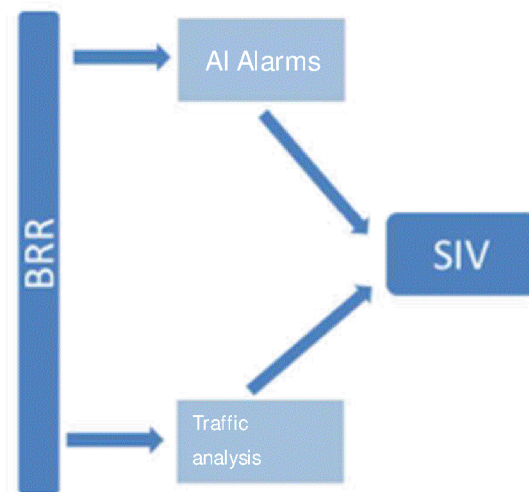


Fig. 10

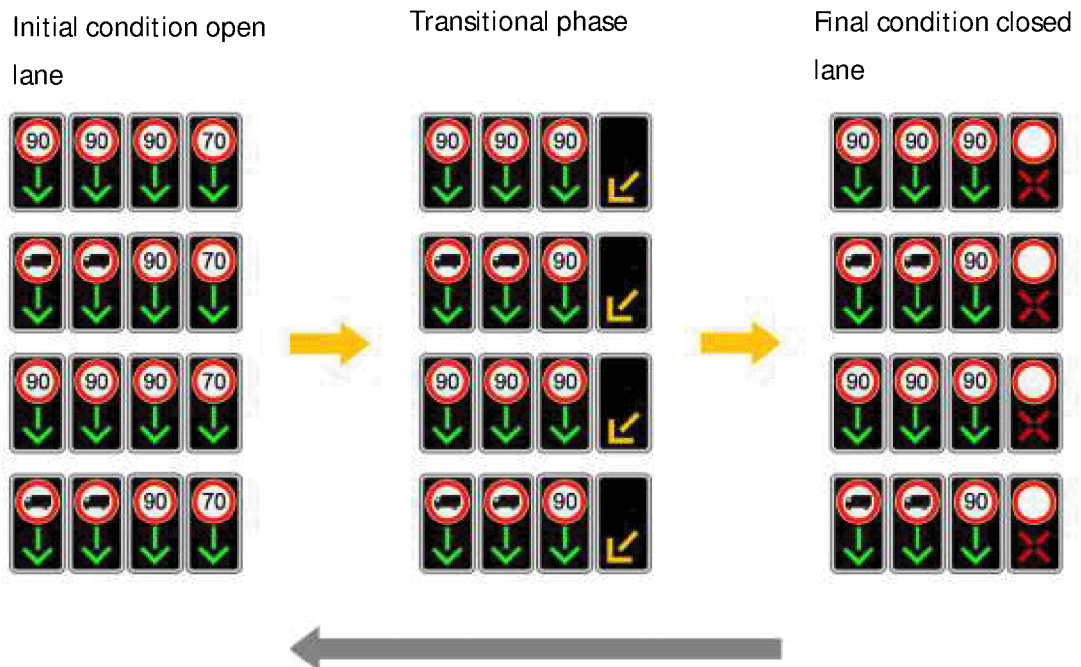


Fig. 11



EUROPEAN SEARCH REPORT

Application Number

EP 26 17 0247

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	AMPOUNTOLAS KONSTANTINOS ET AL: "Motorway Tidal Flow Lane Control", IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, IEEE, PISCATAWAY, NJ, USA, vol. 21, no. 4, 1 April 2020 (2020-04-01), pages 1687-1696, XP011780776, ISSN: 1524-9050, DOI: 10.1109/TITS.2019.2945910 [retrieved on 2020-03-27] * page 1688, left-hand column, paragraph 2 * * figures 1, 4, 5b, 5c * * page 1689, right-hand column, paragraph 3 * * page 1693, left-hand column, paragraph 1 * * page 1692, right-hand column, paragraph 3 * * page 1691, right-hand column, line 3 * * page 1689, left-hand column, paragraph 2 * * page 1688, right-hand column, paragraph 1 * -----	1-7	INV. G08G1/00
Y	Ogier Electronics: "Stopped Vehicle Detection (SVD) Demonstrating Radar Performance on Test Track", , 31 May 2022 (2022-05-31), pages 1-8, XP093324394, Retrieved from the Internet: URL:https://ogierelectronics.com/wp-content/uploads/2024/03/svr-500-case-study-nov-2021-track-day.pdf * the whole document * -----	1-7	TECHNICAL FIELDS SEARCHED (IPC) G08G
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		21 July 2026	Fernández Santiago
CATEGORY OF CITED DOCUMENTS			
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		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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REFERENCES CITED IN THE DESCRIPTION

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