Research Paper Medical Sciences

Localization of Vehicle in Tunnel Section As A Means of Improving Safety in Road Tunnels

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ABSTRACT

In road tunnels, safety is ensured by technical means (sensors, emergency exits), whose purpose is to help resolve dangerous situations. In case of emergency, people can escape from the dangerous areas through emergency exits, while the Tunnel Control Center (TCC) monitors the situation and triggers previously developed emergency scenarios to carry out controlled evacuation of all persons. This paper describes a proposal of extension of the existing evacuation systems with vehicle localization elements including monitoring the number of persons in given tunnel section with the aim of providing this information to the emergency services and enhancing the possibility of escaping from the tunnel safely.

KEYWORDS tunnel, vehicle localization, occupancy of the vehicle, RFID, Tunnel Control Center, OBU

INTRODUCTION

Creating the conditions for safe escape from a road tunnels in case of accident or fire is one of the basic prerequisites that must be taken into account during the tunnel construction (e.g. fire safety systems, emergency exits, deployment of sensors...). The emergency exits, designed according to the length and traffic capacity of the tunnel, must allow safe and timely evacuation of all persons. The duty of creating conditions for quick and safe evacuation of people is partially enforced by laws and other legislation of the Czech Republic.

The problem of safe escape from facilities has been subject of various studies (e.g. [3], [5], [6]), which mostly deal with the area of simulation of evacuation processes with estimated number of persons without any evidence of disabled persons. However, knowing the actual number of persons and disabled persons is, for the authors of this paper, very important when the evacuation is carried out.

Current technical equipment of tunnels allows determining neither the number of persons in vehicles nor their possible handicaps.

If the TCC provided emergency services with information on the number of persons, nature of their handicap and their current location, the services could target their intervention and help these persons.

EXTENSION OF EXISTING TUNNEL SYSTEMS

When resolving this task, it is necessary to determine the number of vehicles in given tunnel section, number of persons in vehicles and the number and character of disabled persons. The task also includes informing vehicle passengers on the emergency situation in the tunnel.

The structural levels are based on a three-level model:

Layer I: Vehicle

- Car Information System CIS

Layer II: Sensors and transmitters in the tunnel

- Input/Output Gate,
- Location System (LCS),
- Emergency exit sensors (person detection sensor, PDS)

Layer III: Tunnel Control Center:

- Control and supervision of the tunnel's technical equipment

SYSTEM ARCHITECTURE

A. Road tunnel scheme

The architectural design of the tunnel system consists of the following parts, see Fig. 1:

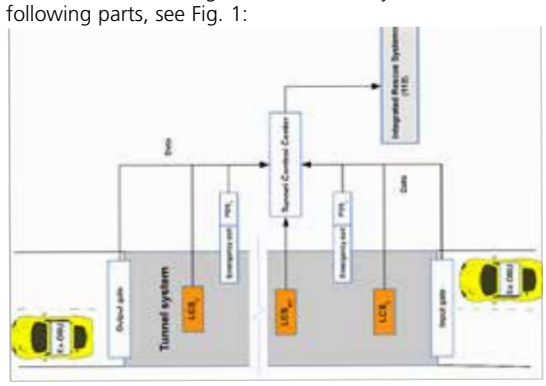


Figure 1: Architecture of the road tunnel localization system

1. Default Tunnel system
The existing equipment of tunnels includes the structure itself and its supervisory systems (Variable Message Signs (VMS), camera systems etc.).

2. Proposal: Extended Tunnel system
Input gate– each vehicle is registered upon entry to the tunnel system. Registration of entering vehicles shall be ensured by RFID technology (active transmitter in the vehicle), which transfers the following data from the Ex OBU (Extended On-Board Unit):

- Vehicle ID (IDV),
- Vehicle category,
- Current number of persons in the vehicle,
- Current number of disabled persons and type of their handicap.

The data are then transmitted to the TCC.

Vehicle – each vehicle must be equipped with an OBC (On-Board Computer), which includes the CIS (Car Information System). Furthermore, the vehicle must be equipped with a special Ex-OBU (Extended On-Board Unit). The data on the number of persons and disabled persons in the vehicle is primarily stored in the Ex OBU. IDV and vehicle category are transmitted to CIS. The data on the number of persons in the vehicle can be collected using various methods (e.g. by camera system in the vehicle, load sensors in the vehicle seats, indication of seat belt engagement etc.). This information is recorded without any active participation of the passengers.

The recorded number of disabled persons and type of the handicap is collected from the ID card (ID handicap - Fig. 2) containing medical information on given person. This card uses contactless short-distance RFID-based communication. The vehicle's Ex OBU contains and active RFID tag, which also serves for communication with LCS and I/O gate. The principle of this communication is shown in the following scheme on Fig. 2.

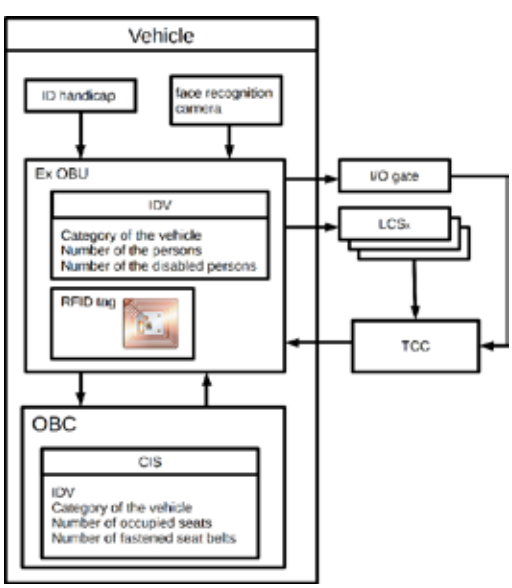


Figure 2: Scheme of communication within vehicle and between vehicle and external systems

Output gate – gate located at the exit from the tunnel transmits information on the vehicle to the TCC, where the vehicle is unregistered.

Location Control System, LCS – vehicle driving through the tunnel is tracked by the LCS system (by means of active RFID sensors). LCS detects the presence of vehicle in the monitored section of the tunnel. LCSs are located at half the distance between emergency exits in the ceiling of each traffic lane. Thus each emergency exit is located in the center of a monitored tunnel section. Vehicle localization is therefore not absolute; their positions are determined with respect to specific emergency exits. The deployment of LCS sensors in the tunnel system is shown in Fig. 1.

Person's Detection Sensor, PDS – each emergency exit is equipped with a laser person detector, which detects each escaping person. This detector is connected to the TCC information system.

Tunnel Control Center, TCC – the control center of the tunnel, which includes a data center; it collects and evaluates data collected from the first and second layer systems. At any moment, the TCC is able to provide information on the total number of persons, the number of disabled persons and type of the handicap, the number of vehicles in given section and number of persons that have escaped through emergency exits.

In case of emergency (accident, fire etc.), the TCC notifies the emergency services (Integrated Rescue System, 112) and provides them with real-time data. The TCC transmits, through RDS-TMC, information to the vehicle, which informs the driver through the Ex OBU. Furthermore, the TCC triggers the operational emergency scenario corresponding to the nature of emergency.

SYSTEM FUNCTIONS
The system brings two main advantages:
1. Localization and determination of number of persons trapped in the tunnel in case of an accident.
- The LCS registers passing vehicle, which only transmits its vehicle ID (IDV). This allows unequivocal determination of the position of each vehicle within given tunnel section (the vehicle is located between LCS_x and LCS_{x+1}). The number of persons is determined using the TCC information system.
- Monitoring of the traffic flow allows prediction of extraordinary events. If a vehicle passes through segment LCS_x but does not pass through segment LCS_{x+1} within an interval of at an average speed of, a Soft Alert is triggered.

$$t(IDV)_{x+1} = \frac{s_{x+1} - s_x}{v(IDV)} * k$$

$$\Delta t \notin \langle 0, t_{x+1} \rangle \Rightarrow \text{Soft Alert}$$

Where:– $k \in \langle 1, 3 \rangle$ – is the tolerance coefficient, which allows for changes in speed; its value depends on the technical equipment of the tunnel and is subject to further research.

IDV – vehicle identifier
$t\ (IDV)_{x+1}$– time of passage through given section
S_{x+1} -S_x– distance between LCS_{x+1} and
$\upsilon\ (IDV)$ – average speed of the vehicle in the tunnel
x– order number of the gate
$\Delta\ t$– maximum permissible passage time through a given section

In case a Soft Alert is triggered, it is verified; if it is evaluated as true alert, the TCC triggers the corresponding scenario.

2. The transfer of information from the TCC to the vehicle in case of an emergency event through RDS-TMC and Ex OBU informs the passengers on the current situation. This information consists of:
- Type of emergency
- Recommended reaction

i. STOP state (stay in the vehicle)
ii. RUN state (run to emergency exit)

The secondary effect of this information consists in influencing the psychological process, which shortens the interval of mental evaluation and reaction time of the persons in the vehicle. In case of fire, the duration of mental evaluation and reaction

is essential. At present, it takes approx. 150 seconds for the passengers to respond to an emergency situation ([7]), which results in high death rate.

Evaluation of Soft Alert

In case a Soft Alert is triggered, it is verified. The following points theoretically outline the scenarios of possible further development (Soft Alert withdrawal, alert trigger, alert trigger with notification of emergency services).

- Visual verification – the operator checks the cameras in given section.
- Testing of passage of following vehicles (it is subject of research), which passed after the vehicle that had triggered the Soft Alert:

a) In case the sensor LCS_{x+1} detects passage of all vehicles, it means that the vehicle in question slowed down considerably or stopped in the section between sensors LCS_x and LCS_{x+1} (it is necessary to distinguish vehicle stop in traffic/bay lane), or the vehicle continues to drive and a failure has occurred in some of the technical elements or in data transfer.

b) In case the sensor LCS_{x+1} does not detect passage of any of vehicles following after the vehicle in question, it means that the traffic flow has stopped. At the same time, Soft Alerts start to accumulate at sensor LCS_{x+1} and, gradually, at all preceding sensors.

c) In case the sensor LCS_{x+1} only detects passage of some of the vehicles.

- In case the vehicle in question passes through the gate, the Soft Alert is withdrawn LCS_{x+n}.

System reliability

The presented architecture of the localization system must ensure the maximum reliability possible. Another of our objective consists in and easy integration of the system with the existing infrastructure as well as utilization of the existing network elements to the maximum extent possible to ensure low operational/purchase costs and minimize the use of different technologies.

The reliability of vehicle localization in given section can be determined by:

- Correctness of previous vehicle localization
- Sensitivity/accuracy of sensors (LCS)
- Architecture of sensor deployment
- High vehicle speed
- HW (infrastructure) reliability
- External influences (smoke, fire etc.)
- Number of subject in the area of detection

CONCLUSION

Vehicle localization in given tunnel section represents an important contribution in terms of the tunnel's operational safety. Information on the number of persons and disabled persons represents added value that helps, in combination with accurate vehicle localization, to faster and better targeted response of the TCC operator to emergency situations. Another important advantage consists in the possibility of informing passengers in the vehicles on the emergency situation.

Knowledge of the number of persons and types of possible handicaps can be used not only in case of evacuation but also for summoning help by means of the eCall system. The eCall system is a current European Commission project, which enables quick help for car passengers involved in traffic accidents anywhere within the European Union territory.

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