AUTOMATIC INCIDENT DETECTION AND ALERTING IN TUNNELS

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ABSTRACT
A system for automatic incident detection and alerting in tunnels is presented. At the heart of the system is a multi-purpose detector, based on induction loops, which reliably detects incidents, whatever their origin, within seconds. As a result, valuable independent or assisted rescue time can be gained. This detector works in a hybrid fashion together with the video system of the tunnel control centre. In an alert case, the image of the tunnel section containing the incident is automatically switched to the alarm screen. The operating personnel are then able to precisely analyse the situation and initiate appropriate supporting measures. The process is tested and results presented.

Keywords: automatic incident detection, automatic alerting, multi-purpose detector

1. INTRODUCTION
It is impossible to avoid incidents occurring on the road network, this is true for tunnels as well. They are inherent to the system and occur unavoidably with known probability. Incidents can easily develop into minor accidents and extend right through to major catastrophes. The risk of this is particularly high in tunnels due to the design-inherent confined space. Unfortunately, history provides some examples.

Therefore, there is a requirement to accurately detect incidents at their onset from the point of view of the safety of the motorists in the tunnel. This permits timely initiation of countermeasures so that a severe or even uncontrollable accident situation cannot occur. If the incident situation is detected in the tunnel control centre within seconds, valuable time is gained to help motorists rescue themselves from an emergency situation. This time saving together with an appropriate incident location description also effectively supports the rescue efforts of the emergency services which have in the meantime been called to provide external support.

Modern-day tunnel control centres have a large number of screens which portray the traffic situation in the individual tunnel sections. Nevertheless, the operating personnel are not normally able to monitor all the screens at any time. If an incident occurs, this may cause a delay in reacting.

The following descriptions are concerned with the possibility of significantly reducing the workload of the operating personnel in the tunnel control centre by provision of reliable, automatic incident detection so that, should an incident occur, operator attention can be immediately drawn to the prevention of harmful accident consequences. Accordingly, the operating personnel are made aware of incidents in the traffic flow in tunnel sections in a targeted and automatic way using alarm screens. Visual analysis of the incident can start immediately and assistance and/or emergency measures appropriate to the situation can be initiated. Consequently, rescue time is gained and tunnel safety is decisively increased.

It is known that automatic digital image processing is operating at the limits of its capabilities in the ambient visual conditions that obtain in tunnels which, dependent on the set decision making thresholds may result in false alerts or missed alerts. These considerably lower the acceptance of such systems.
In the following, this situation is remedied by the presentation of a new, hybrid-type system. Automatic alert generation is achieved using a system with induction loop sensors, while manual analysis of the incident situation or incident cause is carried out by operators via the video alarm screens.

2. AUTOMATIC INCIDENT DETECTION PRINCIPLE

2.1. Requirements

A practical solution for automatic incident detection must fulfil a whole series of requirements. Thus the system should reliably generate an alert within 30 seconds for any incident that occurs. Missed alerts must not occur, they hinder preventative measures in the event of an incident and therefore favour development into an accident situation. False alerts must be reduced to a minimum to guarantee continued operator acceptance of the system.

From a system technology viewpoint, this means that the incident detection sensors must always work reliably independently of the constructional, traffic or any other ambient situation obtaining in the tunnel. They must be capable of automatically detecting any type of incident having an effect on motorist safety.

2.2. Incident causes

In a tunnel, there is a wide range of causes of the above named incidents. For example, the cause may be a stationary vehicle or one that is driving conspicuously slowly. This may breakdown, catch fire or become involved in an accident. However incidents may also be caused by shed loads or pedestrians on the carriageway. Visual impairments such as smoke, dust and snow flurries or blinding caused by reflections may also act as triggers, as can a smooth road surface caused by an oil spill or ice. Motorists driving against the traffic flow are a particularly dangerous incident cause. There are many other causes.

2.3. Multi-purpose detector

It would be very expensive, if not technically impossible to provide and operate a dedicated tunnel sensor for every different type of incident cause as well as to obtain an automatic alert from a combination of the sensors in a detector.

Therefore, a multipurpose sensor is suggested, which can detect any cause having an effect on the safety of motorists in the tunnel.

The principle behind this sensor is the awareness that, in all the above named incidents, there is a direct effect on the driving behaviour of the motorists in the vicinity of the cause of the incident. Thus for example, a vehicle which is following a damaged vehicle, will attempt not to become involved in an accident and will thus correspondingly reduce its speed, or even stop, or change lanes to avoid the danger situation. The following vehicles will also behave in a similar manner. Likewise, this applies to any other incident causes. The common factor to all these manoeuvres is that the vehicles affected will suffer an increase in travel time. These travel time increases are therefore a reliable indicator of an incident of any type. Moreover, they have the system advantage that generally they point to incidents as they develop, i.e. before they actually manifest themselves.

The multipurpose detector detects these travel time losses and immediately generates the alert. The operators are now able to analyse in detail the situation on alarm screens of the incident cause in the disturbed tunnel section and initiate appropriate assistance measures in plenty of time.

Based on knowledge of the vehicles currently located in the respective tunnel section, an indication of the possible fire load can be generated.
2.4. Principle of the multipurpose sensor

The multipurpose detector works with the induction loop sensor in the carriageway in accordance with the RABT (German directive for Equipping and Operating Road Tunnels). The advantage of this sensor is that it always works correctly and reliably independent of the ambient and/or traffic conditions. Impairments caused by a lack of visibility, covering or poor differentiation between objects as occur with optical sensors, do not exist.

The multipurpose sensor works in accordance with the MAVE® principle. This is based on a correlation measurement procedure, which is a development of the MAVE®-S method adapted for use in tunnels. MAVE®-S has been successfully used on the long-distance road network for many years to measure travel time and traffic density. The vehicle sequences at the entrance and exit of a particular tunnel measuring section are continuously, automatically measured using the induction loop sensor and compared with each other (correlation). The multipurpose sensor can automatically detect a "stationary vehicle" or “abnormally slow vehicle” as well as the number of vehicles in the measuring section from the result of the comparison. Moreover, motorists travelling against the traffic flow, local slow motorists as well as vehicle type (passenger car, heavy goods vehicle, etc.) are determined from local analysis.

2.5. Length of the tunnel sections and reaction time

The length of the tunnel sections can be selected according to measurement technology parameters within wide limits. Thus the system has, as described below, been successfully tested with section lengths between 300 and 1300 m.

Based on traffic safety requirements within the tunnel, the length of the section must not however be chosen to be too large, as the section length has a direct influence on the system reaction time. This arises from the fact that the most important measurement is the significant deviation of the actual travel time from the normal travel time. A measurement is significant, if the time for a vehicle to exit from a particular measuring section is significantly greater than its expected travel time. What “significant” means, in particular, can be parameterised.

The reaction time of the system to an incident is dependent on its location within the tunnel section. If the incident is close to the entrance to the tunnel section, then theoretically a minimum reaction time elapses near to the normal travel time, by contrast if it is at the end of the tunnel section, then this minimum reaction time reduces towards zero. In a practical implementation of the system, a parameterisable verification interval of a few seconds is added to the minimum reaction time. The purpose of this is to ensure triggering of an alert and avoid missed alerts. In this way, significant travel time deviations always lead to an alert, correspondingly missed alerts are avoided.

The specification of the RABT directive for installation of measuring sections with induction loops every 300 m gives a sufficiently good reaction time to incidents at any location within the tunnel section. The expected travel time over 300 m at a speed of 80 km/h is 13.5 s, at a speed of 60 km/h, 18 s. Taking into account a suitable verification interval, alerting to an incident can reliably take place within 30 s.

Independent of the above named approach, motorists driving the wrong way are immediately detected when they arrive at the measurement location and an alert triggered accordingly.

2.6. Award

The described multipurpose detector is a central component of the MAVE®-tun system, which automatically detects incidents in tunnels and generates alerts accordingly. This system was recommended by an international expert jury for the innovation award at the international transport fair, Intertraffic 2006, in Amsterdam.
3. RESULTS

3.1. Rennsteig tunnel, A71, Germany

Within the framework of a test installation in the above named Rennsteig tunnel, proof was generated on 26.08.2003 that the measurement procedure MAVE®-tun directly and reliably detected incident-threatening characteristics in the traffic flow within tunnel sections. In particular, a “stationary vehicle” within the traffic was detected as were also abnormal traffic conditions, e.g. caused by particularly slow vehicles, etc.

The tests and checking of the results was carried out by RWTH Aachen University. The results are were published in issue 925 of “Forschung Straßenbau und Straßenverkehrstechnik”, page 91. The procedure is described in the article under the identification SDS 1.

The tunnel section was in a tube with 2 lanes of traffic travelling in the same direction. It had a length of approx. 300m. 12 different scenarios were implemented with stationary and slow-travelling heavy goods vehicles and passenger cars in normal traffic conditions.

All incidents were correctly detected within a maximum of 17 s. There were no missed and no false alerts.

3.2. Elbe tunnel, A7, Germany

Within the framework of a test installation proof was generated between 31.03. – 07.04.07 in the above named Elbe tunnel, that the measurement procedure MAVE®-tun directly and reliably detected incident-threatening characteristics in the traffic flow within tunnel sections. In particular, stationary vehicles were detected as well as abnormal traffic conditions, e.g. caused by particularly slow vehicles, etc.

The test involved 2 sequential tunnel sections. One tunnel section was approx. 300 m long, the other approx. 600 m. The tunnel sections were in a tube with 2 lanes of traffic travelling in the same direction. No scenarios were implemented, rather the normal traffic flow was analysed using the test system and recorded for checking purposes in parallel with video recordings in the tunnel control centre.

Various incidents with stationary passenger cars and heavy goods vehicles occurred. The test phase and checking of the recordings and results was carried out by the tunnel operator. All incidents were correctly detected within a maximum of 30 s. There were no false or missed alerts.

3.3. Felbertauern tunnel, B108, Austria

The described procedure for incident detection in tunnels has been underway since January 2006 in a first expansion stage under controlled operation in the above named Felbertauern tunnel. The purpose is to continuously count the actual number of vehicles in the individual tunnel sections, differentiated between heavy goods vehicles and passenger cars, and to measure the travel time.

The tunnel comprises one tube, which is generally operated with opposing traffic flows. The installation encompasses the entire tunnel in both traffic directions. Each traffic direction comprises 5 measuring sections. Each section length is approx. 1300 m.

Testing is carried out by the operator. The number of vehicles and the travel speed are accurately measured.
In addition to the above named control installation, the capability of the described procedure for generating alerts in an incident case was tested in the Felbertauern tunnel. This took place mainly between 21.01 – 17.02.2008.

The test took place in a tunnel section of approx. 450 m length in both traffic directions. The test procedure incorporated the normal traffic flow within the tunnel. In addition, the operator implemented scenarios with stationary and slowly moving vehicles as well as with vehicles driving against the traffic flow.

The operator checked the results with the help of his video system in the tunnel control centre. All incidents were correctly detected within a maximum of 30 s; vehicles driving against the traffic flow were detected immediately. No false or missed alerts were detected.

4. REFERENCES


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