Road tunnel operation and simulation

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Abstract

Overall safety of road tunnels depends on the mode of operation also. Correct selection of traffic-operation state is very important to successfully solution process of whole emergency event/incident. Tunnel Traffic & Operation Simulator was built at University of Žilina to create possibilities for simulating various tunnel incidents. Manual control module is also a part of Simulator. Evidence of tunnel incidents is important for statistical evaluation of tunnel safety and determination of eventual risk incidents with the high probability.

1. Project of European regional development fund (ERDF)

Tunnel Traffic & Operation Simulator (hereinafter referred to as Simulator) is the main partial result of the project Centre of Transport Research. The applicant of this project was Transport Research Institute, J.S.C. from Žilina, Slovakia and University of Žilina represented by Faculty of Civil Engineering, mainly the staff of Department of Construction Management, was just one partner. Specific purpose No. 1, under the auspices of University of Žilina, was applied research of new technologies to increase operational safety of road tunnels. This new technology we are referring to Simulator. Objectives of workplace Simulator are mainly:

- prepare the data and the data collection for the creation of prediction models,
- regularly check and verify the operators responses on simulated incidents,

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create a space to test different scenarios without direct links to the tunnel technology and with the possibility to connect to existing tunnels of administrative authority.

2. Simulator

Simulator is developed in terms of functionality based on real control algorithms used for management of existing tunnels. Simulations of incidents, which are rare in the real tunnel traffic, are possible to simulate with the aim of verification of correctness and philosophy of management. Visualizations of tunnel management are same as on the real operator workplace twin-tube tunnel. In contrast to real traffic, simulation of video surveillance shows a virtual traffic in the tunnel tubes and before them. As most of operator workstations also operator workstation of simulator is implemented to operate the tunnel by two operators. First operator is managing tunnel traffic system and the second operator is managing tunnel technology equipment. Their work is changeable, so it means that the traffic operator can manage technology and reversely. Of course one operator can control entire tunnel. Always be carried out the recordings of faults, incidents, responses and interventions of CCS and operator.

This simulation workstation for road tunnel control and operation is realized as a real tunnel control centre of virtual 1 km long two tube highway tunnel with unidirectional traffic. Technological equipment of virtual tunnel is in accordance with the Slovak Government Regulation No. 344/2006 on minimum safety requirements for tunnels in the road network and National technical directives for Fire safety in road tunnels, Road tunnel ventilation, etc. The basis for [1] is Directive 2004/54/EC of the European Parliament and of the Council of 29 April 2004 on minimum safety requirements for tunnels in the trans-European road network of over 500 m in length. The device (Simulator) also fully respects the requirements arising from National technical directive 09/2008 Equipment, infrastructure and systems of technological equipment of roads.

Basic composition of the Simulator consists of follow parts:
1. central control system – part of automatic tunnel equipment control,
2. manual control module – part of manual control (separated module),
3. software for prediction of phenomena (EMUT) - evidence of tunnel incidents.

2.1. Central control system of Simulator

Generally, an automatic control of tunnel technology equipment is in central control system divided into 3 main levels presented in Fig.1.

![Fig. 1. Main levels of automatic control.](image)

CCS simulates the operation of the twin-tube highway tunnel with a length of about 1000 m with connections to contiguous crossroads. CCS has following main parts, particularly shown in Fig. 2:
1. operator workstation,
- workstation of coordinator,
- simulation of tunnel CCS,
- simulation of video surveillance,
- simulation of voice communication.

Two large LED panels installed on the wall serve to visualization of longitudinal section of tunnel tubes with technological equipment (Fig. 3):
- measuring and detection equipment,
- fire safety equipment,
- sources of power,
- alternative sources of power,
- ventilation system of tunnel tubes and cross connections,
- tunnel lighting,
- evacuation guidance lighting,
- tunnel reflexes,
- and others.
Under the LED panels there are three LCD monitors for simulation of video surveillance (Fig. 4). All monitors serve for visual display of optional view of virtual traffic surveillance cameras. First monitor from the left side is used also like an alarm monitor what means, that in case of any alarm detection, the corresponding view of the camera is shown at this monitor. Third monitor is divided into four parts and two of them show a view of the cameras sequentially for each tunnel tube separately.

![Fig. 3. Detail of left LED panel from the wall of simulator control system.](image)

**2.1.1. Workstation of coordinator**

Workplace of coordinator consists of two basic modules:
- module of technological tunnel equipment,
- module of 3D simulation of video surveillance.

Coordinator can simulate a lot of main incidents and their combinations with faults of technological devices, for example:
- pedestrian or animal in tunnel,
- breakdown of vehicle,
- lost cargo,
- vehicle in bad direction,
- accident of vehicles (Fig. 5),
- fire after the accident,
- fire of the lost cargo (Fig. 5),
- stopped bus (Fig. 5),
- demonstration,
- terrorist attack,
- intervention of emergency rescue services (Fig. 5),
- etc.

![Fig. 5. Selected simulations of incidents.](image)

### 2.1.2. Workstation of operator

Tunnel control center of Simulator has two position for operators. Each operator has three monitors on which can choose the visualization of three from seven screens in same time:

- traffic management in the tunnel,
- adjacent section of traffic management before the west portal,
- adjacent section of traffic management before the eastern portal,
- ventilation, lighting and measurement of physical quantities (Fig. 6),
- safety,
- power supply – west,
- power supply – east.
There are available other typical elements of real tunnel control center equipment:
- microphone for simulation of announcements to evacuation broadcasting,
- telephone for internal simulation of connection with integrated rescue services, emergency stations, tunnel personnel, safety officer and other responsible people,
- recording device.

2.2. Manual Control Module (MCM)

Manual control module (MCM) is autonomous functional device (Fig. 7) that is used by tunnel specialists as an example of hardware solution of automatic process managing road tunnel technological entities. Configuration of MCM system management comes out from real structure of automatic machine which is used for managing of real road tunnels and highways under the administration of National Motorway Company. Configuration consists of simplified versions of familiarly used communication levels and architectures. Automatic control of technology by CCS is divided to three main levels:
- directive - net of data collection from input/output interfaces which complete managing PLC automatic machines (Programmable Logic Controller) and ensure functional technology managing,
- procedural – net of communication on the level of managed automatic machines; ensures transformation of technological device conditions into the electrical form,
- visualization – visualization net determined to ensure connection of human operator with managed technology.

Manual control module has follow parts:
- variable traffic sign,
- lamella traffic sign,
- traffic lights,
- free-standing distribution box,
- software for managing tunnel technological devices by touch panel.
2.3. Evidence of tunnel incidents

Evidence is carried out in order to increase operational safety of road tunnels in accordance with tunnel’s incident sheets that contain a detailed description of incidents [3]. EMUT allows data classification, creation of graphs and statistically assessment. EMUT can be used for planning purposes and assessment of safety level in combination with other methods of evaluation (e.g. risk analysis, DG-QRAM).

![Incident rate of middle unidirectional tunnel by years](image)

Fig. 8. Overview of the number of operator interventions according to type of incident [4].
Fig. 8 is presenting an overview of numbers of operator interventions due to incidents which has happened in one Slovak road tunnel in the period from December 2009 to December 2014. It is apparent that the failures of technology rapidly increased in the last 2 years. Because of this malfunctions, operators of the tunnel had to reduce traffic (in tunnel tube or in whole tunnel) and tunnel users what is not good for entire tunnel safety.

3. Conclusions

Changes of the traffic-operation states and other equipment are reflecting at the simulated traffic, as well as simulations of various emergency events in traffic initiate changes in tunnel detecting and measuring devices. It is thus possible to simulate emergency states, which can be affected by various faults of technology as well as by climatic conditions. The results are in irreplaceable experiences of Slovak road tunnel operators, changes of traffic-operation states, visualizations of operator technological display screens, technological devices labelling in order to increase operational safety of road tunnels.

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