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Tunnel safety: a growing issue in an increasingly urbanized world

By Christof Maas, Product Manager Intelligent Video, Siemens Building Technologies

Tunnels are becoming an ever more common feature in the world's critical infrastructure. As urbanization accelerates, with more than half of the earth's population living in cities, the pressure on open space to accommodate inter-urban systems will only become greater. Tunnels, both above and below ground, can be a more efficient way of building road, rail and MRT (Mass Rapid Transport) networks. But they offer their own specific challenges in safety terms. Adopting measures which will prevent loss of life, minimize damage in the event of an incident and keep open these arteries which play a pivotal role in the modern economy is therefore fundamental.

The prime concern in tunnel safety is the potential for heavy loss of life. There are a number of incidents that have focused attention on fire: 1995 Baku Subway, Azerbaijan – 289 dead; 1999 Mont Blanc, Italy – 39 dead; 1999 Tauern, Austria – 12 dead; 2000 Kaprun, Austria – 155 dead; 2001, St Gotthard, Switzerland – 11 dead. This threat is not only confined to road tunnels. The Swiss Federal Office of Transport looked at the safety of rail tunnels and found that 110 out of 689 had safety problems.

Even when fire does not result in deaths, the damage can cost millions and lead to severe disruption and consequential losses. Following the fire in September 2000 at the Channel Tunnel linking England and France, the third closure due to fire in the tunnel's history, full service was not resumed until February 2009 after repairs costing an estimated 60 million Euros. In addition to the heavy loss of life, the estimated cost to the Italian economy of the three-year Mont Blanc Tunnel closure was 2.5 billion US-Dollars, while the cost of upgrading was 300 million. Though the occurrences of accidents and other dangerous events may be relatively low in tunnels, any fire may prove difficult to control and this can lead to catastrophic consequences.

An integrated approach to operational risks

Tunnel safety reflects other safety scenarios in that it is based on operational risk management. A number of different factors can present risks in a tunnel environment so integrated solutions are commonly employed which provide the capacity to monitor and detect a range of events. At the heart of these systems is video surveillance which has become more advanced with the introduction of video analytics. One of the issues with video detection is that manual monitoring by operatives is not sufficient. Research studies show that after 12 minutes of viewing two or more monitors, up to 45 percent of the activities are missed, increasing to up to 95 percent of incidents after 22 minutes.

The adoption of IP-based technology and the introduction of intelligent algorithms in the systems has automated much of the detection process, taking the emphasis away from the human operator to spot incidents. With digital technology has come the trend towards using common interfaces for ease of integration, allowing different modules to be 'plugged in' to the main management system. In tunnels, integrated video surveillance is now used to detect a wide range of different scenarios and events, including smoke, stopped vehicles, slow vehicles, traffic queues, vehicles traveling the wrong way, fallen objects, pedestrians and vehicles stopped at emergency niches. All are potential threats to the safety of the tunnel and to those traveling through. They illustrate that in tunnels, as in many other applications, the definition between fire and security is becoming blurred as they are increasingly integrated into a general safety based approach. There is also an increased demand to make this traffic data publicly available on the internet. One possibility would be to synchronise the status messages with the Google Earth real time traffic data services.

Time a critical factor in tunnel safety

In terms of smoke detection, the video-based approach often adopted in tunnels is much quicker than conventional fire detectors. The response time of a conventional detector is around 40 seconds, with the alarm typically activated after a minute. In a dedicated tunnel detector, the average reaction time to smoke, before open flaming occurs, is 10 to 20 seconds. The nature of a tunnel and the limited opportunities to escape in the event of an incident mean that detecting a potential fire at the earliest opportunity is vital. This enables the evacuation process, closure of the tunnel, the fire fighting and the incident management all to commence more quickly, helping to reduce potential for loss of life and minimizing damage. Research has indicated that if an automatic extinguishing system is in place, this needs to happen within three minutes of the smoke being detected.

The intelligent algorithms need to be able to automatically adapt to different environmental conditions and changes in the scene being monitored. For example background analysis, bad weather, sudden light changes and many other factors all impact on the image captured by the cameras. In tunnels, a common factor is lighting but what is not common is the type of lamp

employed which ranges from incandescent or mercury vapor to low or high-pressure sodium lamps. Also the usage of LED lighting is becoming more and more common. Again the safety system in place needs to be able to cope with the effect this has on the images being generated. The positioning of the camera is also important, with placing in high positions necessary to minimize occlusions due to passing vehicles.

Research focuses on preventative approach

So far, the focus of this article has been on safety measures employed to detect incidents within the tunnel. Research is also being conducted into how systems can be used to detect vehicles that may pose a fire risk even before they enter. A three year research project known as SKRIBT – the acronym stands for ‘Protection of Critical Bridges and Tunnels in Roads’ – co-funded by a public grant from Germany’s Federal Ministry of Education and Research, was conducted in Germany, with Siemens and ten partners from government agencies, industry and research institutes. The background to the research was the knowledge that besides human failure most major tunnel incidents involve defective vehicles. Tyres blowing, brakes overheating or engines failing are significant contributors to incidents that ultimately lead to a fire or an accident.

In SKRIBT, the security research has focused on the combination of video images with thermal imaging technology. A video processing program linked to surveillance cameras identifies a passing vehicle and converts a segmented two-dimensional image into a 3D model using newly developed algorithms. The program is then able to recognize components susceptible to fire such as wheels, engines, brakes and axles. If overheating is detected, an alarm is triggered in the control center of the tunnel. Staff can then switch the lights at the tunnel entrance to red, activate flashing hazard signs and redirect the driver to ensure the potentially dangerous vehicle does not enter the tunnel.

This technology could also be employed in rail applications, particularly in view of the trend towards the construction of extremely long tunnels. When loading vehicles onto a train at the terminal, locating the detectors at the loading points enables overheating engines or other components to be identified before the vehicle enters the train’s carriages. This technology is still in the development stage but could prove a significant move in adopting a more proactive approach to preventing fire incidents occurring rather than simply reacting to them when they do. The research is also looking into how hazardous materials can be better detected since they can prove very dangerous in a fire scenario.

Protecting lives and economic prosperity

The development of urban populations inevitably brings an increased need for mass transportation, as well as increased traffic from private individuals. In any densely populated urban environment, commuter trains, inter-city trains, underground trains, trams and buses all play a vital role in

carrying residents and visitors about their business. Even the smallest of disruptions can cause inconvenience to thousands of passengers whereas major incidents can bring about serious social and commercial damage. As space to accommodate this road and rail transport infrastructure becomes more constrained, so the role of tunnels is set to increase and with it the need to protect them, both for the safety of those who are using them and for the contribution they make to the economic development of the regions they serve.

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