FRESH SOLUTIONS NEW CHALLENGES - MANAGING THE RISKS INHERENT IN NEW TUNNEL SAFETY SOLUTIONS

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ABSTRACT

There are no solutions which provide absolute tunnel safety for users, operators, owners and insurers of transportation infrastructure - tunnels are no exception.

There are however developments in tunnel safety which can alter the probability of an incident occurring and/or the consequences of such an incident. This paper explores the dangers of categorising developments in tunnel safety as providing solutions to 'problems' when in reality all that usually occurs is an alteration of the probability and consequences of an incident.

In a world where community, political and legal expectations change, often independently to the evolution of the engineering expertise which underlies the performance of infrastructure, it is inevitable that there will be a tension between the expectations of those who:

- use, maintain and operate facilities
- design, develop and promote new developments in tunnel safety
- insure the ultimate risks.

The challenge is to manage these tensions.

Legal Overview

It is useful to briefly mention some legal principles with respect to potential liability for engineers in tunnel safety design - thankfully the broad principles can be summarised and have global application.

For the design engineer the task is simple to state in broad terms.

- An engineer must bring to the design task such skill as would be expected of a competent engineer expert in the task engaged to perform.

This is generally the test in all countries, see for example:

- German Federal Court of Justice (BGH) 31 January 2002 4 StR 289/01 (Wuppertaler overhead railway deaths)
- American Case - City of Mounds View v Waligarui 263 N.W.2d 420,424 (MINN 1978)
- English Case - Gagne v Bertram 1934 43 C.2d 481, 275 p2d15

Having articulated this broad principle the more difficult question is determining - upon the particular facts - what was appropriate.

In all jurisdictions the test is not with hindsight - it is on the basis of the state of knowledge at the time the experts skills were used. As explained by an English court:

‘In this world there are few things that would not have been done better if done with hindsight. The advantage of hindsight include the benefit of having a sufficient indication of which are unimportant … the standard … to be expected of a professional man must be based on events as they occur and not in retrospect’ (Duchess of Argyle v Beuselinck (1972) 2 Lloyd’s Rep 172p185).
The recent catastrophes at Mont Blanc, Gotthard, Kaprun and the tunnelling component of the World Trade Centre collapse have contributed to changes in what is expected of the engineering expert.

Spare a moment to consider the position of parties after an incident.

For the insurers of infrastructure representations (warranties) about the physical safety characteristics of the tunnel and the way it is operated go to the heart of their preparedness to take the risk - misrepresentations about the characteristics of a particular tunnel to an insurer can in some circumstances allow the insurance company to avoid the obligations under the contract of insurance - Even if the owner made the representations without knowing they were wrong.

While for an operator they may find themselves at the forefront of liability in the event of an incident - because like the driver of a car - there is a universal presumption the exercise of their judgement and skill directly effects the consequences of an emergency/safety incident.

The engineers are caught somewhere in between the parties - and it is for this reason they must be careful to document their professional deliberations.

Factual Examples

In recent years I have been fortunate enough to conducted independent (and often confidential) reviews of the systems, operations and procedures of existing transportation tunnel systems. My views are founded not upon the promises of new or emerging technologies, the undertakings of those who promote it or the excitement of the latest research, but in the often mundane expression of all that work which has gone before as evident in an operational system.

For example I am consistently reminded of the gulf between those who designed the hardware and operational controls that provide the safety and ventilation systems on the one hand, and those charged with the responsibility of operation, maintenance and day to day revision of the procedures. All too often the intimate understanding of the safety solutions touted during the early stages of a project (and often at least in part responsible for the success and funding of the project) have been lost as the project makes the transition between commissioning and operation. This problem can be particularly acute if the safety measures add significant costs to the operation of the tunnel after commissioning.

This observation is equally true for upgrades of old systems, where new technologies are often blended with old to provide an enhanced operational environment. Once again the translation of the theoretical benefits of the new technology are often distorted and diluted in the transition to what is often a comparatively mundane operational environment.

For the purpose of illustrating my argument let me reflect briefly on a number of case studies from my work over the last six months or so.

1 Urban rail tunnels - New York, World Trade Centre Underground

As part of my review of an urban underground rail system’s safety management practices I was required to attend the World Trade Centre in the weeks following its collapse and discuss the effectiveness of the emergency procedures in the minutes following the terrorist attack.
By way of brief overview the New York ‘subway’ system is a blend of previously, separately run, cut and cover railway tunnels which have been bought together as one in recent years and provide a high frequency and high density service under the island of Manhattan. Those portions under the World Trade Centre were purpose built comparatively modern - integral components of the World Trade Centre.

Inspection of the network revealed comparatively old infrastructure with a ventilation and control network system which bears little or no resemblance to that expected in a new project. In other words the New York underground system is typical of that found in most major cities which evolved during the earlier part of the 20th century. It has variously been estimated that to bring the ventilation system up to a standard which is comparable to that of new projects would cost tens of billions of US dollars.

When the terrorist attack occurred on September 11, 2001, an emergency response was initiated which either removed, or stopped entering, in the order of ten thousand people from the underground system, and despite the destruction of much of the underground rail network resulted in the deaths in the order of only 10 people.

In other words the operational response of those responsible for train control in the New York city underground was such that there was a significant number of lives saved and property (trains) protected.

In this instance almost no amount of investment in infrastructure could have saved the physical infrastructure but operational effectiveness reflected in both egress design and operational response was able to save thousands of lives.

Compare that scenario where the safety outcome was highly effective notwithstanding old and what might be argued to be inferior technology with the circumstances of an emergency exercise conducted on another rail network utilising state of the art communications, tunnel ventilation and emergency response systems.

2 Urban Metro System (anonymous)

A pre-arranged emergency scenario (scripted) involving the immobilisation of a single train in a segment of modern rail tunnel (modern signalling, communications, jet fans, etc and evacuation of passengers along a pedestrian ‘friendly’ track.

The train driver attempted to communicate the fact that his train was disabled to the appropriate authority using modern communication technology. The control centre, after hearing a lengthy description of time, train type and location replied that they didn’t understand what the train driver was saying. When an alternative means of communication to the emergency services was used the alternative emergency service refused to take the call seriously thinking it was hoax and terminated the communication. Communication of the incident was eventually communicated - the exercise began.

After thirty minutes the emergency ventilation system was activated (after prompting by embarrassed exercise supervisors).

Discussion - these examples

In the first instance in New York it was not the latest technology which saved thousands of lives but the ability of those responsible for the control of the network to make rapid decisions
on comparatively little information and for those decisions to be followed. In other words there was a chain of command which was understood and respected.

In the second instance - although admittedly only an exercise - the existence of highly sophisticated technologies to assist in the event of an emergency were not used, the chain of decision making, command and response failed. Had it been a real incident the likelihood is many people would have died.

The implications of these comparatively simple observations are many - in fact too many to be fully explored in a short paper such as this. But let me briefly further explore some of them.

3 Incremental components in a safety system

Each engineering development contributes to the overall performance of tunnel safety. That contribution can effect the performance of other safety components in the system.

3.1 Refuges

A simple example is the development and refinement of refuges in tunnels. As an alternative to points of actual tunnel egress they provide a place of comparative safety by providing a tenable environment for human beings which is longer than that expected within the tunnel itself. For this reason their contribution to tunnel safety only arises when people are able to properly access them and then their benefit is measured by the additional time they maintain a tenable environment.

Clearly they provide an improvement in tunnel safety for those people whom are able to access them. But in order to avail themselves of their sanctuary citizens must both be willing to, and able to, make the journey from the vehicle in which they are travelling to the points of refuge. Therefore the change in tunnel safety achieved by building the refuges will be optimised only if:

(a) People want to enter the refuges
(b) People can enter the refuges
(c) People do enter the refuges

On the other hand the existence of the refuges may be used as justification to place less emphasis on in tunnel tenability of atmosphere.

Once again this comparatively simple observation has highly complex implications for tunnel safety. For example in a multi-lane urban road tunnel the lane widths may be critical for commuters to exist their cars. If they are not wide enough, commuters simply can’t open their doors.

Having opened their doors and got into the tunnel environment are we confident that they will overcome their natural urge to go back in the direction they have come (or head in the direction they are going) and make their way to the refuges? Will they overcome their fear of the unknown and enter the refuge? And even if they want to do all of these things are the dimensions of the walkways and the physical obstructions such as barriers, steps or the like such that will not literally be a second jam of human beings? What will the consequences be if there is a disabled person, someone trips, or someone is simply too fat to get through the door?
Risks of ‘improved’ design

A further complication of improved emergency designs and philosophies for apparently similar infrastructure is that within a localised area there may be significant variations in the way infrastructure safety systems have to be operated, maintained and used during an emergency.

Examples of this can be found in most major cities. Whether it be in road or rail tunnels, infrastructure built at different times has different features, notwithstanding that it performs the same primary function of facilitating transportation.

Example 1 - Emergency Egress (Broad discussion):

It is not only common - it is almost expected - in the international tunnelling community that in an underground rail system there will be variations in the means of egress from different types of rolling stock. Once egress is achieved the means of passage in the underground rail system tunnels on foot will vary for dedicated walking paths, to walking up the track. While in many systems no egress will be permitted at all because of the third rail.

In road tunnels, within the one city, there may be examples of transverse, semi-transverse, longitudinally ventilated, longitudinally ventilated with dedicated smoke extract and more recently longitudinally ventilated with parallel tube recirculation.

The design of emergency egress from the affected tube may also be extremely variable - the experience for citizens varying between a short flight of stairs to the surface, a very long set of stairs to the surface, a refuge, a cross passage, a dedicated escape tunnel or the opposing tube with traffic still flowing.

Because of this each project must be viewed not only from the perspective of the new piece of infrastructure but also from the perspective of what the implications will be for safety as a consequence of its installation given the context of other infrastructure serving the same purpose within the region. In other words - how will people react to the new design in this particular location.

Example 2 - Emergency Egress (Specific discussion):

Once again I’ll use an anonymous but nonetheless tangible example is useful in this regard. An existing urban rail network with components of both underground and air right development running rolling stock of varying age and design and then embarking upon a new extension and upgrade programs.

It is proposed that in the new parts of the underground network dedicated passenger egress ways will be incorporated in the tunnel design - this is not the case in any other part of the network.

There will be an emergency smoke management system installed as is the case with other new sections of the railway network. This will impose an additional smoke management systems on the network - with its own control system and operational requirements.

In such circumstances developments in our understanding of tunnel safety have provided new tools to increase the safety of the system, but through incremental installation into the network they have introduced new control systems with differing design and operational
characteristics. The challenge is in ensuring that notwithstanding the new developments in tunnel safety the delivery of the system is integrated with other safety systems in a way which does not result in a degrading of the overall safety of the network.

Conclusion

Ultimately for there to be positive improvements in safety with respect to tunnel safety technological achievements and improvements must be coupled with a conscious effort to integrate and understand the implications of those new systems on the safety of existing infrastructure.

After project construction or upgrading the systems must serve their functions in a world of changing technical and social expectations. We must ensure that knowledge of past safety incidents are translated into a form understood by safety engineers to citizens. Insofar as passive systems can be employed to enhance safety they should be, and where active systems are required or installed appropriate effort should be made to ensure that they are understood and properly utilised by operators, emergency services and the citizens who use these underground transportation corridors.

What cannot be overlooked is the importance of sound communication, command and response on the part of those whom operate and respond to emergencies on the one hand, and informed and active participation by the community whom use these facilities when there is an incident notwithstanding what technology is used in a tunnel.

Having an informed public able to make considered and rapid decisions about their own safety in the event of an emergency remains one of the great areas of tunnel safety available for rapid and comparatively cost effective safety improvements.

For engineers it is essential that they acknowledge new developments in tunnel safety may have unforeseen or even negative implications. However the overall positive contribution to the safety outcome of new initiatives must be identified - and the basis for such conclusions articulated.

It must be recognised that there are some events which cannot reasonably be anticipated or engineered for. The challenge is to learn from past events how to better contemplate and control incidents of the future. The difficulty with proactive incidents and consequences reducing measures is that their effectiveness is difficult to quantify.

It is an extremely difficult task when considering low probability high consequence events to differentiate the non occurrence of ‘incidents’ from effective incident control. The two are not the same, and easily confused.

With fresh solutions come the new challenges of placing the ‘solution’ in context and ensuring that the merits of the changes are both documented and rationally articulated.

In the event that there is an ‘incident’ such documentation will stand the engineer well in demonstrating the appropriateness of his advice. This will also serve the owner, operators, users and insurers well in the event of an incident.