PIARC International Conference on Road Tunnel Operations and Safety

3rd – 5th October 2018 – Lyon

(Summary of proceedings)

23/10/2018

CONTENTS

The presentations can be downloaded from the conference website at:
https://www.tunnel-conference-lyon.com/en

1 Welcome messages

(Jean Luc Da Passano, Claude Van Rooten, André Broto, Marc Tesson)

Jean Luc Da Passano, Vice President of the Greater Lyon Council (Métropole de Lyon), began by welcoming the delegates to the conference. He said that Greater Lyon Council was honoured to host representatives of the world tunnel community, especially since the council has a special department responsible for managing the dozen or so road tunnels within its territory.

He mentioned that Lyon is home to a number of iconic tunnels, including the Fourvière, North Lyon ring-road and Croix Rousse tunnels, all of which have recently been renovated. Mr Da Passano mentioned that the conference programme included a technical tour of the Croix Rousse tunnel, which has a safety gallery open to environmentally friendly modes of transport – a bold political decision by elected council representatives and a world first.

The next speaker was Claude Van Rooten, President of the World Road Association (PIARC). After a brief introduction to PIARC, he thanked the Technical Committee on Road Tunnel Operations for taking the initiative and organising PIARC's first international conference on road tunnel operations and safety.

André Broto used his welcome message to praise PIARC's technical committees for their interdisciplinary work and said he was delighted to see such an active Technical Committee on Road Tunnel Operations, with around 160 members from 36 countries.

Marc Tesson rounded off the welcome messages by welcoming the delegates on behalf of the Technical Committee on Road Tunnel Operations, which was actively involved in planning and organising the event. He said that there were 300 delegates in attendance from around 40 countries, and invited everyone to play their part in the ensuing discussions.

<table>
<tr><td> 
</td><td>  </td></tr>
<tr><td>Claude Van Rooten
President of PIARC</td><td>André Broto
President of PIARC' French National Committee</td></tr>
</table>

2 Opening session

(Sandrine Chinzi, Alexandre Debs, Massimo Schintu, Rafael López Guarga, Ton Coertjens, Carol Bausor)

Representatives of Road Directorates at the opening session

Conference moderator Carold Bausor began the opening session by asking Road Directorate representatives to explain the key issues and challenges facing their respective organisations in terms of road tunnel operations and safety.

Sandrine Chinzi (Head of Transport Infrastructure, France) recalled that France had completed an ambitious road tunnel renovation programme, investing around €2.7 billion in the 100 or so tunnels longer than 300 metres owned and operated by the government. She stressed that the government had focused on the following aspects in particular:

- Reducing the likelihood of major incidents and boosting fast detection capability.
- Managing smoke extraction and keeping conditions inside the tunnels clear enough that users can self-evacuate before the emergency and rescue services arrive on the scene.
- Accelerating emergency and rescue service response times.

She explained that the government's longer-term priorities are to improve safety conditions and to adapt to new risks arising from changing mobility practices.

Alexandre Debs (Ministry of Transport, Sustainable Mobility and Electrification of Transport, Quebec, Canada) spoke next, stressing the unique challenges posed by road tunnel operations in Montreal. He said that, although the ministry only manages around 10 km of tunnels, operating them is extremely complex because of the way different networks are interlinked and because the area is subject to temperature extremes. He added that every tunnel is different, and that equipment heating systems account for 22% of total energy costs.

Massimo Schintu (Executive Director, AISCAT, Italy) then spoke about the huge challenges that Italy faces, given that the country is home to around half of Europe's road tunnel infrastructure and that 65% of its tunnels are managed by concession-holders. These unique circumstances make it difficult to obtain quick approval for tunnel renovation projects. As well as talking about infrastructure work, Mr Schintu also wondered whether it might be a good idea to carry out vehicle safety improvement work.

Rafael López Guarga (Chief, Engineer, Ministry of Public Works, Spain) gave a brief overview of the situation in Spain, where there are 500 tunnels measuring a combined 300 km (200 of which are situated on the Trans-European Transport Network. At present, 63% of Spanish road tunnels comply with Directive 2004/54/EC. He said that the main concerns were around cutting maintenance and repair lead times, managing multiple tunnels from a single remote control station, equipment maintenance planning, and staff training. Mr López Guarga also spoke about the constructive working relationship between the Spanish and French authorities on the Somport cross-border tunnel, where the French side had brought its in-depth expertise in tunnel operations and safety to the table. He also stressed the benefits of international dialogue through the work of the PIARC Technical Committee on Road Tunnel Operations.

Ton Coertjens (Leader of the "Work Stream Tunnel Safety" – NL, B, UK, F) talked about how a spike in traffic was posing major challenges in the Netherlands and said that extreme vigilance was called for in tunnel design and renovation. He also said the Dutch authorities were considering ways to slash the amount of energy that tunnels use.

Carol Bausor then proceeded to ask the representatives specific questions.

On the issue of **safety management systems**, Sandrine Chinzi said that France's Ministry of Transport had recently embarked on a new programme with CETU's support. She said the aim was to further improve organisational arrangements, with a particular emphasis on stakeholder roles and responsibilities, skills (training and certification), intervention procedures, feedback and safety exercises.

As regards **temperature extremes in Quebec**, Alexandre Debs said the main focus was on cutting energy use. He explained that the two key issues were managing the technical constraints posed by the equipment, and clearing snow from tunnel entrances. He said the local authorities were keen to harness geothermal technology for snow clearance operations.

Safety officers are a vital part of tunnel safety provisions. In his answer to a question about safety officers, Rafael López Guarga explained that Spain had recently organised an ITA-COSUF European Forum attended by around 70 safety officers, and had published guidance on their roles and responsibilities. He added that there were plans for special training for safety officers and operators.

Turning to the **"Work Stream Tunnel Safety"** work programme, Ton Coertjens said that current thinking focused on aligning how regulatory measures are applied across the four countries, detecting incidents, training operators, supervising multiple tunnels, detecting over-sized vehicles, so-called "smart mobility", and resilient operations.

Touching on the situation in Italy, Massimo Schintu talked about the major challenges posed by carrying out renovation work while tunnels remain open. For instance, the A10 motorway measures 112 km in length and comprises 62 km of tunnels. Because there is no alternative route, the tunnels cannot be closed while renovation work is carried out – something that is extremely challenging. He said that Italy is currently calling for the provisions of Directive 2004/54/EC to be relaxed.

3 Opening of the exhibition area

Sandrine Chinzi (Head of Transport Infrastructure, France) thanked the sponsors and exhibitors for their contribution to the international conference. She then formally opened the exhibition area in the presence of André Boto (President of PIARC French National Committee), Jean Luc Da Passano (Vice President of the Greater Lyon Council), Claude Van Rooten (President of PIARC), Marc Tesson (Chairman of the PIARC Technical Committee on Road Tunnel Operations) and Michel Deffayet (Director of CETU and Vice-chairman of PIARC's French National Committee).

Opening of the exhibition area

4 Technical session 1 – Safety management tools and systems:

- *Tools for safety management - Effectiveness of risk mitigation measures for road tunnels - Bernhard KOHL - Co-leader of PIARC WG 2 on Safety - Austria*
- *Benchmarking safety management systems - Potential use for road tunnel operation - Eric Premat & Marie-Noëlle MARSAULT - Member of PIARC WG 2 on Safety - France*
- *Overview of tunnel safety measures in Japan – Various attempts made by the East Nippon Expressway Company - Atsushi ICHIKAWA - East Nippon Expressway Company - Japan*

Eric Premat, Atsushi Ichikawa, Bernhard Kohl

One delegate raised two surprising points from the presentation on quantitative risk analysis for new tunnels:

- collision risk is assessed on the basis of traffic flow, which is vital in itself, but collision risk is deemed to outweigh all other risks, despite the fact that traffic speed remains extremely low after the incident
- the fire risk level appears to be very low.

Gary Clark (UK) then asked Bernhard Kohl about how the model could be applied in practice, and in particular about how to demonstrate to customers the benefits of some measures that are hard to measure (e.g. “improving vigilance in the control station”). Bernhard Kohl agreed that that was an issue, perhaps because of uncertainty around these technical measures, but said it could be resolved by working directly with operators to determine the measures.

Another delegate raised a point about the presentation on tunnel safety measures in Japan, expressing doubts about the zero air flow control strategy, which causes CO to build up in the tunnel. Japan has decided to implement this strategy for a limited period of just 15 minutes after the fire breaks out. It is currently comparing its approach with practices in other countries and may report on its findings in the future.

Fathi Tarada (UK) asked Atsushi Ichikawa about the use of sprinkler systems in the event of a tunnel fire, pointing out that, in the example given in the presentation, the sprinklers had already been turned off by the time fire-fighters arrived at the scene of the fire. In Japan, policy dictates that fire-fighters decide whether or not to turn off the sprinklers when they arrive on the scene. In the

UK, however, the recommendation is that the sprinklers should be left running after the emergency services arrive (in particular to stop the fire from re-igniting and to limit electric vehicle-related risks). Speaking from the floor, Les Fielding mentioned a case from 1979 when a fire re-ignited after a few minutes and devastated the New Osaka tunnel.

Colonel Rose, an Australian fire-fighter, then prompted a debate about the zero air flow control strategy in two-way tunnels, which can force the rescue services to operate in a smoke-filled tunnel. Keeping the air flowing for around 10 minutes provides enough time for most of the users in the tunnel to be evacuated. If the rescue services then have to enter the tunnel, smoke-related access issues depend on the point at which they enter the tunnel. In some tunnels (such as a 6.2 km-long tunnel in Vietnam), the ventilation system switches to longitudinal mode once the self-evacuation phase is over and fire-fighters attack the fire from the smoke-free side. Insights from Norway suggest that the strategy needs to be tailored to the circumstances of each tunnel, and that technology can play an important role when rescue services are stationed far away and the tunnel has no emergency exits. Bernhard Kohl (Austria) agreed that tunnels need to be assessed on a case-by-case basis, and that specific circumstances mean that strategies may differ from one tunnel to the next.

Replying to Peter Bishop's (UK) comment about the novel use of flashing red lights on tunnel side walls to prohibit access, Atsushi Ichikawa said that the system had been installed on an experimental basis because Japanese tunnels were not fitted with dynamic entry barriers.

Alexandre Debs (Quebec) asked about how fire-fighting systems, which are difficult to deploy, could be integrated into a safety management system. In his reply, Eric Premat said there were two separate points here: how technology systems can be integrated into safety management systems, and how systems of this type are applied in France. On the second point, he said that the issue only applied to one French tunnel: the A86 duplex tunnel. Returning to the first point, he said that a fire-fighting system can be integrated into a safety management system just like any other tunnel safety system. The key issues as regards the safety management system are project management, risk identification and control, maintenance, and feedback.

Replying to a question from Jean Claude Martin about the inclusion of appropriate indicators in the safety management system, Eric Premat said that indicators are a vital part of any safety management system, in the same way as external reviews and audits.

5 Technical session 2 – Sustainable operation

- *First steps towards sustainable operation of road tunnels - George Mavroyeni - Member of PIARC TC D.5 - Australia*
- *Refurbishment of the Louis-Hippolyte-La Fontaine tunnel - Alexandre Debs - Member of PIARC TC D.5 - Quebec, Canada*
- *Croix Rousse tunnel - "Innovative use of a safety gallery for environmentally friendly modes of traffic" – Mathieu Hermen - La Métropole de Lyon.*

Mathieu Hermen, Alexandre Debs, George Mavroyeni

The first question from the floor was for Alexandre Debs: does Canada have any labour and employment laws that give preference to local contractors? Mr Debs said that no such rules apply to the Louis-Hippolyte-La Fontaine tunnel, but that rules of that type could apply to projects in Canada where there is an emphasis on giving preferential treatment to local labour. He added that, for the Louis-Hippolyte-La Fontaine project, the tunnel would only be fully closed for short periods of time because it carries so much traffic. Plans to keep the tunnel open while work is carried out include keeping two lanes open in each direction during the day, and the option to close one tube at night (with traffic travelling in both directions in the other tube).

Another delegate raised a question about the Croix Rousse tunnel renovation project, asking how the architectural side of the project had been managed. In his reply, Mathieu Hermen explained that the work had been awarded under a design and build contract, and that architectural quality had been one of the award criteria. He said that the main sticking point on this front had been the government architect's insistence that natural stone be used at tunnel portals. Mr Hermen added that, with the benefit of five years' hindsight, the tunnel owner would probably have been less ambitious about the level of equipment installed in the tunnel if the project were run again (according to the operator, not all of the equipment in the tunnel is particularly useful).

Another comment from the floor concerned how cost-benefit analyses can influence political decision-making. Fathi Tarada (UK) pointed out that, in his country, social acceptability is an important concern in projects such as this. Alexandre Debs and George Mavroyeni said that was also the case in Canada and Australia, where social acceptability is an integral part of so-called "sustainability" considerations.

One of the delegates praised the Technical Committee on Road Tunnel Operations for publishing its report entitled "Road tunnel operations: First steps towards a sustainable approach". Mr Mavroyeni said that publications like this were useful because they provided the scientific community with an instant snapshot of the state of the art and international practices.

Michel Deffayet (France) concluded the discussion by stressing that the model adopted for the project in Canada (design, build, funding) demanded serious negotiation very early on in the process, and that such an arrangement could well have limited the tunnel owner's ability to incorporate sustainability considerations at later stages of the project. He asked whether the model was in fact appropriate for this type of project. Mr Debs replied that the main factors that had guided that decision were the sheer complexity of the project and the fact that the local authorities had wanted to compel the contractor to complete the project to very tight deadline. He added that sustainability criteria would be clearly and precisely laid out in the contract.

6 Round table A "Safe operation of road tunnels":

6.1 Part 1 - Tackling safety issues in tunnels with a high level of traffic

- *Ronald MANTE - Leader of PIARC WG 2 on Safety – The Netherlands*
- *Christina KLUGE - Member of ITA-COSUF – Germany*
- *Lieutenant-Colonel Christian Neyret – SDMIS 69 – France*

Ronald Mante, Christina Kluge, Christian Neyret

All operators seem to prefer closing the tunnel during maintenance, for worker and user safety reasons. Closing just one lane is generally considered too risky. They also agree on the need to reduce maintenance times wherever possible to limit traffic disruption on surface diversion routes.

Closing a tunnel for work is often a difficult decision to make. For that reason, it is important to limit how often such work happens. From the discussions, it became clear that this could be done in three key ways:

- investing in reliable, long-lasting equipment
- carrying out maintenance work at the same time as other operations (fire-fighting exercises, inspections, etc.)

- keeping tunnel equipment to a minimum and, wherever possible, installing it outside the tunnel so it is easier to access (e.g. ventilation control panel).

Ideally, members of the public should receive advance warning of scheduled maintenance work by various means (posters, media, variable message signs, etc.). It is also important to remind contractors of the rules they must follow when carrying out work (e.g. do not obstruct access to safety equipment).

Christina Kluge (Safety Officer, Germany) explained that the tunnel under the Elbe in Hamburg has four traffic tubes, meaning that two can be closed for maintenance and renovation work while the other two remain open for traffic to pass through the tunnel.

Incident response

When a vehicle breaks down inside a tunnel, operators prefer to close one lane and impose a reduced speed limit on the other lanes. When a fire breaks out, the tunnel is closed immediately. If the tunnel has two tubes, the operator closes both tubes to make it easier for users to evacuate and for the rescue services to access the unaffected tunnel.

Statement by Lieutenant-Colonel Christian Neyret on fire and rescue service practices in France.

Christian Neyret spoke about the challenges facing the Rhône Fire and Rescue Service, how it organises its response, and what strategies it adopts to deal with two key issues around crisis situations in tunnels:

- arriving at the tunnel portals as quickly as possible
- entering the tunnel to rescue people inside and fight the fire.

Rescue teams are sent to both tunnel portals to ensure that fire-fighters are on the scene as quickly as possible. A liaison officer is also dispatched to the control station to relay information the teams on the scene. The rescue services can reach the tunnel portals by one of two routes – the standard route or a second, pre-defined alternative route. They decide which route to take based on current traffic conditions.

Once they arrive on the scene, they adopt different strategies depending on the tunnel configuration:

- for a single-tube tunnel, they enter with the flow of traffic because the smoke is blown in this direction to protect users behind the incident; however, if their path is obstructed, they make their way to the scene of the fire against the flow of traffic (after first obtaining the operator's permission)
- in a twin-tube tunnel, the decision is an easier one because they can access the scene of the incident via the unaffected tube.

In both cases, the rescue teams can also access the scene of the incident via the emergency exits, if the tunnel is equipped with them.

If the rescue teams arrive at the tunnel portals before the liaison officer reaches the control station (which happens often), they can use the emergency call station at each portal to establish contact with the control station.

Other topics covered

Several delegates asked questions about managing a fire involving an electric or hydrogen fuel cell vehicle, or a vehicle transporting fuel or gas. There was little feedback on the subject, although the

speakers indicated that it would be covered in technical session 4. One possible solution for tackling a fire involving an alternative fuel-powered vehicle with unknown behavioural characteristics is to quickly install fixed fire-fighting systems (e.g. hose on base).

6.2 Part 2 - Tackling safety issues in tunnels managed by a remote control centre

- *Arild SØVIK - PIARC TC D.5 invited expert – Norway*
- *Arthur KABUYA - PIARC TC D.5 member – Belgium*
- *Hélène MONGEOT - French-speaking working group of road tunnel operators – France.*

Arild Sovik, Arthur Kabuya, Hélène Mongeot

Number of tunnels per control station

Norway is unusual in terms of the number of tunnels per control station, with one control station managing a record 260 tunnels. One of the delegates explained that this figure is not as impressive as it seems because most of the tunnels carry very low traffic volumes. Moreover, in Norway, control station staff do not see images from all the cameras in the tunnels, but only those trained on a detected incident.

Volume of equipment

As well as having to manage more and more tunnels from a single control station, there are also challenges around the maintenance and reliability of the growing volume of equipment installed in tunnels. Because this means that many more contractors and operator staff are present in tunnels, there is a greater risk to these personnel and to tunnel users.

One delegate asked whether there were any official limits on the number of tunnels that a single operator can manage before the mental workload becomes so great that it poses a safety risk. In her reply, Hélène Mongeot (France) said that there are no such limits under French law, not least because there is no one-size-fits-all answer and every situation needs to be assessed on its merits. In any case, the operator's mental workload will depend on a range of factors, including how many tunnels he or she is managing, as well as the length of those tunnels, the length of the surface road network he or she also has to manage, traffic conditions across the entire network (tunnels and surface), and the kinds of tasks that the operator has to perform.

From the discussion, it became clear that it was important to:

- train operators to handle exceptional circumstances (multiple incidents, tunnel incidents requiring a fall-back solution, stress management, etc.)
- keep the same operator on duty when an incident occurs
- clearly define who is in control, who coordinates the emergency services, and who makes the decisions.

7 Technical session 3 – Safety systems and equipment

- *Centralised technical management system for expressway tunnels - - PIARC TC D.5 member - South Korea*
- *PIARC report on fixed fire-fighting systems in road tunnels: Current practices and recommendations - - ITA-COSUF Member - Former PIARC WG leader - UK*
- *The use of public address systems to improve tunnel safety: current practices - - PIARC TC D.5 member - Singapore*

		
Nam Goo Kim	*Les Fielding*	*Lim Hock Tay*

The document on the use of public address systems to improve road safety summarises the findings of an internal survey by the Technical Committee on Road Tunnel Operations, launched at the start of the current work cycle. Drafted by the Singaporean committee members, it outlines current practices and uses and supplements the technical report entitled “Improving safety in road tunnels through real-time communication with users”. This valuable contribution will shortly be published as an appendix to that report.

Although operators all agree that users should self-evacuate quickly when a fire breaks out, experience shows that users do not always behave in the right way. Remarkably, some even take videos or photos of themselves standing next to the burning vehicles. Practices around using public address systems in the traffic-carrying parts of tunnels vary from country to country. Such systems do, however, seem to make a real difference when it comes to prompting users to evacuate. Some modern-day public address systems work remarkably well even in tunnel environments, where the acoustics are less than optimal. Such systems have yet to be tested in tunnels where a fixed fire-fighting system is activated, but some can be heard even when the ventilation system is running.

The document does not provide any examples of standard messages. In most cases, pre-recorded messages are played at the start of the evacuation process, with “live” messages from the operator coming later on in the process. Public address systems can also be used to pass on messages to contractors carrying out maintenance work inside the tunnel.

European law does not require safety systems to include fixed fire-fighting systems, but they are recommended in some countries. PIARC’s 2016 technical report outlines current practice. It is a recognised fact that fixed fire-fighting systems tend to cause smoke destratification (which is at odds with the intended effect when a transverse ventilation system is activated). It is therefore important to strike the right compromise between these two strategies (rapid fire-fighting response and smoke management). In some cases, use of these systems is not recommended (for instance, where a fire involves a vehicle transporting dangerous goods). Operators should therefore assess each situation on its merits before deciding whether or not to trigger the system.

Moreover, the reliability of these systems in extreme cold temperatures (such as in Canada), and the consequences of using them in these conditions, have yet to be assessed.

8 Technical session 4 – Future tunnel safety (and operational?) challenges

- *Alternative fuels and the future of road tunnels and road tunnel design - Gary Clark - PIARC WG 4 on Vehicle emissions - UK*
- *Training with virtual reality for tunnel safety (Romano Borchiellini - PIARC TC D.5 member - Italy*
- *Using ITS for safety improvements in road tunnels - Henric Modig - Leader of PIARC WG3 on Human factors and ITS – Sweden.*

Gary Clark, Romano Borchiellini, Henric Modig

Sales of alternative fuel-powered vehicles (electric and hydrogen fuel cell vehicles) are still low, but they are gaining popularity and could make up a large share of vehicles on the road in one or two decades' time. This growth raises questions about the risks that these vehicles pose and what impact they might have in tunnels and other underground spaces. Electric vehicles are prone to catching fire when they collide with other vehicles, and the ensuing fires are difficult to put out, produce extremely toxic fumes, and are at risk of re-igniting. However, an electric vehicle fire is believed to be of similar intensity to a conventional vehicle fire. Hydrogen fuel cell vehicles are at risk of catching fire and exploding when they collide with another vehicle or when the tank is being filled. As with electric vehicles, however, they are said to produce fires of similar intensity to conventional vehicles. Tunnel owners, designers and operators must consider new event scenarios and decide whether these alternative fuel-powered vehicles pose acceptable levels of risk, whether they negatively impact evacuation conditions, and whether incident response procedures need to be adjusted accordingly. PIARC and ITA-COSUF will work together to examine these issues in the next work cycle.

The sheer complexity of tunnel systems – and the fact that decisions need to be made quickly and under immense stress when a serious incident happens – underscores the importance of having properly trained operators and emergency services. Indeed, training is a legal requirement under European law. Immersive, interactive virtual reality tools are an effective way to reproduce all manner of different situations and, as such, offer an innovative way to conduct training exercises. In other words, virtual reality technology can be used to conduct more exercises, at less risk, and without spending as much time and money. Virtual reality exercises can also be constantly monitored and controlled, and the data can be saved and retrieved for future analysis. Today (in

2018), virtual reality can be used to run exercises according to predefined procedures. In future (in 2020-2021), the technology will also be capable of simulating fires and smoke propagation, using in-built digital fluid mechanics models to apply theory in practice and recreate the ambient conditions in the tunnel. Politecnico di Torino is currently working with SDIS 73 and the Piedmont Regional Council on a project to develop tools such as these.

The term "Intelligent Transportation Systems" refers to the application of information and communication technologies and systems to develop driverless, connected, communicating vehicles for goods and passenger transport. They key issues on this front are developing viable business models, handling cyber-security threats, defining driving rules, deciding where liability falls for insurance purposes, and improving existing technologies. In tunnel environments, these issues apply equally in normal situations and in pre- and post-accident settings. Potential issues include the confined nature of tunnel spaces, how radio waves travel inside tunnels, the loss of satellite signals, and emergency response procedures. Moreover, the prospect of driverless vehicles travelling in tunnels demands careful consideration of road markings and lighting conditions, as well as new smoke and fire detection possibilities. Vehicles equipped with Intelligent Transportation Systems will be able to communicate with each other (so-called "vehicle to vehicle" – or V2V – communication, e.g. keeping a safe distance from vehicles transporting dangerous goods, or identifying vehicles carrying such goods) and with the infrastructure (so-called "vehicle to infrastructure" – or V2I – communication, e.g. relaying information about traffic conditions or about the tunnel itself (such as the location of emergency exits), managing vehicles from the tunnel control station, or relaying details of an incident or accident). If an event occurs in the tunnel, Intelligent Transportation Systems could be harnessed for dynamic lane assignment and event management purposes, or to support self-evacuation or people with reduced mobility (providing information about their specific disability and location, and providing personalised assistance).

Questions and comments from the floor:

On the issue of driverless vehicles, one question from the floor concerned who was responsible for setting the safety rules. Henric Modig said that all stakeholders should be involved, including vehicle manufacturers and European bodies, but that it was currently unclear who was actually responsible.

Next, the discussion turned to the challenges of developing a standard V2V and V2I communication protocol. Talks on this matter are ongoing but, as things stand, there are multiple protocols and no agreement has been reached.

Thinking specifically about tunnels, vehicle communication technologies could be harnessed to improve operator information (number of people in a vehicle, how many are still inside, how many have escaped, etc.). However, at present, the standards do not factor in this facility. PIARC therefore has a role to play in ensuring that certain compulsory requirements are included.

On the issue of driverless vehicles, although tunnels pose no specific challenges that do not apply on the surface, the technology will need to be adapted in some aspects (especially side wall detection).

As regards alternative fuel-powered vehicles, some manufacturers are failing to cooperate with the scientific community on improving understanding of the risks that these new engine technologies pose. Manufacturers provide very little information about the technologies they use. Moreover, because batteries can only be rented, not bought outright, it is proving extremely hard to perform destructive testing. Gary Clark agreed that this aspect posed a real challenge because manufacturers set their own rules that researchers have no option but to follow and try to work out things for themselves. Owners and operators will find it difficult to ban such vehicles from their tunnels

because of the sheer weight of political pressure. But they will have a role to play in terms of introducing specific measures and adjusting incident response plans. The discussion then turned to Stockholm's forward-thinking approach to this issue. For instance, information systems are segmented to counter cyber-attack threats, and traffic is managed in such a way as to prevent overtaking of dangerous vehicles.

On the subject of virtual reality, contributors mentioned that simulator-based training only works if the scenarios are sufficiently credible and due weight is given to the consequences of actions and decisions occurring as the exercise progresses. Romano Borchiellini said that, at present, only some scenario types can be simulated. He added that, although the technology is saving time in initial training, the goal is to go further and develop simulations capable of linking a sequence of actions and simulating the consequences of those actions. That, however, will only be possible with greater processing power.

There was broad agreement that virtual reality will have a role to play, but that it will never be a substitute for real-life exercises.

9 Round table B "Technical equipment - current practices and perspectives"

The aim of this round table session was to explore current practices and perspectives around technical equipment.

9.1 Part 1 - Optimising maintenance by applying a "Plug and Play" approach to tunnel equipment

- *Pierre LONGTIN - PIARC TC D.5 member - Quebec, Canada*
- *Fathi TARADA - PIARC TC D.5 member - UK*
- *Jean-Claude MARTIN - Leader of PIARC WG 1 on Sustainable Operation - France*

Pierre Longtin, Fathi Tarada, Jean-Claude Martin

In the first part of this round table session, the focus was on examining whether adopting a "Plug and Play" approach to tunnel equipment could optimise maintenance.

From the discussion, it became clear that this type of technology is well-suited to the maintenance of equipment located inside tunnels carrying high traffic volumes, and that it should be applied to all equipment, from detectors to booster fans.

So-called “Plug and Play” equipment is beneficial in the **acceptance testing phase** because the in-built self-diagnosis functions make the process easier.

The technology could also help to improve **corrective maintenance** because it allows the work to be carried out quicker, improves conditions for maintenance workers, and raises work standards. As a consequence, “Plug and Play” equipment could shorten tunnel closure periods, make it easier to manage minimum operating requirements, and enhance worker safety.

However, “Plug and Play” technology is part of a broader rethink of maintenance approaches, and in particular a focus on **predictive system maintenance** – anticipating and locating possible faults before equipment breaks down and targeting maintenance work on the “just in time” model. For that reason, “Plug and Play” systems should be fitted with smart sensors for self-diagnosis purposes.

There are two aspects of “Plug and Play” systems:

- “Plug”: the system is easy to connect using a standardised socket (power, command/control, standardised plugs and bases) and uses an Open Protocol communication protocol.
- “Play”: the system self-identifies and self-starts (and, in some cases, self-calibrates) so it is up and running quickly, and must be capable of self-testing (or even self-calibrating), either on demand or automatically at regular intervals.

In order to achieve these two aims, system interoperability specifications will be required for the “Plug” aspect of the system, using open protocols that prevent a tie-in to a specific manufacturer. As for the “Play” aspect, the system will need to be SCADA-compatible, with basic coding rules that allow it to communicate its presence, identity and status.

Concluding the session, the speakers stressed that it was vital to standardise communication protocols for “Plug and Play” equipment. PIARC could produce a set of guiding principles to support a transition towards harmonised protocols founded on risk assessment. But beyond that, it will be up to standardisation bodies to produce more prescriptive rules if that proves necessary. Moreover, the speakers underscored that “Plug and Play” systems can help to bring down overall maintenance costs.

There were three particularly noteworthy comments on this subject:

- “Plug and Play” systems are also suited to tunnels carrying low traffic volumes, where they can cut the amount of time workers have to spend inside the tunnel, especially in harsh climates, where lengthy exposure to the elements poses a risk to personnel.
- Replacing a system component with another that is of a lower standard or is not fully compatible could negate the warranty for the entire system.
- “Plug and Play” systems are well-suited to new tunnels, and using them could bring about a brand-new approach to maintenance strategy in general.

9.2 Part 2 - How to deal with Intelligent Transportation Systems in road tunnels?

- *Salvatore GIUA - PIARC TC D.5 member - Italy*
- *Bijan KHALEGHI - PIARC TC D.5 member - USA*
- *Joyce VREEDE – ITA-COSUF representative - Rijkswaterstaat - Netherlands*

Salvatore Giua, Bijan Khaleghi, Joyce Vreede

The second part of the round table session looked at how to deal with Intelligent Transportation Systems in the specific context of road tunnels.

The speakers stressed that in future, connected vehicles will be very different from the ones that exist today, and that the issue will need to be addressed incrementally (for instance, developing capabilities to communicate with connected vehicles). In a similar vein, the speakers discussed how tunnels could be future-proofed so that they do not pose an obstacle to new technologies. However, the fact that current technologies and systems could quickly become obsolete is an ongoing cause for concern.

There are few concrete examples of trials involving driverless vehicles and connected tunnels. Although many tunnels in the Netherlands have been renovated, only one tunnel – in Utrecht – is fitted with smart systems that can communicate with connected vehicles. But what is the value of such systems? Driverless vehicles are progressing at a slow pace, yet there are multiple solutions and they are evolving fast.

Little has been done on this front in the United States barring a handful of pilot projects. Once such project is in Seattle, where urban tunnels and the public transport network are fitted with connected technologies. Amazon and Uber have also equipped their vehicles with connected technologies, and deployed a significant number of driverless vehicles. But will this system stand the test of time? That is a challenge for the coming years.

PIARC was called upon to work with manufacturers to lobby for harmonised intelligent transportation standards and to work towards stable, well-publicised recommendations and practices. At present, there is no white paper explaining how Intelligent Transportation Systems will work in tunnels in the future. There is, however, real pressure to install more Intelligent Transportation Systems in road tunnels to address congestion problems in big cities (especially in the Netherlands and the United States).

The growing popularity of driverless vehicles and connected technologies raises various questions and concerns around accidents:

- how will legal responsibility be apportioned?
- who (or what) has ultimate decision-making authority when a crisis (accident) happens in a tunnel: the user or the intelligent system (connected vehicle and tunnel)?

At present, risk assessment is carried out on a static basis (tunnel design). However, there are calls to move towards a more "dynamic" approach to risk assessment, taking account of real-time information (e.g. managing the distance between vehicles according to current traffic volumes, and whether or not vehicles are carrying dangerous goods).

10 Open discussion on next PIARC work-programme

- *Marc TESSON - PIARC TC D5 chairman - France*
- *Miguel CASO FLOREZ - Technical Director - PIARC General Secretariat - France*
- *Bernhard Kohl – Leader of WG 2 on Safety - PIARC TC D.5 - The Netherlands*
- *Jean-Claude MARTIN - Leader of WG 1 on Sustainable Operation - PIARC TC D.5 - France*

Jean-Claude Martin, Miguel Caso Florez, Bernhard Kohl, Marc Tesson,

The chairman of the Technical Committee on Road Tunnel Operations gave an outline of the committee's work programme for the next cycle, where the emphasis will be on Intelligent Transportation Systems, the impacts of alternative fuel-powered vehicles, connected underground infrastructure, the road tunnels manual, risk-mitigation measures, and maintenance in urban and high-traffic tunnels.

The ensuing discussion on these matters between the speakers and the floor is summarised below.

Until now, the Technical Committee on Road Tunnel Operations has mainly focused on safety. It might be worthwhile exploring the issue of security, i.e. switching the emphasis from risk assessment to threat analysis. A terrorist attack could have a serious impact on tunnel operations, such as closing it to traffic for an extended period of time.

France examined this issue several years ago, finding that the risks posed by acts of terrorism are not fundamentally different from those that arise in normal tunnel operations. For that reason, the resulting recommendations offered little that was new and were merely security measures that built on existing safety measures laid down by law for tunnels on the national road network.

International cooperation on these issues remains extremely difficult because, as experience has shown, most of the available data is considered confidential and/or sensitive information.

PIARC's tunnel safety information and recommendations need to be kept up to date, but it is difficult to update reports that have already been published. However, future reports will specifically state if they update all or part of any previous reports. On the issue of maintenance costs, updating information contained in old reports is not a practical option, but the costs for new equipment could be indicated in future reports (as was the case with public address systems in 2018). The manual will also provide an overview of the latest information and state which documents readers should refer to for more details. Information will be regularly updated on the PIARC website.

On the subject of driverless vehicles and intelligent systems, interactions with manufacturers will be factored into future thinking. At present, development and testing work gives little or no consideration to the specifics of these vehicles travelling in tunnels. These new technologies are likely to impact tunnel operations and safety management, but the tunnel community has yet to make clear what it needs and expects on this front. Lastly, the community will need to take stock of the many driverless vehicle tests that have been performed, and consider how to manage the transitional phase when both driverless and conventional vehicles are on the road together.

11 Main issues and perspectives

- *Max Wietek – Chairman of ITA-COSUF*
- *Michel Deffayet - Vice-chairman of PIARC French National Committee*
- *Attila Eordogh – Representative of European Commission DG-Move*
- *Claude Van Rooten – PIARC President*

Max Wietek, Michel Deffayet, Attila Eordogh, Claude Van Rooten

The moderator opened the session by asking PIARC and partner organisation representatives to outline the main issues and perspectives for the coming years.

- Chairman of ITA-COSUF

Several working groups and research groups are currently looking at these issues. A new working group on alternative fuels was set up 18 months ago. Because of uncertainty around future trends in this area, the group is exploring different vehicle and engine types. Little is known about some of the risks posed by these new fuels. So the key question is this: how do we factor in these risks in tunnels, as well as in car parks where there is less permanent surveillance? Multidisciplinary teams will need to be set up to explore this question. The PIARC Technical Committee on Road Tunnel Operations and one of the ITA-COSUF working groups will focus on these new issues, and everyone involved will need to receive training.

Life cycle cost is another important subject that demands consideration. Underground structures are expensive to operate. In addition, more resources need to be assigned to the construction phase to limit maintenance costs down the line.

- Vice-chairman of PIARC French National Committee

From CETU's perspective, the main issues are as follows:

- Keeping our tunnels as safe as possible while reducing operating costs and ensuring that existing systems remain operational. Improving system reliability will be a key challenge. CETU is currently taking stock of all existing systems (safety management systems used by

operators on the national road network not under private management) – a process that should reveal opportunities to reduce costs.

- Many questions about new vehicles remain unanswered. We will have to address this issue head-on in the coming months, however – for instance, when Lyon City Council launches its new fleet of hydrogen fuel cell-powered vehicles. Will these vehicles be allowed to enter tunnels?
- What will the tunnel of the future look like?

The PIARC French National Committee's view:

The PIARC French National Committee has built up extensive experience through the work of the French-Speaking Working Group of Road Tunnel Operators. This wealth of experience will need to be combined with the work that the PIARC Technical Committee on Road Tunnel Operations is doing at the international level. Interdisciplinary knowledge-sharing between these two bodies is vital.

– Representative of European Commission DG-Move

For citizens, it is important that tunnels are safe. But they also want to keep tunnel closures to a minimum. Moreover, current statistics show that there are fewer accidents in tunnels than on the surface. It is therefore valid to question whether more funding needs to be allocated to tunnels. From another perspective, tunnel safety is still a sensitive subject and the media jump on even the most insignificant incident.

At their meeting in Malta, transport ministers set a target of reducing road deaths to zero by 2050 (Vision Zero). That raises questions about the role that the law will play in achieving this target. Efforts must focus not just on black spots, but on all places where there is an accident risk. PIARC has a vital role to play in this area.

– PIARC President

The main issue in the coming years will be connected vehicles. Infrastructure cannot keep up with the pace of technological progress. For that reason, flexibility needs to be built into new tunnel design. How can we know today what technologies will be available when a new tunnel opens? PIARC has published guidance on road network improvement, but individual countries have the final say. There will be plenty of work to do with manufacturers. One thing is certain: driverless vehicles will improve safety.

Education and training are important issues. PIARC is too small an organisation to manage this alone, but it can provide information to anyone who requests it, and all its publications are freely accessible on its website.

Questions and comments from the floor:

Victims are included in road traffic accident statistics. But, when an accident happens in a tunnel, other people can feel unsafe even though they were not directly involved in the incident. It might therefore be worthwhile introducing a new indicator. The directive should set out the relevant criteria so that operators can assess the extent to which people feel unsafe when an incident happens in a tunnel.

A tunnel is just part of a larger whole and should be open to other professions. Yet PIARC's committees sometimes fail to communicate with one another. Claude Van Rooten replied that PIARC is committed to coordinating activities across all its committees.

What is being done to raise awareness about tunnel risks among users?

In his reply, Claude Van Rooten mentioned the Mont Blanc tunnel, where the control centre broadcasts safety instructions across all frequencies so users hear them on their vehicle radios.

Michel Deffayet said that awareness was being raised in several ways:

- initial driver training (Highway Code) includes questions about driving in tunnels, so that new drivers learn the basics
- as part of their ongoing training, road professionals learn how to respond when an incident happens in a tunnel and can pass this information on to other users when an event occurs
- short, easy-to-understand clips have been posted on YouTube, and operators also communicate about their tunnels via different channels.

Moreover, some tunnel managers arrange public guided tours of their tunnels, and the people who attend these events can then pass on what they have learned to others in a crisis situation.

More generally, it is important to remember that tunnel users expect the tunnel manager to be responsible for their safety. Users therefore perceive risk in markedly different ways in tunnels and on the surface. That is why there is a need to continue investing heavily in tunnels even though the accident rate is relatively low.

12 Closing message

(Marc TESSON - PIARC TC D.5 Chairman - France)

Before closing the conference, Marc Tesson thanked everyone who had contributed to making the event such a success:

- The host organisations: PIARC (Claude Van Rooten, Patrick Malléjacq) and the PIARC French National Committee (André Broto)
- The supporting organisations: European Commission (Attila Eordogh), ITA-COSUF (Max Wietek), CETU (Michel Deffayet) and the French Speaking Working Group of Road Tunnel Operators (Hélène Mongeot)
- The various speakers, sponsors and exhibitors
- Members of the Technical Committee on Road Tunnel Operations and the interpreters
- The four French operators and their staff, who were kind enough to arrange technical tours on day 3 of the event: Joël Faure (Croix Rousse), Gilles Rakoczy (Mont Blanc), Christian Gaïottino (Fréjus) and Jean Yves Frémillon (A 89)
- Mr Tesson gave a special mention to CETU staff and to three people who helped ensure the event ran smoothly: Kristen Drouard, Marie Hélène Brunel and Carol Bausor.

He also thanked all the delegates who contributed to the lively, interactive discussions throughout the conference.

Mr Tesson wrapped up the conference by stressing that, in the view of the Technical Committee on Road Tunnel Operations, the event had met its objectives. He said he hoped that other, similar conferences would follow in the future.

He added that he hoped those who had registered for the technical tours would find the experience worthwhile, said he hoped that those delegates staying in Lyon for the weekend would enjoy their time in the city, and wished everyone a safe journey home.

This summary was compiled by: Louisa Bador, Séverine Besson, Jean François Burkhart, Jean Claude Martin, Hélène Mongeot, Michael Potier, Eric Premat, Bruno Vidal, Christophe Willmann, and Marouane Yaghzar (CETU).

The full programme and presentations can be downloaded from the conference website at:https://www.tunnel-conference-lyon.com/en