Although as we show, there is much ingenuity in the development of specific tunnel subsystems, Lloyd Fuller learns that the way in which these many parts are integrated will ultimately dictate efficient management for operators as well as safe passage for tunnel users.

Illustration courtesy of Magictorch

What lies beneath

Although as we show, there is much ingenuity in the development of specific tunnel subsystems, Lloyd Fuller learns that the way in which these many parts are integrated will ultimately dictate efficient management for operators as well as safe passage for tunnel users.

Illustration courtesy of Magictorch
harmoniously as a complete, unified whole. It is during tunnel incidents that this integrated approach really pays dividends.

**Integrated tunnel management**

In the event of an incident, a truly integrated center would in an ideal world enact a specific sequence of events. The incident would be detected by one of the systems in the tunnel, possibly based on video or data from various traffic counters and other detection devices. The operator would instantaneously receive a video feed on the alarm monitor, verify the situation and from a menu of carefully crafted response plans subsequently select the most appropriate course of action. Everything else would be initiated automatically. If a tunnel or road section needs to be closed, that message would be dispatched automatically to drivers via a public announcement system, broadcast throughout the tunnel via a radio broadcasting system and warnings displayed on LED signage within and at the entrance to the tunnel. Simultaneously, road crews and the emergency services would then be notified as a matter of course by an in-built messaging system, while the information that the tunnel is closed would be sent out to the local media.

A modern, fully integrated tunnel management system should be modular, so allowing for the integration of newly added subsystems as well as factoring for expansion of the system from the addition of new sections of road or elements to it. Independent modules allow for this expansion without or with very limited impact on the rest of the system. Furthermore, the possibility of communicating with other control centers at the same or different level is a must.

As a result of the confined environment, accidents in tunnels – and particularly fires – can have dramatic consequences.

Such integration is advised at all levels, starting from the field level to ensure the fastest-possible response that is completely independent of the control center. The integration should then continue all the way up to highest control center level, in doing so allowing for a comprehensive reaction to influence each and every deployed subsystem. System integration on different levels also enables specific automatic or semi-automatic response on each of those levels, which is enabled by an intelligent alarm generator incorporating the possibility of alerting on a combination

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**Optical allusion**

As there aren’t any specific legislative requirements for electronic signs in tunnels, this means companies such as VMS Limited are able to offer the same solutions for tunnels and highways. “All signs obviously have to comply with the relevant performance requirements for whichever country they are to be used in,” stresses Roger Stainforth, chairman of VMS Limited. “In the UK, for instance, this means the optical and environmental performance requirements in BS EN12966 and the Highways Agency’s TR 2516B.” The performance requirements for signs in tunnels were added to EN 12966 as a result of the Mont Blanc and St Gotthard tragedies. “What subsequently changed for signs was that all sign enclosures must be stainless steel to withstand the heat, as opposed to aluminum,” Stainforth recalls.

“There’s also more control and monitoring now,” he adds. “Rather than just switching on a green arrow or a red cross, today’s operator must know when messages were set, why they were set, what messages are on at any point, and they must be able to monitor the sign. They’re now very much like motorway signs.”

With its vast experience in motorway deployments, this fact alone presented VMS Limited with an opportunity, which Stainforth fully grasped. The company has since won contracts to supply all types of tunnel signs to the Hatfield, Hindhead, Blackwall Tunnel Northbound refurbishment, as well as the Tyne Tunnel. This latter contract is an especially significant one, with 244 lane-control signals and around 30 signs being supplied for the tunnel approaches.

Stainforth found his company’s work on the Hatfield Tunnel most rewarding though. “There is a very restricted height allowance of 355mm,” he details. “By designing the optical system with a sloping front face and doing some clever things with the LEDs and the elliptical shape of the apertures, we’ve been able to get quite close to the normal type of UK signal, the matrix indicator, which is around 550mm high. It’s a little like an optical illusion and has been really interesting work.

“We have also been awarded a contract by Transport for London for an overhead vehicle and lane detection scheme to protect the Blackwall Tunnel northbound portal from vehicle strikes. Once an overhead vehicle and its lane has been identified, the system will read and display the license registration number and warning message on the VMS.”
When driving through a tunnel, you've probably never even paused to consider the lighting – and why should you? As Indal WRTL’s Neil Morris suggests, if the lighting is designed correctly you can drive without thinking about it. The design feature that you didn’t actually shouldn’t notice it at all, which is a shame as the company’s new T-line LED tunnel lighting actually warrants closer inspection. “Our goal when developing T-line was to attain the quality and safety of linear lighting, a total cost of ownership comparable or less than point-source, with maintenance and energy consumption less than either,” Morris says. The main benefits of a linear scheme are uniformities, excellent visual guidance, and good color recognition. The Indal man also believes redundancy is key, as with point-source systems if two lamps in a row fail you could potentially have up to 400m of road without any illumination at all. In some cases this could be deemed a Category 1 fault, so an emergency closure might have to be enacted, which could involve a police roadblock.

“T-line offers some of the best lifetime expectancy figures available from a high-output LED luminaire, made possible by the variety of bespoke design features

Addition to the lens, which introduces further unnecessary losses,” Morris says. As a result, the T-line luminaire has a very impressive light-output ratio when compared with traditional technologies since it’s a pure LED product. With temperature linked directly to efficacy and lifetime, it’s a must to ensure the luminaire doesn’t overheat, which is where COO-LED comes in – Indal’s T-line luminaire has a very low profile, so in tunnels with a low ceiling – which may have designed on the back of the huge success of the world’s longest tunnel completed in October,” he says. “The only component and lamp manufacturers!”

“Often, corrosion starts in low-quality aluminum or fins on the back of the luminaire, which means the luminaire looks consistent so in an installation they all appear the same.”

Light distribution is also vital, hence Indal’s direct-lens approach known as T-line, a bigger luminaire and have spread the LEDs out to keep the temperature down.” Similar to temperature, if you reduce the drive current, lifetime and efficacy also increase. “We drive our interior luminaires at 35mA, so we’re effectively under-driving them,” Morris says. “Many LED luminaires adopt the maximum drive current to get the highest-possible lumen output, so the energy required to light the same tunnel will be much higher, albeit you could achieve a higher lumen flux.”

T-line has a theoretical 15,000 lifetime of more than 200,000 hours, although in reality expected lifetimes are only considered up to 140,000 hours, as this is where the LED manufacturers’ projections end. “Given the industry standard seems to be for a lifetime in the region of 60,000-70,000 hours, some may challenge our claims, but we’re more than happy to back these up,” Morris adds. A question frequently posed is whether customers should go for fixed or replaceable LEDs, partly due to the necessity to replace traditional lamps. “We’ve chosen fixed with T-line because the lifetime is such that the LED will almost certainly outlast the luminaire anyhow,” he says. “The only beneficiaries of replaceable LEDs are the component and lamp manufacturers!”

At just 64mm deep, the T-line luminaire also has a very low profile, so in tunnels with a low ceiling – which may be replaced well before their expected lifetime due to either low-quality aluminum or indeed achieve a much better service life. Morris reveals. “Often, corrosion starts in parts, because COO-LED came in – Indal’s T-line luminaire has a very low profile, so in tunnels with a low ceiling – which may have more favorable cost-of-ownership ratio when compared with traditional technologies since it’s a pure LED product. With temperature linked directly to efficacy and lifetime, it’s a must to ensure the luminaire doesn’t overheat, which is where COO-LED comes in – Indal’s T-line luminaire has a very low profile, so in tunnels with a low ceiling – which may have very carefully,” Morris adds. “White LEDs range from a color temperature of around 5,000 kelvin, a warm yellowish color to 10,000 kelvin, a cool blueish color. We insist on narrow beam angles, which means the luminaire looks consistent so in an installation they all appear the same.”

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has a great deal of experience in tunnel management and already offers a complete ITS platform to promote a truly integrated system, which is beneficial to its users, distinctly ergonomic and easy to use.

Telega amassed its knowledge in tunnel management by participating in a number of high-profile projects in Croatia where, over the past 10 years, it has equipped more than 60km of tunnel tubes with such integrated systems. In recent years, the company has expanded and has provided these completely integrated solutions worldwide. What the company is not offering is an 'out-of-the-box' solution; each system is tailored to meet the individual needs of the client and particular project.

Who is using this new approach?
One of the best examples of this strategy can be found in Telegra’s home country. The Rijeka-Zagreb motorway is a busy 145km road connecting the Croatian capital with the country’s busiest port, Rijeka. One 45km stretch boasts 12 tunnels alone totaling almost 10km, featuring all of the requisite advanced traffic management systems. All of these subsystems comply fully with the European Commission’s Directive 2004/54, covering everything from tunnel signage to video surveillance and SOS systems – a host of subsystems that were simply crying out to be grouped into an integrated and efficient whole.

In 2009, Telegra equipped the main control center for this particular section – which oversees the road and all tunnels – with its topXview complete ITS platform software. The topXview product achieves integration at a number of levels, not least at a field level with the integration of traffic subsystem elements such as variable message signs and displays, barriers, meteorological stations, traffic counters, fire system, etc. topXview also allows for integration on a subsystem level – emergency road telephone system, video automatic incident detection system, and so on. Finally, it allows for the integration and inclusion into overall system control and

LEDs are popular for a number of uses in the traffic sector, yet applying them in tunnels is still relatively fledgling. In 2008, when Willem Zandvliet at the Dutch Ministry of Transport, Public Works and Water management decided to look into their potential for tunnel lighting, he teamed up with the appropriately named ‘LEDexpert’ to conduct a feasibility study. “In tunnels, lighting is the main energy consumer,” says one of the company’s founders, Marinus Jan Veltman. “LEDs consume far less energy than conventional lighting so we set out to establish whether they could be utilized as a light source for tunnels.”

The aim of the feasibility study was to establish some creative solutions with the lowest energy consumption, yet which conformed with the European regulations. Several routes were investigated with regard to colored light and colored road surface, but the strategy that presented itself was to work with white light and a counterbeam luminaire.

“The main advantages were a high efficacy of the source, plus instant light and dimmability,” Veltman says. “Besides that, the control of light with injection-molded optics could give the luminaire the ideal beam control and thus best light-aiming efficiency.”

Based on this research, LEDexpert generated a product specification sheet, describing all parameters for the ideal solution. The most important defined a tunnel of 10m wide and height of 5m, with a luminance of 10cd/m² in the central zone. (The uniformity along the road was defined as better than 0.7.) A scale model was then constructed along with extensive computer simulations to show that LED luminaires bring an extreme uniform illumination compared with high-pressure sodium.

The report was issued in October 2008 and the Dutch Ministry then decided on the Vlake Tunnel as the best place to test such a system. Located near Rotterdam, this 327m tunnel guides the A58 motorway under the Zuid-Beveland canal and has two lanes and one service lane open for traffic in each direction.

“Our next move was to find a manufacturer able to produce a luminaire that could fulfill the requested specification,” Veltman says. “We decided Europe’s Indal was the best candidate.”

LEDexpert tested the first prototypes in relation to light radiation pattern, quality of light, power consumption and expected lifetime. At the end of 2009, Indal began installing the system in the tunnel. LEDexpert monitored the work and measured the performance of the installation, with results presented in April. “We found a 50% energy-saving on lighting, no flickering due to the linear lighting, 90% savings on maintenance costs and 90% less nuisance to traffic,” Veltman reveals. “We also observed better light in the tunnel with a higher comfort level, as well as 10cm more free space above trucks due to the luminaires having low-profile dimensions.”

Veltman is certain that such results prove the real potential of LED lighting in tunnels, so predicts a surge of new projects in the years to come.
Best practice in tunnel safety

Guillaume Ponsar and Steve Morello from Egis Road Operation provide some real-world experience about operational procedures to maximize safety and security in a tunnel infrastructure.

Over the past decade, improvements in tunnel security and safety have become paramount for operators and concessionaires, with minimum safety requirements, service levels and equipment to be maintained and operated frequently becoming increasingly important. Egis Road Operation’s subsidiaries, this has necessitated a new approach to cross-fertilization of best practices within (and amongst them).

In January 2009, drills commenced for the Bonaventura project in Austria, which is one of the company’s most recent operating subsidiaries with tunnels. Before the official opening of the Bonaventura road network and tunnels in November 2009, several drills were organized in the three main tunnels along the motorway. The drills were undertaken during the course of three consecutive days and allowed the operator and its partners to apply and assess several procedures related to emergency evacuation and intervention plans. In addition, various personnel and emergency response units’ staff to be become acquainted with each other.

Egis Road Operation and its subsidiaries are also adept in the development and operational procedures of the police and emergency services. These plans are tested, assessed and updated (if necessary) during regular exercises/drills that are carried out to ensure continuous effectiveness of the response strategies. Advisory services are also supplied by Egis Road Operation for its subsidiaries and other private and public road/tunnel operators during the organization and debriefing of such drills.

In Australia, on the M2 and M5 East Sydney, and Melbourne CityLink, Egis Road Operation’s tunnel operations are provided with deluge systems that are requirements in all Australian tunnels. Fixed fire suppression systems control fires, cool the air temperature and prevent the fire from spreading in a tunnel. Monthly testing and training occurs with the fixed fire suppression system, but deluge systems require permanent maintenance, elaborate and detailed high-level operating procedures and specialized training.

Operating road tunnels requires a high degree of competencies in areas such as equipment needs and maintenance, setting up of drills to mitigate potential incidents, special training and organization, appropriate documentation realization, and implementation depending on local safety and monitoring requirements, etc. With 1.550km of road network under contract, Egis Road Operation has this experience, running 47km of tunnels in total. Among these are bi-directional tunnels, twin-bore tunnels (2.2 and 2.5 lanes per tube), some continuously monitored tunnels, operation of single-tube tunnels, and (as with the Bonaventura) tunnels in a motorway stretch.

A consequence of the Directive is that Egis Road Operation has undertaken an in-depth review of the application of the Directive within its operating subsidiaries in EU Member States and elsewhere. In this regard, it provides support in the implementation of a Tunnel Management System tool (an aid-to-decision support tool) that helps to organize the complete range of tunnel operation requirements. It also allows the operator to ensure maximum security and safety levels for traffic and users.

As required by the EC Directive, everything is spelled out in complete documentation known in the UK and Ireland as the Contractor’s Plan, or the Safety File in continental Europe. This Safety File also contains potential incident and emergencies identified before the opening. The identified, defined and ranked emergency scenarios provide the basis for appropriate response strategies and are included in the tunnel operator’s manual and operational procedures of the police and emergency services. These plans are tested, assessed and updated (if necessary) during regular emergency exercises/drills that are carried out to ensure continuous effectiveness of the response strategies. Advisory services are also supplied by Egis Road Operation for its subsidiaries and other private and public road/tunnel operators during the organization and debriefing of such drills.

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Cooperation and communication between the emergency response units, control room operators and onsite staff always have room for improvement. Emergency service stakeholders (fire services, first aid, rescue teams, and police) experienced different scenarios and situations, such as fire-fighting, treatment and evacuation of injured users inside the tunnels, dangerous goods identification, management of an accident involving a coach with multiple victims, etc. – all of which were previously identified as potential and realistic.

In tandem with the drills, the operator developed appropriate response strategies for the various incidents and incorporated them into the final versions of the tunnel management, and safety, surveillance, and security systems. These plans are tested, assessed and updated (if necessary) during regular emergency exercises/drills that are carried out to ensure continuous effectiveness of the response strategies. Advisory services are also supplied by Egis Road Operation for its subsidiaries and other private and public road/tunnel operators during the organization and debriefing of such drills.

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**New management strategy**

The challenge associated with video-based automatic incident detection (AID) systems has long been how best to manage all of the data supplied by the AID components – particularly as over the years tunnel projects have increased in size and complexity.

A company offering a solution to this challenge is Belgian AID expert, Traficon. When the company was awarded the AID contract for the Paris DIRIF project (for more on this, see page 36), it decided to revamp its existing video detection management software, which led to the creation of a new product called ‘Flux’.

“We’ve always delivered a management tool that can handle all inputs and alarms from our detectors,” explains Johan Gachon, Flux’s product manager. “But as projects have got bigger – from 10-20 cameras a few years ago to some schemes, such as DIRIF, featuring 1,500 cameras today – two issues have really come to the forefront: scalability and redundancy.”

Along with positive feedback from the Paris project, Gachon reports that the team behind Australia’s Clem 7 tunnel are also pleased with their investment in Flux. “Safety is paramount here; the operators have told me that if the AID system went down for half an hour, it would be in the papers the next day!” Redundancy was therefore essential. On all levels, the equipment has effectively been doubled. For instance, if one Flux screen goes down due to a PC crash, another will step in.”

Scalability was also tackled within the new software. Instead of potentially dozens of similar alarms, intelligent filtering means Flux simply and quickly sends one alert to the operator’s screen. “The Clem 7 has up to 20 incident detection alerts a day. They have 224 cameras, so you can imagine the chaos if multiple alarms were popping up from all of those!”

“Often AID is just one part of a wider system (usually a SCADA) so we use an open-source approach and Flux seamlessly integrates with the overall management system. The whole goal is to make life easier for the operators, and to ensure they can swiftly respond to incidents.”

It’s an entire fire monitoring solution, so we can monitor its size, spreading and its direction, and control the activation of fire suppression systems on a larger scale; in the case of a severe accident you don’t close the tunnel in front, just at the most appropriate exit upstream.

Another operating group that would endorse the value of topXview for day-to-day activities are those at the Mala Kapela, the longest tunnel in Croatia – a modern two-tube structure that’s part of the A1 Zagreb-Split-Dubrovnik motorway. All safety and signalization equipment in this 5,780m tunnel is controlled by topXview, while the main control center benefits from...
a videowall that enables a quick overview of the traffic situation and state of any other important subsystem in both tubes.

Additionally, topXview allows operators to run a variety of automatic responses covering regular events, such as escorting dangerous goods vehicles, malfunctions (such as power supply), incidents (such as fires detected in the tunnel), as well as maintenance operations.

**Tunnel management in practice**

Further afield from Croatia, Telegra has recently been involved in projects in Germany, Austria, Qatar and Turkey. In Qatar, the Ras Abu Abboud road interchange tunnel has undergone a deployment of ITS technologies such as VMS, lane-usage signalization, CCTV coverage and video-based incident detection and traffic counting and classifying equipment. In 2009, all of these separate components were integrated into an automatic management system using topXview. A number of scenarios – triggered by alerts about fire, air quality and visibility, overweight vehicle detection and other subsystems – are now automatically dealt with. Meanwhile in Istanbul, two tunnels are also using Telegra’s ITS platform – the 1,745m-long Kagithane-Piyalepasa and 2,195m-long Bomonti-Dolmabahce tunnels, both of which pass under the center of Istanbul in a bid to reduce the crippling traffic congestion from which the city chronically suffers. This particular project includes two tunnel control subcenters and one main control center, all of which are equipped with topXview. Plans are also in place to build more tunnels in the coming years, which will also be controlled from the supplied main control center.

As you would expect, the system covers a range of scenarios, including traffic accidents, special situations (such as pedestrians in the tunnel and even horse-drawn carts!), as well as maintenance scenarios. There is also a lengthy list for scenarios such as controlled applications (e.g. a military convoy passing through the tunnel), while a general situation scenario (e.g. traffic jams at portals) has been implemented.

These examples in Croatia, Turkey and Qatar show what can be achieved through integration. But in many operation and maintenance control centers around the world, truly integrated solutions are not being implemented – in fact, it’s commonplace to see very disparate subsystems controlled by several operators on multiple workstations, which can only be potentially detrimental to smooth operations and ultimately, the safety of those passing through.