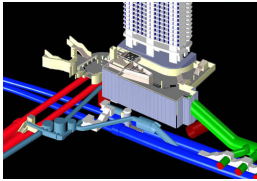


### 1 INTRODUCTION



Halcrow has expert capabilities in the field of tunnel ventilation and fire & life safety in underground spaces, which is underpinned by the extensive experience of its highly qualified staff members. This experience ranges across all types of vehicular transport tunnels (both road and rail) and utility tunnels (e.g. for gas transport and HV cables), and spans all phases of project work (from preliminary design through to detailed design and commissioning).

In designing tunnel ventilation and fire safety systems, we employ international standards combined with an assessment of local conditions to provide systems that achieve their performance goals while remaining robust, simple and with minimum life-cycle costs. Our in-depth knowledge allows us to propose innovative solutions for the most difficult ventilation problems – a recent example being the design of Saccardo nozzles to purge diesel fumes from a 16.3 km rail tunnel in South Korea (Young Dong Railroad Relocation Project). We also have significant expertise in the specification of fire suppression systems for tunnels.

A particular strength of the Halcrow service in this field is the capability provided by its engineering tools (including three-dimensional Computational Fluid Dynamics, CFD) to model potentially dangerous fire scenarios in tunnels and other underground spaces. These models allow an assessment of the risk to human life, and allow alternative ventilation strategies to be tested for their effectiveness in removing smoke.

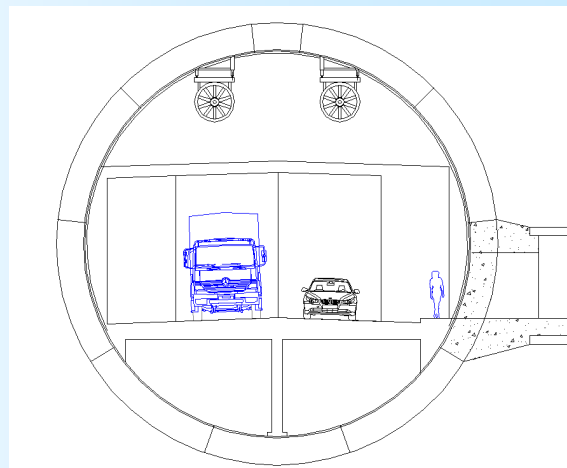
### 2 ROAD TUNNELS

Halcrow provide expert advice on the most appropriate type of ventilation system for road tunnels under design, including natural, transverse, semi-transverse and longitudinal ventilation systems. This advice is based upon an intimate knowledge of the relevant international standards relating to road tunnel ventilation (e.g. NFPA, RABT and PIARC), in addition to being

cognisant of local features that may have an important bearing on the relevance of these standards, such as the presence of a particularly high proportion of high-emission diesel-powered vehicles or the danger of a particularly large potential fire load.



Halcrow's approach in designing road tunnels is genuinely interdisciplinary, putting experts in tunnel civil design together with ventilation, lighting, control and other M&E specialists to give clients the greatest possible benefits. These include low construction costs, minimum number and types of ventilation equipment, and low installed power requirements.



The environmental impact of road tunnels on the environment can be considerable, and careful assessments may have to be made during the planning stage to ensure that the local air quality in the vicinity of the portals or ventilation stacks



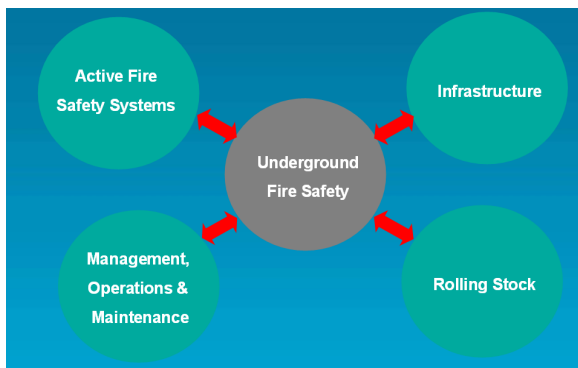
# Halcrow

## Capability in tunnel ventilation and fire & life safety

is kept within local or international guidelines. Within urban areas in particular, affected residents in many industrialised countries are increasingly demanding reassurance in terms of particulate matter (PM) emissions in addition to limits on gaseous contaminants including CO and NO<sub>x</sub>. Halcrow can provide environment impact assessments, and advise on the most effective means of satisfying local planning authority requirements, with solutions such as stack ventilation, tunnel short-circuiting and air filtration where appropriate.

### 3 RAIL TUNNELS

Ensuring the safety of passengers in long rail tunnels is a key design element that must be considered from the concept stage right through to operation. Through careful consideration of the qualitative and quantitative risks, Halcrow can advise its clients on whether or not any emergency ventilation is required in case of fire or hazardous spillage.



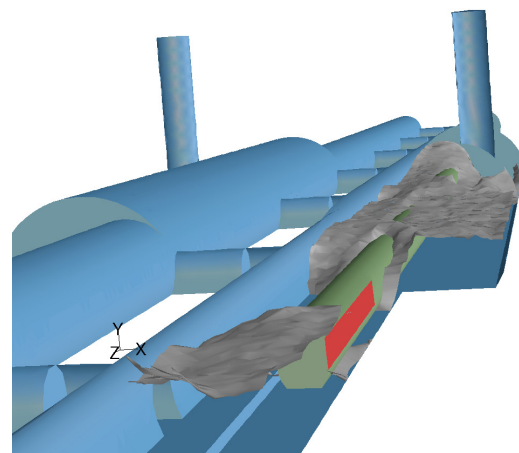
The safe design of rail tunnels calls for an interdisciplinary approach between tunnel designers, rail engineers and ventilation experts. This allows dangerous scenarios to be identified, and to set in place appropriate operational, emergency and ventilation procedures. Halcrow can provide a full, integrated service or can support tunnel design teams in any required area.

If emergency ventilation is called for in a rail tunnel, we can advise on the most appropriate type e.g. longitudinal with jet-fans or Saccardo

nozzles, single point supply and extract or distributed overhead extract within underground stations. Beyond the concept design stage, we have a proven M&E detailed design capability to proceed to layout drawings, performance specifications and detailed tender documentation.

In addition to safety considerations, our experts can advise on the maintenance of good comfort conditions for passengers and staff in railway tunnels, by ensuring appropriate air temperatures and air quality. All relevant parameters including initial rock temperature, tunnel lining characteristics, rail traffic schedules, traction supply arrangements and rolling stock thermal mass are taken into consideration in our tunnel climate simulation programme.

During the construction of very long rail and road tunnels (typically over 10 km in length), tunnel ventilation and cooling during the construction phase can become a difficult issue, due to the heat generated by tunnel boring machines and other equipment, and that emanating from the rock mass, which can be substantial in sections of tunnel with high cover. Adequate air exchange rates must be maintained to avoid explosions due to the seepage of natural gas, and to avoid asphyxiation due to the seepage of carbon dioxide. Halcrow engineers can advise on appropriate ventilation and cooling systems that can be scaled up as construction progresses, to ensure a safe and comfortable working environment for construction crews.



Excessive train-induced draughts can compromise the comfort of passengers awaiting trains on underground platforms. Halcrow designs cost-effective draught relief systems through a combination of designing required civil works (cross-passages and draught relief shafts) and advising on appropriate train scheduling.

Halcrow engineers have experience in designing high-speed railway systems while ensuring the comfort and safety of the passengers. Through aerodynamic simulations, we can advise on the effects of high-speed train movements within train cabins and on the tunnel structure. We can also recommend structural measures (e.g. pressure relief shafts) and improvements in rail operation to ameliorate any negative aerodynamic effects.

#### 4 METRO TUNNELS AND STATIONS

Halcrow has significant experience in developing mass transit systems, and in providing answers to difficult tunnel ventilation and cooling issues within urban metro systems. Halcrow experts provide advice on the most economical arrangement of ventilation shafts within underground metro systems, in order to provide smoke control facilities (in case of a fire emergency on a train) and to act as draught relief shafts if required. Within the stations, Halcrow can design smoke management and evacuation plans to satisfy local requirements or international guidelines (e.g. NFPA 130), including the use of smoke curtains, local extract and natural ventilation where appropriate.

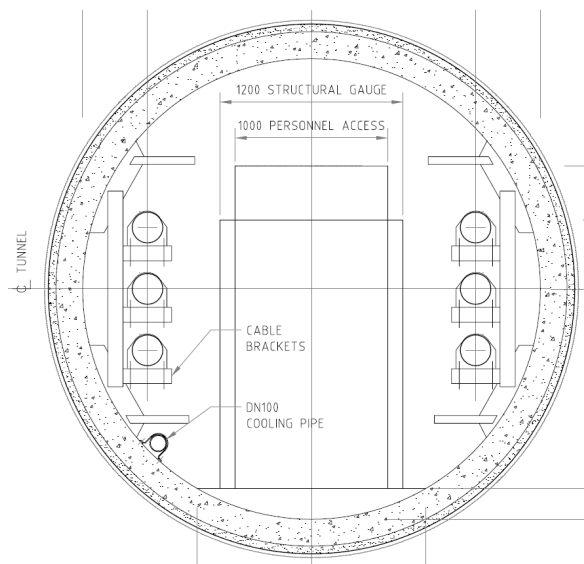
Even in temperate climates, metro stations can become uncomfortable for passengers during the summer due to heat released from rolling stock drives, station M&E services and from passengers themselves. Halcrow can advise on effective environmental control solutions including under-platform extract, platform screen doors and local (spot) air-conditioning. These M&E solutions can then be integrated with other services (e.g. escalators, lifts, local extracts) so that an overall electrical supply, distribution and control scheme can be prepared. We can provide drawings for plant rooms including air-handling equipment,

tunnel fans, supply and return dampers, as well as performance specifications and tender documents for the M&E equipment.

#### 5 UTILITY TUNNELS

Service tunnels may have particular ventilation issues that are important to address for safety requirements. For example, significant amounts of heat are generated in cable tunnels that must be dissipated in order to maintain a safe working environment. In general, all service tunnels and underground spaces should be regularly purged of methane and other hydrocarbon gases, in order to avoid potentially explosive concentrations from developing.

Halcrow can provide specialist advice relating to the ventilation and cooling design of service tunnels, including the design of the civil infrastructure (including shafts, fire barriers and plant rooms) and the complete M&E works (including fans, dampers, gas & temperature sensors and remote control equipment).





# Halcrow

## Capability in tunnel ventilation and fire & life safety

### 6 MEET OUR TEAM

#### Peter Woodburn



MA PhD CEng MIMechE

Peter is an Associate with extensive experience across a wide range of areas of fluid mechanics, particularly related to fire dynamics and applications of Computational Fluid Dynamics (CFD). He has undertaken research into CFD simulations of tunnel fires, including both King's Cross and Mont Blanc tunnel fires amongst others. His work is typically directed towards developing optimum ventilation and smoke control strategies within complex buildings and structures.

#### Patrick Stone



GIFireE

Patrick is a former fire safety officer and has over 28 years experience in Municipal Fire services, performing operational, training and fire safety duties before specialising in fire engineering. He has significant experience in developing and reviewing fire strategies for London Underground refurbishment contracts, and has an appreciation of applied fire engineering and structural fire protection in the built environment.

#### Mike Deevy



MSc PhD CMath

Mike specialises in the analysis and optimisation of systems involving fluid flow. He has a PhD from UMIST (now the University of Manchester) in turbulence model development for Computational Fluid Dynamics (CFD). Mike worked in the Fluid Dynamics team at the Health and Safety Laboratory (an agency of the HSE) for three years, undertaking projects in a wide variety of areas, using both analytical and computational methods. These projects included gas dispersion following a high pressure release; indoor air problems and thermal comfort; particle transport and deposition; explosions.

#### Hal David



BEng

Hal is a fire safety engineer with experience in fire detection and ventilation control systems. He recently provided the specification for a CCTV based smoke detection system and automated ventilation response regime for a major UK road tunnel, and has provided fire risk assessments for a major investment bank in the City of London. Hal has experience in maintaining compliance to British Standards relating to fire safety for various commercial, industrial and residential properties.



## Halcrow

### Capability in tunnel ventilation and fire & life safety

#### Fraser McCourt



BSc

Fraser is a graduate fire safety engineer and has experience in writing fire safety strategies and evacuation calculations for large London Underground projects. This includes specifying compartmentation, detection and suppression measures, and developing evacuation strategies. Fraser also has experience in preparing risk assessments on the risk of fire, and the risk to a project/company due to fire (business risk) for both specific sites and for projects as a whole, and suggesting how these risks could be mitigated.

#### Chris Morley



BA

Chris is an Associate with over 7 years experience in pedestrian planning. Chris is skilled in the use of Pedroute, Paxport and, latterly, Legion pedestrian modelling software, as well as static analysis techniques. Chris is well versed in the corporate standards and measures of pedestrian experience applicable to station planning and design. He has a deep understanding of the requirements of urban designs in terms of facilitating optimised passenger flows.



### 7 TRACK RECORD

An excerpt from our extensive track record follows:

#### Underground rail stations and tunnels

- Reference design for Crossrail eastern branch stations, UK.
- Review of fire safety strategy for Heathrow Express extension to Terminal 5.
- Reference design for Dublin Area Rapid Transit underground system
- Tunnel and station design for Docklands Light Railway's extension to Woolwich Arsenal, UK.
- Upgrading of Highbury and Islington station to achieve step-free access, UK.
- Survey of fire safety precautions for RailCorp underground stations in Sydney, Australia.
- Bid design of tunnel ventilation and fire safety precautions for the Gautrain Rapid Rail Link, South Africa.
- Bid design of tunnel ventilation and fire safety precautions for the Calgary West Light Rail Extension
- Preliminary design for Downtown Ottawa Transit Tunnels and four enclosed stations
- Design of the tunnel and station ventilation and fire safety systems for Edinburgh Airport Railway Link.
- Review of tunnel and station fire safety engineering for New MetroRail, Perth, Australia.
- Young Dong Railroad Relocation Project – risk analysis, concept ventilation design and CFD analysis within the running tunnel and crossing loop station, South Korea.
- Upgrading of fire safety systems within the Vauxhall station step-free access and congestion relief project, UK.
- Upgrading of fire safety systems within the North Greenwich station capacity enhancement project, UK.
- Design of the tunnel and station ventilation and fire safety systems for the DLR extension to Woolwich Arsenal UK.

#### Road tunnels

- Detailed design of fire safety systems and tunnel ventilation for the New Tyne Crossing, UK.
- Development of performance specifications for Automatic Incident Detection, an improved tunnel ventilation control system, and improved safety / evacuation signage at the Medway Tunnel, UK.
- Major Investment Study for the proposed Riverside to Orange County Highway in the USA, which may include tunnels up to 16 km long.
- Recommendation for fire suppression system in New Tyne Crossing, UK.
- A review of the tunnel ventilation and emergency evacuation provisions in the Clyde Tunnel, Glasgow, UK.
- Computational Fluid Dynamics analysis of possible fire scenarios in the proposed A303 Stonehenge Road Tunnel in the UK.
- Investigation of alternative fire suppression systems for the A303 Stonehenge Road Tunnel in the UK.
- Research projects on post-incident recovery in highway tunnels and primary tunnel safety, funded by the UK Highways Agency, in collaboration with TRL.
- A review of tunnel safety provisions for the Kyungju Yangbuk Road Tunnel in Korea.
- Method statements for the operation and maintenance of the New Tyne Crossing, UK.
- Detailed design of the Aden to Amran Highway Tunnels, Yemen.
- Category 3 check on the tunnel ventilation and fire safety precautions for the A3 Hindhead Tunnel, UK.

#### Utility tunnels

- Reference design for ventilation of Ipswich cable tunnel.
- Tender design for ventilation of National Grid cable tunnels.
- Tender design for cooling and ventilation of Abu Dhabi cable tunnel