

Human Behaviour in Tunnel Fire Incidents

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ABSTRACT

The behaviour of people in tunnel fires shows many similarities to that in other types of buildings. The recognition, response/pre-egress activities, and evacuation stages apply in both cases; a person's role has a major effect on the behaviour they will exhibit, and people cluster in family, social or ad-hoc groups. Communication between people occurs throughout the incident, in order to raise the alarm, and give instructions/directions to the exits. Pre-egress activity includes similar actions to those performed in building fires, e.g., investigation, fire-fighting, searching for, warning and rescuing others. Rapidly-worsening conditions in tunnel fires may however reduce the options available to people.

During evacuation, people usually head away from the fire, although they may often find themselves moving through smoke. Tunnel portals ("familiar" routes) will be preferred to side exits unless directions to the contrary are given, or smoke/darkness leaves no choice.

Some differences from other building fires are that drivers are very reluctant to abandon their vehicles, and in rail tunnels, passengers are reluctant to abandon their luggage.

KEYWORDS: human behaviour, egress, tunnel fires

INTRODUCTION

Over 700 people have perished in the last 10 years in a number of serious tunnel fires across the world. Following these disasters it is timely that there is a major research effort concerned with understanding tunnel fires and reducing their impacts. 'UPTUN' (UPgrading TUNnels, website <http://www.uptun.net>) is the largest of a number of current European projects focusing on tunnels and tunnel safety [1], with the main objective to develop innovative, sustainable and low cost measures that will reduce the risk and consequences of fire.

This paper reviews the behaviour of people in tunnel fire incidents, large and small. This knowledge will be used to adapt a generic human behaviour and evacuation simulation in order to model tunnel emergencies, as part of the UPTUN holistic evaluation procedure. The representation of behaviour within the model must be sufficiently realistic for a reasonable estimate of exposure to heat and toxic smoke products to be made.

RECENT TUNNEL FIRE INCIDENTS

The "Fire in Tunnels (FiT)" network website (<http://www.etnfit.net>) lists most recent incidents, with brief details. A recent book [2] also describes a number of tunnel fires, again with brief details. Generally there are few accounts of these fires in the published scientific literature, and fewer still that discuss human behaviour in any depth. The approach adopted in this paper has therefore focussed on a search of the internet for news articles, particularly those with witness statements that shed some light on what people were doing. (Using a search engine would be more fruitful than trying to locate specific

URL's, which in any case would take many pages to list in full). These articles will only give at best a qualitative description of behaviour; it will not be possible to estimate the probabilities of different actions being performed.

Table 1. Recent tunnel fire incidents reviewed in this paper.

Date	Tunnel	Type	Dead
18/02/03	Taegu, S. Korea	M	197+
25/01/03	Chancery Lane, London Underground, England	M	
03/11/02	Homer Tunnel, New Zealand [3]	R	
24/10/01	St Gotthard, Switzerland	R	11
18/07/01	Baltimore (Howard Street), USA	T	
27/11/00	Laerdal, Norway	R	
11/11/00	Kaprun, Austria	T	158
29/05/00	Cross Harbour Tunnel, Hong Kong [4]	R	
29/05/99	Tauern, Austria	R	12
24/03/99	Mt Blanc, France/Italy [5]	R	39
18/11/96	Channel Tunnel, England/France [6]	T	
28/10/95	Baku, Azerbaijan	M	289
15/10/94	Kingsway (Mersey) Tunnel, England [7]	R	
01/03/94	Huguenot Tunnel, South Africa [8]	R	1
19/02/91	Bethnal Green, London Underground, England [9]	M	
16/01/91	Zurich, Switzerland [10]	T	
18/11/87	Kings Cross, London Underground, England [11,12]	M	31
17/01/79	San Francisco BART, USA [13]	M	1

The tunnel type is M = metro, R = road, T = train. Where no reference is given, details came from reference [2], and internet articles

The Fire Environment

Smoke spreads rapidly in the confines of a tunnel, over long distances, particularly when large quantities are being released by a fast-growing fire. Two minutes after the crash in the Tauern tunnel, the control video cameras at the northern portal suddenly showed thick smoke coming up the tunnel at high speed. It took only seconds to obstruct the cameras' view to the point they only showed a black image ($800 \text{ m} \div 120 \text{ s} = 6.7 \text{ m/s}$). In the Huguenot tunnel, 12 minutes after ignition, a detector was activated 768 m down the tunnel from the point at which the fire started ($768 \text{ m} \div 720 \text{ s} = 1.1 \text{ m/s}$). In all the incidents reviewed in this paper, people's exposure to smoke was a factor in their behaviour.

FIRST PHASE OF BEHAVIOUR – RECOGNITION

The time taken for individuals to recognise the existence of a fire is a complex function of many parameters. Communication is critically important in the Recognition stage of the overall evacuation process. However it also has relevance later, with regard to seeking more information (Response stage), being directed to an exit (Movement stage), and enabling/maintaining the formation of groups.

Communication between Different Levels of the Authority Hierarchy

Lines of communication should be open, short, and direct to people with authority. However, in the Baltimore tunnel, the fire department was not notified until over an hour after the accident, and the city's warning sirens were not sounded until 2.5 hours after the accident. The Bethnal Green incident lasted about 5 hours, but could have been over in about half an hour, with no need for evacuation of trains in tunnels, had there not been delays in passing information back from the police to London Underground.

Procedures which the control centre had to apply during the Channel Tunnel incident were too complex and difficult to use. Furthermore there was insufficient time to perform them all correctly, because 4 minutes were lost before the first alarm was confirmed.

The driver of the first train involved in the Taegu disaster apparently failed to make an appropriate report to the station's emergency control centre after becoming aware of the arson attack. Staff in control centre allegedly failed to pay attention to the station's CCTV monitors or give appropriate instructions to the train drivers. The driver of the second train only received news of the fire after stopping at the platform.

It is essential that communication systems remain intact with adequate information flows between relevant personnel. Loss of radio contact was a factor in the Channel Tunnel; in the Baltimore the train engineers were in a dead zone so had to use a cell phone instead; at Kaprun, where the control centre was unaware of the train driver's inability to open the doors; and the Tauern tunnel, where firemen had to retreat to an emergency phone.

CCTV cameras in the Tauern and Huguenot tunnels were quickly rendered useless, due to thick smoke and/or power failure. Other than helping to raise the alarm, they could not provide information to the control centre, or enable the control centre to direct operations.

Communication from Authorities to Members of the Public

The need to persuade passengers to act appropriately is a key focus of emergency response; people must be convinced an emergency is genuine before starting to act. At Zurich, the conductor ran through the train declaring that there was a fire in the tunnel. At Chancery Lane, the driver ran through the train alerting passengers. Where direct contact is not possible, PA systems can be used. Messages could be pre-recorded, or improvised on the spot. In the Channel Tunnel, the crew of the train used to evacuate the injured had some difficulties in reassuring the train passengers, as no pre-recorded messages adapted to this situation were available. An improvised message may contain mistakes, or may not inspire confidence due to the way it is delivered. On the other hand, spontaneous directed messages can be very effective at reinforcing the pre-planned messages [14].

When messages are given, they may not always be received or understood, due to background noise, language differences (to address this at St Gotthard, messages are in four languages), or disabilities among the intended audience. In the Zurich tunnel, passengers often could not understand fire-fighters due to their protective masks.

Following the Channel Tunnel fire, HGV drivers complained that they received insufficient information, both at departure and during the incident. Lack of information was also an issue following the Cross Harbour tunnel fire in Hong Kong. The earlier broadcasts advised tunnel users about a vehicle breakdown, while later ones advised about a car on fire, causing confusion to the people inside the tunnel. Secondly, some

motorists and bus passengers complained about the delay before being directed to evacuate, and that no clear messages were given while they were waiting.

A number of tunnels provide information to drivers by means of radio broadcasts. Questionnaires issued to drivers using the Gudvanga tunnel in Norway found that 36% always listened to the car radio, 49% listened sometimes, and 15% had no radio [15].

Pre-departure information for the Channel Tunnel now explains what information will be provided in an emergency, and the required responses from passengers. The San Francisco BART has safety brochures in English, Spanish and Chinese available at stations. A number of European road tunnels (e.g., St Gotthard, Mont Blanc, and Dartford tunnel in the UK) provide leaflets. The Swiss government has made tunnel safety part of truck drivers' training.

Communication by Members of the Public

Methods for members of the public to interact with one-another are restricted to direct verbal messages, or gestures and other visual communication. Some form of communication occurred in all the tunnel fires reviewed. At Mont Blanc the driver of the burning lorry was warned by the flashing headlights of oncoming vehicles. At Zurich and Chancery Lane, movement of some passengers to the front of the trains encouraged others to follow suit. At Kings Cross, members of the public attempted to direct other people away from the burning escalator, although these attempts were frequently ignored. In the St Gotthard tunnel, a lorry driver was more successful in giving directions.

Members of the public will interact with authority figures to raise the alarm, seek information, or ask for assistance. Systems need to be in place to facilitate this. At Kings Cross, a ticket collector was eventually alerted by members of the public. They had walked some distance from the fire, and the message had to be given by several people before he took action. On the other hand, when someone pressed the emergency stop button on the burning escalators, the transport police immediately went to investigate.

In the Zurich metro, smoke was entering the carriages of the second train because the air conditioners could not be turned off. "The vents pulled smoke so quickly that soon you could not see through the wagon. Some people were shouting: turn off the air!" Shouting was the only way the passengers had of attempting to communicate with the driver.

SECOND PHASE OF BEHAVIOUR – RESPONSE

Non-Egress Activities

"Authority figures" have a wide range of non-egress (or pre-egress) activities that are connected with their roles and training. Interestingly, members of the public also engage in very similar behaviour, which is frequently altruistic in nature. It is not clear to what extent these activities are intrinsic to being "a member of the public," or whether members of the public decide to act as surrogate "authority figures." If the latter, we would expect to see individuals exhibiting sequences of "altruistic" behaviour; if the former, altruistic behaviour would occur randomly, with no correlation between individuals exhibiting one aspect and another.

Investigation was less common than in building fires; this may have been because it was less feasible, or the first cues to the fire were unambiguous. However at Kings Cross, transport police immediately investigated once the escalators had been stopped. In

contrast a ticket inspector did not investigate until 3 escaping passengers had warned him of the fire, clearly showing the influence of role on behaviour. At Tauern, there was also evidence of investigation - one lorry driver said “they left their cars, had a look around, and a German driver was taking pictures.”

Fire-fighting by train passengers did not feature in the incidents covered by this review. On the Kaprun funicular railway, there were extinguishers in the engineer’s room in both the bottom and in the top stations, but not in the train cabins or the tunnel itself, because legislation did not require this. The Taegu fire was started deliberately when the arsonist threw the flaming bottle inside the train. Other passengers unsuccessfully tried to stop him. In a drill conducted by Seoul Metropolitan Subway Corporation following the Taegu fire, two-thirds of the participants said they were aware of the locations of the fire extinguishers on the trains (under the seats), but it took as long as 33 s to find them.

On the bus in the Huguenot tunnel, the co-driver attempted to smother the flames with clothing, which promptly caught fire. No one thought to use the fire extinguisher onboard the bus, or the tunnel extinguishers which were only 50 m away. During the Tauern fire, the first extinguisher was taken out of its housing 5 minutes after the crash. Clearly the extinguishers had not been used effectively, since the fire kept growing. At Mont Blanc the truck driver had “no time to use his fire extinguisher.”

It must be remembered though that this survey has concentrated on those serious enough to be newsworthy, and in common with building fires there may be a (large) percentage of unreported fires where first-aid fire-fighting has been successful. One of the Mont Blanc references said fires in vehicles passing through the tunnel were “commonplace.”

Train staff would often provide passengers with information, either by PA or face to face. Operators of the San Francisco BART will issue evacuation instructions to passengers via the PA system. In the Zurich fire, passengers on the first train were warned by PA. Although the tone of voice seemed uncertain and nervous, the passengers heeded the advice (to wait until told to leave). Those who tried to disembark were held back by fellow passengers. Passengers on the second train knew something was wrong when the conductor ran through the train declaring that there was a fire in the tunnel.

At Chancery Lane, various witnesses described how information was provided, but not reassurance - “We could hear the driver going ‘mayday, mayday everybody get off’.”

In contrast, the calmness of the Chef de Train and catering steward during the Channel Tunnel fire helped to prevent the passengers from panicking, despite very difficult circumstances (the door had been opened, filling the Amenity Coach with smoke). Once the cross-passage had been located, the Chef de Train then proceeded to evacuate the passengers and crew from the club car and into the cross passage. Minimal direction would have been required, once the order to leave was given.

At King’s Cross, there were numerous instances where members of the public and London Underground staff attempted to warn and direct people entering the station away from the fire, although these efforts were mostly ignored. On the other hand, the police managed to get people to follow instructions with little exception. The influential role of the police stems from people’s reaction to them as figures of authority in general. Members of the London Fire Brigade were also successful in directing people. Members of the public were more effective at directing others in the St Gotthard incident, although the fire may already have been obvious to those being directed, unlike at Kings Cross.

The actions of the train crew at Zurich and Chancery Lane could be considered to constitute a search and warn pattern. Members of the public do not seem to perform these actions; rapid fire growth in many cases may have made this option too hazardous and in any case, all members of the public would have been alerted at much the same time.

Search and rescue operations will usually be confined to fire brigade personnel. Given that they will probably have to travel some distance before they get to the seat of the fire, anybody they rescue will need to have taken shelter in some sort of refuge - either an officially-designated one, or improvised. Examples of the latter include the Channel Tunnel train driver, who was found in his cab by the First Line of Response team and led to safety; the three people at Tauern who were rescued from an emergency telephone box and 12 drivers rescued from their vehicles by Italian operatives at Mont Blanc. A tunnel maintenance worker, riding his motorcycle, saved 10 people in four journeys into the Mont Blanc tunnel. On the last journey, he died in a refuge with a person he tried to save.

Members of the public may also rescue people they encounter. Irada (eyewitness, Baku, aged 19): "I felt myself totally lost and ready to collapse. That's when I made myself call out for help. A guy reached out and somehow found my hand and pulled me to safety." Rescues may only involve short-lived assistance, abandoned as soon as an obstacle has been surmounted. Zarifa (Baku), said "Young men tried to break the glass of the train windows with their bare fists. Finally, some succeeded and managed to lift us through." During the Zurich evacuation, passengers remarked in particular that people helped one another and that no one shoved. The older people were assisted by others. Procedures for evacuation of both the San Francisco BART and the Heathrow Express Trains [16] request passengers to co-operate and assist those who may need it.

In some of the worst disasters (Baku, Kaprun, Taegu), the train doors were not opened, either because a power failure made this impossible, or human error/negligence by the staff. A student taking part in the drill on the Seoul subway system took almost 2 minutes to manually open the doors. Victims of the Taegu fire would have had about 60 s to get the doors open before being smothered by smoke, according to CCTV records.

Members of staff will usually behave in accordance with their training, but mistakes can be made. The training and procedures may also turn out to have been flawed after the incident. For example, in the Channel Tunnel fire, the initial decision to drive on through the tunnel, and the subsequent decision to stop there, were both in accordance with the procedures at the time, although revised following the inquiry.

One area in which training seems to fail quite frequently is in the use of breathing apparatus. The driver in the Channel Tunnel did not use his breathing apparatus because he considered it "impractical," and as a result failed to open the cross-passage door. The first two recovery staff who arrived at the incident site in the Hong Kong Cross-Harbour tunnel did not wear smoke masks, and as a result could not stay at the scene. The fire brigade is not immune either. At Kings Cross and Mont Blanc, fire officers died because they were not wearing BA kit.

Frequent tunnel users may benefit from familiarity with their environment. In the St Gotthard tunnel, some drivers attributed their survival to "knowing where the exits are."

Group Formation and Behaviour

As is well known from research on fires in buildings, social groups tend to remain together. The tightest bonding is exhibited by members of the same family. One

eyewitness to the Tauern fire reported fathers carried children in their arms. Others said people were looking for relatives. On the Baku Metro, a mother recounted how her 2 daughters helped her off the train, but as conditions worsened she ordered them to leave her and save themselves (she was rescued later). This last example is interesting because it shows the family group breaking up under extreme stress.

Larger groups may be formed by people who have some form of social affiliation. The Mersey tunnel fire involved a coach on private hire, carrying a party of 40 women out on a celebration. The size of this group, and the fact that they had consumed a significant quantity of alcohol, caused difficulties in taking care and control of them.

A study into the effect of group size concluded that fatalities were more likely in larger groups [17], as these were less receptive to initial cues, and took longer to organize themselves. On the other hand, if the group leader acts swiftly and decisively, the benefits to the whole group may more than compensate for any disadvantages due to the group's size. In the Homer tunnel the bus driver formed the passengers into a single chain linked by holding hands; none died, although 3 people were treated for smoke inhalation.

Ad-hoc groups may be formed by those who have no affiliation beyond finding themselves in the same emergency. A number of incidents have led to groups of people holding on to one-another (due to poor/zero visibility) and moving slowly in single file to the same exit. These groups can provide mutual encouragement for their members. Zurich eyewitness: "In one of the lighted niches, the man in front of us sat down. I sat down too and told my girlfriend that I wanted to stay there. She became upset, started shaking the man and screamed that he had to go on." Other ad-hoc groups may be formed from rescuers and the dependents they are helping. The rescuers may include members of the public, unrelated to the people they save.

A series of experiments in the Benelux tunnel in the Netherlands [18], where people were exposed to a simulated fire and smoke, also suggested the existence of "herding" effects. Of those people who had not responded before the announcement to leave was made on the PA system, there was a delay until the first person left their car, whereupon the others followed rapidly behind them. It was also noted in some of the tests, where significant numbers of people left before the PA announcement, they responded shortly after the first of their number had started to leave.

Reluctance to Abandon Property

Accounts of the road tunnel fires make it clear just how attached motorists are to their vehicles. This may be due to a desire to avoid losing their property; a commitment to finishing the journey; or simply the inconvenience. The inside of the car may also act as a "refuge," keeping out the worst of the smoke for a short period. Motorists are therefore inclined to stay in their cars, and if asked to leave them unlocked with keys in the ignition, are unwilling to do so for fear of theft.

In unpublished tests carried out for Eurotunnel [12], people in cars behind the "fire" were observed to sit and watch developments, in some cases just closing their windows to keep "smoke" out. They only evacuated when instructed to do so, or they saw others leaving. Research in the Netherlands [18] observed similar behaviour, with many drivers only leaving their cars when a PA message warned of a possible explosion risk. Some drivers got out of their cars, but then remained beside them until the PA warning was given.

For many motorists, the instinctive reaction is to attempt to drive out of the tunnel. While the fire is still small it may be possible to drive past. In other cases, drivers may turn and leave the tunnel by the way they came in – this happened in the Huguenot tunnel fire, at Tauern, St Gotthard and Mont Blanc, to name just four well-known examples. Of about 200 vehicles in St Gotthard tunnel, about 100 cars turned and drove out, then a bus full of passengers managed to reverse, as did about 15 trucks. Some drivers stayed in their vehicles and tried to telephone for help. Six of the bodies of the victims were found on the tarmac, while the remaining four were in their cars. Of the 10 passenger vehicles in Mont Blanc, 4 had started to make U-turns, but all failed. 27 victims were found in their own vehicle, 2 in other vehicles, and 9 elsewhere in the tunnel/refuges.

Commitment to the journey was shown when a fire started in a bus carrying about 50 people to the opening ceremony within the Laerdal tunnel. No one was hurt, the smoke eventually cleared, and all passengers were able to re-board and continue their tour.

The Huguenot tunnel fire CCTV recording showed passengers leaving the bus in an orderly manner and attempting to retrieve their belongings from the roof rack. In contrast, passengers lost all their luggage in a coach fire in the Homer Tunnel. Train passengers also have been observed attempting to evacuate with their luggage. Procedures for the evacuation of Heathrow Express Trains [16] recognise this desire; if people wish to take their luggage, they are instructed to wait behind until all other passengers have left first.

Observations have been made of people alighting normally from trains, with and without luggage [18]. The effect of luggage was to slow the flow rate by about 50%, from about 1.4 per s/s to 0.7 per s/s. For other types of train, where there was a difference in height between the train and the platform of about 0.3 m, the flow rate was much less, and the additional reduction in the flow rate due to luggage was less marked, about 70%.

THIRD PHASE OF BEHAVIOUR – MOVEMENT

Movement Speeds

The movement speed of “able-bodied” individuals varies widely. However there seems to be reasonable agreement regarding an “average” value in the region of 1.2 ~ 1.4 m/s. Attempts to run may be thwarted by poor/zero visibility, uneven ground (for example, railway tracks) or obstacles - including bodies of victims. In zero visibility, movement speed may be as low as 0.3 m/s [19]. However a recent experiment found that people evacuating a smoke-filled tunnel initially moved at ~0.4 m/s, but this rose to ~0.9 m/s as they gained confidence and did not encounter obstacles [20].

Stamina is another important issue. At Bethnal Green, 33 people went to hospital, suffering mainly from exhaustion, out of 5,500 people evacuated. In the Zurich fire, the travel was about 700 m, and many people had nearly run out of strength by the end. The presence of rescuers encouraged the escaping passengers to continue and to reach the portal; several people were unsure if they could have made it without this reassurance.

Traversing Changes In Height

In rail/metro tunnel fires, leaving the train frequently caused difficulties and delays. If part of the train is in a station (e.g., Chancery Lane), some passengers may have to move between carriages via the end doors, which are usually quite narrow and therefore introduce a significant delay. If it is necessary to evacuate passengers to the track level

(typical drop ~1 m), side doors may be used if the tunnel is wide enough (Zurich) or the end door (Bethnal Green). In one incident, 400 passengers required an average of 12 seconds per passenger to negotiate the exit and ladder. The passenger population in this case included elderly/infirm people, and passengers evacuating with their luggage. At Bethnal Green, the detrainment lasted from 0858 to 1330; even if numbers were evenly distributed, this represents one person for 6 seconds in each direction. Passengers in wheelchairs caused serious problems, and following this incident, London Underground now provides “carrying sheets” for evacuating disabled customers.

In some situations it may not be possible to use the carriage doors during an evacuation, and passengers will try to break windows instead (e.g., Baku, Kaprun, Chancery Lane). Finally, two full-scale evacuation experiments [21] were performed in an overturned carriage. The evacuation rate at the end exit was about 9 people per minute, falling to 5 people per minute in the presence of (non-toxic) smoke.

Height differences are not only restricted to rail tunnels. In the Hatfield and Heathrow tunnels in the UK, to name but two, walkways are on raised ledges, with steps for access.

Exit/Direction Choice

In a tunnel, members of the emergency and rescue services (and members of tunnel staff acting in a similar fashion) would be familiar with the tunnel layout, and thus would use the emergency exits. For most other people, the tunnel portal corresponds to the “familiar route” and as such will be the most popular exit choice provided it is not too distant.

Doors on the side of the tunnel will all look the same until a person actually goes through the door and sees what is on the other side. Thus, whether a door ultimately leads to the outside, or to a dead-end refuge, will not be a factor in exit choice.

People in the St Gotthard tunnel who escaped on foot used the parallel escape route, accessed at 250 m intervals. In zero visibility conditions, they felt their way along the tunnel walls until they found an exit. In the Mont Blanc tunnel, four car drivers died after moving about 100 to 500 m, so should have been able to reach a refuge area, yet did not do so. The bus passengers in the Huguenot tunnel did not realize that the cross connections were places of refuge, although they were not signed as emergency routes.

The direction of exit choice will almost certainly be away from the fire. Of the 155 people who died in the Kaprun disaster, 60 had managed to leave the train, but were quickly overcome as they tried to flee by running upwards. The 12 survivors went down the tunnel instead, past the fire which had started at the back of the train. In Baku, the fire also started towards the rear of the train, and the direction of evacuation was to the front. Due to conditions of almost zero visibility, the fact that the ventilation system was sending smoke in the same direction would not have influenced their exit choice. At Zurich, 140 passengers moved away from the fire, and only one in the opposite direction

In the experiments in the Benelux tunnel [18], nobody went past the “fire.” This example was unusual in that all people used side exits rather than the tunnel portal. The fact that the two nearest exits were only 50 m apart (thus the nearest exit was less than 25 m away) may well have been a factor here. 94% of people used the nearest exit, and 6% used the first exit they encountered when moving in the driving direction (i.e., towards the fire). In another experiment, 89% of people used side exits from a smoke-filled tunnel, when guided by loudspeakers above the doors repeating the message “exit here” [20].

Directions given by people in “authority” are clearly a strong influence on exit choice, as evidenced by Kings Cross (police and firemen; London Underground staff and members of the public were ignored), St Gotthard (instructions to back up given by truck drivers, and later police), Zurich (directions to the portal given by the train drivers), etc.

In building evacuations, the size of the queues may be a factor when choosing an exit. In the tunnel fires examined, the speed of fire development meant that people had to make their exit choices long before any queues could form. Also, near-zero visibility meant that exits frequently could not be seen when the direction choice was made. In some cases (e.g., Zurich, Homer tunnel) people moved in single file to a common exit.

ROLES AND BEHAVIOUR

As in building fires, a person’s role has a major effect on the behaviour they will exhibit. In tunnels, the roles can be generalised to include members of tunnel staff, members of the rescue and emergency services, other members of staff (e.g., train or bus crew), and members of the public.

The actions of control room staff may be reflected implicitly, for example in determining the length of the time delay before the emergency and rescue services are summoned, or in determining the time delay for other people to respond to an alarm (which would also depend on the type of alarm or warning message that was given).

The main effects of role on behaviour are that:

- Members of the public tend to wait for information, rather than investigate to seek it out. People in authority may investigate before undertaking positive action.
- Members of the public can only communicate face-to-face. Members of staff can communicate at a distance (e.g., by radio amongst themselves, or by P.A. to members of the public) - as long as the system is still working.
- Members of the public will tend to remain in pre-existing groups, or may form ad-hoc groups, particularly if directed by “authority figures” such as drivers and staff.
- Members of staff may attempt to fight the fire; the public are less likely to.
- Members of staff will attempt to control the evacuation by giving orders, directions, etc. Members of the public are less likely to do this, and more likely to be ignored if they try. However they may be followed by others once they start to evacuate.
- Members of staff may search and warn/rescue others, whereas members of the public only warn/rescue on an impromptu basis if they discover someone in need. They may also assist others to cross obstacles (e.g., to get off a train), and then escape independently when they have done this.
- Rescue services will head towards the fire in order to fight it. They will rescue or give directions to people that they encounter.
- Disabled people may either have helpers with them, or may receive impromptu assistance; in either case, their capabilities may not be quite so restricted (although the able-bodied helper may be slowed down for a time).

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