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Human behaviour in emergency situations: Comparisons between aviation and rail domains

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Abstract This article presents a comparative review of the knowledge base regarding human behaviour in emergencies for both aviation and rail domains. Generic models of human behaviour in emergency situations are introduced and specific attention is then focussed on methods of behaviour prediction, exhibited behaviours in emergencies and methods of aiding evacuation across both modes of transport. Using established knowledge from the aviation domain, it has been possible to make observations and comparisons about the rail domain. Traditionally, the aviation domain has been a major focus of research attention and this is used to inform and interpret the rail domain. By drawing comparisons across these domains for human behaviour in emergency situations, the observations are discussed along with recommendations for future policies/planning for emergencies and future research areas.

Keywords: rail; aviation; emergency situations; human behaviour; models of behaviour

Introduction

On 15 January 2009, 6 min after takeoff from LaGuardia Airport and as a result of a birdstrike incident during its initial ascent, an Airbus A320-214 successfully landed in the Hudson River close to midtown Manhattan. In many ways, the National Transportation Safety Board (NTSB, 2010) regarded the incident as a miraculous landing because of few passengers or crew sustaining any serious injuries. Overall, the evacuation of passengers was relatively orderly and timely, however, in the subsequent accident investigation a number of issues were highlighted that could have led to a more serious situation. With the rear end of the aircraft immersed in water, passengers seated in this area were not able to exit through their nearest emergency exits. As a result, they moved forward, towards the over-wing exits and flight attendants later reported that passengers crowded and 'bottlenecked' at these exit points (NTSB, 2010). As queues had already developed to exit through these doors further bottlenecking occurred along the passageways. This situation was only alleviated when cabin crew took control of the situation and called passengers forward to the front emergency exits. It was also reported that as the water levels at the rear of the aircraft rose quickly, cabin crew ordered passengers to climb over seat backs rather than use the passageways in order to reach a usable exit (NTSB, 2010). This action may have helped alleviate crowding and kept any casualties or injuries to a minimum.

Later the same year (18 May 2009) a station closure at Kings Cross Railway Station on the London Underground network resulted in over-crowding at exits and widespread public concern over the handling of the situation. The Confidential Incident Reporting and Analysis System for the rail industry (CIRAS, 2009) outlined two incidents (a defective train that took 25min to reach its destination and a pregnant passenger going into labour elsewhere on the underground network) that caused the station to become congested and then to be closed. The effect of this was that widespread crowding occurred both inside and outside the station. In the immediate confusion and lack of situational knowledge, there appeared to be no procedures in place to disperse members of the public once they had left the only exit to the station (a situation confounded because of ongoing building work inside the station blocking other exits). There were no station personnel to instruct passengers to move on or to turn those away who were still trying to enter and, as the crowd built up, it got harder for people who were still inside the station to get out (CIRAS, 2009). The problem was compounded as members of public who smoked cigarettes normally congregated around the exit adding to the increasing bottleneck situation. In contrast to the previous example, the station evacuation was not effectively organised; there was a lack of efficient crowd control measures in place as well as an awareness of other behaviours (such as smoking) that exacerbated the situation.

These examples illustrate how emergency situations can evolve and become quickly exacerbated with often little warning for passengers and characterised by initial confusion, sometimes apparently chaotic behaviours and an underlying importance that trained staff are present to mediate these initial factors. However, in these situations it is important to understand how members of the public might behave and respond to real or perceived dangers confronting them.

Models of Behaviour in Emergencies

Various models of human behaviour have been developed to help explain how people react in emergency situations. They each take a different perspective on human behaviour and no single theory has emerged as the leading paradigm. This underlines the complexity of understanding human behaviour in these situations and the need for an integrated approach to develop more robust policies for handling emergencies. There are also important lessons to be learned across different modes of transport in order to inform the public and policymakers alike. From the study of human behaviour in emergencies over the last 50 years, a number of established models exist:

● Panic model (Sime, 1980) and bounded rationality (March, 1994; Pan et al, 2006)
● Social attachment model (Mawson, 1978, 1980) and affiliation model (Mawson, 2005)
● Self categorisation model (Turner et al, 1987) and emergent norm theory (Turner, 1964)

Panic model and bounded rationality

The panic model assumes that members of the public become overwhelmed in emergencies leading to confusion, disorientation and a lack of coordination (Sime, 1980). This type of behaviour was illustrated in the station example above. Building on the traditional view of a 'fight or flight' response under extreme stress (usually as a function of adrenaline released into the bloodstream) panic can be defined as an inappropriate (or excessive) response to a stimulus (Mawson, 2005). This model considers the movement of people in public spaces as uncoordinated objects that behave irrationally, selfishly, competitively, anti-socially and who may abandon social norms (Drury, 2004). This type of behaviour might be exhibited when people become aware of an emergency situation too late to evacuate in an orderly manner (Sime, 1983). In what often appears to support the principles of a panic model, bottlenecks at exit points may occur because of a large number of people attempting to leave through the same restricted route (Sime, 1983). A consequence of the panic model is that uncoordinated behaviours can lead to large physical forces being exerted on people and environmental structures that can then lead to crowd crushing. Although this type of behaviour can occur in emergency situations, it can be largely negated if people are given usable information about an incident (Cocking et al, 2009). In all but a few examples, the panic model has been contested as people often exhibit some rational behaviours and social norms can remain intact (Drury, 2004).

A further critique of the panic model is presented with the theory of bounded rationality (Pan et al, 2006). This theory argues that individuals are capable of making rational decisions in an emergency, albeit with limited information and cognitive resources (March, 1994). The seriousness of an impending emergency may take longer to perceive and evaluate as people might be distracted by other normal events, and the immediate situation might receive more attention than speculating on future scenarios (Pan et al, 2006). As a consequence, this may lead to apparently non-supportive crowd behaviours. For example, if a queue stops moving an individual may push the person in front to resolve their immediate situation without thinking through the impact of their behaviour in crowding an exit and slowing egress (Pan et al, 2006).

Social attachment and affiliation models

Attachment and affiliation models acknowledge the social nature of human behaviour and present the argument that people will gravitate towards familiar places, groups and/or individuals even if this leads them away from immediate safety, or that they might remain in a dangerous situation longer if familiar people are with them or require their help (Mawson, 1978, 1980, 2005). Both models propose that it is more stressful for humans to be detached from familiarity than to be exposed to danger (Mawson, 2005). Being among familiar people can have a calming effect but can also slow down or reduce opportunities for egress (as illustrated in the 9/11 terrorist attack on the World Trade Centre) because of greater efforts to help friends and colleagues, rather than immediate individual evacuation (Aguirre et al, 1998). The affiliation model helps explain why individuals might exit the same way that they entered a building rather than evaluate all possible alternatives or actively search out the nearest emergency exit. The reasoning for this is that as specific fire exits that are not commonly used therefore represent unfamiliar exit routes (Mawson, 2005). People are less likely to use them because of their lack of salience than a more familiar main route (Sime, 1983; Mawson, 2005).

Self-categorisation model and emergent norm theory

The self-categorisation model argues that members of crowds tend to conform to social norms that characterise emergency situations (Cocking et al, 2009). It also states that a sense of common identity is created within informal groups in these situations particularly when individuals do not know one another. Incident reports often recount how leaders emerge to coordinate activities or physically stronger members of a group have delayed their egress to aid weaker or injured group members (Sime, 1983).

Related to the self-categorisation model, emergent norm theory argues that in unusual circumstances, collective behaviours evolve as people re-define their situation, by interacting to form new processes that guide their behaviour (Aguirre et al, 1998). Manifestations of this theory in emergencies have included quicker responses by small (rather than large) groups and smaller groups having greater chances of survival than larger groups (Feinberg and Johnson, 2001). An explanation for this is that larger groups expend more effort, energy, resources and time through extended interactions in defining and proposing strategies with an emphasis on evacuating the whole group rather than focussing on specific actions for evacuation (Cocking et al, 2009). As a result, 'evacuation by committee' can be hampered by developing multiple hypotheses that are only partially tested. Another aspect of this behaviour could be the way in which we process and store mental schemata associated with physical locations we remember (for example, evacuation exits) and or category exemplars that constitute fuzzy representations of what elements people might expect to find (and where) (for example, the siting of evacuation tools by windows and extinguishers by exits). In this way, people develop cognitive representations of the social self-categorisation model that may (or may not) help them in a real emergency situation.

Figure 1 illustrates the key models of human behaviour in emergencies based on indices of rationality and social norms.

INSERT FIGURE ONE ABOUT HERE

To clarify the principles of the models they have been positioned along the axes of rationality (ranging from irrational to rational) and social norms (ranging from high to low). These are critical factors that differentiate the models. For example, the panic model suggests mainly irrational behaviour and low influence of social norms whereas the emergent norm theory is associated with more rational behaviour, but remains towards the lower end of the social norm axis because of the emphasis on emergent social behaviour in crises. The self categorisation model sits higher on both axes as it is built upon social consensus and more rational behaviours.

Aviation: Human Behaviour in Emergencies

Methods of behaviour prediction

It is critical both in the everyday use of aircraft and in emergencies that passengers are able to exit aircraft quickly and efficiently. With the drive towards increased regulation by agencies such as the European Aviation Safety Agency (EASA) and Federal Aviation Agency (FAA), aircraft manufacturers should ensure that the full evacuation of an aircraft is completed within 90 seconds (Muir, 1996). It also specifies that demonstrations should be conducted in daylight and darkness (with only the aircraft's emergency lighting system to illuminate the exit paths and evacuation slides). In addition to this, according to the Office of Technology Assessment (OTA, 1993), a range of participants must be used and no more than half of the emergency exits may be operational in trials.

A range of methods can be employed to investigate aircraft evacuation. One approach involves using human volunteers in full-scale evacuation trials (OTA, 1993). This approach allows for real user data to be collected, however such trials have a number of limitations. They can be hazardous to conduct as participants have been injured in the past (OTA, 1993) and are often expensive to organise. Full-scale trials can also suffer from a lack of ecologically validity if they are not representative of emergency situations. In any trial it is difficult to reproduce the effects of decompression, or an impact or fire from which passengers must evacuate (OTA, 1993). In addition, although trial participants should represent typical passenger demographics, this approach has been criticised for using able bodied and younger participants (Muir and Thomas, 2004). As these trials do not always use representative groups of people and as they do not necessarily simulate the traumatic effects of an aircraft accident, it is often the case that the results produced are optimistic (OTA, 1993). However, exposing participants to fire, smoke and/or debris would increase the danger posed to them leading to serious ethical issues for this kind of research. Any method of predicting human behaviour in emergencies that involves participants therefore has to involve a trade-off between levels of realism and the potential to cause mental or physical harm to participants (Muir, 1996). As a result of this, alternative methods of predicting human behaviour in aircraft emergencies would be beneficial.

Aircraft cabin simulators may provide an alternative to full-scale evacuations as they offer a safe and more controlled environment for testing human behaviour in aircraft emergencies. These simulators may contain evacuation slides, oxygen masks, seatbelts, life jackets and refreshment trolleys and it may also be possible to reconfigure the layout to emulate different types of aircraft or disrupted environments caused in an accident (for example, spilt and fallen debris blocking gangways and exits). Simulators such as these have been used to investigate passenger egress rates in different types of emergencies and to examine the procedures that cabin crew follow. Trials can be conducted with the cabin filled with nontoxic smoke and participants have been filmed during evacuations using thermal imaging or infra-red sensitive cameras (Muir, 1996). This offers a powerful analysis tool as well as educational and training material for future use.

Another alternative is to use computer-based models to simulate emergency situations. These are often more cost effective and safer than full-scale evacuations or cabin simulators, however they require an extensive and complex database of factual information in order to provide realistic outputs (Owen et al, 1999). The data required are often obtained from accident reports however this can be hard to obtain and analyse in a systematic fashion. Computer-based models can, however, provide information regarding the physical, psychological and physiological responses of humans that may influence egress (Galea et al, 2003). Software such as 'airEXODUS' can be used to simulate aircraft evacuations using various sub-models that interact with each another in order to produce realistic outputs of human behaviour (Galea et al, 2003). These sub-models include characteristics of individuals (differentiating between passengers and cabin crew) and their responses to their environment (including immediate responses and overall goals). This approach can be used to compare simulated and real evacuations, (where exhibited behaviours may differ) and can also ascertain whether an aircraft complies with the 90-second certification requirements. In addition to this, it can also be used in post-incident analysis of accidents, to develop crew training programmes and procedures and to aid future aircraft design (Galea et al, 2003).

Aiding egress in aviation emergencies

It has been noted that people behave very differently in 90-second certification trials when compared with real aviation emergencies (Muir, 1996; Galea et al, 2003). During certification trials, people are likely to listen to and obey instructions from cabin crew but in real evacuations, passengers may behave more selfishly (Galea et al, 2003). This finding suggests that self-interested behaviour is not in line with the theories proposed by the social attachment, affiliation or the self-categorisation models. In some real life cases, this self centred behaviour has occurred Although in other cases it has been noted that people have behaved in a more orderly fashion (Muir et al, 1996). It has been hypothesised that the motivation of individual passengers may be a cause of these differences (Muir et al, 1996). If the objective is to ensure that everyone on board is evacuated as safely and quickly as possible, people tend to collaborate and social norms are retained. If their individual aims are to ensure their own safety (and perhaps the safety of their families or friends) they work independently and the evacuation process becomes less orderly and more competitive (Galea et al, 2003). This in turn may lead to crowding at exits and in aisles as well as behaviours such as individuals climbing over others (who have fallen) or over (not always unoccupied) seats (Muir et al, 1996). It has been suggested that this type of behaviour is more likely to occur when there is a perception of immediate threat to life. By introducing payment incentives during trials for the first people to evacuate the aircraft, competitive behaviours found in real emergencies can be demonstrated (Muir et al, 1996). Likewise, introducing payment incentives for all participants if they evacuate the aircraft within 90 seconds can induce the types of collaborative behaviours that may also be found in emergencies (Muir, 1996; Muir et al, 1996).

According to the Air Accident Investigation Branch (AAIB, 1988) it has also been reported that in some instances, people have been found to freeze in the initial moments of an aircraft emergency and that, in particular, older women may be more prone to such behaviour (Muir et al, 1996). This can produce a 'closed-loop' effect whereby freezing produces a delay that, in turn, increases the amount of toxins inhaled, causing people to become incapacitated (Owen et al, 1999). Freezing, also known as cognitively induced paralysis, has been explained in terms of a person's cognitive responses to such situations (Leech, 2004). Working memory can only retain a certain amount of information at any given time and also has a maximum rate at which it can process information (Wickens, 1992). In sub-optimal circumstances, and when responding to unfamiliar situations for which no appropriate response is embedded in long-term memory, this maximum rate may be reduced and people have to rely on immediate perceptions and understanding to rationalise their behaviour (Leach, 2004). In addition, other reasons why freezing may occur include a fatalistic perception by the individual that that there is no possible way of preventing harm or conversely that they fail to assess the full danger of the situation (Muir et al, 1996). Hesitation at exits has also been observed that may be because of individuals waiting for the exit to clear or considering how to negotiate the exit (Blake et al, 2002). This behaviour can exacerbate crowding at exits and affect the behaviour of others and their potential survival.

In order to ease the evacuation process, cabin configuration is an important factor. The design and layout of aircraft furniture (aisle widths and seat dimensions and arrangements) and the cognitive processes of the passengers can affect the success of egress

(Owen et al, 1999). For example, the implementation of floor-level lighting (Muir, 1996) and additional space around exits (Muir et al, 1996) as well as the number and location of seats and exits, and physical cues leading to exits have been shown to aid egress (Snow et al, 1970). However, it should be noted that allowing too much space around exits can lead to more direct competition rather than a steady stream of people, especially in the case of over-wing exits (Muir et al, 1996). When competitive behaviours are exhibited, the flow rate of people increases as a function of aperture width; however, when non-competitive behaviours occur, narrower aperture widths promote faster evacuation times (OTA, 1993). Therefore, in situations where individuals are highly motivated to escape, narrow apertures will compromise egress rates because of blockages in aisles and around exits. It is evident that the likelihood of blockages occurring can be significantly reduced through appropriate configurations of cabins (Muir et al, 1996).

The role of cabin crew has also been investigated. When they are more assertive, evacuation times can be significantly reduced (Muir, 1996). It can, therefore, be assumed that this has implications for the importance of training cabin crew for such situations so that they have existing knowledge of how to behave, as well as coping strategies in order to help members of the public who may be in shock (Leach, 2004). It has been suggested that devices could be developed that are able to look for and assist people who are suffering from cognitively induced paralysis (Leach, 2004). In addition to this, it is thought that if safety and evacuation equipment is designed so that it is obvious and intuitive in terms of how if should be used without the need for training, the rate of egress should increase (Leach, 2004).

Rail: Human Behaviour in Emergencies

Methods of behaviour prediction

In rail travel, emergencies that require evacuation occur relatively infrequently (Galea and Gwynne, 2000a). However, it is still important to ensure that in such situations passengers are able to exit carriages quickly and safely. In order to make predictions of human behaviour and egress times in emergencies, full-scale trials can be conducted and simulation methods can also be used. In a similar way to the aviation domain, guidelines from the Railway Group Standard Board (RGSB, 2009) dictate minimum egress rates for railway emergencies:

● Where passengers are evacuated from the sides of the carriage, this should be completed within 90 seconds

● When the evacuation is carried out through the end doors of the carriage, there should be a minimum passenger flow rate of 30 passengers per minute

● On occasions where passengers are evacuated to other trains, this should occur within 90 seconds with a minimum flow rate of 40 passengers per minute where the vehicle is at the end of a formation.

All new internal carriage layouts that may affect egress should be validated either through evacuation trials or direct comparison with existing designs (RGSB, 2009).

Apart from the first factor specifying a 90-second rule, unlike the aviation domain, the guidelines reflect flow rates rather than specific evacuation times from trains (Capote et al, 2009). However, as a general rule, the time required to exit should be less than the available time to escape (Jong-Hoon et al, 2009).

Various methods can be employed in order to predict human behaviour in rail emergencies. As in aviation, one such method is the use of computer simulations. Software, such as Simulation of Transient and Pedestrian movements can be used to predict pedestrian movement in both emergency situations and under normal circumstances. The software allows for individual passenger parameters to be incorporated so that specific population demographics can be used in trials (Capote et al, 2009). Using detailed plans of rail carriages or even platform and station layouts, these models can then be used to identify bottlenecks, profile exit use and test different evacuation routes as well as the time taken for egress under different circumstances (for example, peak and off-peak travel) (Mott MacDonald, 2010). This approach is particularly useful in assessing different train carriage configurations or identifying factors that may impact on potential egress in specific situations (for example, for large social or sporting events) (Capote et al, 2009). Computer simulations provide a safe method of testing emergency evacuations without the need to recruit participants and can also be used to evaluate future designs at a virtual prototype stage that cannot be easily trialled using human participants (Gwynne et al, 1999). However, the degree of accuracy in computer simulations is still a contentious issue because of the lack of emergency evacuation data available, the variety of possible scenarios that could be encountered (Capote et al, 2009) and timing issues such as time taken to move from the carriage to the trackside (Jong-Hoon et al, 2009).

Full-scale trials can also be conducted. These may employ real train carriages and use a representative number of participants in an attempt to obtain realistic data. In a similar way to aviation research, these trials can make use of atmospheric effects (for example, reduced visibility) to provide an insight into how people respond and behave. The use of video cameras both inside and outside carriages can aid the analysis of such behaviours (Capote et al, 2009). They can also provide information about issues relating to the layout of carriages and how their design might help or hinder egress. However, as with computer simulations, there are limitations of the use of full-scale trials.

For ethical reasons, the population demographics are often not representative of real life situations. In research trials, passengers are usually young and able-bodied individuals and not family groups, elderly or handicapped users who often use trains when driving is less suited to their travel needs (Oswald et al, 2005). In addition, participants involved in trials do not suffer from injuries or shock induced by the emergency situation (Galea and Gwynne, 2000a; Oswald et al, 2005). The use of non-toxic smoke also means that trial participants do not experience the irritation and heat caused by real smoke (Galea and Gwynne, 2000a).
In full-scale trials, the participants are usually given a briefing before carrying out the evacuation and are therefore more prepared than they would be in reality (Oswald et al, 2005). Furthermore, when participants have taken part in multiple trials they may have been positively influenced by practise and learning effects that affect how they react to each situation (Galea and Gwynne, 2000a). These aspects mean that the evacuation times predicted in full-scale trials are usually quicker than those in real life situations (Galea and Gwynne, 2000a; Oswald et al, 2005).

Aiding egress in railway emergencies

In rail emergencies, there is a threshold below that people tend to respond to a situation rationally and exhibit levels cooperative behaviour, often helping each other (Galea and Gwynne, 2000a). Above this threshold, people may start to behave in a less collaborative manner perhaps because of their perceptions of a more immediate danger. Competitive behaviour can also arise as a result of passengers being in confined spaces or in crowded conditions typical of rush hour commuting (Galea and Gwynne, 2000a). Previous incidents and trials have shown that some passengers may attempt to take on a leadership role, locating exits and giving other passengers instructions (Galea and Gwynne, 2000a; Oswald et al, 2005). It has been suggested that this behaviour may be exhibited by passengers because of the comparatively low proportion, or low visibility, of official staff who might otherwise take on this role (Oswald et al, 2005). It has also been stated that if people cannot sense any danger, they tend to react more slowly to the situation (Kangedal and Nilsson, 2002).

Studies have shown that when exiting trains, people tend to adopt one or a combination of three key strategies: jump from the train; sit on the floor of the train and slide out; or use handrails (where installed) to pull themselves out (Oswald et al, 2008). Observations have shown that when people adopt the sitting strategy, others can pass through the door at the same time. However, both of the other strategies involve the passenger's body spanning the width of the door thereby preventing others from passing simultaneously (Oswald et al, 2008).

On trains people often listen to music, sleep or read and therefore may not take an active interest in their surroundings. As such, they are actively engaged or disengaged from their environment in terms of maintaining awareness. If passengers do not sense any real danger, they may delay their evacuation further by taking time to collect their personal belongings (Kangedal and Nilsson, 2002; Capote et al, 2008). In addition, the Rail Safety and Standards Board (RSSB, 2007) witness statements from previous incidents have shown that when passengers were subject to dark environments, they tended to perceive the situation to be more threatening because of the absence of visual information.

The presence of fire in emergency situations has an effect on the behaviours exhibited by passengers. Apart from presenting a tangible cue of the severity of an evolving situation, smoke in real incidents can cause both minor and major physiological effects, reduce an individual's visibility and can be toxic (Oswald et al, 2005). By reducing visibility, smoke can make it more difficult for the affected people to find their way to their desired location (Galea and Gwynne, 2000a). This is either directly attributed to the volume of smoke within the immediate environment or reduce the ability for the individual to perceive visual cues from their surroundings. Reduced visibility or a lack of light may also reduce other cues and lead people to misinterpret the severity of the situation that can cause them to act contrary to the desired behaviour. For example, in a less severe situation, it may be desirable for passengers to remain on the train but a loss of light may cause them to interpret the situation as being more serious and therefore attempt to evacuate (RSSB, 2009). In the absence of visual cues it has been found that people tend to seek out walls in order to aid their navigation (Galea and Gwynne, 2000a) as well as to walk more slowly, take known routes, maintain contact with other people and walk towards lit areas (Capote et al, 2009). Thus in a situation whereby smoke plays a significant role, it may also act as a catalyst to drive common behaviours that could suddenly lead to bottlenecks, as individuals arrive at similar behaviour strategies. Another factor that may affect the behaviours of people because of a misinterpretation of the severity of the situation is the smell of fuel (RSSB, 2009). Close proximity to flames and an increased density of people in relation to nearby fire may induce competitive behaviours and attempts to flee. All of these effects that may be caused by the presence of fire may lead to slower egress (Galea and Gwynne, 2000a).

Previous studies have identified a number of factors that could aid evacuation in railway emergencies. It has been found that ease of egress depends on the nature of the emergency, the design of the train, the population demographics and what the passengers are doing at the time of the emergency (Capote et al, 2009). In addition to this, any incapacitation of passengers or vehicle damage caused as a result of an accident will also impact on the ease of evacuation (RSSB, 2007). The design of the train may dictate that exits can be used. For example, if a train has overturned, some doors may be more difficult to open because of the need to push them upwards and opposing gravity. It has been suggested that the doors on either side of train carriages should open in opposing directions so that it should be possible to open at least one set of doors with relative ease if the train overturns (Galea and Gwynne, 2000b; RGSB, 2009). It has also been suggested that carriage end doors should incorporate 'burst through panels' so that in the event of their door mechanisms jamming, passengers are still able to escape. Emergency ceiling hatches could be implemented to provide additional exits in the event of an overturned train and to help emergency workers get access to injured passengers more rapidly (Galea and Gwynne, 2000a; 2000b). It is also important that passengers are made aware of the presence of such technologies to assist their evacuation, as previous accidents have illustrated that a lack of knowledge has resulted in failures to use such facilities appropriately (RSSB, 2009). For example, the operation of emergency release mechanisms for external doors through the use of appropriate signage and relevant instruction is particularly important.

When trains overturn, any vertical fixtures spanning the height of the train (such as passenger poles or partitions) become horizontal obstacles and can impede egress. Where these fixtures are not essential, it is has been suggested that they should be reduced in height or removed altogether (Galea and Gwynne, 2000b). In addition, luggage (which is rarely secured) can move and cause obstructions or injury to passengers. In order to reduce this risk, it should either be secured to the luggage racks (Galea and Gwynne, 2000a) or stored in alternative locations between the seats (Galea and Gwynne, 2000b).

The way in which passengers are notified of an emergency situation can also influence the time taken to evacuate. Research has illustrated that egress times are faster when passengers are notified before the train comes to a stop (Capote et al, 2009). In this way passengers are able to begin processing what is happening and prepare their exit strategies.

Notifications should be audible rather than visible because of the potential for reduced visibility (Kangedal and Nilsson, 2002; Oswald et al, 2005). It has also been suggested that announcements should contain detailed information such as: evacuation instructions, information about the status of the evacuation process and the environmental conditions (Oswald et al, 2005). These announcements should be timely and made at regular intervals in order to minimise uncertainty and confusion (Oswald et al, 2005; RSSB, 2009). Passengers are more likely to follow instructions if communications are presented with increased frequency and in an authoritative manner, especially when the instructions relate to actions that are not intuitive (RSSB, 2009). In addition, when communications are made face to face, they are more effective than those made over loudspeaker systems although this may be more difficult on trains where official staff are usually limited in number (RSSB, 2009).

Although visibility may be compromised, the use of signage can assist the evacuation process. Signs can be placed to both direct passengers to emergency exits and emergency equipment as well as to indicate how to use such apparatus. However, it should be ensured that the signage is simple and easy to understand (Oswald et al, 2005). Emergency lighting such as that found in aircraft and ships may also be used to direct people to emergency exits (Galea and Gwynne, 2000a; Oswald et al, 2005). Suggestions have also been made that information regarding emergency procedures could be made available on trains either within on-train magazines, on the backs of seats or using seat back entertainment systems where present (Galea and Gwynne, 2000b). However, analysis of past accidents has shown that when safety cards had been available, passengers did not read them (Galea and Gwynne, 2000b). Therefore, alternative approaches are required in order to ensure that passengers are aware of emergency procedures or that aviation style safety briefings are conducted (RSSB, 2009).

While various methods of aiding egress have been discussed above, it is also acknowledged that evacuation is not desirable in all rail emergencies (RSSB, 2009). It has been suggested that in general, passengers should aim to remain on the train unless they are in immediate danger. They should attempt to move to a safe location within their current carriage and await rescue. Passengers should only fully evacuate the train where it is not possible to move to a safe location within the train. Train carriages can be designed in such a way that they encourage passengers to remain in their carriage by including features such as emergency lighting that aids passengers in identifying the severity of the situation without leading them towards the exits. In addition, windows should not be promoted as an egress route as their height above the ground on the outside of the train can make them dangerous to use. They should also be made of materials that are designed to contain passengers within the carriage and protect them from external objects (RSSB, 2007).

Discussion

Given the generic models of human behaviour in emergencies, it is apparent that the two modes of transport and the environments in which they operate exhibit different characteristics in their operational domains. Table 1 summarises the key differences between aviation and rail.

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From this overview, there is more potential to control how passengers behave in the aviation domain than in the rail domain. In the rail context, passengers are largely unknown and it can be more difficult to account for those that might have been travelling on a specific train or in a particular carriage. As the rail domain represents an open security system, where people can enter and leave stations freely, there is usually very limited information about the number or nature of the individual passengers. Once on a train they are free to move around as they wish without necessarily having a specific seat reservation or allocation. The environment may be more restricted as large and bulky luggage is stored in passenger compartments in an ad-hoc manner with very little (if any) oversight. There is little staff visibility and unless there is information displayed in the carriage it may not be apparent what the correct course of action should be in an emergency or for different types of emergency. The rail domain therefore offers a more challenging environment to monitor and coordinate activities in an emergency as it may not even be known how many passengers occupy a particular carriage or have wandered away or been thrown from a train in the event of an accident.

In reviewing the rail and aviation domains, specific focus has been given to methods of behavioural prediction, behaviour in emergencies and methods of aiding egress. Although the operational contexts of rail and aviation are different, the methods employed have similar characteristics and researchers need to be aware of the potential concerns. Trials involving participants pose ethical issues such as the risk of injury and stress (OTA, 1993). There are also concerns about the validity of behaviours demonstrated in recreated or simulated emergencies and how far the findings transfer to real world contexts (Muir and Thomas, 2004). An alternative approach used in both rail and aviation is computer-based simulations.

Again this approach is not without limitations. In particular a simulation is only as good as the data upon which it is built. However it does allow for the investigation of factors such as fire, smoke and explosions that would be unethical to study using actual passengers in real environments (Owen et al, 1999).

Considering the behaviour of passengers in emergencies, both rail and aviation domains demonstrate changes in the level of altruism shown by passengers, in relation to an awareness of the event, the perceived danger of the event or the relative time to evacuate. Cooperative behaviours have been demonstrated in both domains but these can be susceptible to experimental effects such as priming, practise and motivation. It has also been demonstrated in aviation that some passengers may exhibit signs of cognitively induced paralysis (Leach, 2004). This could be because of the perceived locus of control by passengers. As procedures are more controlled in aviation, it could be that passengers expect to be told what to do, whereas in the rail domain there is an expectation of a higher degree of self-reliance and a necessity to conduct self-initiated evacuations.

The specific circumstances of any given emergency situation seem to dictate how people behave. Differences have been shown as a result of different environmental factors, differences between individuals in different populations and the timing of notifications and the way in which these have been delivered. Different behaviours can be linked to the generic models of human behaviour described earlier. The behaviours exhibited by passengers in rail emergencies are similar those shown in aviation emergencies. At times, people in both modes of transport have been shown to exhibit both self-centred (Sime, 1980; March, 1994) and collaborative behaviours (Mawson, 1978, 1980, 2005) depending on the circumstances. This would appear to suggest that no single model of human behaviour fully captures the diversity of potential behaviours that may be displayed by a given individual when confronted with an emergency situation. Furthermore, while the panic model might not be generally accepted, there are occasions when people may exhibit selfish and irrational behaviours (CIRAS, 2009).

It has been identified that in both aviation and rail, the internal configuration of the train carriages or aircraft cabins and the location and type of emergency exit can play a part in ease of egress in an emergency (Snow et al, 1970). In addition to this, it has been suggested that railway carriages would benefit from audio communications as well as improved visual cues to facilitate exit identification (RSSB, 2009). Taking established knowledge from the aviation domain it is also considered that the provision of training or information regarding emergency procedures could assist passengers in carrying out the appropriate actions for a given situation (OTA,1993). However, it is noted that the way in which this information is reinforced may require further research. In aviation, it has been shown that when cabin crew are assertive, egress is faster (Muir, 1996). As trains do not usually have the same ratio of staff to passengers on board, other methods of passenger communication and control (such as detailed announcements made through dedicated channels at regular intervals) might provide a useful alternative.

Finally, it is worth noting that both domains share a drive towards increasing levels of regulation as illustrated by the activities of the EASA, FAA and the RSSB. Although evacuation regulations provide stringent standards that designers and operators must abide by, it is apparent that there are lessons to be learned through increased dialogue between these transport modes, especially as, in the future, there will be an increasing need to consider the requirements and user experience of multi-modal travel through continuous journey initiatives.

Conclusion

Two different operational contexts have been reviewed alongside the current models and theories of human behaviour in emergencies. It is apparent that no single model or theory exists to capture the complexity and diversity of behaviours in different emergency contexts but that a clear understanding of human behaviour in these situations is vital. A large amount of research attention has been focussed on the aviation domain that offers a basis to expand the knowledge base and future policy in dealing with rail emergencies.

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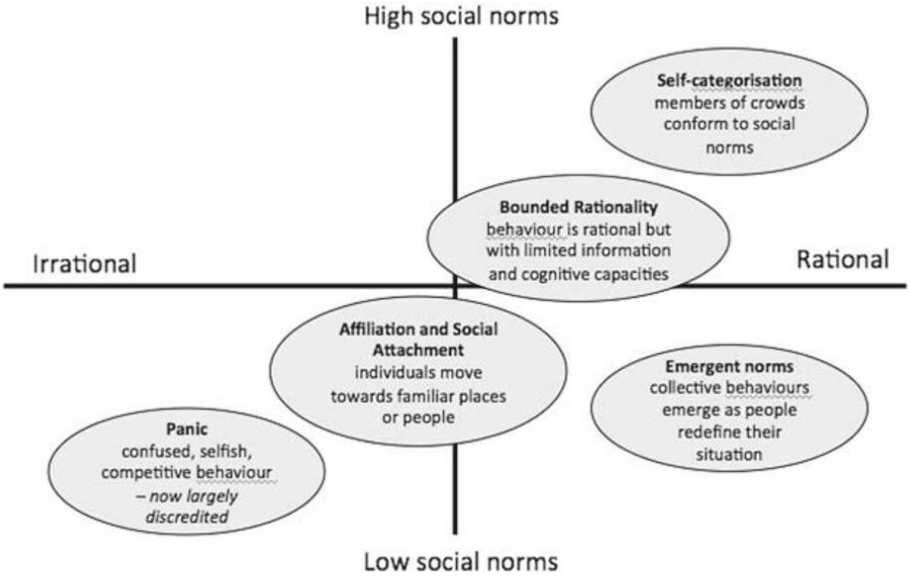

Figure 1: Models of human behaviour in emergencies based on indices of rationality and social norms.

Table 1: Comparison of operational contexts for aviation and rail

	Aviation	*Rail*
Staffing	Staff visible to most passengers	Staff not visible to all passengers
Evacuation briefings	Formal briefings always provided and demonstrated to all passengers	No formal briefings although some information might be posted on displays in carriages
Passenger control	Largely controlled by air operators (ground crew and cabin crew)	Passengers generally uncontrolled (although may be monitored by CCTV)
Contact with crew	Regular updates from cockpit crew and allocated cabin crew that are frequently in view	Automated announcements and unlikely to see staff
Passenger identity	Numbers and identities known from check-in records and passports	Largely unknown – although records may exist for ticket sales for specific journeys
Passenger movement while in transit	Regulated by aircrew during the flight	Generally free to move around as they wish
Passenger location	Strict numbers assigned to areas of the aircraft and passengers located in specific seats during important phases of flight	Irregular amounts of passengers (sometimes overcrowded, other times relatively empty cabins) Passengers may be seated or standing anywhere in cabin at any time
Environment	Within aircraft the environment is controlled and access denied to specific areas based on class of travel and actively supervised by flight crew	The train environment is largely uncontrolled as passengers may move between carriages and are not actively supervised by staff
Potential for distraction	Low – controlled use of personal electronic devices and other media	High – free use of personal devices and media
Time of day	Some commuter traffic but generally aircraft passengers are more controlled and constrained within aircraft and terminals	Passenger numbers fluctuate on trains and in stations during the day
Luggage/baggage screening	Passengers usually only have small hand luggage with them, larger luggage is transferred to the hold – all baggage is screened	Passengers have to carry all their luggage into the carriage – very limited baggage screening (for example, Eurostar)