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Implications of overcrowding on railways

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Implications of overcrowding on railways

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EXECUTIVE SUMMARY

The purpose of this review is to consider the evidence surrounding the health and safety implications of overcrowding on trains, particularly following the findings of the Clapham Junction accident which occurred in 1988. In that Inquiry, the pathologist concluded that the injuries sustained by passengers were probably not exacerbated by the fact that, due to one train being filled beyond capacity, many passengers were standing at the time of the collision.

After a discussion of the effects of overcrowding on physical, physiological and psychological responses, consideration is given to the consequences of overcrowding for people using public transport. Some other transport accidents are briefly reviewed, including an analysis of the injuries sustained by those involved in the Cannon Street Station accident in 1991 (and associated computer models) and work drawing upon findings from aircraft accidents.

For higher-speed train collisions, the consensus of the opinions expressed in the material reviewed indicates that whether a passenger is seated or standing makes little difference to the overall severity of injuries sustained. However, seated passengers may be less likely to sustain serious injuries in lower-speed collisions, particularly in the admittedly unlikely scenario in which passengers have sufficient warning to brace themselves. In overcrowded conditions, in which there will be a large number of standing passengers, the situation may be somewhat more complex. Whilst it was argued that a large number of standing passengers may protect against some forms of injury (such as those sustained as a result of hitting carriage fittings or other passengers), it is possible that other injuries (e.g. head-to-head collisions) would be more prevalent. It was concluded, therefore, that no evidence exists to suggest that the *net* level of risk to the individual standing in an overcrowded train is any greater than that presented to a person standing in a non-overcrowded train. This reinforces the findings of the Clapham Junction Inquiry that there is no evidence to suggest that overcrowding *per se* is a safety issue.

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CHAPTER 1 BACKGROUND: THE ACCIDENT AT CLAPHAM JUNCTION IN 1988

Just after 8am on Monday 12 December 1988, a collision between two passenger trains and a third train of empty coaches occurred just outside Clapham Junction Station in London. As a result, 35 people died and almost 500 were injured, many of them receiving serious injuries. The fatalities had all been travelling in the passenger train which ran into the rear of the other passenger train which was stationary at the time. The former suffered considerable structural damage. The Investigation into the accident (Department of Transport, 1989), conducted by Mr Anthony Hidden QC, pinpointed the principal cause of the accident as a wiring error which led to incorrect information being transmitted via the railway signalling system. However, the Investigation also highlighted many additional underlying factors which it was felt contributed to the accident. Subsequently, recommendations were made to:

- address contributory management factors;
- improve British Rail's (B R) safety culture;
- mitigate the effects of any future accident.

This final point included a specific recommendation for BR to *"ensure that overall train loading criteria are achieved"* (DoT, 1989, page 172). Although no definitive information concerning the numbers travelling on the two trains that morning was available, it was concluded from available evidence that one of the two passenger trains was probably heavily crowded[1] whilst the other was probably not. The concern here was the possibility that overcrowding may have led to a greater net injury severity than would have been the case had all passengers been seated. Pathological evidence presented to the Investigation by Wing Commander Hill suggested that *"the severity of injury, or the risk of fatality, was no greater for standing than seated passengers"* (DoT, 1989, page 144). This implies that the overcrowded conditions on this train did not present a greater risk to the individual rail user than would have been the case had all passengers been seated. Mr Hidden continued by recommending that the Department of Transport and BR were to continue to monitor the numbers travelling on trains and ensure that the existing load factor criteria were met.

The purpose of this review is to establish what, if any, evidence has accumulated since the accident at Clapham Junction to either confirm or modify the Hidden conclusion that, in the event of an accident, overcrowded conditions *per se* do not present a greater risk to rail passengers than non-overcrowded conditions.

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[1] At the time, the existing British Rail target was that passengers should not have to stand for journeys over 20 minutes and that the load factor - the ratio of passengers to available seats - should not exceed 110%.

CHAPTER 2 OVERCROWDING

Issues of crowd safety became increasingly prominent following tragedies such as those at the football grounds at Bradford (1985) and Hillsborough (1989). In the latter example, a large number of fatalities resulted from very substantial pressure exerted from within the crowd, which, through numerous management failures, had been allowed to substantially exceed the recommended capacity within a section of the ground. Similar examples have also occurred at concerts (Wertheimer, 1996), notably the incidents in Cincinnati in 1979 (in which 11 people died) and, more recently, in Arad, Israel in 1995 (producing 3 fatalities and approximately 150 injuries).

The term 'overcrowding' has been defined as a situation in which:

"the number of people in an area is sufficiently large to give the potential for harm through:

- *build up of internal crowd pressure;*
- *build up of crowd pressure against a fixed or moving object such as a wall or a fairground ride;*
- *trampling underfoot when people who have fallen are unable to right themselves because of the crowd around them;*
- *pile-up where people fall one on top of another."*

(Trainor and Pittard, 1993).

The presence of a crowd can have an influence physically, physiologically and psychologically. The physical aspect is obvious - the more densely packed the crowd, the less able a crowd member is to make individualised movements. Indeed, in more extreme cases, surges, pulses and more uncontrolled movements can occur (Ventre, Stahl and Turner, 1981). Clearly, when caught in the midst of a crowd, an individual is so physically restricted that independent movement is impossible and there is no choice but to 'go with the flow'. There is also an increased chance of sustaining physical injuries such as bruising, fractures or, in more extreme cases, asphyxiation due to the crush of people (e.g. the incident at the Hillsborough football ground in 1989).

From a physiological perspective, becoming trapped in a densely-packed crowd is a highly stressful experience. However, the degree of stress experienced will be governed by how the individual perceives the behaviour of the crowd. If the crowd is undergoing a controlled evacuation, the situation is likely to be perceived as less extreme, and thus less stressful, than one in which there is no control and the behaviour of the crowd members more haphazard.

A psychological effect of crowd membership that may arise is known as deindividuation. This occurs when individuals appear to cut themselves off from events surrounding them. It is suggested that this is an adaptive response which enables the individual to intensify their alertness and enhance their ability to think and it seems that this may be an additional consequence of the type of sensory 'tunnel vision' associated with high-stress situations.

Other consequences of deindividuation which may be experienced are a diffusion of responsibility and a diminishing of inhibitions. The latter can result in a wide range of behaviours, from a mild lessening of restraint (e.g. insulting or baiting) through impulsive self-gratification (e.g. theft or vandalism) to more extreme destructive reactions (e.g. rioting) (Berlonghi, 1995). Festinger, Pepitone and Newcombe (1952) described deindividuation as a loss of self-awareness resulting in a sense of anonymity. The effect of this may be for an individual to become less able (or willing) to regulate their own behaviour, less concerned for others and less likely to be able to act rationally. In these cases, behaviour is governed more by the situation than the individual (Berlonghi, op. cit.). Whilst it is unlikely that many of these behaviours, such as vandalism or rioting, would occur during an emergency, the same sense of deindividuation may have other effects which influence the outcome. The most insidious of these is the sense of diffused responsibility in which crowd members assume that someone else must be responsible for the situation and must have taken some action to resolve it (by alerting the authorities, for example). Of course, it is possible that all crowd members have thought this way and therefore that no action is taken. Another related concept is that of 'pluralistic ignorance' where, in trying to interpret what is happening, the individual looks to others for information. If they perceive that others do not think that situation is threatening, this is likely to lead to an assumption that that truly is the case, despite what initial cues may have been suggesting.

The central concept here seems to be one of responsibility and the implication is that crowd control would be less of a problem if the individual members were encouraged to take responsibility for their own actions. Unfortunately, it is hard to see how this can be achieved as many situations in which crowded conditions may develop (e.g. within large public buildings or on public transport) do not allow for any kind of planning or training. Perhaps the best that can be achieved is to ensure that good crowd management strategies are in place for any eventuality and that effective communication can be achieved during an emergency. This was highlighted most dramatically in the Hillsborough incident. In his inquiry, Lord Justice Taylor concluded that much valuable time was lost because there was no system in place to recognise that a problem was developing (Home Office, 1990).

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CHAPTER 3 OVERCROWDING ON PUBLIC TRANSPORT

Some research into overcrowding on public transport has been conducted over the years, particularly with regard to physiological responses to passenger densities. A Japanese study (Hashimoto et al, 1966, cited by Kogi, 1979) showed a dramatic upturn in mean passenger heart rates when passenger density rose above 7 persons per square metre. In addition, work by Lundberg (1976) found that adrenaline excretion was higher in passengers travelling under more crowded conditions. However, it was suggested that, in this case, factors such as a lack of choice in the selection of seats and company had more of an influence on the stress experienced than the duration of the trip.

The situation on an overcrowded train, or other means of public transport, is somewhat different to that encountered when attending a large scale event. In the former situation, the sheer numbers present in any one restricted area (e.g. a railway carriage) are not likely to be as great. Furthermore, the problems which can occur in larger crowds may develop over a period of time, whereas injurous contact with other people or fixtures on a bus or train is likely to be much more sudden due to rapid deceleration upon impact. This suddeness of impact also reduces the likelihood that individuals will have sufficient time to effect some kind of behavioural response to the situation.

CHAPTER 4 RAILWAY ACCIDENTS SINCE CLAPHAM JUNCTION

Fourteen railway accidents since Clapham Junction were reviewed (see list in Appendix A) with the specific aim of determining whether or not overcrowding factors impacted upon the injuries received. Of these incidents, three did not involve passengers. However, passengers suffered at least minor injuries in the remaining 11 incidents. Fatalities occurred in five cases, four of which involved fatal injuries to passengers.

In six of the 10 incidents producing passenger injuries, further details of the nature of those injuries were not specified in the relevant reports. Given the times and days of the trains in question, it is highly unlikely that any were sufficiently full to be considered 'overcrowded' and hence any passengers standing are likely to have being doing so of their own volition. Whether or not this was actually the case remains undocumented.

The five incidents giving details of passenger injuries are:

- Stafford Station (August 4 1990) (HSE, 1994a)
- Cannon Street Station (January 8 1991) (HSE, 1992)
- Severn Tunnel (December 7 1991) (HSE, 1994b)
- Cowden (October 15 1994) (HSE, 1996)
- Watford South Junction (August 8 1996) (HSE, 1998)

A brief summary, with any details of injuries reported, are presented below.

4.1 STAFFORD STATION

Shortly after midnight, a train of empty stock ran into the back of a passenger train at a standstill at Stafford Station. The driver of the former was killed and injuries were sustained by 36 passengers. One injury is described in the HM Railway Inspectorate's report on the incident. Upon impact, a woman, located towards the rear of the train and with her back to the locomotive, was thrown under the table in front of her, which subsequently collapsed on top of her. Reports suggest that most of the tables in this part of the coach suffered a similar fate.

4.2 CANNON STREET STATION

A commuter train collided heavily with the buffer stops at Cannon Street Station. Two passengers were killed with a further 542 suffering varying degrees of injury. The incident report noted that the number of passengers on the train at the time may have contributed to the overall severity of the accident. Evidence presented by passengers indicated that many people were standing at the moment of the impact. The fact that there appears to have been no indication that anything was amiss in the seconds immediately prior to the impact implies that people would have been behaving as they normally would under the same circumstances. Some of those standing had been doing so throughout their journey (despite spaces being available elsewhere on the train), but it is likely that most will have risen from their seats as the train approached the station.

The nature of the injuries sustained by the 104 people who received hospital treatment tell us something about the accident. Many suffered injuries (e.g. cuts, bruises and fractures) to the upper torso whilst a similar number had facial or head injuries. There were also a number of lower limb and a handful of back and neck injuries. Unfortunately, no definitive records regarding the patients' positions on the train were recorded, making it difficult to establish precise cause-effect relationships for all injuries. Nevertheless, the Senior Consultant Orthopaedic Surgeon, Mr Lettin, who saw practically all of these casualties, felt able to offer probable causes of most of the injuries sustained. The main points of his conclusions were:

- Most upper body/head injuries resulted from impacts, either from hitting seats, fittings, walls or other passengers or being struck by loose items such as broken fittings or luggage.
- Chest/rib cage injuries were probably caused as a result of being crushed up against walls, furniture or other people due to the pressure of people forced forward by the sharp deceleration of the train.
- Lower limb injuries were primarily caused by passengers becoming trapped between seats as the train structure became severely distorted.

Mr Lettin argued that standing passengers would have been more vulnerable than seated passengers to the first two types of injury, but the third type would have affected both seated and standing passengers. He felt that the risk of falling against potentially harmful fittings would be reduced in a crowded carriage, thus reducing the likelihood of the first type of injury. However, the probability of receiving the second class of injury may rise in these circumstances. Overall, Mr Lettin concluded that *"it would be safer if all passengers were seated"* (HSE, 1992, page 21). However, it is not possible to determine the likely net effect from this information.

So was the train 'overcrowded'? British Transport Police identified 832 people who had been on the train. Whilst the seated capacity of this train was 922, the distribution of passengers along the train was not even. Estimates of the numbers in each carriage were made based on the minimum known to have been in each carriage and also based on the maximum numbers possible. Using the minimum estimations, the front two coaches were respectively 39 and 16 per over-capacity. If maximum numbers are assumed, the front four coaches had between 29 and 47 per cent more passengers than seats. In addition, a small number were travelling in the front guards brake van. In other words, between two and four carriages were exceeding the recommended maximum load factor of 110 per cent.

Analysis of the injuries and the locations (i.e. the carriage in which they were travelling) of those receiving those injuries, shown in Table 1, reveal some patterns. The injury figures are the (minimum) percentage of those travelling in each carriage who received injuries to each part of the body considered.

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Table 1
Loading factors and prevalence of injuries by carriage

Carriage	Loading (min %)	Loading (max %)	Head (%)	Arm (%)	Torso (%)	Leg (%)
1	139	143	44	3	11	7
2	116	138	47	3	8	9
3	95	147	31	10	10	12
4	87	129	39	6	10	20
5	96	100	35	6	16	19
6	56	59	11	4	7	42
7	70	78	17	4	20	6
8	61	82	6	4	6	6
9	27	38	11	4	4	4
10	46	48	13	8	8	3

A higher proportion of people in the front two carriages than throughout the remainder of the train received head injuries, although the numbers tail off more significantly beyond the fifth carriage. In contrast, the prevalence of torso injuries was reasonably evenly spread throughout the train. Lower limb injuries were more common in the middle section of the train. Unfortunately, it is difficult to read too much into these figures as the injuries will naturally also be dependent upon the extent of the damage to each carriage.

Further work into the injury consequences of this type of accident to seated and standing passengers was commissioned by the HSE as part of the Inquiry. Mathematical models to consider impacts at 5 mile/h and 15 mile/h were derived and the consequences to passengers standing and seated (facing forwards and backwards) were estimated. Whilst all scenarios considered implied that some injuries would be sustained, it was concluded that the type and extent of those injuries would differ. For the lower impact speed, it was argued that passengers might be able to avoid injury if they had prior warning of the impact (although it is difficult to envisage how this might occur in practice) and could brace themselves and thus minimise the extent to which they are thrown around the carriage. If such warnings were not apparent, as seems to have been the case for the majority of passengers on the Cannon Street train, the authors concluded that standing passengers might be at greater risk. For the higher impact speed considered, it was felt that neither standing nor seated passengers would be able to prevent their being thrown around the interior and becoming exposed to numerous potential impacts. Therefore, the risks presented to seated and standing passengers in this scenario were equivalent.

Whilst unable to model the full intricacies of human behaviours in a rail accident, this work may partly explain the contradictory conclusions expressed by the medical experts in the Cannon Street and Clapham Junction accidents. The latter impact occurred at approximately 35 miles per hour which, extrapolating from the computer models developed during the Cannon Street inquiry, would present an equal risk to standing and seated passengers. This supports Wing Commander Hill's assertion that, in the Clapham Junction accident, standing passengers were at no greater risk than those who remained seated. The lower impact speed at Cannon Street suggests that those passengers who were standing were more likely to suffer serious injuries.

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In addressing the issue of overcrowding, Mr Lettin argued that, whilst the number of passengers was unlikely to have been a factor in the extent of the injuries received, the more people there are on a train, the more people there are at risk of injury.

4.3 SEVERN TUNNEL

A Sprinter train collided with the rear of an inter-city high speed train in the Severn Tunnel on a mid-Saturday morning. Opinions vary as to the exact speed of impact, but it is likely to have been at least 20 miles per hour. Of the almost 300 passengers on the trains, 185 sustained injuries, of which five were serious. The driver of the Sprinter train also received serious injuries. The more serious injuries included: a broken leg; a number of spinal injuries; broken arms and jaws. Approximately 75 people suffered some form of facial injury. The surgeon reporting to the accident Inquiry argued that these injuries were *"consistent with people's faces hitting the plastic seat-back in front of them"*. It was also concluded that those injured on the Sprinter train had been either standing (perhaps suggesting that the train had a load factor in excess of 100 per cent?) or sitting facing the direction of travel at the moment of the collision. Further details of injuries were not available.

4.4 COWDEN

This incident was a head-on collision between two passenger trains on a Saturday morning. Five people were killed, including two passengers, and a further 12 were taken to hospital with minor injuries. The time of day and route mean that there was no question of overcrowding on either train. The two fatally-injured passengers were seated in the first class compartment of their train and were ejected from the carriage as a result of the impact. No further details of their injuries, or those of any other passenger, were reported.

4.5 WATFORD SOUTH JUNCTION

Whilst stationary at a set of lights, the front end of a "well-loaded" passenger train travelling from Euston was struck by an empty train on route to the same station. The main cause of the accident was identified as a failure on the part of the driver of the passenger train to correctly observe signals indicating that caution was necessary when approaching a red signal. As a result, that train came to a halt further down the track than necessary to avoid the train approaching in the opposite direction as the latter changed tracks. As a result, one passenger died and a further 69 suffered injuries. The passenger who received fatal injuries was ejected through a window at the rear of the leading coach. No further details were presented. Although the train had been quite full at the start of its journey, many people were known to have left the train prior to the collision. It was estimated that there were between 190 and 200 passengers on the train at the time of the collision and thus that it was well below its capacity (303) at this time. It was not felt, therefore, that this accident had any 'overcrowding' component.

CHAPTER 5 RELATED TRANSPORT ACCIDENTS

Many of the injuries sustained in the Clapham Junction and Cannon Street accidents appear to have resulted from loose objects flying through the carriages. Some of these objects were part of the carriage fittings which had become detached in the impact and some were items of luggage such as briefcases.

Similar injuries have also been noted in other transport accidents, notably aircraft. Of particular relevance is the accident near Kegworth in 1989 in which a Boeing 737-400 crash-landed onto an embankment of the M1 motorway after an engine failure. The fuselage split into three sections on impact, resulting in a severe loss of structural integrity. From the resulting inquiry, Professor David Anton (1992) concluded that many of the head and facial injuries sustained had probably been caused by loose items within the cabin, principally due to the failure of overhead luggage bins. His main recommendation was that all attempts should be made to ensure that the internal fittings are able to withstand the maximum load factors they would encounter upon impact. However, the fact that rail passengers are unrestrained means that they have the added problem of hitting, rather than being hit by, internal fittings. To offer maximum protection, these fittings would have to have such high impact attenuating properties that they would be rendered insufficiently durable. As Professor Anton concluded:

"The key to passenger protection lies with the control of occupant kinematic response to the impact. This requires that no passenger should stand and that all seats should face in the same direction... The local environment of the passenger could then be engineered to be more 'impact friendly'" (Anton, 1992, page 8).

He goes on to recommend that longitudinal luggage racks found on trains are preferable to transverse racks as the latter are poor at retaining baggage in the event of an impact and are a potential source of injury to standing passengers. However, these suggestions would require that substantial changes be made to existing rolling stock.

CHAPTER 6 DISCUSSION

So are passengers travelling on overcrowded trains more at risk of a serious injury in the event of a collision? Unfortunately, there is precious little evidence available and what evidence is available suggests that the situation is far from straightforward.

6.1 RISKS TO SEATED AND STANDING PASSENGERS

Firstly, there is the question of whether standing or seated passengers are at greater risk. The Clapham Inquiry concluded that the risk of a serious or fatal injury was no greater for standing passengers than those seated. However, evidence from the Cannon Street accident suggested that standing passengers were likely to sustain injuries to the upper torso and head. The differences noted here are more likely to stem from the relative speeds at which the two accidents occurred. The moving train involved in the collision at Clapham Junction was travelling at approximately 35 miles per hour and hence the impact forces present, and consequently the extent of the injuries, will have been much greater than those which occurred at Cannon Street station. In a higher-speed collision, it is more likely that both seated and standing passengers will receive serious injuries, particularly given the assertion that a significant source of injury resulted from being hit by loose items (either baggage or detached fittings)

The computer models derived as part of the Cannon Street Inquiry again predicted that serious injuries could be sustained by both seated and standing passengers. However, it was shown that seated passengers who had time to brace themselves may be able to avoid some of the more serious injuries. This would be much more likely to happen if passengers were able to receive sufficient warning of an impact. If this were the case, it is likely that seated passengers involved in lower-speed collisions may be able to protect themselves from some of the more serious injuries and thus be less vulnerable than those standing and those involved in higher-speed collisions. Unfortunately, in the vast majority of situations, adequate warning of an impact is extremely unlikely. This evidence suggests that the overall risk presented (i.e. when all possible impact scenarios are considered) is greater to standing passengers, even if this is not the case in every distinct scenario. From the passenger's perspective, it is suggested that the risk may be reduced by sitting and being able to protect vulnerable parts of the body. Of course, no one knows that they will be involved in a collision, but those who are generally more aware of warning signs and a suitable brace position may be able to reduce the risk of serious injury in a minority of cases.

6.2 THE IMPACT OF OVERCROWDING

I have also been asked to consider the evidence for a 'cushioning effect' in overcrowded trains. It is hypothesised that this may occur in situations in which the proximity of other people offers some degree of protection from injury. Whilst it has previously been argued that standing passengers may be at greater *overall* risk in the event of a collision, this may not be true in overcrowded conditions due to this cushioning effect.

Evidence from the Cannon Street Inquiry suggested that one of the main types of injury to which standing passengers are particularly vulnerable occurs to the upper body or head as a result of collision with the carriage structure or other people. In overcrowded trains, passengers may be less likely to be thrown into fixed objects or other people due to the fact that they are more likely to be in extremely close contact with those objects or people. Therefore, the high density of other passengers may offer some degree of cushioning against the types of upper body and head injury resulting from impacting with the carriage structure or other people and also, to a lesser extent, from flying debris. Nevertheless, the very high impact forces will almost certainly mean that the proximity to others may result in an increase of head-to-head clashes. Without further data, it is not possible to weigh one scenario against the other and draw a firm conclusion as to which holds the greater risk. However, it seems likely that whatever protection may be offered by overcrowding will be offset to at least some extent by an increase in other forms of injury.

6.3 CONTROL OF PASSENGER BEHAVIOUR

Given the earlier assertion that standing passengers may be more at risk, how would it be possible to ensure that passengers remain seated? Of course, if there are more passengers than seats, there is little that can be done other than to increase the numbers of trains running on such routes. However, as occurred at Cannon Street, passengers have a tendency to choose to congregate towards the front of the train to minimise transit time at the destination, leaving spare seats towards the rear. The only potential solutions to this problem would be either for rail staff to have responsibility for redistributing passengers evenly along the length of the train or to issue passengers with tickets for specific seats. In practice, however, both approaches would almost certainly prove to be impossible to implement and police.

A further problem lies in the fact that many passengers rise from their seats as the train approaches a station. Although trains will be travelling more slowly as they approach the station, we have already noted that, at slower speeds, standing passengers are more vulnerable than those seated . The only solution to this would be to establish a means of ensuring that people remain in their seats until the train come to a standstill. However, it is hard to envisage how this might be implemented, particularly given that it has always been difficult to dissuade passengers from opening doors before the train comes to a standstill. Although there is reasonable (though far from perfect) compliance with this requirement on aircraft, this is almost certainly due to the fact that aircraft passengers are required to wear seat belts, particularly on take-off and landing. Indeed, the two environments are quite different in several important ways. Firstly, air travel is perceived as intrinsically more dangerous than rail travel and thus passengers are more likely to recognise the importance of safety features such as seat belts. Secondly, rail travellers are largely left to their own devices whereas air passengers travel in an environment in which many actions (from finding their seat to being allowed to undo their seatbelt) are performed only on instruction from a figure in authority (i.e. a member cabin staff) and in which compliance with seat belt regulations is actively checked.

6.4 WEIGHING UP THE RELATIVE RISKS

Finally, it is worth exploring Mr Lettin's assertion that more people are likely to be injured on an overcrowded train due to the simple fact that there are more people exposed to the possibility of injury. Whilst this argument is undeniably true, the situation is somewhat more complex than might at first appear. By definition, overcrowded conditions mean that a proportion of people will have to stand. We have already established that these people may be at greater risk than their seated counterparts. Therefore, the risk presented to passengers on any one particular train is greater if more people are standing. So what would happen if the 'excess' people were removed and put on an extra train? There may be an increased risk to the population of rail travellers simply due to the addition of the extra trains required to deal with the excess passengers. The question is, how does the risk presented by the first (overcrowded)

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scenario compare with that presented by the second? At present, there is no substantial evidence to enable these two scenarios to be compared. However, should this be suggested as a means of managing the risk to rail travellers, it is recommended that this argument be given due consideration.

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CHAPTER 7 CONCLUSIONS

A range of injuries can be sustained during impacts for both seated and standing passengers. Regarding the differences in severity of harm incurred by seated and standing passengers, the incidents reviewed, including further evidence derived from the Cannon Street Inquiry computer simulations, provide largely inconclusive evidence. Nevertheless, it is possible to draw some conclusions:

- The evidence from rail accidents suggests that injuries can be sustained at any speed of impact to passengers, whether standing or sitting (facing either direction).

- For collisions occurring at higher speeds, serious injuries can be sustained by both seated and standing passengers. Although the types of injuries sustained in these two scenarios may differ, there is no evidence to suggest a difference in *severity*.

- At lower speeds, it was considered that seated passengers would be less at risk of serious injury, particularly if they had sufficient warning to prepare for the impact.

- In overcrowded trains, whilst there may be a 'cushioning effect' provided by other passengers, it is likely that whatever protection this offers may be offset by an increase in injuries sustained from head-to-head collisions.

- Evidence from events such as Hillsborough suggest that severe chest injuries leading to asphyxiation are a real possibility in heavily overcrowded situations, but there is no evidence to suggest that the degree of overcrowding experienced on trains ever reaches the densities witnessed in those extreme circumstances. In fact, no evidence for an increase in upper torso injuries in overcrowded situations was found from analysis of the Cannon Street injury data.

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APPENDIX A ACCIDENTS REVIEWED

The rail accidents reviewed for this document were:

Incident:	Date of Incident:	Date of Report Publication:
Mersham Tunnel	29 January 1989	1993
Holton Heath	20 April 1989	1993
Taplow	26 October 1989	1994
Huddersfield	6 November 1989	1993
Chorleywood	16 May 1990	1992
Reading	1 August 1990	1994
Stafford	4 August 1990	1994
Hyde North Junction	22 August 1990	1992
Cannon Street Station	8 January 1991	1992
Newton Junction	21 July 1991	1992
Severn Tunnel	7 December 1991	1994
Cowden	15 October 1994	1996
Rickerscote	8 March 1996	1996
Watford South Junction	8 August 1996	1998

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