Cox, T., Houdmont, J. & Griffiths, A. (2006). Rail passenger crowding, stress, health and safety in Britain, *Transportation Research: Part A, 40,* 244-258.

ABSTRACT

There has long been a question as to whether crowding in rail passenger transport poses a threat to passenger health related to the experience of stress. A review of the scientific literature was conducted. Little rail-specific empirical research was identified. The more general research that does exist suggests that high-density environments are not necessarily perceived as crowded and that stress-related physiological, psychological and behavioural reactions do not necessarily follow from exposure to such environments. Several factors are identified that may moderate the impact of a high-density environment on perceptions of crowding and the subsequent experience and effects of stress. These include, inter alia, perceptions of control and predictability of events. However, if caused, the experience and effects of stress may be made worse by inadequate coach design that gives rise to discomfort. The model that emerges from these findings offers a suitable framework for the development of research questions that should help translate emerging knowledge into practical interventions, for the reduction of any adverse health outcomes associated with crowding.

Keywords: rail, passenger, crowding, density, stress

1. INTRODUCTION

Over the last century there has been inexorable urban growth expressed both in terms of the number of large urban conurbations and in terms of the size and density of their populations. The world's urban population which reached 2.9 billion in 2000 is expected to rise to 5.0 billion by 2030. It is projected that by then, 60% of the world's population will live in such environments (United Nations, 2002). In 1950, New York existed as the sole city of more than ten million people; by 2001, the number of cities in this category had risen to seventeen and continues to grow (United Nations, 2002). The relationship between urban population growth and density is moderated by a number of factors, not least, physical constraints upon urban development. Hong Kong offers an exemplar of an urban centre that has experienced massive population growth within a bounded perimeter, forcing a parallel increase in population density. The population of 2.0 million in 1951 had risen to 6.8 million by 2002 and is predicted to reach 8.7 million by 2031 (Hong Kong Census & Statistics Department, 2003). Moving people around in increasingly densely populated urban environments is a major challenge, and economically a

crucial one. Many rail systems are fast approaching maximal passenger capacity. This problem is particularly acute in Britain due to a long period when there was little or no expansion of rail capacity, while demand continued to grow. Rail travel within British urban centres has grown at an exponential rate in recent years to the point at which in 2003 18,725 passenger trains operated daily (Strategic Rail Authority, 2003a) on a rail network that carries 2.06 billion passengers per year (Railfuture, 2002). Passenger numbers rose by 25% overall between 1992/3 and 2002/3 and are expected to rise by another 25% by 2010 (Department for Transport, 2002a; 2003). High passenger density is not uncommon across the British rail network and has become the norm on many commuter services. Routes in and around the South East are notoriously problematic but passenger loading levels as high as 213% have also been identified elsewhere (Rail Passenger Users Committee North Western England, 2000). In London, each weekday the increasingly overcrowded Underground rail system alone carries more people than the mainline network (Department for Transport, 2000b).

Not only is the number of passenger trains that operate at the limits of passenger capacity rising, so too is the number of stations operating at this level. It has become evident that station capacity may be reached in some areas before that of the network and trains serving these stations. High passenger and train density at stations have been identified as critical factors that may impair the level of service that can be provided by the rail network as a whole (Strategic Rail Authority, 2003b). At the turn of the new millennium, Network Rail was forced to consider a number of radical measures to alleviate station crowding including restricting passenger access to stations at busy times (Network Rail, 2003). More recently, the British Government has expressed concern at the problem of high passenger density in stations and a determination to address the issue (Department for Transport, 2004).

Despite the fact that in many British urban centres the railway system is fast approaching operating levels that challenge reliability (Network Rail, 2003), commuters appear reluctant to abandon rail travel and for a variety of economic, social and psychological reasons (Meyer & Dauby, 2002). The proposed expansion of congestion charging for vehicles entering city centres at peak times is an example of the economic forces that may further sustain a reliance on rail travel. Indeed, since the introduction of the congestion charge in central London in February 2003, 50,000 fewer cars per day have entered the payment zone, the vast majority of displaced drivers having switched to public transport including rail services (Transport for London, 2003).

The British rail network is approximately 60% of the length it was in 1962, prior to the closing of many rural lines that followed Richard Beeching's report, *The Reshaping of Britain's Railways* (British Railways Board, 1963). However, since the mid-1970s substantial sections of line have

re-opened and this trend has accelerated post privatisation in the 1990s. A strategy of bringing defunct lines back into operation cannot, however, solve the problem of how to accommodate increasing passenger numbers. Nor can the problem be answered solely by more efficient utilisation of existing assets. Since 1996, an additional 1,600 daily train services have been squeezed onto existing lines (Department for Transport, 2004). The potential for further efficiency gains that would permit more services is limited by the number and size of trains that can be safely run on the system and high costs associated with the purchase of new rolling stock. Likewise, replacement of first class with higher density standard class provision and conversion of guard only accommodation into passenger space can only marginally reduce the problem. Britain's rail network was largely developed in the Victorian era to suit trains of that time and radical infrastructure alterations would be necessary to greatly enhance capacity. The use of double-decker commuter trains, for example, would require a major programme of tunnel widening and bridge raising (Department for Transport, 2004). Alterations of this kind are generally costly and involve implementation periods in excess of ten years (Network Rail, 2003).

The probability of rail passenger density within trains and stations reaching a level that is associated with a perception that the rail environment is *crowded* and *stressful* is now a real issue. Moreover, it is one that may have considerable implications not only for passenger health and safety but also for the logistics and running of railway systems, for their design and management, and for the UK rail industry as a whole (House of Commons Transport Committee, 2003). Service quality ratings for rail companies typically reside at 28 out of a possible 100 and this is seen as evidence of widespread dissatisfaction with the British rail service (House of Commons Transport Committee, 2003). Although passengers may be reluctant to abandon rail travel, as trains become increasingly crowded and standards of service fall, they may well ultimately feel they have no choice but to consider alternative modes of transportation.

The impact of crowding is of particular concern to British business. Delays on commuter trains, which invariably increase with passenger density, are associated with low productivity and low efficiency in tired workers and are estimated to cost the city of London alone at least £230 million per annum (Oxford Economic Forecasting, 2003a). Such concern regarding the economic and organisational cost of crowding has been echoed by the Transport Committee of the House of Commons (2003), which recently observed that,

> *"Failure to provide an efficient public transport system means that employers are faced with staff who are tired, stressed and uncomfortable on arrival at the workplace. Lateness at work, loss of productivity, sickness absence, missed and rescheduled*

> *meetings and lost business due to public transport overcrowding and delays all impose real and significant costs."*

The British Government has sought to address rail passenger overcrowding in its *10 Year Plan for Transport* that came into effect in April 2001 (DETR, 2000). The Plan was announced with great fanfare by the Deputy Prime Minister, John Prescott, who promised,

> "*A railway system which is better for passengers, better for freight, better for the economy, better for the environment, indeed a win, win, win and win again* [*situation*] (Department for Transport, 2000a)."

The Plan set objectives to be achieved by 2010 involving the reduction of overcrowding to meet Strategic Rail Authority standards that stipulate no passenger should be forced to stand due to the unavailability of a seat on a journey of more than twenty minutes, or for more than 30% of shorter journeys. To date, the *10 Year Plan for Transport* has made little progress towards reducing overcrowding. Furthermore, serious accidents at Potters Bar and Great Heck, amongst others, served to shift Government and railway industry attention towards the more fundamental objective of maintaining a safe and reliable railway (Department for Transport, 2002a). Despite this, the Government remains committed to prioritising the reduction of rail passenger overcrowding (Department for Transport, 2002b, British Government, 2004; Department for Transport, 2004).

Following a major rail crash at Ladbroke Grove in West London in 1999 that resulted in the death of 31 people and injured some 400 others, a new industry body was created; Railway Safety, charged with the promotion, integration and monitoring of safety performance. Subsequent to Railway Safety's inception, several important developments in rail safety thinking within the rail industry emerged that reflected the collective cognitive shift initiated by the Government's *10 Year Plan for Transport*. This change in approach clearly demonstrated in Railway Safety's final year of operation[1], has been considered to represent a mini-paradigm shift in thinking for the railway industry (Cox, Griffiths & Houdmont, 2003). The new way of thinking encompassed intensified concern for passenger satisfaction, expressed in terms of greater awareness of the role of public perceptions of safety and an increased recognition of the role of management and organisational factors in determining passenger safety, comfort and security. Partly as a result of the new mind-set, the British rail industry has become increasingly aware that rail passengers are sensitive to crowding and may go to great lengths to avoid

[1] Railway Safety was replaced in 2003 by the Rail Safety & Standards Board on the recommendation of Lord Cullen as part of an inquiry into the Ladbroke Grove crash (Cullen, 2001).

crowded rail travel, in extreme cases even moving house or employment (Strategic Rail Authority, 2003c). Reflecting this increase in interest and concern, the authors reviewed the literature on crowding on trains and its relationship to passenger health and safety on behalf of the Rail Passengers Council (Cox, Lotinga, Houdmont & Griffiths, 2002). An initial reading of the available literature allowed three important observations:

(1) Much 'knowledge' about rail passenger crowding is derived from assumption and belief rather than based on sound empirical data. While many of the statements made do not sound unreasonable, there is a need for research to establish their validity.
(2) Little research has been conducted on the effects of passenger crowding within passenger rail provision.
(3) No substantive theoretical frameworks have been developed to guide research: developments have evolved in a piecemeal fashion, largely mirroring the state of commuting research across transportation modes (Koslowsky, Kluger & Reich, 1995).

If the British Government and the railway industry are to achieve long-term objectives concerning the expansion of passenger provision without risk to passenger health and safety, a theoretical framework is needed to guide future research into the effects of rail passenger crowding. The review of the literature presented here points to the potential for outlining the essential architecture of such a model. The advantages of such a working model are clear: it will facilitate and focus future research on particular and important aspects of the model and promote the integration of individual studies, ensuring research is conducted in a joined up fashion. However, it will also inform the translation of emerging knowledge into practical action and the evaluation of that action. It is anticipated that the proposed model will serve as a framework for the next generation of rail passenger crowding research.

2. TOWARDS A MODEL OF CROWDING

The current review of the literature on the health and safety implications of rail passenger crowding was based on data harvested from transport studies within a wide range of disciplines including medicine, organisational behaviour, occupational health psychology, ergonomics and engineering. Relevant papers were identified through computerised database searches and then the reference lists of the articles identified as relevant by the computerised search. The literature search was restricted to English language publications. This was defended on the basis that the majority of the relevant world-class journals are published in English. The approach was also consistent with that applied in other reviews of stress research (e.g. Daniels et al, 2004). Furthermore, although some non-English language publications exist concerning psychological factors in rail transportation, the focus in such research has largely been on the

workers' experience; little or none has applied to the passenger experience. The state of the literature precluded a meta-analysis. Despite this, and having extensively reviewed the literature, it is the authors' contention that the existing body of knowledge, small as it is, provides sufficient foundation upon which to attempt a theoretical integration and framework for future research. The review identified several key concepts and findings that appear to define the core of the rail passenger crowding, health and safety issue:

(1) Passenger density and crowding are separate but related constructs. Crowding is essentially a psychological phenomenon; it is a perception created from an interplay of cognitive, social and environmental factors, whereas density refers to objective physical characteristics of the situation. To use the terms interchangeably constitutes a disservice to this research domain,
(2) Passenger density may not be simply and linearly related to perceptions of crowding,
(3) There are a multiplicity of likely outcomes associated with passenger crowding including particular perceptions of risk to personal safety and security, actual risks to safety, psychological and physical discomfort, and longer term ill-health,
(4) There may be an explanatory role for the experience of stress as a psychological phenomenon within a model mediating some of the linkages between passenger density, perceived crowding and health and safety related outcomes,
(5) Mechanisms of moderation within the model are not yet fully understood and are worthy of further investigation. It is clear that a relationship exists between physical density and perceived crowding but the roles of factors such as perceptions of control and the predictability of events, design characteristics of the ambient and physical coach environment, individual differences, purpose of journey and perceptions of risk to health and safety all need exploring.

These five points are discussed below as the basis for a new theoretical model.

The first point that emerges from the literature, that 'high-density' and 'crowded' environments are not necessarily synonymous, is a crucial one. High-density situations are not always perceived as crowded and it has been suggested that the perception of crowding is contingent upon several aspects of the situation (Stokols, 1972; Altman, 1975). In short, density relates solely to the physical make-up of a situation whereas crowding is a subjective interpretation of objective reality (Beeghley & Donnelly, 1989; Westover, 1989). The non-linear nature of the density-crowding relationship becomes evident when psychological elements are factored into the equation. The failure to appreciate the unique characteristics of rail passenger coach design may be responsible, in part, for our poor understanding of the phenomena (House of Commons

Transport Committee, 2003) - an assertion refuted by the British Government (HM Government, 2004).

There is empirical evidence, albeit limited, to point towards an association between crowding and negative health outcomes (for a review, see, Cox et al, 2002). However, the paucity of literature in this regard was highlighted as an issue of concern to the House of Commons Transport Committee (2003). Following its inquiry into crowding on rail and other forms of public transport, the Transport Committee concluded itself to be,

> *"…astounded by the lack of emphasis given to health and safety aspects of overcrowding itself."*

The Transport Committee (2003) was minded to assume, in the absence of extensive research, that stress related health outcomes associated with crowded trains may be of great consequence. Interestingly, this view was not supported by the Health & Safety Executive, Britain's authoritative body on such issues, which asserted in its evidence to the inquiry that,

> *"In most circumstances [crowding effects] amount to the unpleasant effects of too many people fitting into a confined space, and are a matter of passenger wellbeing".*

The available literature suggests that passengers' perceptions of crowding may be central to their experience of stress in relation to rail travel and as such stress may be an important factor within the present model. Indeed, crowding has been defined as a 'psychological state characterised by stress and having motivational properties' (Bell, Green, Fisher & Baum, 2001). The concept of 'motivational properties' refers to the elicitation of attempts to cope with crowding by avoiding crowded situations or by reducing the associated discomfort in some way. The relationship between these two phenomena was effectively demonstrated in a large scale study of almost two thousand Italian and Dutch commuters who reported crowding to be the most common form of discomfort within their daily commute. Stress related disorders were significantly more prevalent in commuters compared to a non-commuting control group (European Foundation for the Improvement of Living and Working Conditions, 1984).

[INSERT FIGURE 1 HERE]

Figure 1 sets out a model concerning high-density environments, perceived crowding and associated stress effects, and the role of moderating variables within the relationship, suggested by an integration of the available literature. Attention is now turned to a review of the research informing this model, with particular reference to that which is specific to passenger rail travel.

2.1 MODERATING FACTORS

A host of factors that may moderate the density–crowding relationship in non-rail environments has been suggested. These include a perceived lack of control, stimulus overload, a lack of behavioural freedom or privacy, the presence of other stressors, and the relationships between the people involved and the intensity of their interactions (Bell et al, 2001). A small number of researchers have in recent times developed a focused research agenda concerning the psychological effects of residential crowding (e.g. Evans, 2002; Evans, Lercher & Kafler, 2002; Evans, Rhee, Forbes, Matta Allen & Leopore, 2000; Gomez-Jacinto & Hombrados-Mendieta, 2002;). Others have focused on the prison environment (e.g. Layton MacKenzie & Parent, 1991; Leger, 1988; Paulus, 1989; Sechrest, 1991). A paucity of rail-specific literature exists and many gaps in our knowledge remain.

2.1.1 Lack of control over the situation

The term *control* has been used in the literature on transport, health and safety to refer both to 'subjective perceptions of controllability and to objective commute characteristics (Kluger, 1998). Laboratory research has demonstrated that the likelihood of a high-density situation being perceived as crowded, results from, among other factors, a general perceived lack of control, (Langer & Saegert, 1977) and, more specifically, lack of control over proximity to others (see, for example, Nicosia, Hymen, Karlin, Epstein & Aiello, 1979; Loo & Ong, 1984; Lam, Cheung & Lam, 1999). There is also some evidence to suggest that stress effects associated with perceived crowding are likewise moderated by control (Lundberg, 1976). Swedish research has shown that rail passenger stress levels may positively correlate with the number of passengers within the coach at the point of entry (Singer, Lundberg & Frankenhauser, 1978). Singer and colleagues (1978) found lower adrenaline and noradrenaline excretion rates in passengers who boarded the train at the first stop on its route and thus avoided having to compete with others for space. The finding that levels of stress were higher in those who joined the train midway along its route and therefore entered a more crowded environment may suggest that, in rail travel, having to stand in a high-density environment may be salient to the development of crowding effects. The experience and effects of crowding appear to be moderated by the degree of control passengers are able to exercise over the high-density situation aboard the train; the ability to choose seats and control proximity to others appear to be key factors in reducing passenger stress. Such findings accord with studies of urban density that have demonstrated the moderating function of conflict with others for space (Chan, 1999). It may be the case that in public transport, the passive nature of passenger

engagement with the journey may protect from stress effects caused by factors such as journey length that have been found salient in commuters who drive to work (Kluger, 1998).

Research into choice and perceptions of control in rail travel is virtually non-existent. However, in relation to commuters who drive in the United States, Schaeffer, Street, Singer & Baum (1988) found that choice concerning alternative routes to work failed to determine perceptions of control when all routes were equally unattractive. Despite this, choice regarding journey characteristics, such as route options and mode of transportation, have been found elsewhere to relate to a host of stress-related measures in US car commuters (Kluger, 1998). Bringing these findings together allows the prediction that in relation to rail travel it is not simply the number of choices that exist regarding factors such as seating, alternative routes and train operators that are important to a perception of control, but the quality of those choices.

Some studies of car commuters have failed to demonstrate the moderating role of control in the relationship between commute characteristics and stress effects (Kluger, 1998). This may be largely attributable to small sample sizes and inconsistent operationalisation of the construct (Kluger, 1998). However, main effects of control have been demonstrated and where the construct has been operationalised as a personality variable (Montag & Comrey, 1987) or as a perception of the environment (Evans & Carrere, 1991).

2.2.2 Unpredictability of Events

In the laboratory, the absence of control tends to encourage people to seek predictability (Seligman & Miller, 1979). Extrapolated to the rail travel context, such findings suggest that the predictability of the journey may offset a perceived lack of control. Unpredictability in a journey is thought to demand high levels of attention and produce high cognitive load in US car commuters (Kluger, 1998) that may be associated with crowding perceptions in rail travel. Unpredictability in journey length has been demonstrated to correlate positively with subjective (Kluger, 1998) and objective (Evans et al, 2002) stress-related measures in commuters. Koslowsky et al (1996) found commuter impedance - a combination of time and distance between home and work - is associated with the experience and effects of stress. Interestingly, the time component of impedance was not always *predictable*, and it was this lack of predictability that appeared to induce stress. Taken together, the limited number of studies of commuters suggests that in addition to a lack of perceived control, the unpredictability of events may be associated with an increase in the likelihood of stress and stress-related outcomes (Koslowsky, 1997). Koslowsky's 1997 review encompassed various forms of commuter transportation and was not specifically focused on rail travel.

The Japanese rail network has attracted attention due to its investment in a highly effective rail system that can cope with enormous levels of demand. Part of its apparent success is attributed to passengers' willingness to accept a level of discomfort within densely packed trains when offset against the guarantee of expedient, reliable and predictable transportation (Meyer & Dauby, 2002). The evidence from the Japanese rail system implies the potential for mitigation of the effects of crowding through the assurance of predictability relating to journey characteristics.

Surveys of British workers have revealed perceptions of rail travel as unreliable, and thus unpredictable, as the main factor dissuading commuters from considering rail as a viable travel option (Kingham et al, 2001) and a key factor affecting stress outcomes (Evans, Wener & Phillips, 2002). These findings are supported by surveys of employees within a number of large employing organisations (Boots Plc, 1998; MORI, 1999). The former found that 45% of respondents would consider rail commuting if reliability were improved.

2.2.3 Satisfaction with Living and Working Conditions

A somewhat dated study, but notable for its use of a large sample in a research domain that appears to have relied on small, unrepresentative samples (Kluger, 1998), found that rail passengers reporting the highest level of perceived crowding and stress-related illness were those exposed to less advantageous living and/or working conditions (European Foundation for the Improvement of Living and Working Conditions, 1984). While this might simply imply a confounding factor, it was suggested that satisfaction with living and working conditions may buffer the negative effects of a high-density commuting environment. The study, that involved two thousand Italian and Dutch rail and non-rail commuters, further identified higher levels of perceived crowding and greater stress effects in Italian workers - conjectured to be a consequence of lack of choice in the decision to commute due to difficulties in finding employment and housing conditions (European Foundation for the Improvement of Living and Working Conditions, 1984). Despite the groundbreaking nature of these findings, no further research appears to have been conducted to explore relationships between satisfaction with work and domestic life and crowding and stress effects.

3. COMFORT AND STRESS

Comfort factors may be important in the model suggested here (Figure 1) and in three ways. First, comfort may perform a moderating function within the relationship between passenger density and perceptions of crowding; high levels of comfort serving to reduce the likelihood of crowding and its effects. Second, stress effects associated with perceived crowding may be

exacerbated by discomfort. Finally, discomfort may directly generate the experience of stress, irrespective of perceptions of crowdedness. The complex nature of comfort factors in relation to crowding was identified in a small body of research generated in the 1970's that focused on crowding in general terms rather than on rail travel (see, for example, Rapoport, 1975). The report of a survey of Italian and Dutch rail and non-rail commuters (European Foundation for the Improvement of Living and Working Conditions, 1984) speculated that crowding may be detrimental to comfort owing to an elevation in internal coach temperature caused by the dense containment of passengers, but by the same token may promote comfort in circumstances where in the absence of warmth associated with dense human containment the effects of cold weather may be felt more acutely. Unfortunately the survey was designed so as to be descriptive rather than analytical, preventing the drawing of conclusions in this regard.

The relative absence of sound evidence regarding the relationship between comfort and crowding in rail travel was noted with concern in the report of the British Government's Transport Committee (House of Commons Transport Committee, 2003); see earlier. The inquiry that informed the report received evidence of an almost exclusively anecdotal nature that generally focused on a combination of high temperature and poor ventilation as responsible for health problems on long journeys and on trains stationary for extended periods. A small number of studies have explored the impact of noise, temperature, ride quality and seat design upon comfort, although few, if any, have done so in relation to crowding (see, Cox et al, 2002)[2].

4. PERCEPTIONS OF RISK TO PERSONAL SAFETY AND SECURITY

The simplicity of the question *'do passengers feel their personal safety and security is more at risk when on a crowded train?'* belies the complexity of the relationship between perceived crowdedness and perceptions of risk. The report of the British Government's Transport Committee into crowding on public transport noted that crowding can be stressful and uncomfortable, experiences that together may contrive to create a 'positively frightening' situation (House of Commons Transport Committee, 2003). How such fear may translate to perceptions of risk to personal safety and security remains uncertain. Research concerning rail passenger safety suggests that one in five passengers feel unsafe while travelling by train (Railway Forum, 2001). How such figures relate to passenger density and perceptions of

[2] Discomfort associated with crowding in the station context has only recently begun to be empirically explored following a growing appreciation that more people on more trains equates to increased station utilisation (Department for Transport, 2004). Discomfort has been identified as particularly acute around train information screens, along circulation routes and in queues (Strategic Rail Authority, 2003a).

crowding is unknown, although public perceptions of railway safety gathered as part of the inquiry into the major rail crash at Ladbroke Grove in West London support the notion that crowding may be an antecedent of a perception of risk to personal safety (Cullen, 2001) and especially, and obviously, in relation to train crashes. Concern has been expressed about the lack of research that has explored the relationship between rail passenger crowding and risk of injury in the event of a crash (House of Commons Transport Committee, 2003).

Studies on risk highlight the complexities of risk perception and the many factors that help shape it (Feigenson & Bailis, 2001; Sjöberg, 1998; Sjöberg, 2003). One such issue is again that of *control*. Many British rail passengers report perceiving the risks involved in rail travel as greater than those inherent in alternative forms of transportation owing to a lack of control (Ladbroke Grove Rail Inquiry, 2000), even though the reality is otherwise. This is important because rail passengers with a sense of control over their journeys are also less likely to perceive high-density situations as crowded and to experience stress.

It is possible that the relationship between crowding and personal security is contingent upon crime type. For example, a crowded environment may afford few opportunities for muggings. Conversely, crowding may be negatively correlated with crime forms such as pick pocketing and verbal and physical abuse. Survey evidence is suggestive of a perception of rail travel as involving high security risk. One, British study that addressed the various forms of public transport, found that over a twelve month period, nationally, 11% of passengers reported being stared at in a hostile or threatening way and 12% reported being pushed deliberately or similarly assaulted (Crime Concern/Transport and Travel Research, 1997). It is unfortunate that data were and are not collected concerning crowdedness at times of high perceived risk.

5. IMPLICATIONS FOR PRACTICAL INTERVENTIONS

The existing body of research, weak as it is, points towards the potential effectiveness of crowding mitigation initiatives targeted at moderators of the relationship between high density and the perception of crowdedness. Furthermore, the enhancement of passenger comfort may reduce subsequent stress-related effects. Many interventions could be integrated at the point of coach design. Since 1996 rolling stock operators in the UK have invested £4.2 billion in bringing into service 4,500 new vehicles (Department for Transport, 2004). In this era of high rolling stock investment, consideration of aspects of coach design that could serve to reduce stress effects associated with discomfort is to be welcomed. Furthermore, design innovations focussed on passenger control over elements such as space, choice of seat and point of entry and exit from the coach and others that enhance perceptions of safety and security may all mitigate perceived crowdedness. The Strategic Rail Authority intended to introduce rolling stock design

specifications (British Government, 2004) that would help ensure maximum flexibility of usage across the rail network. This was to extend to specification in franchise agreements of features expected in new or refurbished rolling stock. Consideration in the specification of design to reduce perceived crowdedness would have been beneficial.

The model of crowding described here (Figure 1) suggests that individual differences in adaptive processes and coping mechanisms influence perceptions of crowding. That being the case, it should be possible to alter passengers' expectations and attitudes towards the moderating factors in the density-crowding relationship. Research that has identified control as a salient factor when operationalised as a personality variable (Montag & Comrey, 1987) attests to this assertion. Initiatives may include changing passengers' personal definitions of 'crowded' and attitudes to crowding, in addition to educating passengers to better plan for and cope with their journeys (Cox, Griffiths & Houdmont, 2003). The Japanese example, mentioned earlier, may provide an illustration of this point. In practical terms, it may be possible to alter expectations and plans through re-branding of particular services as purely for commuting purposes, offering no frills other than predictable transport. Similar re-brandings have been successfully achieved in the airline industry. Such 'psychological' interventions may prove cost-effective on services that operate at or near capacity and for which there is little scope to introduce structural modifications.

There is some recognition in Government and across the British rail industry of the need for crowding reduction initiatives (British Government, 2004). Some of the initiatives proposed by Government are consistent with the model of crowding proposed here. Ideas advocated have included improved communication that allows the driver to keep passengers informed and reassured at times of delay and crowding (increased predictability), and enhanced ventilation in coach design (increased comfort). However, others neglect the perceptual aetiology of the problem and consequently fail to address the problem directly. Crowding will at times be inevitable due to the walk-on nature of the service (British Government, 2004). However, initiatives such as fare incentives to encourage travel outside of peak hours, can at best only afford temporary relief from a problem that is likely to worsen as the rail industry strives to achieve Governmental targets for a 50% increase in passenger km by 2010.

British passenger lobbies, such as the Rail Passengers Council, have repeatedly called for crowding reduction measures (see, for another example, Oxford Economic Forecasting, 2003b), but such calls have often gone unheeded, possibly owing to the dearth of empirical evidence. Furthermore, where interventions have been attempted, an engineering perspective has informed strategy. It is increasingly obvious that inherently high cost engineering initiatives are not always sufficient in themselves. Intervention strategies focused on psychological, social and

organisational factors are sadly few and far between, perhaps owing to a lack of knowledge in the British rail industry necessary for their effective implementation. In the absence of such knowledge extreme solutions have been advocated such as the closing of Britain's railways for conversion of tracks to roads. Such a position was advocated in the 1960s by bodies such as the Rail Conversion League. For the next twenty years the idea was to receive occasional airing, culminating in the early 1980s with the Serpell Report that suggested, as one of a range of options, the reduction of the rail network from 11,000 to 1,600 miles. This is tantamount to curing the disease by burying the patient. Advancements in understanding rail passenger crowding afforded by the proposed model of crowding serve to highlight the limitations inherent in an engineering-only approach.

6. CONCLUSION

Rail passenger crowding is a problem across the British rail network and one that is likely to worsen as the rail industry strives to boost passenger km by 50% in accordance with Government targets set out in the Ten Year Plan for Transport (DETR, 2000). In view of the potential scale of the problem, it is surprising how little is understood about the transaction between the individual and the rail passenger environment in terms of crowding.

Although the literature is by no means complete, two things are clearly indicated on the basis of the existing evidence relating to issues of crowding, passenger stress and health. First, crowding should be accepted as a possible threat both to the healthiness of the rail industry and passengers. Second, recognising the gaps in current knowledge, investment in a programme of applied research should be undertaken, designed to elaborate the relationship between high density and perceived crowdedness and the experience of stress, and between these and associated risks to health, safety and security. The overview of the literature presented here is framed by a model that could guide this research. The advantages of working within the parameters of such a model are clear: it will facilitate and focus future research on particular and important aspects of the problem and facilitate the integration of individual studies, ensuring that research is conducted in a joined up fashion. It will also provide a basis for the translation of knowledge into practical action and for the evaluation of that action.

The British Government is keen for researchers to engage with a research agenda that has its focus on new challenges facing the rail industry (Department for Transport, 2001). The model advocated here could constitute one vehicle for realising the UK Government's ambition for a renewed focus on customer satisfaction as set out in the *10 Year Plan for Transport*. Overall, a focus on research into rail passenger crowding effects could prove a cost-effective means of

improving the passenger experience, bolstering passenger numbers and satisfaction, and the long term sustainability of the British rail network.

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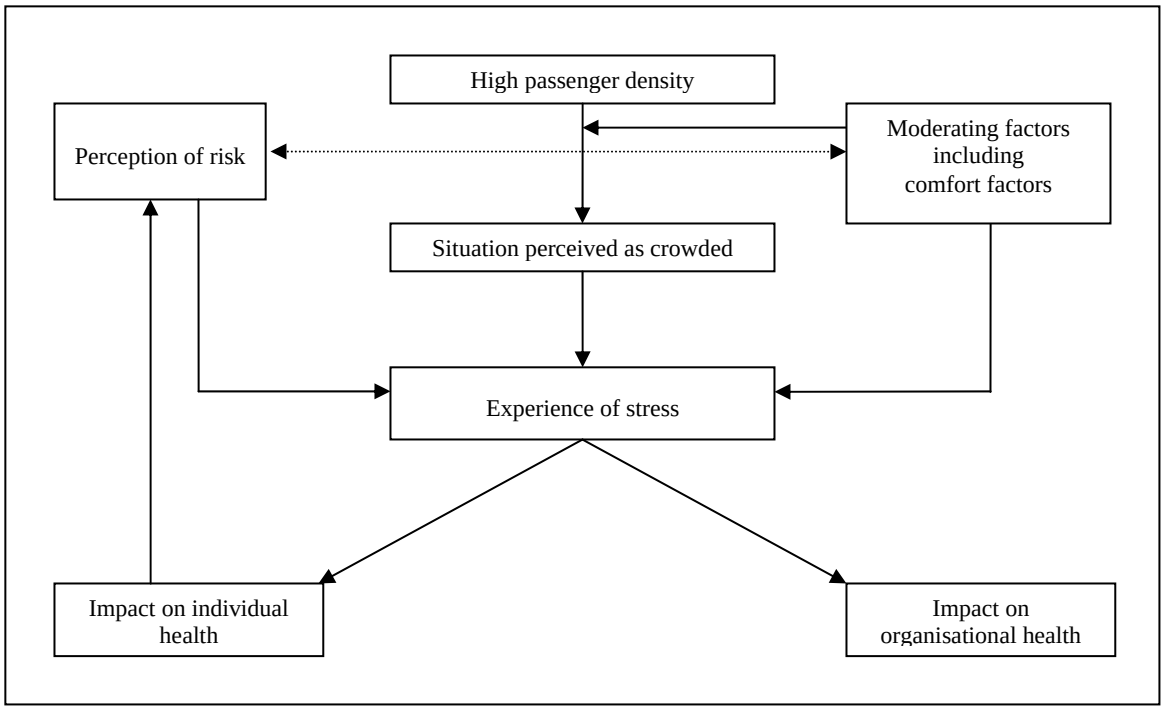

Figure 1: Model of crowding, stress, health and safety