Development of a Rail Passenger Seat Comfort Specification and Performance Scale

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Abstract In recent years, there has been a public and media perception of a decline of train seat comfort levels in Great Britain. This is reflected by passenger satisfaction scores, which are below the national target of 90% by 2035. As seat comfort is a contributing factor to overall passenger satisfaction with rail journeys, focus on improving these scores is an important area for research. Seat comfort is complex and has been found to be very difficult to quantify, due to its subjective nature and the multitude of factors that can impact upon an occupant's levels of comfort and discomfort in different contexts and environments. The rail industry does not have a standardised method to assess and score the comfort of seats in order to make an informed decision in the procurement and specification stages of design. This research produced a seat comfort selection process by identifying the minimum seat comfort dimensions, minimum seat pad thickness and hardness requirements and developing a seat comfort attractiveness survey. A pre-weighted scoring system was developed to assess multiple features which can impact upon comfort, which was validated with subjective feedback. A validation test with 7 existing train seats showed a positive correlation between objective comfort rankings, following the method proposed by this research, and the subjective comfort rankings from participants. The results indicate that the seat comfort selection process this research delivered is repeatable and can provide a reference point for industry.

Keywords: Passenger Comfort; Train Seat Design; Performance Scale; Customer Experience

1 Introduction

It has long been recognised that seating should not be viewed as a luxury, but as a fundamental requirement [1]. This is pertinent to the rail industry, with over 1.7 billion passenger journeys recorded in 2017/18 [2]. Whether it be leisure passengers or commuter passengers, who typically use trains as an extension of their working environment, comfort of the seat and the seating area demands attention. A consistent approach to seat specification and performance has not been established for rail passenger comfort.

Whilst passenger journeys in rail is high, 2017/18 saw the first drop in GB numbers since 2009/10 [2]. Furthermore, public dissatisfaction stemming from annual fare increases places pressure on the industry to deliver on all aspects of the customer experience. Passenger comfort during rail travel is an important aspect of the customer experience, and forms part of the rolling stock vision for comfortable and attractive train interiors.

Furthermore, a key aspect of passenger comfort is attributed to the seat and the seating area, which contribute to the overall impact on customer satisfaction. The 2018 passenger satisfaction scores revealed that 64% of passengers were satisfied with the current comfort of seats across the network as a national average [3]. This was below the national average of 79% passengers satisfied with their journey [3], and 26% below the industry wide target of achieving 90% satisfaction by 2035 [4]. Therefore, it can be assumed that improvements in seat comfort may contribute to reaching this target, by offering passengers better value for money and comfort during their journey.

Given the public and media perception of a decline of seat comfort levels in Great Britain, the rail industry needs the development of a robust and measurable seat comfort assessment [3]. The objective is for this new seat comfort assessment process to enable the industry to make informed decisions when specifying and procuring seats for rolling stock. This would give seat manufacturers a defined set of requirements with a testing method in order to achieve more comfortable seats.

Designing comfortable seating is challenging, especially given that humans are more comfortable in an open posture, typically when standing. Indeed, muscle efforts required for a sitting task are significantly greater than for a standing task [5]. Furthermore, quantifying seat comfort is a complex area that depends on the human, the product, and the environment [6]. Consequently, it is dependent on a whole host of parameters. In fact, De Looze explicitly states that: (a) comfort is a construct of a subjectively defined personal nature; (b) comfort is affected by factors of a various nature (physical, physiological, psychological); and (c) comfort is a reaction to the environment.

Transport research has identified 3 key considerations when thinking holistically about seat comfort and the onset of discomfort. These include:

- Static factors, e.g. seat dimensions, legroom, anthropometry
- Dynamic factors, e.g. vibration, seat pad material/composition and compression
- Temporal factors, e.g. variation in journey length.

Static and dynamic factors are equally important when considering seat comfort, as the presence of motion and vibration will increase discomfort even when the seat static factors (e.g. dimensions) have been well designed for the user population. Indeed, in automotive research this has been described in a model for assessing seat discomfort [7]. Research into rail vehicle seating has identified that the most important source of variability between seats, which affects the transmittability of vertical vibration, is individual seat differences (e.g. wear and tear), rather than occupant factors (e.g. posture) [8]. This may indicate that a reliable manufacturing process twinned with a robust method to test the durability of seats can help to manage and design for the dynamic factors associated with a comfortable seat.

The length of the journey is crucial, as previous studies have shown that the perception of overall discomfort increases with the duration of exposure [9]. Perceptions of comfort and discomfort occur through the interaction between the passenger and seat within a context. As such, the activities performed while sat in the seat (e.g. reading, sleeping, working on a laptop) can have a bearing on the level of comfort experienced. This aligns with length of the journey, which often determines the type of activities that a passenger will perform whilst travelling.

Another contributory factor to seat comfort is the opportunity for changing posture and the length of time sitting in the same seated position. Humans instinctively fidget and search for the body posture allowing the lowest expenditure of energy within the limits of that which is physiologically and biomechanically possible [10]. In automotive seat comfort research, a higher rate of seat fidget movements (SFMs) have been shown to correlate with higher levels of discomfort during a laboratory experiment [11]. This highlights that the opportunity for changing postures (thus changing the muscle groups which are supporting the body weight) is just as important as a comfortable fit [12].

Whilst physical parameters affect an occupant's comfort, the perception of comfort is also influenced by psychological factors. Literature suggests that a person's first impression of a seat can have an influence on perceived comfort [13]. The way in which we process information means that the amygdala part of the brain reacts quickly and emotionally, which ultimately gives a person their first impression of a product. Furthermore, aesthetics can play an important role during the first 0-40 minutes of sitting [14], demonstrating that those first impressions count. It is important to acknowledge when developing a seat comfort model that a person's pre state of mind, based on factors outside of the seat's comfort, is likely to influence perceived seat comfort [15].

It is expected that by assessing and scoring the physical (static and dynamic) factors, the influence of time and the impact of perception, seat comfort can be quantified, and a seat comfort selection process can be developed, tested and validated. The aim of this research was to establish if this quantified selection process based on objective measures can correlate with subjective comfort ratings of participants during a validation fitting trial and seat ranking exercise. This paper will outline the approach that was taken to develop a robust test method and seat scoring system and a validation test with existing rail seats.

2 Development of a seat comfort selection process

Findings from a detailed literature review were used to define the minimum seat comfort requirements, which considered seat dimensions, seat accessories, seat pad thickness and hardness, and the perception of comfort. A recommended weighting was given to each of the individual components which make up the comfort selection process:

- Seat dimensions – 50% of the overall score
- Seat pad thickness and hardness – 35% of the overall score
- Seat attractiveness survey – 10% of the overall score
- Seat accessories – 5% of the overall score.

2.1 Minimum seat dimensions

There are several seat dimensions that are integral to accommodating the 5th to the 95th percentile population, in terms of fit. For example, the seat width (distance between the armrests) needs to be wide enough for a passenger with a 95th percentile hip width to physically fit in the seat. Seat parameters and the corresponding body dimensions are detailed in Table 1.

Table 1. Seat parameters and corresponding body dimensions considered.

Seat parameter	*Body dimension*
Seat height	Lower leg length
Seat depth	Buttock – Popliteal length
Seat width (distance between armrests	Sitting hip breadth
Seat width (longitudinal seating)	Elbow to elbow breadth
Backrest width	Shoulder breadth
Armrest height	Sitting elbow height
Underside of headrest to seat	Sitting shoulder height
Point of contact – nape of neck	Cervicale height
Angle of seat	n/a
Angle between seat and back	n/a
Legroom (including height, clearance under table/flip down tablet)	Buttock – Knee length, knee height, thigh clearance

The minimum seat comfort requirements for passengers of non-limited mobility were based on anthropometric dimensions of people from ‘BS EN ISO 7250-2:2013 [16]. UK anthropometric data on offer is quite outdated and often based on estimations using children’s data and limited anthropometric survey data. Although there is currently no UK data in this standard, the UK population has a very similar profile to that of Germany, and so the German data was used for reference. The minimum seat comfort dimensions were intended to encompass the 5th to the 95th percentile female and male passenger profile, with allowances for clothing, shoes and the ability to ingress and egress the seat.

To accurately measure the seats under load, a weighted chair measurement device (CMD) was used, in accordance with ISO TR 24496:2017 [17], as seen in Figure 1. The CMD replicates the weight distribution of a human being and provides adjustable seat and back panel, with integrated measurement rules to provide accurate measurements. This CMD has been used to measure chair dimensions for office seating and provides a robust method for measuring seats.

Fig. 1. CMD used to measure seat dimensions (ISO TR 24496:2017).

2.2 Accessories

Accessories that are synonymous with train seating and train journeys, which can influence overall passenger comfort, were selected and incorporated as part of the proposed test method. In order to determine which seat accessories are most useful for different journey types, a confidential survey was conducted with staff across the UK (n=440). The survey asked respondents to rate the level of usefulness for each seat accessory for Metro, Regional, Inter-City and Very High Speed/First class train seats. The selected accessories included, but weren't limited to, armrests, footrests, flip down tablets, and seat spacers between seats.

2.3 Seat pad thickness and hardness

A minimum seat pad thickness of 50mm and a minimum back pad thickness of 25mm was specified for comfort requirements. The seat pad thickness includes any combination of seat cushion interlayers, including the outer fabric, fire barrier materials, foam, mesh and compression springs. It does not include the thickness of the rigid seat shell structure. To determine the minimum seat pad hardness requirements, the pad is required to provide enough compression for a lighter 5th percentile female to feel comfortable, and enough pad hardness to accommodate a heavier 95th percentile male without bottoming out i.e. the occupant feeling the ridged structure beneath the pad and receiving no support from the pad itself. To achieve this, the following method was used:

- A force of 500N applied to the seat pad using a Ø200mm indenter for 30 seconds. The seat pad shall compress to a minimum of 40% of the overall seat pad thickness.
- A force of 1100N applied to the seat pad using a Ø200mm indenter for 30 seconds. The seat pad shall compress to a maximum of 70% of the overall seat pad thickness.

2.4 Seat attractiveness survey

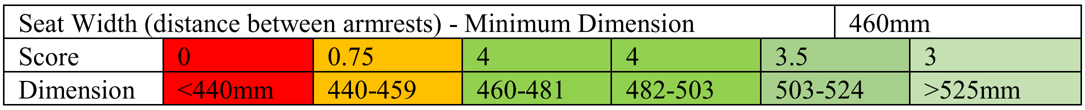
A seat attractiveness survey was designed as an optional element of the test method. This was designed to give train operating companies (TOCs) and rolling stock owners (ROSCOs) the opportunity to present a selection of the seats, which have already met the minimum seat dimension, pad thickness and hardness requirements, to passengers. This method promotes passenger engagement and customer feedback, but also caters for individual perceptions of comfort. An example of a question for the survey was:

Question: When approaching the seat, how attractive does it look?

Considerations: Shape of seat; Size of seat, width and height; Accessories; Colour/pattern and the fabric/leather.

2.5 Comfort rating scale

A comfort rating scale was developed to score seats and ascertain their comfort level, shown in Figure 2. Each seat feature that influences comfort can be tested, measured and scored, including seat dimensions, seat accessories, seat pad hardness and thickness. The individual scores for each seat feature can be added together to calculate an overall seat comfort score. The scores are pre-weighted based on the importance and effect that each seat feature has on seat comfort. For example, where minimum fit is essential for comfort, that seat feature would have a higher weighting. This scale also considered findings from the literature around adjustments and the ability to change postures, by having higher scores for seat dimensions that enabled the user population to adjust themselves within the seat.



Seat Width (distance between armrests) - Minimum Dimension					460mm	
Score	0	0.75	4	4	3.5	3
Dimension	<440mm	440-459	460-481	482-503	503-524	>525mm

Fig. 2. Seat comfort scoring performance scale for seat width (distance between armrests).

To validate the objective minimum seat comfort dimension scores, and the assumed link that comfort is based on anthropometry and physical fit, it was necessary to test a range of dimensions for each seat feature with a pilot trial. An adjustable seat rig was designed and constructed. The rig allowed the dimension of each seat feature (e.g. seat depth, seat width etc.) to be adjusted incrementally to assess how dimensional changes affect comfort. Additionally, different pad thicknesses could be added and removed from the rig for testing.

Participants (n=7) covering a diverse anthropometric population were recruited. An ergonomist evaluated and recorded how each seat feature fitted the participants when set in different incremental dimensions. Each participant was then asked to rate each seat feature dimension in order of preference. The results from this pilot identified several adjustments to the score weighting needed to be made for certain features. For example, the tolerance for seat height was increased to 440mm ±15 (from 440mm ±5mm) to account for the popularity of 425mm as a height. Lower than 425mm would begin to be more uncomfortable for 95th percentile occupants and higher than 440mm would prevent 5th percentile occupants from being able to place their feet flat on the floor.

The seat and back pad thickness tests were achieved by combining foam sheets to achieve the required thickness. The seat and back pad thicknesses were adjusted to reflect the minimum seat comfort requirements and associated comfort scores. Additionally, thicknesses deemed to be uncomfortable were assessed. Once each participant had experienced each seat pad thickness, they were asked to rank them in order of preference. The results showed that thicker seat and back pads were perceived to be more comfortable than thinner pads, and so the scoring and score weightings were reviewed to reflect this.

3 Comfort validation with existing train seats

The minimum seat dimensions and the seat pad thickness and compression tests were conducted as part of this validation trial. The scoring of accessories and the seat attractiveness survey were not included in the trial, as the seats were assessed independently and were not installed in their respective train carriage environment. Participants (n=12) were asked to sit in seven different train seats sourced from TOCs and seat manufacturers. The participants were asked to rank the seats in order of comfort (1 being the least comfortable to 7 being the most comfortable). The seat dimensions and seat pad hardness were then objectively measured and scored by the researcher and combined to calculate an overall seat comfort score. To determine if there was a correlation between objective and subjective seat comfort scores, a Spearman's Rank correlation coefficient test was used. This technique is used to summarise the strength of a relationship between two variables, with the results always being either positive or negative.

4 Results and discussion

The seat comfort testing and scoring test resulted in the high end of a moderate positive Spearman’s Rank correlation of 06.43, shown in Figure 3. This result indicates alignment between the objective measurement of seat comfort (seat dimensions and seat pad compression hardness tests) and the subjective assessment of seat comfort.

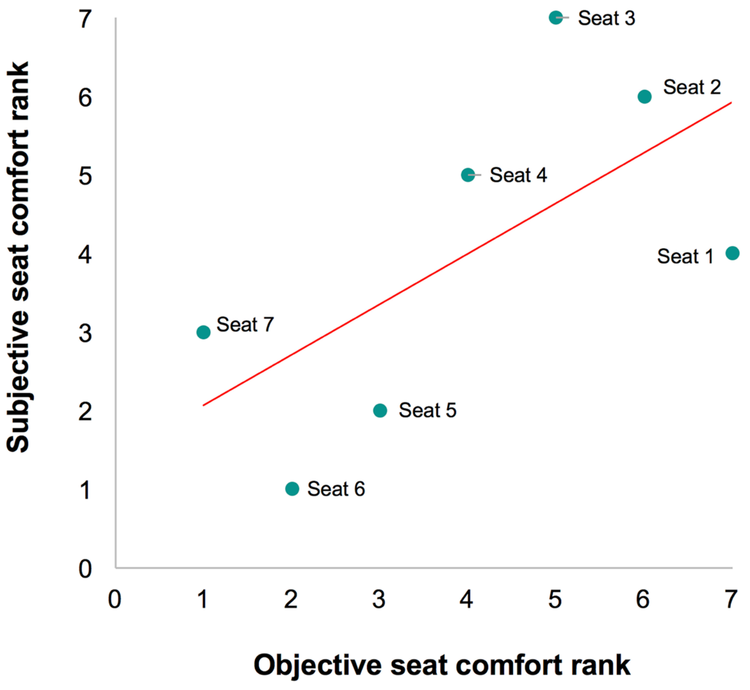


Fig. 3. Correlation between objective and subjective seat comfort ranks.

It was observed how a single individual parameter such as seat width, armrest height, and seat pad hardness influenced the participants views on overall seat comfort. This highlights the effect that each seat feature has on overall comfort. It also demonstrates that unless some of the seat features are adjustable, the fixed dimensions are often a necessary compromise to accommodate the 5th and 95th percentile body sizes.

The development of this specification and performance scale indicates that, whilst complex, a method considering a multitude of factors can produce a robust starting point for assessing seat comfort. Furthermore, as a comfort model, this specification has been developed with the individual, the product and the environment in mind [6]. Not only does this method outline key features to consider, but it also provides a robust methodology to reliably measure and test these based on existing ISO standards. This is important when accounting for repeatability in the rail industry's seat manufacturing. Passengers require and expect a certain level of seat comfort for different journey and train types. To ensure the level of seat comfort is appropriate for the type of train journey, the expected comfort rating range has been mapped against 4 distinct train journey types, shown in Figure 4. This allows the seat manufacturer or TOC to design and select a seat that is appropriate for their operational requirements. It is recommended that this specification and performance scale is reviewed periodically to account for innovative seat design developments and comfort level expectations across the industry.

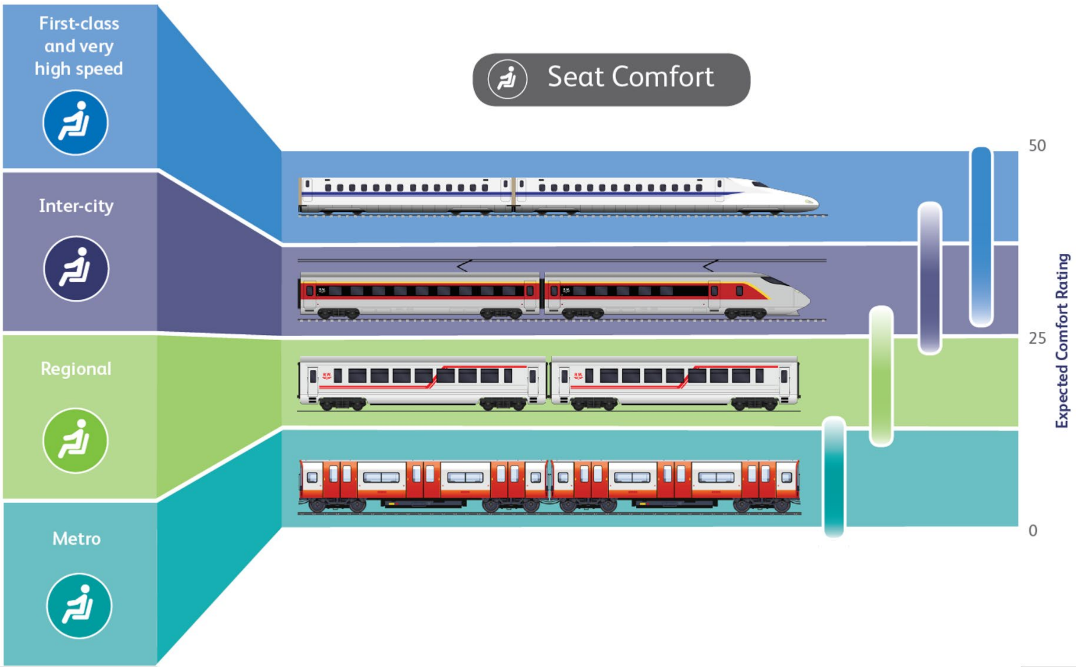


Fig. 4. Expected seat dimension scoring range for seats across journey types.

5 Conclusions

This research aimed to develop a robust seat comfort scoring system with a repeatable test method. The seat comfort requirements and scoring system are based on objective anthropometric dimensions and weights of passengers, combined with more subjective feedback on the perception of comfort from people. This was validated by assessing existing train seats with a positive correlation. The method of testing utilises robust test methodologies and equipment developed for ergonomic and compression testing used in other seating industries and was shown to be repeatable for industry stakeholders. Passengers expect different levels of comfort for different train journey types and the seat comfort scoring system provides different target scores for different journey categories.

The seat comfort selection process will provide stakeholders such as train TOCs, ROSCOs, and train seat manufacturers with a reference figure or percentage of how comfortable a seat is. Furthermore, having individual seat feature scores will allow stakeholders to understand which features can be refined to improve the overall seat comfort score on existing seats. Having identified areas for improvement, operators can integrate seat comfort in to planned refurbishments of their trains. Also, this enables stakeholders to make informed decisions when specifying seat comfort requirements in the procurement of new trains and new seats. Finally, this enables stakeholders to objectively assess seat comfort on existing trains, giving a better understanding of key issues driving customer dissatisfaction.

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