EUROSPEC Seat Comfort – spread academic news in the railway world

R.S. Mastenbroek[1*], A.Kiese[2]

[1] Department of Engineering, Interiors, NS Treinmodernisering, 2031 CC, Haarlem, Netherlands

[2] Swiss Federal Railways SBB CFF FFS, Rolling Stock Development Passenger Traffic, Wylerstrasse 123, 3000 Berne 65, Switzerland

* Corresponding author. Tel.: +31-(0)6-4496-3558 ; E-mail address: rombout.mastenbroek@ns.nl

Abstract The comfort of train seats is highly disputed within the railway industry. Reports of unhappy passengers lead to expensive changes and redevelopments. Before the end of 2019, the EUROSPEC Seat Comfort focusing on seat ergonomics is due to be published on http://EUROSPEC.eu/. This paper describes the need for a train operator driven specification and how academic knowhow is being transferred to the railway industry.

Keywords: Seating comfort, specification, public transport, railway.

1 Introduction

The Railway Industry as a whole currently lacks a common understanding of comfort of seating. Operators, Train Manufacturers and Seat Manufacturers apply a broad spectrum of requirements when specifying seat comfort. These specifications are typically based on the best available information within each organization, but more often these specifications are copied from the previous specifications for lack of a better one. Typical specifications refer to European legal requirements for seats. These are called Technical Specifications for Interoperability, TSI in short. In these legally binding texts comfort is required but not specified. Precursors of the TSI legislation written by the International Union of Railways (UIC) also mention comfort without specifying it in total.

The Railway Operators part of the EUROSPEC initiative identified a gap in the common knowledgebase regarding comfort. Therefore a Working Group was put together to create a common specification for Railway Seat Comfort. The Working Group identified the latest scientific research in the Seat Comfort field and applied the most relevant to a set of specifications. The result of this effort is a common specification based on the latest scientific understanding of what Seat Comfort for Railways Seats should be.

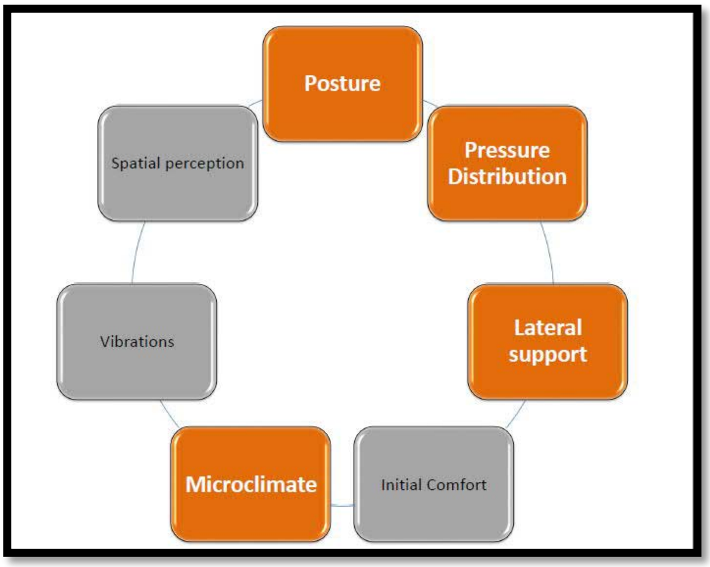

Fig. 1. Basic principles of seat ergonomics development process.

As a first contribution towards potentially a wider range of EUROSPEC seat comfort specifications, the first edition covers the areas “posture”, “pressure distribution”, “microclimate” and “lateral support” to describe the ergonomics of passenger seats on trains. It focuses on “conventional” seats for day trains, i.e. no sleeping, business class, tip-up seats or similar.

2 Approach

The members of the EUROSPEC Seat Comfort Working Group are all responsible for writing the seat functional and technical specifications for Railway Seats for their corresponding organizations. These specifications are all different in layout and content. On the contrary, the EUROSPEC initiative has a standardized approach for the creation and use of syntax for a specification. Standard EUROSPEC Excel and WORD templates have been used to draw up the initial specifications. Multiple specifications from all the organizations were copied into the EUROSPEC formats without bias or filter. A typical seat specification consists of legal, safety, technical, functional, operational and procedural requirements that have a SMART syntax. In SMART the letters generally mean Specific, Measurable, Achievable (or attainable), Relevant and Time-bound.

To better understand the concept of Comfort all Working Group Members consulted with Dr. Barbara Held. A workshop by Dipl.-Ing. Ulherr (Technische Universität München) and a Master Class by Prof. Dr. Vink and Dr. Mastrigt (Technical University of Delft) added to the knowledgebase of the Working Group. Personal interviews with Vink and Mastigt deepened the understanding.

Identification of the work by Vink, (2016) [1] led to the identification of work done by Mastrigt, (2015) [2] which led to work by Carcone & Keir, (2007) [3] Franz, et al., (2011) [4], Goossen & Snijders, (1995) [5], Groenesteijn, et al., (2014) [6], Hartung, (2006) [7] Kamp, Kilincsoy, & Vink, (2011) [8], Kilincsoy, Wagner, Vink, & Bubb, (2016) [9], Korte, (2013) [10], Mergl (2006) [11], Molenbroek, (2019) [12], Naddeo, (2017) [13], Nijholt, Tuinhof, Bouwens, Schultheis, & Vink, (2016) [14], Vink & Lips, (2017) [15], Zenk R. ,(2008) [16] and Zenk, Franz, Bubb, & Vink, (2012) [17].

All these works were scanned for possible requirements. Where requirements are normally identified by the syntax “shall” in technical specifications, the word “should” is mostly used in academic works. Scanning the identified works for sentences containing “should”, and copying these sentenced added to the preliminary requirements set. The preliminary requirements were categorized to a major component part of a seat, according to EN 15380-2:2006. Component parts like seat pan, seat back, reclining, armrests, footrest etc. Additional categories like legroom, width of passage and sensory analysis were added to the specification to complete the framework.

The Working Group initially set out to create a SMART technical requirements set by categorizing train types, travel times, classes, body measurements etc. The goal was the making of a SMART table containing required seat comfort levels (i.e. levels 1 to 5) in relation to train type, mission statement, population, classes, and travel times. It was recognized that what is “metro” or “urban” in one country did not correspond with “metro” or “urban” in another country. A “Regional Express” in Germany can have longer travel times than an “Intercity” in the Netherlands or Switzerland. With a similar travel time the London Urban Metro has a totally different kind of seat applied. This meant that creating a table that lists European seat comfort levels in relation to train-types, mission statements, travel times, classes and population would not result in one universally applicable categorization. The conclusion was drawn that a SMART technical specification only would never capture the know-how of the academic works identified.

The Working Group adopted the idea that the specifications should to be true for any population. Comfort cannot be described by specifying any one fixed measurement valid for all Europeans since all Europeans are not identical. Europeans can however be subdivided into populations. Identification of the intended population and corresponding anisotropic dataset (i.e. [12]), including weight, was added to the specification. Identification of the desired passenger activities and intended travel time was added to the specification.

The 2D parameters, see fig. 1, of a seat describe the basic dimensions of a seat like width, height and depth. For internal body measurement the P5 Female is prescribed. For external body measurements the P95 male is prescribed. For the measurements between armrest and seat pan width the external P95 female is used. All technical requirements were rewritten to not mention one SMART fixed measurement but to reference either the P5 female, P50 male or P95 male. P5 female was applied to all “internal” measurements like “Seat Pan Height, Sitting”. P95 male was applied to all “external” measurements like “Seat Back Height, Sitting” but also for requiring i.e. the minimal pitch or table height. P50 male is almost never used in the EUROSPEC Seat Comfort. The “mean” of the population is ignored based on the idea that 95% of the population is “comfortable” when using the P5 and P95 percentiles. The external body measurements also prescribe the available space needed behind and below front facing seats. Here the P95 male is expected to be able to stretch his legs and extent them below a seat in front. By extending the legs the P95 male can achieve an optimum in the pressure distribution on the seat pan. Adjustability of the seat pan height would increase the potential of a seat to be comfortable for P5 and up passengers.

Identification of postures [6] is based on the intended activities. The postures result in the necessary seat back and seat pan angles [2] [5]. When postures result in multiple seat back and seat pan angles, adjustability of the seat back and seat pan is a necessity. The relationship between the seat back angle and the preliminary seat pan angle is given by minimizing the shear forces acting on the body [5]. This is also true for a reclined seat, therefore selection of the most favourable rotation/translation “point” during reclining is necessary. The friction coefficient of the upholstery should profile enough friction to prevent involuntary sliding of the passengers in the seat while traveling, accelerations and going through switches.

To compensate the difference in body measurements adjustments should be able to be made by the passenger. Adjustment of seat pan height, head rest height, headrest angle, seat pan depth, etc. are recommended in the requirements set, but not required. Here available budget and intended comfort levels can affect the choices made for the needed adjustability. Further optimization of the seat can be achieved by providing adjustability to the tables and armrest orientation and contour. These adjustments are specified as optional since the costs of implementation can be significant.

Requirements for adjustability were added to the specification as “design recommendations” or “options”. When applied, the adjustability (see i.e. [13]) of seat features allow passengers to adjust the seat to their personal needs between the P5 - P95 range. Giving passengers something to adjust not only provides comfort to the body, but also to the brain. A sense of control over one's environment will increase comfort perception [13].

Design evaluation and optimization by pressure mapping [7] [9] [11] [15] [16] [17] of the seat pan contour [2] [4] has been added to the specification. Here optimal pressure distribution, gradient, maxima and prevention of hotspots are specified. Combined with requirements for body contour [2] [4] [14], limitation of shear forces [5] [15], by choosing the correct seat angles [2] and by choosing the shape of lumbar support [3] [10] and head support further optimization of comfort can be achieved, also while reclining. Starting from scratch or based on previous know how any 3D contour geometry can be the basis for further development. Optimal pressure distribution can be achieved by iteration of evaluation and contour optimization. It should be noted that a sports car seat pan and seat back will most likely not meet the postures requirements for railway seats. Multiple techniques are available to the suppliers to achieve this goal. Combined with the questionnaires in the requirements set the improvements in comfort, after each iteration, can be made insightful. The travel times intended by the customers, selected population and intended postures can be used as input for the evaluations.

Generally accepted Railway Standards were scanned to identify applicable requirements. The section for microclimate as described in the UIC 567:2004 [18] is referenced to by the specification. These requirements ensure temperature and humidity control behind the back and below the buttocks. The section for upper limits to hand operating forces was identified in UIC 566:1990 [19]. This will limit the forced needed to operate the adjustable features of the seat.

The application of the measurements required by the EUROSPEC Seat Comfort do not include constraints to seat dimensions imposed by EU Commission Regulation TSI PRM 1300/2014 [20]. A Statement in the EUROSPEC Seat Comfort is provided that the requirements in the TSI PRM 1300/2014 (or any future versions) supersede the EUROSPEC requirements.

The measurable requirements in the EUROSPEC offer the first set of requirements. The second set of requirements is meant to evaluate the perception of comfort. See figure 2.

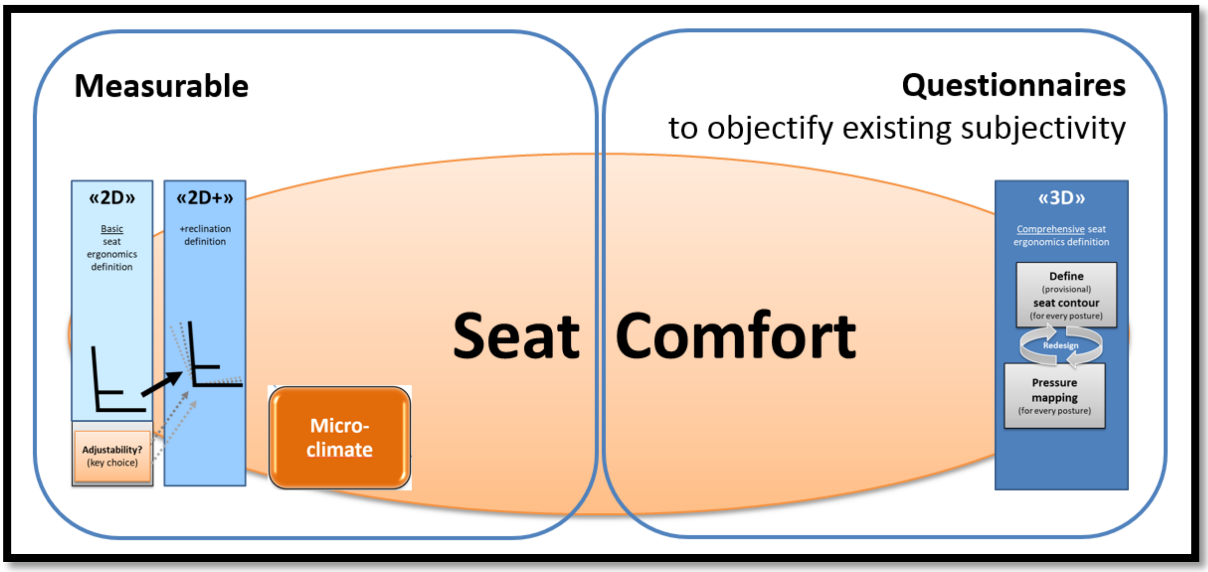

Fig. 2. Basic principles of seat ergonomics development process.

To objectify the subjective comfort perception the evaluation is procedurally standardized in the EUROSPEC specification. Statistical analysis should be applied to quantify the evaluation. The evaluation can be used to optimize the comfort by redesign. Questionnaires based on [2] [21] to [38] were identified as widely applied in academic works. These were added, unchanged, to the specifications in an attempt to procedurally harmonize comfort evaluation. Depending on the project phase these questionnaires will allow seat manufacturers and operators to evaluate the seats and possibly identify points of improvements.

Application of ISO standards [39] to [44] for Sensory Analysis of Foodstuffs has been identified as applicable to the procedures used for the sensory analysis of seat comfort. Since sensory perception of the skin/muscle/body is processed basically the same as the sensory perception of olfactory information created by the nose and mouth the ISO standard for foodstuffs [39] to [44] could also be made applicable to sensory evaluation of the skin / muscles / body. Specific ISO standards used in the food and beverages industry have detailed descriptions of how to prevent observational bias. Other ISO standards detail the environment in which an unbiased evaluation of, in this case, seat comfort can be best achieved. Further ISO standard detail statistical analysis methodologies that should be applied in combination with the before mentioned Questionnaires to draw better conclusions. See https://www.iso.org/ics/67.240/x/ for an overview of Sensory Analysis standards.

All the specifications were discussed. Irrelevant, double and non-comfort related requirement were removed from the requirements set. The requirements were reorganized, per section, to state “Requirements” (RE) first, then Design Recommendations (DR) followed by “Options” (O). Application of just the Requirements will set a new minimum comfort level for Railway Seats. Applying design recommendation and options will further increase comfort perception of the seats.

These requirements should allow seat manufacturers to optimize the seat components in an iterative way. Once experience has been gained with application of these requirements the optimization process cost should be reduced.

3 Evaluation

Part of the EUROSPEC creation process is evaluation by experts. The international Railway Technology Fair INNOTRANS in Berlin, 2018 was used to identify Railway Seat Manufacturers that will serve as experts for the evaluation of the initial version of the EUROSPEC Seat Comfort. All manufacturers acknowledged and welcomed the EUROSPEC initiative. Together with the feedback of the UNIFE members the EUROSPEC seat comfort will be updated. The final document will have achieved the goal to spread academic news in the railways world.

4 Results

The result of the work done by the Working Group is a draft specification that lists exactly one-hundred requirements.

These requirements cover key inputs, a basic seat ergonomic definition, a reclination definition and comprehensive seat ergonomics definition. By following the process in figure 3 and applying the referenced scientific works to the development process the resulting a seat will be as comfortable as possible for the chosen population, postures and travel times.

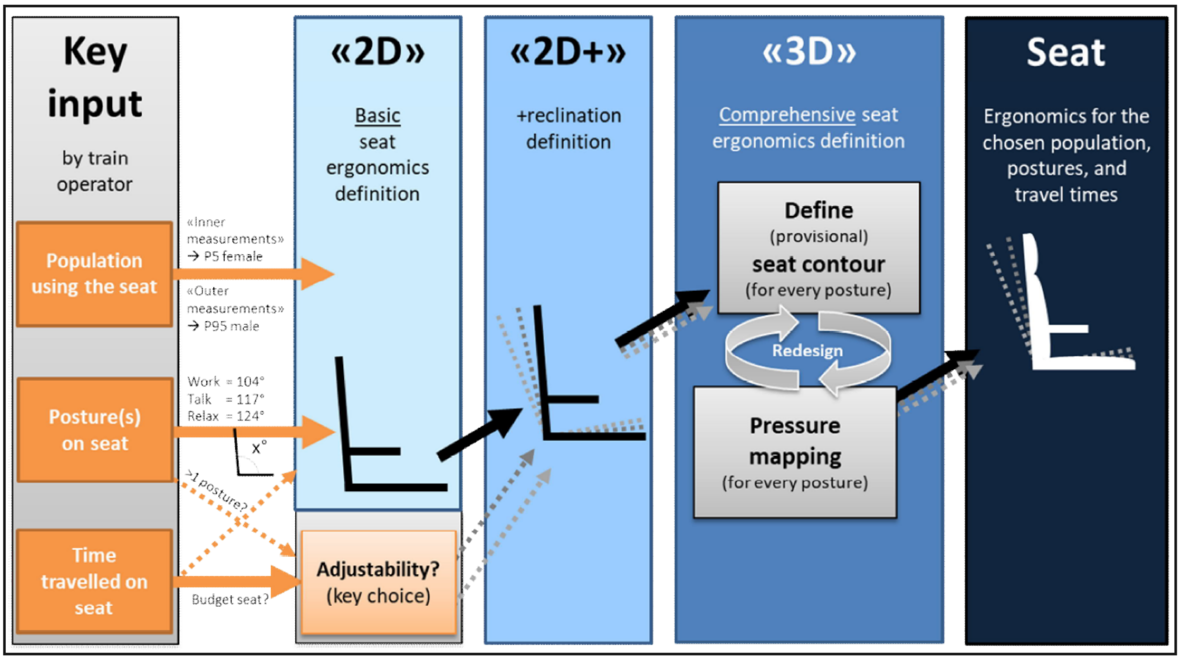

Fig. 3. Basic principles of seat ergonomics development process.

The combined requirements set in the EUROSPEC Seat Comfort represent a common framework for rolling stock operators, OEM engineering departments and Seat Manufacturers.

5 Discussion

The Working Group identified slightly different ideal pressure distributions in the academic works [1] [2] [7] [9] [11] [15] [16] [17]. Since most of the studies were performed on custom rigs, car seats or aircraft seats it is unclear what the ideal pressure distribution should be for railways seats. The technology of pressure mapping used is identical, but the ideal pressure distribution may be different since the activity of steering a car does not apply to railway passengers. The difference in postures for railway passengers may result in slightly different ideal pressure distribution and further study should be done to identify if a specific railway ideal pressure distribution exists.

During the application of the ideal pressure distribution in one project the seat manufacturer identified that the current academic works seem to lack guidelines on how to project the ideal pressure distribution on any given seat. The best guidance the Working Group could find was used by Kilincsoy [9], but even this study mentions the lack of guidance. Further guidance should be provided in future updates of the EUROSPEC Seat comfort.

Depending on the population the differences in anisotropic measurements between P5 and P95 for the Seat Pan Height, Sitting may result in un-ergonomic conditions for the P95 persons. The EUROSPEC Seat Comfort offers no guidelines for this eventuality at this point in time other than to state that proper ergonomic choices may supersede EUROSPEC Seat Comfort requirements. This is particularly true for persons with reduced mobility as identified in EU Commission Regulation TSI PRM 2014/2004.

1 on 1 application of the Goossens [5] Shear Force lines (1995), while at the same time applying the ideal Mastigt seat pan and seat back angles [2] may result in a contradictory EUROSPEC Seat comfort requirements set.

Nijholt [14] and Mastigt [2] detail how seat contours can be optimized. Alas the contours described are not publically available in a digital format. Therefore the seat manufacturers cannot use the contours provided as a starting point. Seat Manufacturers will either use the pressure mapping techniques to optimize their own current contours or repeat the studies to create a reference contour.

Application of traditional Go/No Go, Pass/Fail requirement management style is not suited for the evaluation of EUROSPEC seat comfort requirements. Since comfort perception is not binary the evaluation of meeting the EUROSPEC seat comfort requirements is also not binary. The (RE / SHALL) requirements seem to offer a binary evaluation opportunity, but even these should be evaluated on a sliding scale. For example. Not meeting the P5 female seat pan depth, but meeting P10 female, will not make the seat uncomfortable in a binary sense. It will make the seat less comfortable. Even this less comfortable level of comfort may be acceptable when evaluating against the principle of AHARP, as high as reasonably possible. AHARP being the opposite of ALARP, as low as reasonably possible, which is a well-known methodology within the Railway industry.

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