

Abstract published in B. Helgadóttir (Ed.) 'NES 2008 Ergonomics is a Lifestyle', (pp. 73), Gutenberg 2008.

## Ergonomic Assessment of the Driving Cabs of Railway Vehicles

Steve Summerskill<sup>1</sup>, Fiona Bird<sup>2</sup>, Keith Case<sup>3,4</sup>, Mark Porter<sup>1</sup>, Russ Marshall<sup>1</sup>

<sup>1</sup> Design & Technology Department, Loughborough University, UK

<sup>2</sup> Rail Safety and Standards Board, London, UK.

<sup>3</sup> Mechanical and Manufacturing Engineering, Loughborough University, UK

<sup>4</sup> The School of Technology and Society, University of Skövde, Sweden

### Abstract

The GB Rail Safety and Standards Board (RSSB) is currently revising the rail-specific human factors recommendations for an update to Railway Group Standard GM/RT2161, 1995, "Requirements for Driving Cabs of Railway Vehicles". With this objective, the human modelling system SAMMIE (System for Aiding Man Machine Interaction Evaluation) has been used to test a number of train cab designs. An anthropometric review of the train driving population was undertaken to provide data for this analysis. This was done to allow a comparison between the train driving population and the national population, with the aim of creating multivariate human models that could be used in SAMMIE. 109 train drivers were measured giving ten dimensions per driver that were then used to create human models in the software. These train drivers were measured at 4 locations in England and Scotland. In parallel with this activity the (former) GNER (Great North Eastern Railway) Class 43 train cabs (original and revised) were measured and modelled in the SAMMIE software. Each train cab was then assessed using a range of human model sizes in order to determine if they meet existing standards regarding track visibility, seat design, control and displays design, and distance of the eye point from the windscreen. The assessment highlighted a number of recommendations regarding seat design and control location. It is anticipated that the successful analysis of the Class 43 train cab will result in an expansion of the use of human modelling software in the rail industry.

### Introduction

Human factors assessments of working environments are becoming more common place in the UK railway industry due to the efforts of industry organisations, which include the RSSB. Traditionally (albeit rarely) Human factors input was achieved through full-scale mock-ups and using real people to assess the design. However this can be expensive, time-consuming and limiting in terms of the size of the user population that can be assessed. Costly full-scale mock-ups can also limit the amount of iterative testing that can be done throughout the design cycle. With these limitations in mind the RSSB contacted Loughborough University with the intention of assessing the use of human modelling software in the human factors assessment of train cab designs. The SAMMIE human modelling system has been developed and used for consultancy work and teaching at Loughborough University for the past 30 years. SAMMIE uses anthropometric data sources such as the DTI ADULTDATA (Peebles, L. and Norris, B. (1998)) to create virtual human models that can be used to assess the designs of workstations such as car interiors and aircraft cockpits. These evaluations determine if adjustability ranges, reach and vision to controls and displays are appropriate for the defined population. The use of human modelling software can therefore be considered as a virtual user trial, which can be used to inform the design process at an earlier stage than would be possible by the use of full size prototypes. A project proposal was created in collaboration with the RSSB that was designed to show the abilities of human modelling systems to influence the train cab design process. A case

study was defined that exploited a current cab design challenge that had been presented to the RSSB by the train operator GNER. This involved the retro fitting of a new seat and control panel design to the Class 43 Intercity locomotive. The new control panel and seat had already been designed. The aims of the project were;

- To examine the original cab design (circa 1960) of the Class 43 locomotive using the human modelling system
  - To evaluate the adjustability range of the seat and reach and vision of the controls for use by the UK population
  - To test the cab design using appropriate recommendations from the Rail Group Standard (GM/RT2161,1995)
- To perform the same testing structure on the revised design of the driver's seat and the control panel, to identify whether the changes imported any risk to the railway
- To measure 100 train drivers to determine how the train driving population compares to the UK national population
  - To identify train drivers who exhibit useful anthropometric dimension combinations to be modelled in the human modelling system and used in the evaluation of the Class 43 train cab design
- To support the production of rail-specific human factors recommendations for the update to Railway Group Standard GM/RT2161, 1995, "Requirements for Driving Cabs of Railway Vehicles"

This paper describes the methodology used, results, and recommendations that were generated by the project. The project was named 'T698 Human Modelling of Train Cabs and Train Driver Anthropometrics'.

### **Methodology**

The use of the SAMMIE system follows established ergonomic practice. This involves understanding the tasks that are to be performed with the workstation under assessment, creating a virtual version of the workstation environment in the human modelling system, and populating the virtual workstation with a suitable sample of humans. The virtual humans are then driven to recreate the tasks that are associated with the workstation. An overview of SAMMIE analysis techniques can be found in Porter et al (1999).

#### *Understanding the task*

In order to understand the operation of the Class 43 locomotive a task analysis was performed. This was done by observing and video recording the tasks performed by train drivers during two eight hour journeys from London in England, to Aberdeen in Scotland. This journey provided examples of different signal conditions under which the trains must be driven, (e.g. restricted signal conditions, or where the driver has been warned that there are children on the track) and illustrated the primary and secondary controls that must be operated by the driver. Interviews with the train drivers were also performed to further improve understanding of the train driving task.

#### *Creating the virtual model of the train cab*

The virtual model of the Class 43 cab was created using a set of engineering drawings, combined with direct measurement of a real cab. Figure 2 shows the Class 43 cab in the SAMMIE system.

The adjustability ranges of the seat were recreated in the SAMMIE system. This was followed by the creation of the new Class 43 cab by replacing the seat and control panel designs based upon information provided by engineering drawings.

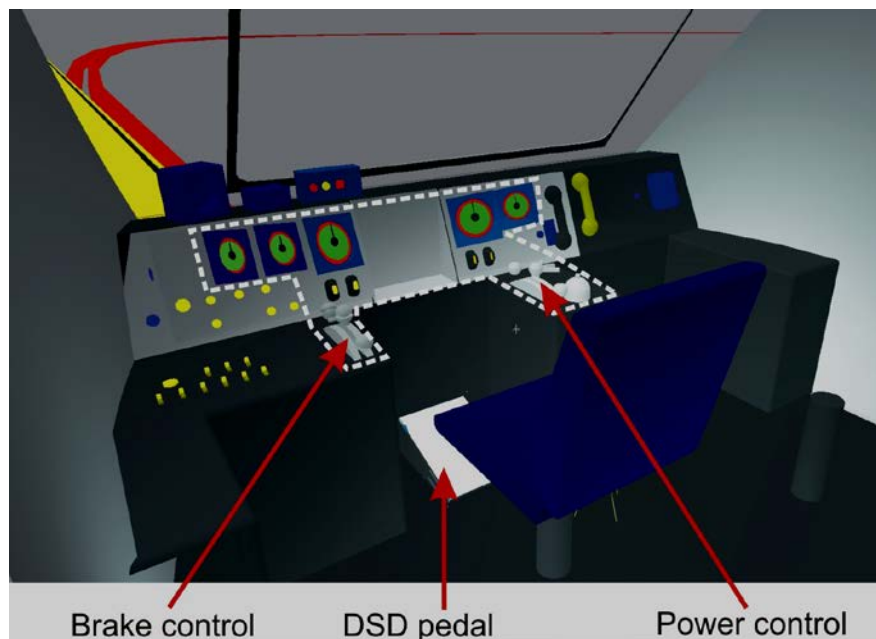


Figure 1. The Class 43 train cab modelled in the SAMMIE system. The primary controls and displays are highlighted by the dotted line. The DSD (Driver Safety Device) pedal must be periodically depressed by the driver to demonstrate alertness

#### *Defining the human model sample*

In general the human models that are created within human modelling software are univariate, i.e. a human model that is created with a stature of 90<sup>th</sup> %ile (10% of the defined population would be taller) would have all body dimensions of 90<sup>th</sup> %ile e.g. sitting height, arm length etc. This does not reflect reality where typically people exhibit a mixture of percentiles for each body dimension. In order to account for this it was decided to measure 100 train drivers (109 were actually measured). This allowed for the selection of train drivers that were considered to be ‘challenging’ in terms of body dimension combinations. An example of this would be a very tall, long legged person, who also has relatively short arms. The long legs and body of the driver would take the shoulder further away from the control panel, and the short arms would reduce the reach to the control panel. The aim of the study was to determine the accommodation of the UK population by the Class 43 cab and the revised Class 43 cab. This was done using a 99<sup>th</sup> %ile UK population by the Class 43 cab and the revised Class 43 cab. This was done using a 99<sup>th</sup> %ile UK male human model, a 1<sup>st</sup> %ile UK female human model as these represent the maximum and minimum human sizes within the UK population data. In addition to this three human models created from the dimensions taken from the 109 train drivers that were measured. These three human models had statures of 95<sup>th</sup> %ile UK male, 51<sup>st</sup> %ile UK male and 18<sup>th</sup> %ile UK male, with the aforementioned ‘challenging’ body dimension combinations, i.e. long body long legs and short arms, short body long legs short arms, and short legs short body short arms respectively. For further details see the final project report (RSSB 2008).

*The tests performed using the SAMMIE system on the original and revised Class 43 cab*

The tests performed on the cab design with the selected human models were a combination of standard SAMMIE tests and tests that are defined by the Rail Group standard (GM/RT2161,1995). The standard SAMMIE tests involved assessing the adjustability of the seating package, and reach and vision to the controls and displays for the defined population, whilst replicating the postures observed during the task analysis phase. The tests defined are as follows;

- For each viewing case, a person's eyes shall be considered to be at a point contained within an imaginary reference cube. The reference cube shall have 400 mm long sides and have its centre situated 800 mm above the centre of the surface of the driver's seat cushion, with the seat adjusted vertically and horizontally to its mid-position. The imaginary cube shall be orientated with sides parallel to the longitudinal axis of the vehicle.
- A view of level track up to 500 metres beyond the buffers (or vehicle end) when entering a curve of 1000 metres radius. This view shall be visible, whether on a left-hand curve or a right-hand curve, from a common point within the reference cube.
- The eye point should always be at least 500mm from the inner surface of the windscreen (in case of bird strike)

These two Rail Group standard entries relate to the visibility of signals by the driver and the safety of the train. The analysis using the 'reference cube' was performed in human modelling system to see if the driver's eyes were within the cube for postures that were adopted when interacting with the primary train driving controls.

## **Results**

The full results of the T698 project can be found in the final project report (RSSB, 2008). The analysis of the Class 43 train cab, with the original and revised layout, illustrated some common design issues between the two conditions.

### *Issues identified that were common to both the original and revised cab layout*

The primary control locations and their position in relation to the driver's seat were unchanged between the two conditions. These controls require the driver to lean forward in the seat in order to move the controls for power and brake through their full range of motion, producing an undesirable posture. These postures can be maintained for prolonged periods of time when the vehicle is under restricted signal conditions. See Figure 2 below.

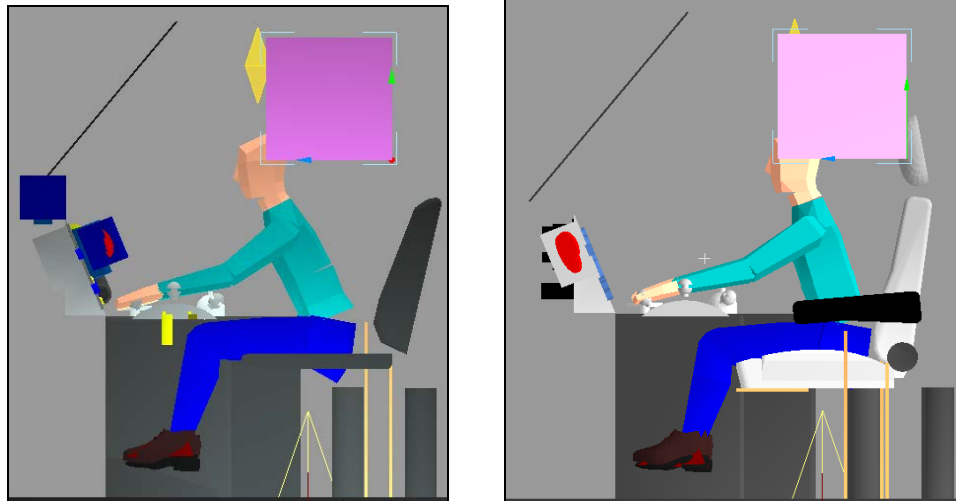


Figure 2: The 1<sup>st</sup> %ile UK female interacting with the power and brake controls in both cab design conditions. The eye point is outside of the 'reference cube'

The smaller human models that were used in the analysis demonstrated that when adopting a posture that allow the use of the primary controls, the eye point moved outside of the 'reference cube' within which the eyes must be located in order to correctly view the on-track signals. In both conditions the seat did not lower enough to allow the smaller human models to place their feet flat on the angled DSD pedal. This pedal (illustrated in Figure 1) must be periodically depressed, when a sound is heard, to demonstrate alertness. The 'tip toe' posture that is adopted by smaller female users is likely to cause a pressure point on the back of the thigh where it interacts with the seat front edge. This is undesirable.

#### *Issues identified that were improved by the new seat design*

The adjustability range and quality of support provided by the seat was improved in the revised version of the Class 43 train cab. This allowed both smaller and larger users to adopt improved postures with the new seat. Smaller users were able to get closer to the control panel reducing the severity of the forward leaning posture, whilst also having improved overall placement on the seat base. The original seat design would require the smallest users to change their fore/aft position on the seat base between the active, forward leaning posture required for restricted signal conditions, and the more relaxed posture that can be adopted in the green signal condition. Larger users could also be placed closer to the control panel, reducing forward lean.

#### **Conclusions**

The analysis of the two train cab designs highlighted undesirable postures that are forced by the layout of the primary controls in relation to the seat placement (however, for the purposes of the study, it was identified that these did not import additional risk to the railway). A redesign of the primary control locations is required to solve these issues. The analysis also showed some benefits from the redesign of the seat. The negative aspects of the Class 43 train cab affected the smaller user in the sample. There is the potential to recommend a minimum height for drivers of the Class 43 train cab based on the safety criteria in the Rail Group Standard, i.e. the eye point being slightly outside to the 'eye reference cube' that is used to assess the visibility of exterior signals. This project has illustrated that the benefit that has been demonstrated by the use of human modelling systems in the design of automobiles, translates to design for the rail industry. When compared to the production of full scale mock-ups, the use of human Modelling systems

allow iterative design at little extra cost, and can be used earlier in the design process. It should be emphasised that human modelling systems should not replace the use of full scale mock-ups in the design process, but should be used to refine the design allowing full scale mock-ups to be used later in the design process. It is anticipated that the use of human modelling systems will increase in the design of railway vehicles for both passengers and drivers.

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