

Institution: University of Nottingham
Unit of Assessment: 15 General Engineering
Title of case study: Advances and Applications in Rail Human Factors
<p>1. Summary of the impact</p> <p>A University of Nottingham research programme on rail human factors, in collaboration with Network Rail, has delivered significant impact to practitioners and professional services within the industry. New tools for workload management and efficiency are now routinely used as part of Network Rail's ergonomics toolkit and are supporting the fulfilment of the company's National Operating Strategy. Risk analysis tools have also contributed to Network Rail's programme providing enhanced asset information.</p> <p>These tools have also been taken up by international train operators in Australia and the Netherlands.</p>
<p>2. Underpinning research</p> <p>Over the past 15 years, railway companies around the world have understood the serious need to improve the reliability, use of capacity, costs and safety of their systems and operations. One key to jointly achieving such goals is to make better use of, and design to enhance, the human resource available. This need for substantial human factors understanding and improvement is found particularly in the management and control of the network and in the safe and effective maintenance and engineering enhancements.</p> <p>Since 1998, the University of Nottingham (UoN) has run an extensive programme of rail ergonomics/human factors research (funded by EPSRC, industry and the EU). The fundamental research has underpinned applied research through a £1.5M 'needs-led' programme with Network Rail, driven by the on-going upgrading of signal environments and the major Network Rail modernisation scheme. The research, including <i>inter alia</i> simulator and model development, field research of real practice and development of analytical tools and human-centred design guidance, has been led by Professors John Wilson (Professor of Human Factors, UoN 1991-2013 (deceased), Network Rail Principal Ergonomist 2001-2013) and Sarah Sharples (Professor of Human Factors, UoN 1999-present) [2.1].</p> <p>Two particular programmes from the work are emphasised in this case study:</p> <p>a) Work analysis, workload and automation for signallers and controllers.</p> <p>Between 1999 and 2008, tools were developed on the basis of new experimental, and especially field-based research work, for the assessment of mental workload of key railway operatives, and in order to plan for staff loading and crew sizing generally [2.2]. These tools emerged from Nottingham's detailed investigation of the roles and functions of key staff [2.1], use of adapted and new investigation and analysis methods based on cognitive work analysis, task analysis, scenario analysis and strategy description [2.3]. In 2007, the work was extended through inclusion of approaches to assess the situation awareness of signallers and exploration of load and performance for partially automated signalling, providing insight into the needs for human-centred automation systems [2.4]. Research techniques developed, adapted or employed with signallers, network controllers and electrical controllers ranged from mass surveys (including the largest ergonomics/human factors civilian survey of its kind), workshops, ethnographic observation for hundreds of hours in the field, assessment of prototype electronic versions of tools, the use of dedicated signalling simulators (in which real signallers were placed in a subject matter expert-managed scenario simulating two types of control scenario (disruption and non-disruption) along with three types of signalling automation, and newly developed analytical frameworks for participatory design and technology acceptance.</p> <p>b) Human factors issues and risk analysis for rail work on track:</p> <p>Until the Nottingham programme commenced, the work of people and machines on the railway</p>

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track was virtually un-researched, yet a considerable amount of the risk (effective performance as well as safety) resides in work carried out on track. Particular issues identified in early exploratory research (2005 onwards) and involvement in Network Rail high level working groups were: operational risk of delays in engineering operations; difficulties in planning and in communicating plans; managing “possessions” of the track (i.e. cancelling, delaying, re-routing or allowing passage of trains); safe and efficient access onto track (including for individuals working as track engineers); utilizing the short planned access times fully; signalling engineering and other trains through; general communications on-track and with those in the signal box, and management of hours of work, fatigue and safety. A number of new research and analysis techniques were developed to explore these areas, including: new forms of function analysis and human factors disturbance analysis [2.5]; visual scenario analysis tools to allow groups to visualize, analyse and improve possession management plans (2006–2010), [2.3]; use of resilience engineering insights (2007–2011) to assess weaknesses in planning; exploration through user experience case studies and structured laboratory study of interfaces and implementation of mobile computing on track (2006–2010); in-depth observations and interviews concerning safe behaviour and safety culture and local knowledge of operatives (2009–2013); and electronic and diary survey techniques to study on-call working (2009–2013).

3. References to the research

References (*The three most significant references are indicated with an asterisk*);

- 2.1 *Wilson, J.R., Farrington-Darby, T., Cox, G., Bye, R. and Hockey, G.R.J., 2007, The railway as a socio-technical system: Human factors at the heart of successful rail engineering. *Proceedings of the Institute of Mechanical Engineers, (Part F), Journal of Rail and Rapid Transit*, 221, 101-115. DOI: 10.1243/09544097JRRT78
- 2.2 *Pickup, L., Wilson, J.R. and Lowe, E., 2010, The operational demand evaluation checklist (ODEC) of workload for railway signalling. *Applied Ergonomics*, 41, 393-402. DOI: 10.1016/j.apergo.2009.09.003
- 2.3 Schock, A., Ryan, B., Wilson, J.R., Sharples, S. and Clarke, T., 2010, Visual scenario analysis: Understanding planning in rail engineering. *Journal of Production Planning and Control*, 21, 386-398. DOI: 10.1080/09537280903454123, copy available on request.
- 2.4 *Balfe, N., Wilson, J.R., Sharples, S. and Clarke, T., 2012, Development of design principles for automated systems. *Ergonomics*, 55, 37-54. DOI: 10.1080/00140139.2011.636456
- 2.5 Wilson, J.R., Ryan, B., Schock, A., Ferreira, P., Smith, S. and Pitsopoulos, J., 2009, Understanding safety and production risks in rail engineering planning and protection, *Ergonomics*, 52, 774-790. DOI: 10.1080/00140130802642211.

UK Grants;

- EPSRC, Human-centred automation in rail traffic control, 2006-2009, £111,200, and Human factors of CCTV monitoring, £126,536 – Rail Research UK 2 grant (EP/D080207/1) total value £3,974,001 (Col Wilson, Sharples)
- EPSRC, Centre for Rail Systems Research (EP/GR/S12784), 2003-2006, £149,393, Multi-partner grant total value £4,209,264 (Col Wilson)
- EPSRC DTA funding, 1998-2013, £374,000 in 12 grants.
- Dept for Transport, Impacts of rail research (with TRL), 2008-2009, £107,021 (PI Wilson, Sharples)

Network Rail grants/contracts (PI Wilson, Sharples);

- (relevant to impact area a): Workload understanding and assessment tool development 14 grants 1999-2011, £549,000+ ; Work analysis, strategies and automation in rail regulation & control: 12 grants 2003-2010, £357,000+; total = £906,000
- (relevant to impact area b): Human error assessment and analysis tools 8 grants 2000-2007, £251,000+; Risk and human factors issues in rail engineering and maintenance: 10 grants since 2003-2010, £450,000+; total = £701,000.

4. Details of the impact

The University of Nottingham’s research into human factors has transformed industry approaches to reliability, cost and capacity considerations in rail operations both in the UK and internationally. Engagement with industry has been central not only to the furthering of the research but also to the widespread adoption of its outcomes. This is particularly true of the collaborative relationship

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between the research team and Network Rail, which has facilitated and enhanced ongoing knowledge transfer and exchange. A key distinguishing feature of the work has been the close integration of the researchers with company employees (in the Ergonomics Team and other company groups/functions), most of the researchers being embedded within the company as adjunct employees. This ensures that the research deliverables are fit for purpose and meet the company's current and future needs, supporting real operational benefits and innovation needs. Since 2008, eight Nottingham researchers have gone on to become company employees, (the benefits include the direct application of their specialist knowledge of design and evaluation methods, and specific Human Factors concepts such as workload and vigilance within Network Rail), and Wilson was 50% employed by Network Rail [4.1].

Theresa Clarke, formerly Head of Ergonomics, Network Rail commented, "The value of the programme [has] been enormous... regarded as a model of its kind, within the company and within the rail industry ..." [4.2].

Prior to the development of tools by Nottingham, there were no tools available suitable for use within the Rail industry. Specific impacts are highlighted below for the multi-project programmes identified in Section 2.

a) Work analysis, workload and automation for signallers and controllers.

The programme of research developed and applied various forms of work analysis tools to support workload and task loading assessment and human-centred automation has found application and thus impact in Network Rail and elsewhere in the rail industry. The workload tools, specifically the Operational Demand Evaluation Checklist (ODEC) and the Integrated Workload Scale (IWS) have been used to make safety and performance related assessments, with consequent benefits of the reliable performance of signalling staff. Emma Lowe, Principal Occupational Psychologist, Network Rail commented "... [the] workload tools were developed, piloted, and validated in real practice in 45 (ODEC) and 30 (IWS) signal boxes/centres" [4.3]. These tools are now routinely used to support replacement, upgrading, and redesign of signal boxes, and Mike Carey, Head of Ergonomics at Network Rail further added "The use of these tools since their development has consistently increased and from 2007 to date, all Network Rail resignalling and re-control projects (approximately 180) have involved use of the workload tools developed by the University of Nottingham" [4.4]. Emma Lowe also points to further importance of ODEC for Network Rail: "The principles of the ODEC tool have been used to develop more specific analytical and assessment tools for assessing the workload associated specifically with engineering work. As a result the Line Blockage Quota Tool has now being rolled out in approximately 100 locations. This has assisted operations and maintenance reach agreements about an appropriate level of access for engineering works that does not introduce a workload risk for signallers to manage. ODEC was also adapted in 2010 to support decisions about requirements for supervision in our operating locations and forms the basis of an objective decision making process about when a supervisor is required to oversee the work of signallers." [4.3]

The work analysis tools, representation techniques, and insights into appropriate automation, were used subsequently to support the determination of roles (for staff and technical/automated systems) in the National Operating Strategy programme for a number of major regional control centres (of which there are 12 nationally); the guidance to human-centred automation was also used to support the on-going National Operating Strategy [4.5]. The work analysis approaches developed and the guidance on automation have been used to reduce design risk for enhanced new control centre designs, to optimise the level of reliable performance in signalling and control, and to support crew sizing decisions with the aim of reducing operating costs by giving a larger area to one operator. An example of a new technology that has been supported by Nottingham's methods is the Train Graph (a predictive tool modelling future rail traffic to help with an operators situational awareness), which was evaluated in post-implementation studies, and is now being incorporated within Network Rail's Traffic Management System [4.5]. Development of the methods for signalling and network control enabled subsequent research with rail electrical control and intelligent infrastructure, the first such work worldwide. To meet cost reduction and work effectiveness goals, the ODEC tool has been used as a basis to help operational managers balance the work associated with facilitating access to the track and with routing trains to timetable [4.4], and efforts at benchmarking for crew sizes and efficiency of performance against other

European railways, drew from the ODEC tool and automation guidance.

b) Human factors issues and risk analysis for rail work on track

The starting point for this programme was membership of university staff/researchers on a special working group set up by Andrew McNaughton, formerly Chief Engineer, Network Rail [4.1]. The role of the Nottingham team was to use workshops, archive and incident report analysis and many hours of observation on track and in briefing and control rooms to identify the functions undertaken in possession management and track work delivery, the communications which support those functions, and human factors risks potentially affecting safety and efficient performance (2006 – 2010). This led to particular developments of visual scenario analysis and function description techniques to help participant groups to understand the issues impacting on possessions, and to identify key times and functions where risk resides. Subsequently, in 2011, the tools were used within the company’s ORBIS (Offering Rail Better Information Services) programme to provide enhanced asset information industry-wide [4.6]. The function analysis and human factors risk approach was widened, since being used as the basis for support of function and risk analysis and new system implementation for electrical isolation work.

International significance

The programme of rail human factors research has led to significantly increased prominence of rail human factors research, evidenced through Nottingham’s joint organization with RSSB and Network Rail of the only four international rail human factors conferences (including 2009 and 2013) and editing of the only four major texts on rail human factors (two were in 2012 and 2013).

Intergo bv, a Dutch consultancy in human factors and ergonomics, has used the UK tools in the Dutch rail industry. Richard van der Weide, Managing Director, Intergo bv [4.7] confirmed that Intergo had developed a set of tools to assess workload of Dutch train dispatchers. He went on to indicate that the solid experimental development of [Nottingham’s] IWS in British rail was very useful in justification ... it was used in almost every signal box / centre in the Netherlands ... and as part of a generalised workload toolbox.

During his time as Professor of Risk and Human Factors at UNSW, Australia (Post jointly funded by UNSW and Nottingham), Wilson managed the transfer of methods and tools from the UK programme into research funded by the Australian Research Council and rail industry - including the development of specific tools such as error identification taxonomies [4.8].

The European Railway Agency defined Wilson *et al* (2009) [2.5] as the only journal paper required for reference by tenderers for a new Support Study for Human Factors Integration: Human Functions in European Railways [4.9].

5. Sources to corroborate the impact

- 4.1 Andrew McNaughton, formerly Chief Engineer, Network Rail, now Technical Director: HS2.
- 4.2 Overall value of rail human factors programme - Theresa Clarke, formerly Head of Ergonomics, Network Rail, now Head of Operability: HS2 (letter 26th April 2012)
- 4.3 Workload tool implementation - Emma Lowe, Principal Psychologist, Network Rail (email 3rd September 2013)
- 4.4 Use of Nottingham’s tools by NR - Mike Carey, Head of Ergonomics, Network Rail (letter 11th October 2013)
- 4.5 Work analysis tools implemented in the NR National Operating Strategy - Peter Nock, formerly Programme Manager, Network Rail, now Operational Concepts Manager, HS2
- 4.6 Visual scenario and function analysis technique implementation - Alex Schock, Senior Project Manager, Network Rail
- 4.7 Transfer of tools to other countries - Dr Richard van der Weide, Intergo bv, the Netherlands
- 4.8 Transfer of approaches/tools to Australia - Dr Carlo Capponechia, Senior Lecturer, School of Aviation, UNSW (email dated 29th Jan 2013)
- 4.9 The European Railway Agency Tender: Human Functions in European Railways (Tender ERA/2012/SAF/NP/02) page 14. Pdf available on request.