Applied Ergonomics 53 (2016) 343–356

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

21st century trucking: A trajectory for ergonomics and road freight

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ARTICLE INFO

Article history:
Received 30 October 2014
Received in revised form 14 April 2015
Accepted 15 June 2015
Available online 28 June 2015

Keywords:
Heavy goods vehicles
Commercial vehicle drivers (CVD)
Roadmapping

ABSTRACT

Over the past decade there has been significant pressure to minimise emissions and safety risks related to commercial driving. This pressure to meet the triple bottom line of cost, environment, and society has often resulted in the rapid application of vehicle technologies designed to mitigate undesired effects. Often the cognitive and behavioural effects of technologies on the commercial driver have not received in-depth analysis to determine comprehensive viability. As such, this paper aims to identify a timescale for implementation for future technologies for UK road freight, and likely associated human factors issues, improving upon the currently employed 'trial-and-error' approach to implementation which may carry high economic, environmental, safety-related risk. Thought experiments are carried out to broadly explore these future systems. Furthermore, this work aims to examine whether technology alone will be enough to meet future CO_2 reduction targets, and assess the role of behavioural and systems interventions for future research.

1. Introduction

1.1. Triple bottom line

Over the past decade there has been significant pressure on the logistics industry to minimise emissions and safety risks related to commercial driving, augmented by the tension created by growing operational demands. Since the passage of the Climate Change Act of 2008, the UK Department of Energy and Climate Change has set the ambitious goal of reducing carbon emissions to 80% of reported 1990 levels by 2050. Department for Transport figures from 2009 reported that freight vehicles above 3.5 tonnes contributed to approximately 20% of all domestic transport carbon emissions and 4.2% of total national carbon emissions (Department for Transport, 2009a). Despite this, logistics activities are fundamental to economic growth and are on a trajectory to rise further with globalisation and consumer trends such as mass personalisation (AEA, 2012). This means the triple bottom line of cost, society, and environment have and will become increasingly difficult to achieve. Due to the UK's limited space, transport congestion and existing rail infrastructure, modal changes are unlikely to meet future needs and alternative manufacturing methods such as 3D printing have not yet reached a level of maturity which is suitable for mass adoption (McKinnon et al., 2015). A great deal of existing logistics research has converged on system-level practices such as life cycle carbon accounting and integrated assessments to ensure that this triple bottom line is met, by considering the supply chain as a whole (e.g. Giminez et al., 2012; Hacking and Guthrie, 2008; Rodrigues et al., 2015; Schaltegger and Csutora, 2012). Systems approaches to these complex problems at the finest level of granularity are growing in use, and engineering interventions – particularly in vehicle design – also offer some attractive solutions. However, studies of human–technology interaction at the operational level are rare, despite the potential of designed technologies to support human behaviour throughout logistics activities (e.g. Allen & Brown, 2008). Logistics, therefore, is a fertile new ground for applied ergonomics with scope for significant impact. This paper attempts to demonstrate the role of human factors and technology design in future logistics systems to holistically assess the impact of carbon reduction measures in road freight, and to serve as a platform for future human factors work.

1.2. Moving forward from 'hyper-rationality'

Ergonomics is often the intervening variable between the expected benefits of technology and its actual outcomes, which can sometimes be substantially less than originally expected (Beekun, 1989). The roots of this paper are in localised end-user behaviour, particularly from the perspective of the commercial driving task. Road freight vehicles carry disproportionately significant carbon impact and safety risks in comparison to other transport modes; both of these are crucial points for which there exist considerable pressure to develop preventative technological solutions. As such, they are often trialled and quickly implemented without consideration of potentially substantial human factors issues such as the ability of people to reclaim control from automatic systems (e.g.

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http://dx.doi.org/10.1016/j.apergo.2015.06.022
0003-6870/

Norman, 1990), the new and sometimes arbitrary tasks created (e.g. Bainbridge, 1983), behavioural and risk adaptation (Wilde, 1982), and the panoply of effects arising simply from all the unplanned adaptions people perform in order to make a new technology suit their own needs and preferences (Clegg, 2000).

The often rapid application of vehicle technologies designed to mitigate undesired effects and balance the triple bottom line means that the cognitive and behavioural aspects of the commercial driving task have been impacted. Disparities between actual versus expected outcomes seem to reside in a tacit theory of human behaviour: that within the logistics system humans are ‘hyper-rational’ (Croson, 2013). According to Croson (2013), hyper-rational actors are characterised by the following:

1. they are motivated by self-interest in ultimately monetary terms;
2. they always operate in a conscious, deliberate manner; and
3. they behave optimally for a specified objective function.

Despite the growing acknowledgement of contextual human behaviour which defies this ‘hyper-rational’ characterisation – as evidenced by the recent increase in behavioural operations management literature (Bendoly et al., 2009) – penetration of human factors research in the logistics sector is limited. The majority of human factors research in this domain has focused for a brief period of time on manufacturing activities – such as work published by the International Journal of Human Factors in Manufacturing – or otherwise on the physical ergonomics of assembly line work subsystems (e.g. Bartholdi et al., 2010; Sundin et al., 2004). Bendoly et al. (2009, p. 450) recommend that future work in behavioural operations management should centre on the question: ‘can this observed (though perhaps unanticipated) result be linked specifically to human behaviour? [. . .] Can we change the conceptualization of this effect from an ‘unanticipated’ one to one we can in fact expect?’ This trajectory speaks towards this high level aim and draws from established literature and industry insight to address it.

1.3. Profiling the commercial driver

The focus of the technology trajectory is the commercial driver, a relatively neglected human factors subject in comparison to the private car user (e.g. Quimby and Watts, 1982; Walker et al., 2009; Young et al., 2011). To provide a robust analysis of the effects of new technology a profile of the commercial driver end user was constructed from the academic literature. The commercial driver naturally spends more time behind the wheel in comparison to private vehicle drivers (up to 56 h in any given work week) (European Directive (EC) 2003/88/EC, 2003), and the sustained mental workload associated with long-term tasks may cause performance to deteriorate (Lim et al., 2010). It was found that (relative to private vehicle drivers) commercial vehicle drivers may exhibit stronger stress reactions to traffic conditions and commit more risky driving behaviours (Oz et al., 2010), a factor which may compound itself in the time pressure which exists the industry. Commercial vehicle drivers (CVDs) may also exhibit heightened criticism of automation due to professional identity, exposure or familiarity with the traditional task, and some degree of technical knowledge of the current system (Donmez et al., 2006), a finding which can be further supported by similar human factors research in air traffic control (Bekier et al., 2012). Working consistently along familiar routes may foster inattentional blindness, which is of particular relevance to ensuring the safety of vulnerable road users (Yanko and Spalek, 2013). Naturalistic data also suggests that professional drivers have faster response times when performing an evasive manoeuver when compared to private vehicle drivers (Dozza, 2013). In terms of occupational health, long-term exposure to noise and vibration may affect the ability to engage with vehicle feedback (Majumder et al., 2009). Quality of rest of CVDs may also be salient, as this affects attention as well as the potential for safety-critical incidents (Baulk and Fletcher, 2012; Bunn et al., 2005; Darwent et al., 2012; Hanowski et al., 2007; McCartt et al., 2000; Pirrera et al., 2010). It is possible that further considerations may be necessary in technology design in order to accommodate the British CVD workforce which has a disproportionately increasing average age (Charlton et al., 2013; Lees et al., 2012; Llaneras et al., 1998).

This characterisation of the CVD as an end user group, and an examination of the existing knowledge base as such, supports a platform for effective practical contributions to both research and practice in the logistics sector. Endeavours to meet the triple bottom line balancing economic, environmental, and safety benefits are currently operating under a complex set of industry constraints, in an extremely time-sensitive sector. Attempts to meet the triple bottom line through isolated interventions suggest a sensitivity of the behaviour in the logistics system to a plethora of situational factors, which may hinder the radical changes necessary to meet carbon reduction targets (Ricardo AEA, 2012). This complexity necessitates a wider systems approach that considers not only future technology use, but the future task context in which operations will take place. This work is designed to take such a systems approach to holistically assess interventions which may, in reality, have minimal – or potentially even detrimental – environmental and safety-related effects, sometimes at considerable economic cost.

1.4. Technological trajectory

In order to support a systems approach, the trajectory below will not only address technologies related to operational driving tasks but also technologies related to distribution and delivery tasks. This paper aims to outline future logistics technologies and their associated human factors. A survey involving a cross-section of major UK logistics companies was performed to gain insight into future real-world systems, by direct line of communication with key decision-makers developing and implementing commercial vehicle technology. Using a semi-structured interview format, technologies are identified by domain experts for potential implementation by 2020, 2025, 2030, and 2050. A framework for identifying appropriate human factors relevant to technologies in the commercial driving task is outlined and applied, based on past research in technology development and human-automation system performance. The degree of automation of each technology is reviewed to further link individual operational capabilities and behaviour with system design. Results support a more user-centred approach to meeting key logistics challenges, and a way to identify novel behavioural interventions.

Logistics technologies intended to reduce fuel costs, road accidents, and carbon emissions all hold the potential for unexpected and previously unstudied human–technology interactions, and this work aims to highlight where and of what types these interactions may be, as relevant to future system design. However, the primary focus of this initial work is to assess the impact of carbon reduction technologies set for implementation in commercial vehicles, in order to evaluate the progress toward government-set reduction targets and determine whether or not this goal can be achieved by technology alone.

2. Materials & methods

2.1. Design

To provide the necessary insights into technology-induced impacts on the commercial driver a survey of leading logistics practitioners was performed. Industry-led insights were reflected by a systematic review of the knowledge base. The focus of the review