Transportation Research Part A 82 (2015) 204–215

Contents lists available at ScienceDirect

Transportation Research Part A

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

A model for exploring the relationship between payment structures, fatigue, crash risk, and regulatory response in a heavy-vehicle transport system

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ARTICLE INFO

Article history:
Received 22 September 2014
Received in revised form 28 September 2015
Accepted 29 September 2015

Keywords:
System
Safety
Agent-based-models
Heavy-vehicles
Transport
Work

ABSTRACT

Investigations of heavy vehicle crashes have predominantly taken a reductionist view of accident causation. However, there is growing recognition that broader economic factors play a significant role in producing conditions that exacerbate crash risk, especially in the area of fatigue. The aim of this study was to determine whether agent-based modelling (ABM) may be usefully applied to explore the effect of driver payment methods on driver fatigue, crash-risk, and the response of enforcement agencies to major heavy-vehicle crashes. Simulation results showed that manipulation of payment methods within agent-based models can produce similar patterns of behaviour among simulated drivers as that observed in real world studies. Simulated drivers operating under 'per-km' and 'per-trip' piece rate incentive systems were significantly more likely to drive while fatigued and subsequently incur all associated issues (loss of license, increased crash risk, increased fines) than those paid under 'flat-rate' wage conditions. Further, the pattern of enforcement response required under 'per-km' and 'per-trip' systems was significantly higher in response to greater numbers of major crashes than in flat-rate regimes. With further refinement and collaborative design, ABMs may prove useful in studying the potential effects of economic policy settings within freight or other transport systems ahead of time.

1. Background

Around 250 are people killed in Australia as a result of crashes involving a heavy vehicle each year (BITRE, 2013). This makes heavy-vehicle driving one of the most dangerous occupations available to Australian workers (Transport Workers' Union of Australia, 2011).

Despite acceptance that workplace accidents occur within complex sociotechnical systems (Goode et al., 2014; Rasmussen, 1997; Salmon et al., 2013), investigations of heavy vehicle crashes have predominantly taken a reductionist view of accident causation, focusing on direct technical (e.g., mechanical faults, safety equipment), demographic (e.g., age, experience), and behavioural (e.g., sleepiness, speeding) causes of accidents (Brodie et al., 2009; Brooks, 2002; Duke et al., 2010; Häkkänen and Summala, 2001; Raftery et al., 2011). There is, however, a recognition that broader economic and system-level factors such as financial pressures and compensation methods play a significant role in producing conditions that encourage

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http://dx.doi.org/10.1016/j.tra.2015.09.016
0965-8564/

fatigue-related driving and increased crash risk (Quinlan and Wright, 2008; Thompson and Stevenson, in press; Williamson et al., 1996).

Despite convincing evidence of the influence of compensation methods on driver fatigue, the links between payment rates and safety are often publicly challenged by industry groups (Australian Industry Group, 2014; McKillop, 2014). Disparate views are forwarded regarding whether fatigue constitutes an ongoing concern at all, or if it does, how fatigue management systems should be regulated. Worker representative bodies such as transport unions have generally advocated additional system regulation to ensure safety standards are met or maintained (Rumar, 1999; Transport Workers' Union of Australia, 2011). Owner-drivers, trucking companies and industry bodies, however, have shown preference for more flexible, self-regulated environments that place responsibility on individual companies and drivers for safety, whilst also promoting principles of driver education and enforcement of existing laws and regulations (Australian Fleet Managers Association, 2011; Australian Logistics Council, 2011). In Australia, such tension has also played out politically in the establishment, and then proposed removal, of oversight bodies such as the Road Safety Remuneration Tribunal set up to establish and monitor safe payment rates for drivers (Transport Workers Union of Australia, 2014).

Increased public focus and scrutiny of existing heavy-vehicle safety laws often comes in response to the failure of self-regulation to ensure safety standards are upheld. Tragic road incidents can provide impetus for what appear to be sudden transitions between 'business as usual' operations occurring below critical levels of safety to almost complete overhaul of safety operations and processes within individual organisations or industries. For example, in 2013, a fuel tanker crash and explosion that resulted in two deaths and five serious injuries instigated a major New South Wales government safety audit of a large, Australian trucking company, Cootes Transport. The mechanical failures that contributed to the incident revealed an operation that was running below accepted levels of safety. Upon inspection, over 40% of Cootes' fleet was issued with formal mechanical safety warnings (ABC News, 2014) and over 300 charges were laid against Cootes in relation to breaches of safety (Dingle, 2014). Rather than a welcome example of existing law and regulation enforcement, however, representatives of Cootes' parent company described the safety audit as an instance of "unprecedented government scrutiny" driven by "negative press that government officials react to and feed" (O'Sullivan, 2014b). The representative also warned that because of the safety audit, company profits would be negatively affected (due in part to increased maintenance costs) as would up to 540 jobs (O'Sullivan, 2014a).

Whilst the case above is particular to mechanical safety rather than fatigue, it is perhaps a clear example of a company's sensitivity to the opportunity cost of having trucks 'off the road' (Burawoy, 1979). Further, whilst an audit process can demand inspection of a company's fleet and identify tangible safety defects, it is a far more difficult task in relation to fatigue where the phenomenon is unobservable and dynamic, and where both causes and 'safe levels' of fatigue are contested.

1.1. Methodological restrictions

The majority of methodological strategies designed to provide insight into the impact of compensation methods have attempted to draw linear 'dose–response' relationships between remuneration and outcomes such as average speed, driving hours, income, or fatigue (e.g., Sharwood et al., 2013, 2012; Thompson and Stevenson, in press). Although instructive, there is a risk that designs considering only simple relationships between variables (Kay and Schneider, 1994) may mask the underlying dangers of various compensation methods for heavy-vehicle drivers operating within complex economic and workplace systems. For instance, although mean speed or mean time taken between driving breaks could potentially be similar between compensation methods, it may be that various methods create incentives for greater likelihood of infrequent but extreme driving behaviours (e.g., driving overnight without sleep in order to make schedule) that might otherwise be masked by 'averaged' figures. Added to this is that, whilst devastating and unacceptably frequent, heavy-vehicle transport is so ubiquitous that crashes are still relatively rare events (National Transport Commission, 2011; Newnam and Goode, 2015). Capturing them in sufficient volume to consider the long-term implications of any policy or safety setting is therefore extremely challenging.

1.2. Systems-based accident models: mapping the causes of heavy vehicle crashes

Systems approaches have been successfully applied to understanding and enhancing safety and performance (Goode et al., 2014; Salmon et al., 2013). According to Salmon et al. (2013), three accident causation models currently dominate the Human Factors literature: Rasmussen's (1997) risk management framework; Reason's Swiss Cheese model (2000); and Leveson's (2004) Systems Theoretic Accident Modelling and Processes model.

Rasmussen's (1997) risk management framework is based on a socio-technical system that describes the control of hazardous processes as an interplay between actions and decisions across six system levels (i.e., government, regulators, company, management, staff, work). According to Rasmussen, a system can function safely through a process referred to as 'vertical integration'. Safe practice decisions at higher levels (i.e., government, regulators, company) should be reflected in practices occurring at lower levels of the system, whilst information at lower levels (i.e., work, staff) should inform decisions and actions at the higher levels of the hierarchy (Cassano-Piche et al., 2009; Svedung and Rasmussen, 2002).

Rasmussen's (1997) risk management framework and the associated Accimap technique has been applied to analysing the causal factors of accidents in truck driver safety (Newnam and Goode, 2015). Although this methodology presents a novel and highly effective approach to investigating accidents and the circumstances that produce them, two limitations are