Applied Ergonomics 44 (2013) 764–774

Contents lists available at SciVerse ScienceDirect

Applied Ergonomics

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

Sounding the warning bells: The need for a systems approach to understanding behaviour at rail level crossings

Gemma J.M. Read [a,*], Paul M. Salmon [b], Michael G. Lenné [a]

[a] Human Factors Group, Accident Research Centre, Monash Injury Research Institute, Building 70, Monash University, Victoria 3800, Australia
[b] University of the Sunshine Coast Accident Research (USCAR), Faculty of Arts and Business, School of Social Sciences, University of the Sunshine Coast, Queensland 4558, Australia

ARTICLE INFO

Article history:
Received 20 June 2012
Accepted 21 January 2013

Keywords:
Rail level crossings
Systems approach
Systems theory

ABSTRACT

Collisions at rail level crossings are an international safety concern and have been the subject of considerable research effort. Modern human factors practice advocates a systems approach to investigating safety issues in complex systems. This paper describes the results of a structured review of the level crossing literature to determine the extent to which a systems approach has been applied. The measures used to determine if previous research was underpinned by a systems approach were: the type of analysis method utilised, the number of component relationships considered, the number of user groups considered, the number of system levels considered and the type of model described in the research. None of research reviewed was found to be consistent with a systems approach. It is recommended that further research utilise a systems approach to the study of the level crossing system to enable the identification of effective design improvements.

1. Introduction

In the ten year period between 2000 and 2009, 695 collisions between road vehicles and trains occurred at rail level crossings in Australia. Ninety-seven fatalities resulted from these collisions, accounting for approximately 30% of rail fatalities over that period (Independent Transport Safety Regulator, 2011). Pedestrians were struck by trains in 98 level crossing incidents over a similar time period (Australian Transport Safety Bureau, 2011). With approximately 10,497 road and pedestrian level crossings in Australia (Rail Industry Safety and Standards Board, 2009), this longstanding safety concern is not only a priority for the Australian rail industry, where it has been identified as one of the top five safety risks (Stroud, 2010), but also internationally. The United Kingdom experiences approximately 11 fatalities each year due to accidents at level crossings (Evans, 2011), while the United States government recorded 249 fatalities in the year 2011 (Federal Railroad Administration, 2012).

Collisions at level crossings result in a higher mortality rate than other types of road traffic accidents (Wigglesworth, 1976) and, due to the disparity in mass between the train and the road vehicle, the impact is usually extensive leading to traumatic scenes. A recent trend of heavy vehicle involvement in these accidents, in Australia at least, has led to risk to the train and its passengers, in addition to the road vehicle, with the potential for catastrophic outcomes (Australian Transport Safety Bureau, 2008). With growing numbers of longer and heavier freight vehicles using the road network, coupled with increased train services and speeds, this catastrophic risk may be increasing (Road Safety Committee, 2008).

Given the safety issues at level crossings and their impact on road and rail systems internationally (United Nations, 2000), there has been a substantial research effort to understand why these accidents occur and how they might be prevented. Much of this effort has focused on the behaviour of motorists with the vast majority of accident investigation reports identifying motorist error as the cause of level crossing crashes (National Transportation Safety Board, 1998). However, researchers have suggested that understanding of road user behaviour at rail level crossings remains limited (Edquist et al., 2009).

Many within the discipline of Human Factors have articulated the need for a systems approach when tackling road safety issues (e.g. Larsson et al., 2010; Salmon et al., 2012), in line with the modern approach to analysing complex safety critical systems. Modern safety science has experienced a paradigm shift away from individual, reductionist approaches to analysing and improving safety issues and now emphasises the recognition of system influences on safety and the occurrence of accidents

* Corresponding author. Tel.: +61 3 9905 1804; fax: +61 3 9905 4363.
E-mail address: gemma.read@monash.edu (G.J.M. Read).

0003-6870/$ – see front matter
http://dx.doi.org/10.1016/j.apergo.2013.01.007

(e.g. Dekker et al., 2011; Leveson, 2004; Rasmussen, 1997b; Reason, 2000).

The increased uptake of systems-based approaches to analysing safety critical domains has prompted some researchers to consider the extent to which these approaches or principles have been applied. For example, a review of patient safety literature was undertaken by Waterson (2009) to determine which publications could be judged to have adopted a systems approach. The analysis found that few studies considered all levels of the system, and suggested that the term 'systems' may be being used inappropriately. It is currently unknown to what extent the systems approach has been applied in the level crossing literature.

The aim of this paper is to review the current research approach to safety issues at rail level crossings. Firstly, two research approaches are discussed and contrasted; the individual approach and the systems approach. Next, key concepts from systems theory are outlined and are synthesised into criteria for a systems approach. These criteria build upon some of those applied by Waterson (2009). The criteria are then applied within a structured review of the rail level crossing literature. Conclusions are drawn regarding the extent to which a systems approach has been applied in the research literature in this domain.

2. The individual approach

Traditionally, research into road user behaviour has focused on individuals, their information processing capabilities and limitations and their resultant behaviour (Salmon et al., 2010b). For example, there is extensive research on the performance impacts of impairment in transport settings due to fatigue or alcohol (Baulk et al., 2008; Lenné et al., 2010; Oxley et al., 2006; Sung et al., 2005) stress (e.g. Desmond and Matthews, 2009; Hartley and El Hassani, 1994; Rowden et al., 2011), and distraction and inattention (e.g. Blanco et al., 2006; He et al., 2011; Noy et al., 2004). Researchers in this field have predominantly preferred reductionist, analytical methods such as laboratory experiments and field studies. The aim of these empirical studies is to control as many variables to enable isolation of cause and effect relationships. There may or may not be a theoretical basis for selecting the variable of interest or predicting it's affect on behaviour, with some researchers noting that, for example, road safety evaluation studies often lack a strong theoretical basis (e.g. Elvik, 2004).

Studies employing the individual approach tend to view the person as another component, similar to a piece of technology, and provide recommendations for increasing the reliability of this component. Often, little consideration is given to the context of behaviour and its influence. This approach leads to proposals for behaviour change through education and enforcement measures that increase compliance with laws. A behavioural approach to improving level crossing safety has been advocated (for example, Sochon, 2008; Wallace et al., 2006). The propensity for accident investigators to 'blame the victim' of systemic deficiencies has been noted specifically in regards to level crossing accidents (Bade, 2011; Green, 2002). This 'hunt for the broken component' mentality is now accepted in the literature to be a flawed approach to improving safety in complex systems (e.g. Dekker, 2011).

3. The systems approach

In contrast, the systems approach takes the overall system as the unit of analysis, looking beyond the individual and considering the interactions between humans and between humans and technology within a system. In cognitive systems, where functioning relies on people to perceive, think, act and collaborate with one another (Lintern, 2011), a systems approach incorporates consideration of human cognitive and/or behaviour. However, this should not limit the investigation of the system to behaviour only. From an accident prevention perspective, barriers or controls within the system may influence safety without directly affecting behaviour (for example, through affording error tolerance or mitigation of injury severity). The systems approach also encompasses factors within the broader organisational, social or political system in which processes or operations take place. According to this approach, safety is an emergent property arising from the interactions between components at all levels of the system (Leveson, 2004). This can be contrasted with the reductionist or analytical approach which looks at the components (such as humans) in isolation and views the whole as merely the sum of its parts.

The field of human factors has traditionally worked within a psychological paradigm, focussing on the physical and cognitive capabilities and limitations of humans. This knowledge about people is combined with information about the context in which they are behaving in order to understand and analyse behaviour. Qualitative methods such as task analysis (Stanton, 2006), workload analysis (e.g. Pickup et al., 2010) or human error identification (e.g. Kirwan, 1998; Stanton et al., 2009) are often used when exploring behaviour in context. Applied to safety critical systems, the focus of human factors has been understanding human behaviour, particularly human error, and how it can be managed or controlled. There can be a tendency to recommend more and more strict barriers to control and restrict behaviour, particularly in response to accidents (Dekker, 2002). However, this can create increasingly complex systems (Dekker et al., 2011; Hollnagel, 2004), or situations where people become frustrated with the lack of flexibility, and find ways to circumvent controls. Thus, a more sophisticated understanding of people's interactions with different controls, and in different contexts, is vital.

Modern human factors approaches are moving away from the psychological approach that considers humans as limited information processors. While understanding human capabilities and limitations is still important, there is greater focus on the context of behaviour and the constraints on behaviour imposed by the environment. This movement has been guided by systems theory and the advent of systems-based methods to understanding cognition such as found in the cognitive systems engineering field. There has been a move away from individual to distribution cognition (Hutchins, 1995) with cognitive processes such as situation awareness seen as distributed amongst actors in a system (human and technical), rather than being a property of an individual (Salmon et al., 2009). There has also been a shift in thinking from a focus on human error, to a consideration of performance variability acknowledging that the same processes lead to successful and unsuccessful (erroneous) behaviour. Accordingly, much can be learned from studying situations where things go right (Hollnagel, 2009). Rather than conceptualising the human as the weak link in an otherwise well designed technological system, humans are viewed as flexible and adaptive decision makers who are integral to the safe and effective functioning of the system (Lintern, 2011).

3.1. The rail level crossing system

It is essential, prior to developing criteria for a systems approach to research, to first establish the applicability of systems theory to rail level crossings. In this section we confirm the