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A review of models relevant to road safety

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ABSTRACT

It is estimated that more than 1.2 million people die worldwide as a result of road traffic crashes and some 50 million are injured per annum. At present some Western countries' road safety strategies and countermeasures claim to have developed into 'Safe Systems' models to address the effects of road related crashes. Well-constructed models encourage effective strategies to improve road safety. This review aimed to identify and summarise concise descriptions, or 'models' of safety. The review covers information from a wide variety of fields and contexts including transport, occupational safety, food industry, education, construction and health. The information from 2620 candidate references were selected and summarised in 121 examples of different types of model and contents.

The language of safety models and systems was found to be inconsistent. Each model provided additional information regarding style, purpose, complexity and diversity. In total, seven types of models were identified. The categorisation of models was done on a high level with a variation of details in each group and without a complete, simple and rational description. The models identified in this review are likely to be adaptable to road safety and some of them have previously been used. None of systems theory, safety management systems, the risk management approach, or safety culture was commonly or thoroughly applied to road safety. It is concluded that these approaches have the potential to reduce road trauma.

1. Introduction

Road traffic injury is listed in the top ten major causes of mortality and morbidity worldwide (WHO, 2010). It is estimated that more than 1.2 million people die as a result of road traffic crashes and some 50 million are injured per annum (WHO, 2009). Road safety strategies are developed to choose, guide and describe actions to reduce this burden of injury. Road safety strategies focus on road users, vehicles, roads, and socio economic factors (Haddon, 1980). Recently, road safety strategies have been described as being a safe systems approach (Wegman et al., 1995; OECD, 2008).

Strategies to understand and reduce accidents and injuries have been developed in many domains, for example in occupational health (Rasmussen, 1980), hazardous industries (Johnson, 1980) and other modes of transport (Gibson, 1961; Helmreich and Merritt, 1998), thus being applied to different contexts. Types of safety models from these and other fields may be applicable to road safety but do not meet the description of a system (Wilson, 2014a; Perrow, 1984; Leveson, 2004). The full range of safety model types which may be applied to road safety strategies, such as the safety management system (Standards Australia and Standards New Zealand, 2001a,b) are not evident in road safety. Therefore, other types of model may potentially be applied to improve road safety strategies. In order to determine whether that is the case or not, the different types of safety models need to be categorised according their characteristics and compared. If however, the range is known, then the most appropriate model type may be used to develop more comprehensive and effective road safety strategies.

1.1. Models

A 'model' is a simplified description or representation of something to assist understanding. Models assist in creating a mental picture, facilitate questioning and information, establishing rules, checking, evaluation, analysis, identifying and assessing

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countermeasures and communication (Kjellén, 2000). Physical, visual, mathematical and descriptive models have been constructed for a variety of purposes. In this review, models are defined as concise descriptions of a whole entity, variously called models, frameworks, concepts or other terms. In this case, the purpose of applying the models was to explore possible ways to improve safety. At the highest level, these models are generally descriptive, often with a visual aspect (diagrammatic), rather than the more detailed mathematical and quantitative models used for particular analytical purposes. The utility of models is dependent on the context and application, and therefore it is important to recognise the distinction between descriptions (the models) and how they are applied (a process) (Underwood and Waterson, 2013a). Models are not perfect, neither in description, nor in application, which leads to criticism and conflicting preferences between proponents or practitioners (Underwood and Waterson, 2013a). Weaknesses in high level models are often overcome by the application of more specific analytical techniques (Underwood and Waterson, 2013a). The present review considers models of safety at a high and holistic level. However, the term model is ambiguous and may be applied in other ways, such as those used for quantitative analysis or simulation, or qualitative descriptions of principles or concepts, as described below.

Taxonomy of types of models is rare in the literature. System theory, energy models, process models, information-psychology theories and other approaches have been applied (Kjellén and Larsson, 1981) but not categorised. There is reference to types of research where data sources were broadly classified as accident analysis, field studies, questionnaires of safety participants, expert opinion, theory or literature, and simulator studies (Hale and Hovden, 1998). Studies have also classified by purpose (e.g., model, audit, analysis tool, training, etc.) and in finer detail by topics included in the study (e.g., structural, human resources, political or symbolic) (Hale and Hovden, 1998), originally being devised for categorising organisational purpose (Bolman and Deal, 1984). Experimental, ethnomethodological and survey research types have been proposed for ergonomics research (Dekker and Nyce, 2010). However, such approaches are neither holistic nor systematic classifications of all possible models of road safety at the strategic level, and thus excluded from the current review.

1.2. Systems concepts

Systems concepts are highly influential in safety, although the term 'system' is widely, but inconsistently used (Waterson, 2009). Furthermore, studies suggest that applying systems concepts techniques provide a deeper understanding of how dynamic, complex system behaviour contributes to accidents, resulting in better safety outcomes (Underwood and Waterson, 2013b). The term 'system' and its related concepts may be defined variously and used differently depending on its situation, users, foundational theories and application (Underwood and Waterson, 2013a). While not unambiguously defined, the literature describes:

i. system (an operating entity),
ii. systems theory (an underlying rationale for definition of systems characteristics),
iii. systems approaches (a process to analyse and understand a system), and
iv. systematic processes (a manner of application).

There is a general agreement that systems involve the processes of transforming input to output for a purpose, but a deep and broad conceptualization of systems theory and its application is lacking (Waterson, 2009; Wilson, 2014b). A system may exist and be investigated in non-systematic ways or not according to systems theory. A systems approach to analysis (or process) would be consistent with systems theory and should be systematic, but other approaches to analysis may also be consistent with systems theory, without necessarily following the thorough systems approaches described in the literature. However, a thorough description of these differences and the variations in different literature is beyond the scope of the present review, but summarised below.

Systems theory is a scientific exploration of wholeness, covering various constituent elements and their relationships (Von Bertalanffy, 1968). Systems theory challenges reductionist views and analysis, which attempts to draw information and conclusions of certain sections in isolation from other parts of the system. Systems theory describes that systems exist when there are interdependent, but related components achieving a valued pre-set objective, purpose or function (Wilson, 2014a; Leveson, 2004; Perrow, 1984). According to system theory, the fundamental constructs of a system are components, relationships, joint purpose and interdependency, which may be complemented by other descriptive principles or dimensions, such as time. These characteristics are used to describe a system, proving a system model. However, other models may also exhibit characteristics of systems.

A systems approach to safety is a process which views accidents as the result of unexpected, uncontrolled relationships between different parts of the system, instead of being limited to traditional cause-effect accident models (Underwood and Waterson, 2013b). Importantly, in this approach, systems are analysed as whole entities, rather than considering their parts in isolation (Underwood and Waterson, 2013a; Waterson, 2009). Systems approaches may be described by principles, characteristics, processes or constituent parts. The systems approach offers the benefits of understanding and consideration of the whole subject, providing a deeper knowledge on how dynamic, complex system behaviour contributes to accidents (Underwood and Waterson, 2013b). As a method, it is comprehensive, rigorous, founded in theory and proven in practice. Other approaches may be more reductionist and overly simplistic in assessing individual aspects in isolation, ignore complementary effects and interdependence or not yet be demonstrated to be valuable. Systems theory and techniques have successfully been applied to improve safety in the most complex operations and situations including aviation, rail transport, nuclear power and health (Waterson, 2009) and aerospace, production industry, water supplies, and the military (Leveson, 2011). Any investigation or analysis may be conducted systematically without recognising any system characteristics. Systematic investigations are logical, thorough and robust. Some of the clearest systematic approaches are systematic literature reviews (Cochrane Reviews, 2011), which may not relate to a system as understood in system theory or safety as a particular outcome.

Applying systems theory and systems approaches have been accepted as being meaningful despite the lack of widely accepted explanations of exactly what this means in relation to theory, principle and practice (Waterson, 2009; Wilson, 2014a). Some safety procedures have been codified based on accepted principles or practical expertise and judgement from experienced practitioners, but have little or no scientific basis (Hale and Hovden, 1998). The limitations of traditional cause-effect accident models have been acknowledged, but the use of system models is not always considered appropriate (Underwood and Waterson, 2013b) depending on the application, organisational culture, an individual's previous experience and training or availability of data. Therefore systems theory and systems approaches should be applied more thoroughly.

1.3. Models relevant to road safety

Several types of models have been used to understand and improve road safety. However, the justification for the choice of

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