

Conceptual construction safety archetypes to improve worker behaviour to improve safety in road construction projects

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Abstract:

Occupational health and safety (OHS) in a dynamic work environment of road construction projects are influenced by worker behaviour. Although several studies have been made by using analytical methods the mechanisms that underline the occurrence of accidents and improve safety concerning worker behaviour at road construction sites have not been explored explicitly in developing countries. Therefore, using the context of road construction projects in developing countries, the study explored causal feedback relationships among different worker behaviour factors and develop a conceptual safety archetype to examine the mechanisms that cause the occurrence of accidents and also improve safety. A conceptual System Dynamic (SD) Modelling method premised upon the Systems Analysis approach was used. Findings suggest that worker behaviour, and their attitude towards safety codes and practices, are critical for the occurrence or prevention of accidents in the construction of roads. Lack of knowledge and awareness regarding safety codes and practices combined with a poor attitude leading to the violation of safety codes and practices can lead to the occurrence of accidents. So, knowledge and training to improve the awareness concerning safety codes and practices, would improve their attitude and assist in the effective implementation of the safety codes and practices as the leverage points would enable the enhancement of OHS on account of worker behaviour in road construction projects.

Keywords:

Archetypes, construction, OHS, road, system dynamics, worker behaviour

1 Introduction

According to an estimate, the construction industry accounts for approximately 29% of the total number of industrial workers and contributes significantly to the economy. Among the construction projects, road projects specifically in developing countries form a major component of construction. However, concurrently, safety challenges and the occurrence of accidents in construction projects including road projects are serious issues experienced across the world. For example, about approximately 40% of workplace accidents occur in

construction projects (Mohammadi, Mehdi & Khosravi, 2018). Therefore, Occupational health and safety (OHS) become an essential element of the road construction environment. It impacts road construction in several ways, specifically in terms of the project cost, and project duration. In other words, poor safety or occurrence of accidents may affect the cost of the road project adversely and cause delay. Furthermore, it also affects the performance of the workforce. So, compliance with OHS is paramount for the success of construction projects within the schedule and cost. However, worker behaviour in road construction plays a critical role in the compliance of OHS in projects. OHS and the behaviour of the workers are argued to be interlinked and affect the performance of the workers (Rowlinson & Jia, 2012).

Literature suggests that significant efforts have been made by governments and companies at policy and strategic levels to improve OHS in construction. For example, several studies have been conducted on safety management systems (SMS) by using analytical methods based on statistics and empirical analysis (McKinnon, 2020). In other words, efforts are being made to prevent the loss in terms of time, wastage of financial resources, material and equipment as well as human resources. However, despite the efforts, OHS challenges, particularly the occurrence of a significant number of accidents at work continue to occur (Ardeshir & Mohajeri, 2018; Cheng, Kelly & Ryan, 2013; Mohammadi *et al.*, 2018; Shin, Lee, Park, Moon & Han, 2014). According to several scholars, such safety challenges occur because of the dynamic work environments, worker behaviour, organisation and management (O&M) issues, scope creep, design errors, cost over-runs, delay, use of improper construction methods, and poor technology, machines and heavy equipment and so on (Hallowell & Gambatese, 2009; Mohammadi *et al.*, 2018). In addition to these aspects, in road construction, certain exogenous factors such as traffic on the roads, pedestrians and driver behaviour of the vehicles, plying on the roads during the construction also influence the occurrence of accidents. Moreover, each of these aspects is influenced by several endogenous and exogenous parameters, and the causal interaction among these parameters causes an unavoidable chain of events leading to complex scenarios, which engender accidents in construction (Bouloiz, Garbolino, Tkiouat & Guarnieri, 2013; Mohammadi *et al.*, 2018). Therefore, it is necessary to comprehend these complex interactions and mechanisms and clearly know how the various factors work in mechanisms that influence the occurrence of accidents to develop remedial measures.

While each of the above-mentioned aspects (the dynamic work environments, worker behaviour, organisation and management (O&M) issues, scope creep, design errors, cost over-runs, delay, use of improper construction methods, and poor technology, machines and heavy equipment, etc.) contributes to the occurrence of accidents, worker behaviour is one of the most important challenges that need critical examination. Furthermore, although studies have been conducted to understand the archetypes of the occurrence of accidents, specifically related to the construction process, such as design, supervisors, subcontractors and cost of safety (Mohammadi *et al.*, 2018), studies related to workers (human resource [HR]) behaviour issues have not been attempted, and continue to be research gaps in the literature. Therefore, the objective of the study was to develop safety archetypes by using System Dynamics (SD) modelling principles to examine the mechanisms of how different factors linked to worker behaviour influence the occurrence of accidents through their causal feedback relationships. Although such studies could be conducted by considering any construction project since the road construction is a very significant part of the construction industry and many accidents

occur during the road construction, and worker behaviour plays a critical role, the scope of the study was conceptualised within the context of road construction projects and the worker behaviour of these projects.

2 Literature Review

2.1 Road construction H&S and the worker behaviour

OHS challenges specifically workplace accidents occur in all types of construction projects, including road projects (Das, 2019, 2022). Road construction is a major part of the construction industry across the world, specifically in developing countries and being exposed to different aspects, ranging from organisation and management, and environment to human behaviour, the occurrence of accidents during road construction is significant. The management of OHS in road construction has been emphasised strongly in mainstream literature (Abad, Lafuente & Vilajosana, 2013; Das, 2022). However, despite several remedial measures that have been undertaken, challenges of occurrence of accidents continue (Ardeshir & Mohajeri, 2018; Cheng, Kelly & Ryan, 2013; Mohammadi *et al.*, 2018; Shin *et al.*, 2014).

Unsafe workplace behaviour of the people engaged in construction including road construction, such as incorrect use of equipment, negligence during work, failure to warn others of danger, working without authority, not attending safety training, and not adhering to safety and housekeeping rules, amongst others contribute to the occurrence of accidents (Choudhry, 2014; Mohammad & Hadikusumo, 2019; Zaira & Hadikusumo, 2017). Literature evidence that the reasons for the occurrence of accidents vary depending on the context, situation, and conditions of the construction work (Meena *et al.*, 2013). The various factors include organisation and management aspects, project planning-related factors, construction methods and equipment-related, safety culture and policy, to mention a few (Vinodkumar & Bhasi, 2010; Xia *et al.*, 2020; Yang *et al.*, 2021; Zahoor *et al.*, 2017). Furthermore, factors that are related to worker behaviour include worker motivation, safety knowledge, and safety skills (Vinodkumar & Bhasi, 2010; Zahoor, *et al.*, 2017). It is argued that the participation of construction workers and their motivation concerning OHS are crucial to performance improvement (Burke & Signal, 2010). Construction workers' motivation to ensure OHS is the willingness to comply with workplace rules and regulations and to adopt OHS behaviour (Basahel, 2021; Hardison *et al.*, 2014; Yang *et al.*, 2021).

2.2 An overview of systems thinking for OHS

OHS is essential for the success of road construction projects. Poor or ineffective OHS management might lead to accidents on road construction sites. So, it is essential to explore and examine the causes of accidents that would assist to develop remedial interventions to improve safety (Mohammadi *et al.*, 2018). Scholars have argued that clear elucidation of the cause-effect relationships and understanding of the chains of events that lead to accidents would make it possible to develop appropriate remedial measures and interventions (Swuste, Frijters & Guldenmund, 2012). In this context, qualitative, SD modelling, premised upon systems thinking, can be very useful to unravel the complex and causal feedback relationships. Several scholars such as Marais *et al.* (2006), Kontogiannis (2012), and Guo *et al.* (2015) have used this premise to develop archetypes to examine the interaction between OHS factors in

construction. Accident safety archetypes assist in improving the understanding of causal feedback relations among the related factors premised upon practical, and real-life scenarios that would lead to the occurrence of accidents in construction (Katsakiori, 2009). Such qualitative models that are premised upon systems thinking and consequent mechanisms help the construction workers and other stakeholders to understand the systemic mechanics of the accident causation process, without the requirement of advanced knowledge or assistance of experts. It has also been argued that the principle of SD modelling premised upon systems thinking helps to understand the various aspects related to safety or occurrence of accidents in construction because of the ability to combine related factors and their feedback relationships (Kontogiannis, 2012; Marais, Saleh & Leveson, 2006). In other words, the systems archetypes, or the qualitative SD models, depict the complex interactions in a manner which facilitates the identification of the mechanisms that cause accidents (Goh *et al.*, 2015) and can provide a powerful perspective on the complexity and dynamism OHS management in the construction industry including road construction projects (Mohammadi *et al.*, 2018; Underwood & Waterson, 2013).

3 Research Methodology

3.1 The approach of the study and delineation of factors

Road construction projects were considered as the context for this study. Literature review and qualitative SD modelling approach were used to develop the safety archetypes. However, before the archetypes were developed, the causal feedback relationships among the relevant factors within the context of worker behaviour in road projects were established by using the evidence from the literature. For this purpose, an extensive literature review was conducted by using several databases such as peer-reviewed journal articles, conference proceedings, books and book chapters. Also, several unpublished reports were referred. The databases searched include Elsevier (Science Direct), Wiley, Routledge, Taylor & Francis, and MDPI open access journals, etc. Also, platforms such as Google Scholar, Academia.edu., Research Gate, etc. were searched. Keywords such as OHS, Health and Safety (H&S) in construction and road construction projects, accidents in construction, worker behaviour, system thinking and SD modelling for OHS or H&S, were used to search relevant literature. Out of more than 200 articles collected 39 articles, which included 33 journal articles, 2 articles in conference proceedings and 3 book chapters and 1 report were found relevant and were referred to in the study. The extant literature from the last 22 years (2000-2022) was generally used. Factors and interlinkage/ causal relationships among the relevant endogenous factors which influence the occurrence or reduction of accidents because of worker behaviour and related aspects were delineated from the findings of the literature reviewed. Based on the findings from the literature and the causal feedback relationships among the factors, safety archetypes were developed by using qualitative SD modelling principles.

3.2 Development of archetypes by using conceptual SD modelling

SD Modelling approach was used to develop the archetypes. The Systems theory premise was used to develop interlinkage between relevant factors. Based on the findings of the literature reviewed first one-way causal relationships between relevant factors within the worker behaviour context relating to the occurrence of accidents were developed. The relationships

were then checked for two-way causal relations or feedback relationships. While developing the causal feedback relationships the mechanism of information, decision, action and impact on the environment (system behaviour) (Aiyetan & Das, 2015; Olaya, 2012) was used. In this process, it was depicted that information leads to a decision, based on which actions can be taken. The actions can have an impact on the environment or cause system behaviour (in this, the occurrence of accidents in road projects). Also, while developing the causal relationships, polarities such as (positive and negative) were checked and assigned. A positive polarity enhances the effect of the preceding parameter on the immediate succeeding parameters and will have no impact on the further succeeding parameters. Similarly, a negative polarity indicates that the impact of the preceding parameter on the immediate succeeding parameter decreases. The causal feedback relations were then combined as relevant to develop Causal Loop Diagrams (CLDs), which form the basis for the archetypes. A positive CLD is regarded as a reinforcing loop and a negative CLD was considered as a balancing loop. Based on the archetypes premised upon the reinforcing and balancing CLDs, dynamic hypotheses and leverage points for the occurrence of accidents and improvement of safety were evolved. The archetypes were developed by using Vensim SD Modelling Software. The CLDs were validated through an internal and structural validation process of examining their corroboration with the evidence found in the established literature.

4 Findings and Discussion

The archetypes were developed and discussed at different levels of dynamic complexity, such as causal behaviours based on CLDs, dynamic theory (hypothesis), dynamic mechanisms, and leverage points (points of policy/strategic intervention). However, before the archetypes were developed, the factors influencing OHS through worker behaviour were explored based on evidence from Literature.

4.1 Factors influencing construction workers to ensure OHS

The factors which influence the occurrence of accidents in construction owing to worker behaviour as evidenced from literature are critical workforce, pressure on human resources, violation of safety codes and practices, compliance with safety codes and practices, careless attitude, knowledge and training, awareness of safety codes and practices, and implementation of safety codes and practices as provided in Table 1.

Table 1: Causal relations between factors influencing OHS because of worker behaviour in construction

Cause	Effect	Polarity	Source
Critical human resources (workforce)	Pressure on human resources	+	Behavioral Safety (2012); Choudhry (2012)
Pressure on human resources	Worker behaviour	-	
Worker behaviour	Violation of safety codes and practices	+	Aziz & Osman (2019); Behavioral Safety (2012); Choudhry (2014); Ibrahim <i>et al.</i> (2018); Ismail, Doostdar & Harun (2012); Nawi <i>et al.</i> (2017)

Cause	Effect	Polarity	Source
Violation of safety codes and practices	Accidents	+	Aziz & Osman (2019); Ibrahim <i>et al.</i> (2018); Ismail, Doostdar & Harun (2012); Nawi <i>et al.</i> (2017); Zhang & Fang (2013)
Accidents	Critical human resources	-	Zhang, Fang (2013)
Knowledge and training	Awareness of safety codes and practices	+	Cooper, Cotton (2000)
Awareness of safety codes and practices	Implementation of safety codes and practices	+	Cooper, Cotton (2000)
Implementation of safety codes and practices	Worker behaviour	+	Choudhry (2014); Ismail <i>et al.</i> (2012);
Attitude	Worker behaviour	+	Aziz & Osman (2019); Choudhry (2014); Ibrahim <i>et al.</i> (2018); Ismail <i>et al.</i> (2012); Ismail, Doostdar & Harun (2012); Nawi <i>et al.</i> (2017)
Worker behaviour	Complying with safety codes and practices	+	Choudhry (2014); Ismail <i>et al.</i> (2012);
Complying with safety codes and practices	Accidents	-	Aziz & Osman, (2019); Choudhry (2014); Ismail <i>et al.</i> (2012); Ibrahim <i>et al.</i> , 2018; Ismail, Doostdar & Harun, (2012); Nawi <i>et al.</i> (2017)

4.2 The archetype for worker behaviour to ensure OHS

The archetype for safety in road construction projects related to worker behaviour was developed by combining two CLDs, such as the reinforcing loop (ROA) and balancing loop (BRA) (Figure 1). Poor worker behaviour because of poor attributes and /or pressures on the workers to complete a job within a limited time or haste, which results in the occurrence of accidents at work sites. Furthermore, the occurrence of accidents leads to the reduction of the availability of critical human resources. This exerts pressure on the operatives to work within their limited time and human resource availability. This limitation consequently reinforces the negative impact on worker behaviour through a causal feedback relationship (ROA). So, a reinforcing causal feedback relationship between worker behaviour and accidents, compounded by the reduction in critical human resources, consequent pressure on the human resource, and worker attitude, lead to the occurrence of accidents during construction in road projects. On the other hand, awareness of safety codes and practices and measures helps in their implementation which assists in reducing the occurrence of accidents. However, the creation of awareness of safety codes and practices and consequent implementation can only happen if knowledge and training are imparted to the workers. In other words, imparting knowledge and training on safety aspects engender awareness of safety codes and practices, and their implementation would likely improve worker behaviour which, consequently, would reduce the occurrence of accidents through a balancing, causal feedback relationship (BRA).

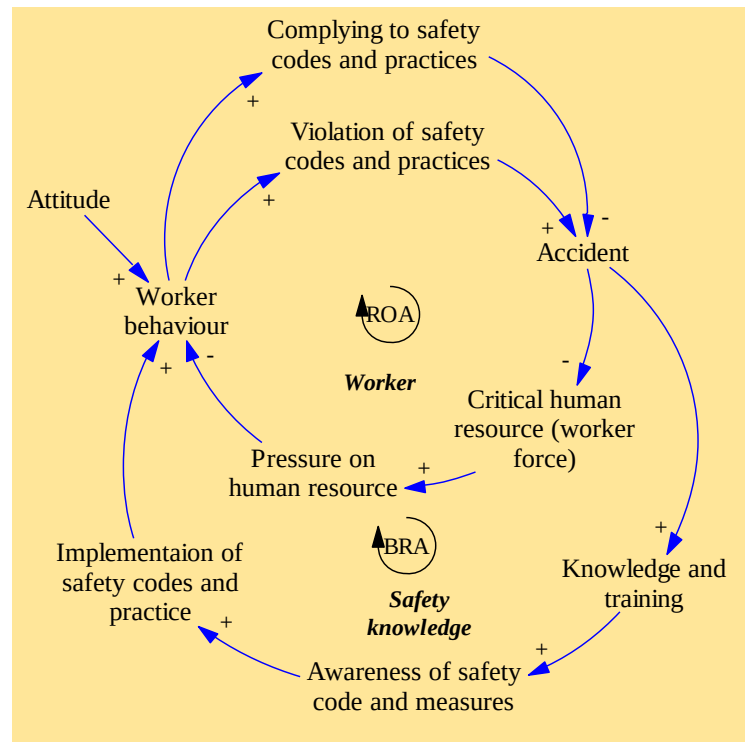


Figure 1: An archetype for worker behaviour influence on safety during construction projects

These causal relationships create the following dynamic theories:

Dynamic Theory 1 (DH1): The worker behaviour is dependent on the attitude of the operatives and the pressure on them, which leads to the violation of safety codes. This violation of safety codes and practices prevents effective implementation of safety measures and practices and consequently causes accidents.

Dynamic theory 2 (DH2): Knowledge and training are critical for the creation of awareness about safety codes and practices, which enables the effective implementation of safety measures. The effective implementation of safety codes and practices would lead to the reduction of accidents in road construction projects.

Based on the analysis of the archetypes it was found that worker behaviour and work pressure (on design and construction) are potential predictors of poor OHS. However, knowledge and training about safety can be considered as the leverage points relating to worker behaviour which can be acted upon to reduce the occurrence of accidents in road projects.

5 Conclusions

The objective of the study was to examine conceptually and develop archetypes to understand how worker behaviour in road construction projects incidence accidents at worksites and how

can be reduced. The study was conducted by using a conceptual SD modelling approach premised upon systems theory. Findings suggested worker behaviour, and their attitude towards safety codes and practices, are critical for the occurrence or prevention of accidents in the construction of roads. In other words, the lack of knowledge and awareness regarding safety codes and practices combined with the poor attitude leading to the violation of safety codes and practices can lead to the occurrence of accidents. Therefore, knowledge and training to improve the awareness concerning safety codes and practices, that would improve their attitude and assist in effective implementation of the safety codes and practices should be considered as the leverage points to enhance OHS on account of worker behaviour in road construction projects.

The limitations of the study are that it is a qualitative study premised upon evidence from the literature and only worker behaviour was considered. Despite this, it contributes to the literature about construction OHS archetypes for worker behaviour to offer project stakeholders the dynamic theories, mechanisms and leverage points which should be considered when planning to improve worker behaviour and enhance safety in road construction projects.

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