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Identifying behaviour patterns of construction safety using system archetypes

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ABSTRACT

Construction safety management involves complex issues (e.g., different trades, multi-organizational project structure, constantly changing work environment, and transient workforce). Systems thinking is widely considered as an effective approach to understanding and managing the complexity. This paper aims to better understand dynamic complexity of construction safety management by exploring archetypes of construction safety. To achieve this, this paper adopted the ground theory method (GTM) and 22 interviews were conducted with participants in various positions (government safety inspector, client, health and safety manager, safety consultant, safety auditor, and safety researcher). Eight archetypes were emerged from the collected data: (1) safety regulations, (2) incentive programs, (3) procurement and safety, (4) safety management in small businesses (5) production and safety, (6) workers' conflicting goals, (7) blame on workers, and (8) reactive and proactive learning. These archetypes capture the interactions between a wide range of factors within various hierarchical levels and subsystems. As a free-standing tool, they advance the understanding of dynamic complexity of construction safety management and provide systemic insights into dealing with the complexity. They also can facilitate system dynamics modelling of construction safety process.

1. Introduction

Despite the fact that improvements in construction safety have been made over the last decades (Howell et al., 2002; Hinze et al., 2013a), accidents and injuries still occur repeatedly on sites. It appears that construction safety has reached a plateau (Howell et al., 2002; Bhattacharjee et al., 2011) and that the construction remains one of the most dangerous industries in many nations (Waehrer et al., 2007; Pinto et al., 2011; Shin et al., 2014; Zhou et al., 2015). This situation can be partly attributed to the unique characteristics of construction industry such as different trades, multi-organizational project structure, constantly changing work environment, and transient workforce (Rowlinson, 2004). The industry is labor intensive, dominated by a large proportion of small businesses with low level of ability and motivation to manage safety because of resources constraints (Legg et al., 2009). Less educated workers move from one project to another, which poses barriers against the development of safety culture (Lunt et al., 2008). Various pressures (e.g., production pressure and peer pressure) that exist on site are likely to undermine site safety (Wilson and Koehn, 2000; Mullen, 2004; Kyle, 2013). The tendency toward standardized safety practices makes organizational learning less effective (Howell et al., 2002; Mitropoulos et al., 2005). In addition, multiple stakeholders (e.g., regulators, union, clients, main contractors, subcontractors and workers) play various roles in contributing site safety, which causes coordination problems (Smith and Roth, 1991; Toole, 2002; Rowlinson et al., 2003; Huang and Hinze, 2006). These unique characteristics set construction apart from many other industries and pose significant challenges to site safety management (Hallowell and Gambatese, 2009; Liao et al., 2013). They often make intervention programs that are transferred from other industries less effective in the construction industry (Rowlinson, 2004).

1.1. Construction safety management

To improve construction safety performance, continuous efforts have been made by both researchers and practitioners. In many countries, safety legislation systems have shifted toward a performance-based approach, with an aim to motivate companies themselves to take "all practicable steps" to ensure health and

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safety of their employees (Gribble et al., 2006; Wilson, 2012). Over the last three decades, considerable research attention has been paid on identifying and designing effective safety measures and practices to reduce construction accidents (Dedobbeleer and German, 1987; Choudhry et al., 2008; Hinze et al., 2013a; Zhou et al., 2015). Practices, including but not limited to toolbox meeting, safety training, hazard management, tasks analysis, form a strong empirical basis for the development of safety management systems. A safety management system consists of policies, procedures, programs that are targeted at managing safety risks (Wachter and Yorio, 2014). The link between safety management systems and safety performance has been supported by studies (e.g., (Aksorn and Hadikusumo, 2008; Vinodkumar and Bhasi, 2010; Hinze et al., 2013a).

Nevertheless, such a practices-based accident prevention strategy is subject to criticism. Koh and Rowlinson (2012) argued that this approach focuses on normative compliance and error prevention. However, complex social processes and cultural factors (e.g., values, norms and behaviours) inherent in construction project settings are largely ignored (Choudhry et al., 2007; Wachter and Yorio, 2014). The criticism seems to be valid, given the fact that collective attitudes, values, and norms are widely recognized as core preconditions and components of high safety standards in the construction industry (Törner and Pousette, 2009). In addition, construction work processes are loosely defined and workers have many degrees of freedom in how to perform their tasks (Saurin et al., 2008). As a result, while such a normative approach emphasizes what people ought to act by establishing detailed safety procedures and rules, it is often not effective to explain why workers make mistakes on sites (Dekker et al., 2008). Saurin et al. (2005) stated that it remains doubtful that whether the existing best practices are effective means to tackle some usual root causes, such as financial pressures, poor product design and short program time scale.

These limitations may be in part caused by a limited understanding of complex accident processes (Mitropoulos et al., 2005). Mitropoulos and Cupido (2009) pointed out that existing construction accident causation models do not take into account the mechanisms that shape human behaviour. Traditionally, accidents are viewed as the result of a sequence of linear events (unsafe conditions and unsafe behaviours). As a result, accident prevention strategies mainly focus on creating safe working conditions and eliminating unsafe behaviours (Howell et al., 2002, Shin et al., 2014). Although researchers (Sawacha et al., 1999; Fang et al., 2004; Haadir and Panuwatwanich, 2011; Ismail et al., 2012) have identified a number of significant individual and organizational factors, such as management commitment to safety, training, competency, and safety motivation, complex cause-effect relationships between the organizational, technical, and human factors are poorly defined and understood, and the mechanisms by which these factors shape human behaviours at the sharp end remain unclear.

1.2. Systems thinking in safety

Recent years, a systems thinking approach has often been used to better understand complex organizational and human processes. Systems thinking has been defined as "*the art and science of making reliable inferences about behaviour by developing an increasingly deep understanding of underlying structure*" (Richmond, 1994). It has been considered as a framework of thought that helps people to deal with complex systems in a holistic way (Flood and Carson, 1993). The rationale behind the use of systems thinking in safety research is that a holistic approach is able to provide a "big picture" of safety and therefore yield more useful insights into accident prevention strategies.

Historically, systems thinking played an important role in the development of accident theories (or models). One of the most popular systemic safety models is the Swiss cheese model (SCM), developed by Reason (1997). Various accident investigation tools, like human factors analysis and classification system (HFACS), were then developed based on the SCM (Shappell and Wiegmann, 2000; Celik and Cebi, 2009; Olsen and Shorrock, 2010). The SCM, as well as related accident investigation tools, adopts a holistic view on safety, extending the causes of accidents to organizational factors and emphasizing the interactions between organizational deficiencies (latent failures) and human errors (active failures). Despite its popularity and usefulness in accident analysis, the model is not immune from criticism. For example, the model has been criticized for adopting a static perspective on complex accident causation process and thus failing to indicate how failures at different system levels (appeared as holes in the model) are likely to align (Le Coze, 2013). Dekker (2006) argued that the layers of defense are dynamic, rather than static or constant. Reason also acknowledged that "holes" in the model should be constant flux, rather than fixed and static (Reason, 1997, p. 9).

Rasmussen integrated the systems concepts, such as hierarchy and feedback loop, into his two safety models: the model of migration and the sociotechnical system view (STS) (Rasmussen, 1997; Rasmussen et al., 2000). Safety management in the sociotechnical system is described in several hierarchical levels, ranging from government and regulators, via organization and management, to staff and working condition. Vertical flow of information across these hierarchical levels forms various feedback loops, which play an essential role in safety management. In addition, the model of migration graphically describes the dynamics of the safety state of a system. The central idea of it is that under the work load and economic pressure, the state of safety tends to migrate closer to, and even cross, the boundary of functionally acceptable performance. Such a dynamic perspective was further expanded by Dekker who developed a notion of "drift into failure" (Dekker, 2011). The concept of drift was defined as "*an inexorable slide towards ever smaller margins, toward less adaptive capacity, towards a growing brittleness in the face of safety challenges that the world may throw at the organization.*" (2011) (p.18). He claimed that traditional approaches that are based on "reductionism" and "determinism" are ineffective to deal with complexity of a system (Dekker, 2011; Dekker et al., 2011). Similar to Rasmussen's models, Leveson's STAMP (2004), based on the control theory, focuses on complex interactions between system components and sees accidents as emergent properties of complex system. Understanding safety as a control problem, the model emphasizes the system's control structure. However, it seems that such a control metaphor has been mainly adopted in high-tech industries, like nuclear, chemical process and oil industries (Wahlström and Rollenhagen, 2014). Its application to occupational safety research has been rather limited (Howell et al., 2002).

Systems analysis (SA) has been widely used as a problem-solving methodology to analyse accidents in various industries, with an attempt to generate deeper insights into accident causation and prevention strategies by using different tools and models such as Accimap, Swiss cheese model, HFACS and STAMP (Lawton and Ward, 2005; Vicente and Christoffersen, 2006; Cassano-Piche et al., 2009; Santos-Reyes and Beard, 2009; Goh et al., 2010; Patterson and Shappell, 2010; Lenné et al., 2012; Underwood and Waterson, 2014). One of common conclusions of systems analysis is that accidents were not caused by a single causal factor, but by system failures. Despite the advances, the gap between research and practice with regard to systemic accident analysis still exists and systemic accident analysis methods need considerable empirical validation before they are accepted by practitioners (Underwood and Waterson, 2013).

Dynamic complexity, as a defining characteristic of today's high-tech systems, poses challenges on safety management