THE CONTRIBUTION OF CONSTRUCTION PROJECT FEATURES TO ACCIDENT CAUSATION AND HEALTH AND SAFETY RISK: A CONCEPTUAL MODEL

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Construction project features (CPFs) are organizational, physical and operational attributes that characterize construction projects. Although previous studies have reported the contribution of CPFs to accident causation and the extent of their contribution, the insight into the health and safety (H&S) risk implications remains an elusive issue which needs elucidation. A critical examination of the subject through an interrogation of H&S literature yields insight into this grey area. CPFs contribute to accident causation through the introduction of proximal accident causal factors, and the extent of their contribution to accident causation is influenced by two key factors: the extent to which the proximal factors contribute to accident causation; and the degree of prevalence of the proximal factors within CPFs. It is subsequently revealed that the extent to which CPFs contribute to accident causation influences H&S risk through the exposure of the workforce to CPFs. These findings are represented by a conceptual model which furthers the understanding of the accident causal influence of CPFs and also provides a stepping stone towards a systematic comparative analysis of the risk associated with CPFs.

Keywords: accident, health and safety, risk.

INTRODUCTION

An accident is any unplanned event that results in injury or ill-health of people, or damage or loss to property, plant, materials or the environment or a loss of a business opportunity (Hughes and Ferrett 2008). Accidents are thus associated with adverse health and safety (H&S) outcomes which have dire cost implications for the construction industry (cf. Hughes and Ferrett 2008). The adverse H&S outcomes of accidents have created the need for accident prevention which requires the knowledge of accident causal factors, how the causal factors contribute to accident causation and the extent of their contribution to accident causation (Suraji *et al.* 2001). Another hugely important consideration is the risk associated with these causal factors, which is their likelihood to cause harm (Hughes and Ferrett 2008). Although previous studies have reported the contribution of CPFs to accident causation, those studies have mainly dwelt on the pattern/process of causation and the extent to which CPFs contribute to accident causation. However, regarding the H&S risk associated with CPFs little insight exists. Building on previous studies, this study through a critique of health and safety (H&S) literature interrogates this grey area in H&S knowledge to

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Table 1: Summary of literature highlighting the accident causal influence of CPFs

Const. Project Features \ Literature Source	Mayhew& Quinlan (1997)	Egbu (1999)	HSL (1999)	Gibb (1999, 2001)	Entec UK Ltd (2000)	McKay et al. (2002)	Strategic Forum for Construction (2002)	Wright et al. (2003)	Perttula et al. (2003)	Loughborough University & UMIST (2003)	Loughborough University & Milan Polytechnic (2004)	Chua & Goh (2005)	Loughborough University (2006)	Ankrah (2007)	Hughes & Ferrett (2008)	Loughborough University (2009)	HSE (2009)
Nature of Project		✓									✓		✓		✓		✓
Method of Construction				✓		✓	✓	✓	✓	✓							
Site Restriction					✓					✓						✓	
Project Duration	✓				✓					✓						✓	
Procurement System			✓		✓					✓							
Design Complexity					✓					✓						✓	
Level of Construction												✓			✓		✓
Subcontracting	✓		✓							✓				✓		✓	

provide this insight. The insight having been provided, the study subsequently examines the implications it has for accident prevention and for further research.

THE ACCIDENT CAUSAL INFLUENCE OF CPFS

Manu *et al.* (2010a) through an extensive review of H&S literature within the construction industry reported the accident causal influence of construction project features such as the nature of project, method of construction, site restriction, project duration, procurement system, design complexity, level of construction, and subcontracting. These CPFs are organizational, operational, and physical attributes that characterize construction projects and like other originating influences in construction accidents, these CPFs are high level determinates of the nature, extent and existence of immediate causes of accidents (Haslam *et al.* 2005). A succinct representation of the review presented by Manu *et al.* (2010a) is shown by Table 1 which clearly indicates that the accident causal influence of CPFs is undeniably existent and has been reported appreciably though in a disparate and fragmented manner.

Nonetheless, studies that have examined the accident causal phenomenon of CPFs in greater depth have largely focused on the process/pattern of causation and the extent to which CPFs contribute to accident causation with a diminutive look at the H&S risk implications. For instance, Manu *et al.* (2010a) highlighted the accident causal phenomenon of CPFs indicating the pattern/process by which CPFs contribute to accident causation, and Manu *et al.* (2010b) examined the extent to which CPFs contribute to accident causation. However, like other similar studies on the causal phenomenon of CPFs, Manu *et al.* (2010a, 2010b) did not examine the health and safety (H&S) risk emanating from the contribution of CPFs to accident causation. Seeing that effective accident prevention requires insight into the H&S risk associated with factors that have the potential to cause harm (Hughes and Ferrett 2008) it is essential to examine the H&S risk associated with CPFs as a result of their contribution to accident causation. The subsequent section of the study sheds light on the relationship between the extent to which CPFs contribute to accident causation and H&S risk.

A CONCEPTUAL MODEL OF THE CONTRIBUTION OF CPFs TO ACCIDENT CAUSATION AND HEALTH AND SAFETY RISK

Construction accident causation is complex (Behm 2005, Loughborough 2009) and as such models have often been used to aid the understanding of this complex phenomenon (cf. Suraji *et al.* 2001). To aid the understanding of the relationship between the extent to which CPFs contribute to accident causation and H&S risk, a conceptual model which integrates these issues would thus be useful. In conceptualizing this relationship, the process by which CPFs contribute to accident causation and the extent of their contribution need to be examined together with the risk evaluation associated with CPFs.

Concerning the process by which CPFs contribute to accident causation, literature indicates that CPFs do not directly cause accidents but do so through other accident causal factors (cf. Manu *et al.* 2010b). These other causal factors which directly lead to accidents are termed proximal causal factors (PFs) (Suraji *et al.* 2001, Haslam *et al.* 2005). Proximal factors are closer to accident events than CPFs which are distal to accident events and are therefore also termed distal/root/originating causal factors (Suraji *et al.*, 2001; Haslam *et al.*, 2005). It is by their introduction of the proximal factors that CPFs contribute to accident causation. These CPFs emanate to a large extent from the client's brief, design decisions and project management decisions at the pre-construction stage of project procurement (cf. Suraji *et al.* 2001, Cheng *et al.* 2005 and Haslam *et al.* 2005). Building on this background, the process by which CPFs contribute to accident causation can be illustrated as shown in Figure 1.

Concerning the extent to which CPFs contribute to accident causation, the review by Manu *et al.* (2010b) demonstrates that it varies depending on the degree of prevalence of proximal factors within their associated CPFs. This implies that the more common/prevalent a proximal factor is within a CPF the greater the extent to which the CPF contributes to accident causation as shown by the continuum in Table 2. It can however be also argued that the extent to which CPFs contribute to accident causation is primarily influenced by the extent to which their related proximal factors contribute to accident causation (Manu *et al.*, 2010b). This is because it is by reason of the related proximal factors contributing to the causation of accidents in the first place that the CPFs are also able to contribute to accident causation as a result of their introduction of the proximal factors. This means that if a proximal factor does not contribute to accident causation, no matter its prevalence within a CPF that CPF will not also contribute to accident causation. Advancing this argument further, the extent to which a CPF contributes to accident causation is therefore the combined effect of;

- the extent to which the related proximal factor contributes to accident causation (represented by 'R'); and
- the extent to which the proximal factor is prevalent/common within the CPF (represented by 'r').

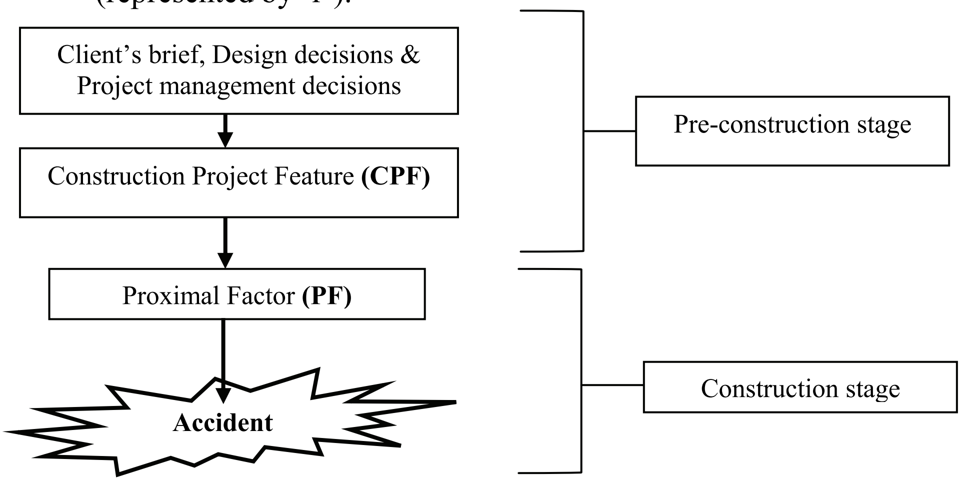

Figure 1: Pattern of contribution of CPFs to accident causation (Adapted from Suraji et al. 2001 and Haslam et al. 2005)

From Table 2 it can be seen that whereas factor 'r' alone provides the opportunity for relative comparison among CPFs of the same kind (e.g. partnering and management contracting), in terms of the their extent of contribution to accident causation, the combined effect of 'r' and 'R' would enable the relative comparison among CPFs of different kinds (e.g. conventional construction and management contracting) as the combined effect takes into account the direness of proximal factors (i.e. 'R'). The combined influence of 'r' and 'R' is therefore a holistic and a better depiction of the extent to which CPFs contribute to accident causation (Manu *et al.*, 2010b). The extent to which CPFs contribute to accident causation indicates the extent to which they contribute to harm and hence an indication of their potential to cause harm. This is a useful insight for accident prevention as it provides the opportunity for identifying CPFs that have a high potential to cause harm.

Concerning the H&S risk associated with CPFs, the insight provided by H&S literature is limited to a few CPFs. For instance refurbishment has been associated with a higher risk than new work (cf. Loughborough University 2006), and conventional construction has also been associated with a higher risk than pre-assembly construction (cf. McKay *et al.* 2002). Evidently, these risk evaluations reflect the illustration in Table 2 where refurbishment and conventional construction have a higher extent of contribution to accident causation than new work and pre-assembly construction respectively.

Table 2: Extent of contribution of CPFs to accident causation

Proximal Factors	Extent of Contribution of CPF to Accident Causation (Prevalence of proximal factor within CPF) Low → High
Uncertainty and complexity of hazards (Egbu, 1999; Loughborough University, 2006)	New work → Refurbishment, Demolition
Manual handling (McKay et al., 2002; Wright et al., 2003)	Pre-assembly construction → Conventional on-site construction
Site congestion (Loughborough University and UMIST, 2003; Loughborough University, 2009)	Unrestricted site → Restricted site
Time pressure (Loughborough University and UMIST, 2003; Loughborough University, 2009)	Unconstrained duration → Constrained duration
Fragmentation of project team (HSL, 1999; Entec UK Ltd, 2000; Loughborough University and UMIST, 2003)	Design and Build, Partnering → Traditional procurement → Management contracting
Difficulty in constructing (Loughborough University and UMIST, 2003; Loughborough University, 2009)	Simple Design (Simple aesthetic qualities) → Complex Design (Intricate aesthetic qualities)
Working at height / Confined space (Hughes and Ferrett, 2008; HSE, 2009)	Low-level construction → Multi/High-level construction, Underground construction
Fragmentation of work force (Mayhew and Quinlan, 1997; Loughborough University and UMIST, 2003)	Single-layer subcontracting → Multi-layer subcontracting

Regarding this link between the extent of contribution of CPFs to accident causation and H&S risk, the risk expression put forth by Chicken and Posner (1998) and the Canadian Centre for Occupational Health and Safety (CCOHS) (2008) provides some illumination. Chicken and Posner (1998) and the CCOHS (2008) indicate that risk is a function of hazard and exposure, expressed as Risk = Hazard x Exposure. Duffus and Worth (2001) argued that risk is a function of hazard and exposure because, no matter the severity of a hazard if there is no exposure, there would be no risk of harm. Hazard is the potential of a source or substance to cause harm and risk is the likelihood of a source or substance to cause harm (Hughes and Ferrett, 2008). Exposure is the extent to which people are subjected to the hazard (CCOHS, 2008) and can be assessed in terms of duration (cf. Duffus and Worth (2001) and CCOHS (2008)). Given that the extent to which CPFs contribute to accident causation indicates their potential to cause H&S harm, the above risk expression is useful in providing understanding into the relationship between the extent of contribution of CPFs to accident causation (i.e. their potential to cause H&S harm) and H&S risk (i.e. their likelihood to cause H&S harm). The extent of contribution of CPFs to accident causation thus relates to H&S risk through the exposure of the construction workforce to CPFs.

A conceptual model that emerges from the discussion is as shown in Figure 2. The model in its depiction of the ‘reality’ regarding the accident causal phenomenon of CPFs sheds light on the elusive subject of the H&S risk implication of the contribution of CPFs to accident causation.

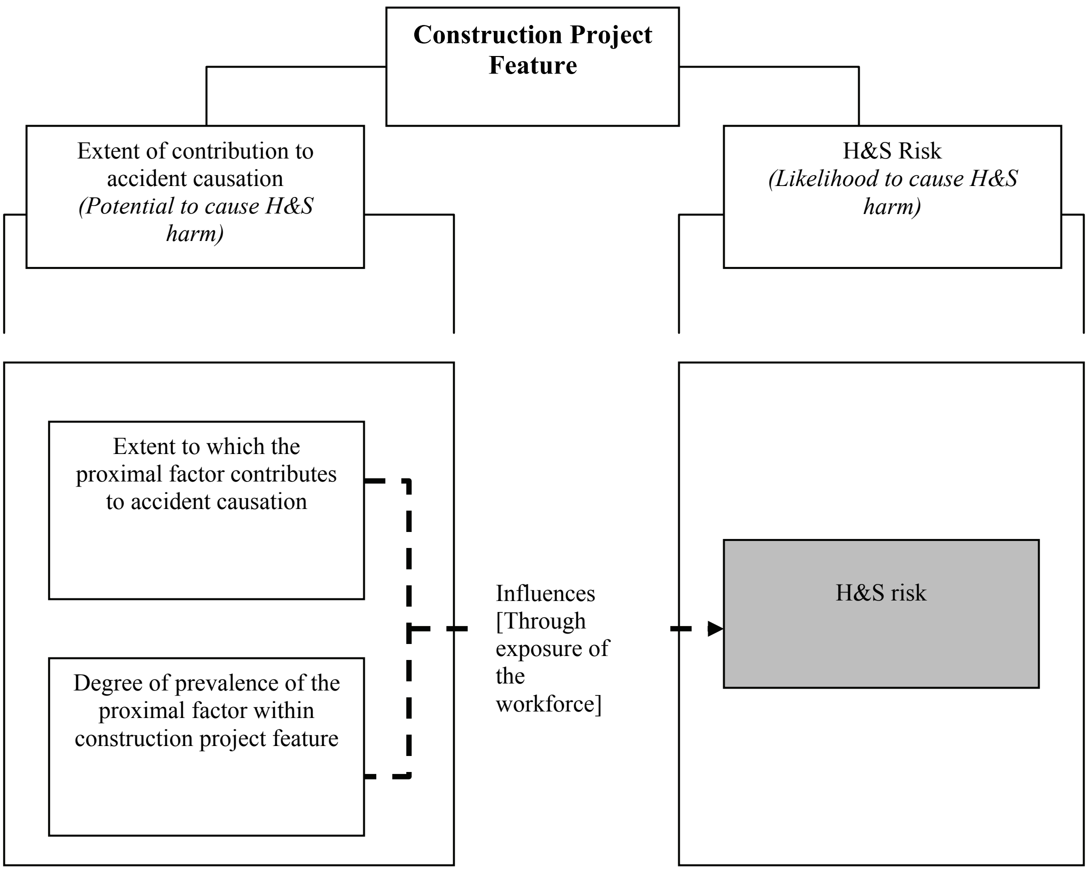

Figure 2: A conceptual model of extent of contribution of CPFs to accident causation and H&S risk

The model unifies in a coherent piece two key facets of the accident causal phenomenon of CPFs i.e. their potential to cause harm; and their likelihood to cause harm. The unification of these key facets is important as it offers detailed understanding into how the drivers of the extent of contribution of CPFs to accident causation influence H&S risk, and thus offering the opportunity for accident prevention. Having put forth the conceptual model, what then remains is an examination of its implications for accident prevention and for further research.

Implications for accident prevention and research

As previously indicated, CPFs emanate to a large extent from pre-construction decision-making/planning which has a significant influence on the H&S outcomes of projects (cf. Szymberski 1997 and Egan cited in the Strategic Forum for Construction 2002). The conceptual model thus provides an opportunity for the design team, project management team and client from whose decisions CPFs emanate to positively influence the H&S outcomes of projects. Through its illustration of how the extent to which CPFs contribute to accident causation influences H&S risk, the model provides further insight into the accident causal influence of CPFs. This insight can be more entrenched by operationalizing the logic of the model by a mathematical expression which combines the determinant factors of the extent of contribution of CPFs to accident causation, and the degree of exposure of the workforce to obtain a measure of H&S risk. Evidently, such an expression will provide the means for a systematic comparative analysis of the risk associated with CPFs. By that, pre-construction decision-makers could thus select CPFs taking into account their extent of contribution to accident causation (i.e. potential to cause harm) and/or the risk associated with them (i.e. their likelihood to cause harm). In line with the hierarchy of risk control which first recommends the elimination of sources of risk (cf. Hughes and Ferrett, 2008), CPFs that contribute greatly to accident causation (i.e. have a high potential to cause harm) could thus be avoided. Also, based on the potential of CPFs to cause harm together with the anticipated degree of exposure of the workforce to CPFs, the pre-construction decision-makers/planners could again select CPFs that would have lesser risk. Given that these decisions can be constrained by certain factors as acknowledged by Suraji *et al.* (2001), the selection of CPFs that have a high potential to cause harm or have high risk may be inevitable. In such situations, risk mitigation measures which reduce exposure or the degree of prevalence of proximal factors could be adopted.

Clearly, the systematic analysis of risk through the proposed mathematical expression will require a quantitative assessment of the extent to which proximal factors contribute to accident causation and their prevalence within CPFs. This is achievable by research and thus implies the need for further interrogation of the extent to which CPFs contribute to accident causation.

CONCLUSIONS

Beyond highlighting the contribution of CPFs to accident causation, this study has shed light on how the extent to which CPFs contribute to accident causation influences H&S risk. The study has put forth a conceptual model which depicts the parameters that influence the extent to which CPFs contribute to accident causation and how these parameters together influence the H&S risk associated with CPFs. By this, the model has provided further understanding into the accident causal influence of CPFs. The usefulness of the conceptual model can be more enhanced by a mathematical model which combines quantitative measures of the parameters within the conceptual model to obtain a quantitative measure of the H&S risk associated with CPFs. This is currently informing an ongoing research which aims to develop a H&S risk evaluation model based on the extent of contribution of CPFs to accident causation.

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