A MODEL OF HOW FEATURES OF CONSTRUCTION PROJECTS INFLUENCE THE OCCURRENCE OF ACCIDENTS ON PROJECTS

Patrick Manu

University of the West of England, United Kingdom

Summary
Although the accident causal influence of features of construction projects has been noted in construction health and safety (H&S) literature, empirical insight into how these features influence accident occurrence is lacking. This chapter presents a study which sought empirical verification of a model of how construction project features (CPFs) influence accident occurrence. A qualitative strategy, in particular phenomenology, involving a range of in-depth interviews with practitioners was used and the findings were subsequently validated using a credibility check involving a survey. Altogether, the findings of the interviews and credibility check confirm the model as a realistic explanation of the mechanism by which CPFs influence accident occurrence. The model has the potential of facilitating the devising and implementation of accident prevention measures by pre-construction project participants to mitigate the H&S impact of CPFs. The model also has the potential of facilitating accident investigation on projects, particularly root cause analysis, thus enabling the contribution of CPFs and hence the contribution of pre-construction project participants in accident occurrence to be ascertained. Further research in this area is also encouraged to augment the utility of the model in supporting pre-construction H&S risk mitigation.

Introduction

With numerous injuries, deaths and work related illnesses reported in the construction industry of several countries (see HSE, 2014; U.S. Bureau of Labor Statistics, 2015), the need to tackle the health and safety (H&S) performance of the industry cannot be overstated. An important step towards tackling the H&S situation in the industry has been the emphasis on the early planning of H&S in project delivery which in the UK is mandatory under the Construction (Design and Management) Regulations (CDM Regulations). Central to the early planning of H&S is the need for construction project participants to pay attention to underlying accident causal factors that originate from the pre-construction stage (Haslam et al., 2005). In fact, studies have stressed that in order to prevent accidents on a long-term and sustainable basis (in other words have sustainable H&S improvement) there is the need to pay attention to these underlying accident causal factors (Haslam et al., 2005; Brace et al., 2009). This is further reinforced by the fact that the pre-construction stage from which underlying accident causes emanate offers project participants the greatest opportunity to influence H&S on projects (Szymberski, 1997). Construction project features (CPFs) which are organisational attributes (e.g. procurement method), physical attributes (e.g. level of construction in terms of height/storey) and operational attributes (e.g. method of construction) of construction projects emanating from pre-construction decisions are among such underlying causes of construction accidents (Manu et al., 2012), and as such their H&S influence merits attention.

This chapter presents and empirical inquiry into how CPFs influence accident occurrence. It commences by highlighting the accident causal influence of CPFs and the gap in the extant literature in relation to how CPFs influence accident occurrence. This is followed by a review of accident causation models leading to a conceptual view of how CPFs influence accident occurrence. The research design employed for the study (i.e. a qualitative design) together with the supporting arguments are subsequently presented. The research findings, discussion and steps taken to validate the findings are described and finally, conclusions are made.

The Accident Causal Influence of CPFs

Despite the established significance of underlying accident causal factors to H&S (Haslam et al., 2005; Brace et al., 2009), there has been a dearth of empirical work with a focus on the accident causal role of CPFs. Even among the studies which have reported underlying causes of construction accidents, limited empirical focus has been accorded to the accident causal phenomenon of CPFs (see Suraji et al., 2001; Haslam et al., 2005; Brace et al., 2009; Cooke et al., 2011). Although there have been reports on the accident implications of CPFs such as nature of project, method of construction, project duration, level of construction, subcontracting, design complexity, site restriction and procurement system (as summarized in Table 1), there still remains aspects of this accident phenomenon which require empirical clarity. This is partly due to the inherent difficulties in examining underlying causes of accidents whose influence tend to be subtle and could thus go unnoticed (Haslam et al., 2005; Cooke and Lingard, 2011). An understanding of how CPFs influence accident occurrence is important if effective accident prevention measures are to be devised and implemented to mitigate the H&S impact of CPFs. Although the H&S literature is replete with several accident causation models which attempt to explain how accidents occur, these models usually provide a generic view (Suraji et al., 2001) and often from a particular stand point (e.g. human errors models (e.g. Hinze, 1996)). Again, with the exception of a few causation models (e.g. Haslam et al., 2005), the models have also often focused on immediate/proximate causes of accidents (e.g. Hinze, 1996). The existing models therefore do not specifically address how CPFs influence the occurrence of accidents.

Table 1: Example of literature sources highlighting the accident causal influence of CPFs

Literature Source / CPFs	Mayhew and Quinlan (1997)	Egbu (1999)	Horbury and Hope (1999)	Gibb (1999; 2001)	Brabazon et al. (2000)	McKay et al. (2002)	Strategic Forum for Construction (2002)	Wright et al. (2003)	Perttula et al. (2003)	Hide et al. (2003)	Anumba et al. (2004)	Chua and Goh (2005)	Anumba et al. (2006)	Ankrah (2007)	Hughes and Ferrett (2008)	Brace et al.(2009)	HSE (2009)	Manu et al. (2013)
Nature of Project		✓									✓		✓		✓		✓	
Method of Construction				✓		✓	✓	✓	✓	✓								
Site Restriction					✓					✓						✓		
Project Duration	✓				✓					✓						✓		
Procurement System			✓		✓					✓								
Design Complexity					✓					✓						✓		
Level of Construction												✓			✓		✓	
Subcontracting	✓		✓							✓				✓		✓		✓

Source: Adapted from Manu et al. (2012)

Given the significance of underlying causes of accidents to construction H&S, an empirical insight into how CPFs influence accident occurrence is thus warranted. A useful starting point is to consider the accident causation literature. The following section therefore reviews accident causation models/theories in relation to the accident causal role of CPFs.

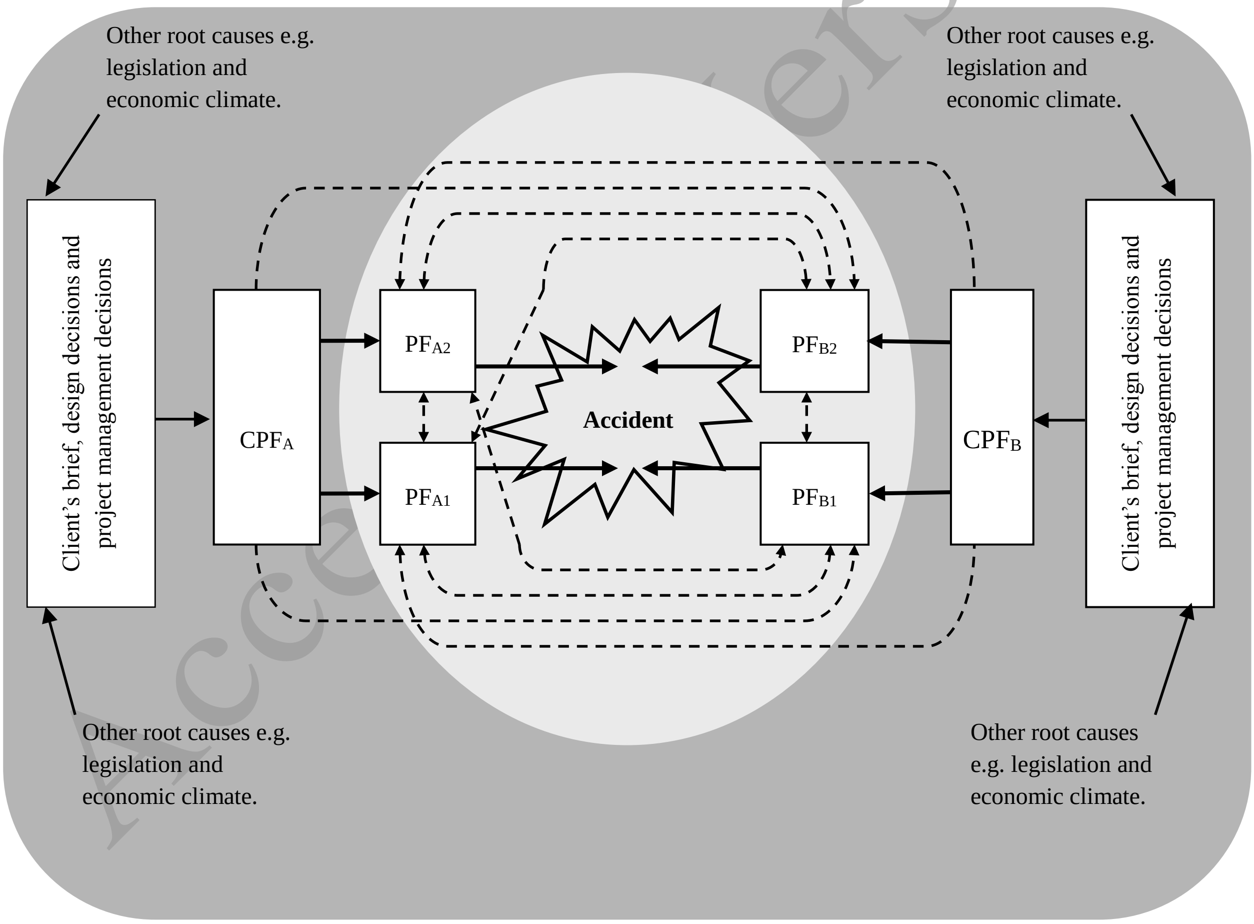
Accident Causation Models/Theories

In reviewing the accident causation literature, a vital point is accident causation models and theories which essentially attempt to explain how accidents occur in reality. Following the seminal work by Heinrich (1936), there have been further efforts towards investigating how accidents occur and these have resulted in other accident causation models and theories. Prominent amongst these are: energy transfer models; individual/human models/theories; and systems models.

Energy transfer models consider the causation of accidents as the release of uncontrolled energy from a source which is then conveyed through a path to the victim (Chua and Goh, 2004). Energy transfer models view accident occurrence as a one-dimensional phenomenon (from energy, through path to a receiver) despite the complexity and multi-causal nature of accidents (see Groeneweg, 1994). In terms of providing insight into how CPFs influence accident occurrence, the energy transfer models are thus unhelpful.

The individual models/theories emphasise the direct contribution of individuals to accident occurrence (Chua and Goh, 2004). They identify the causes and effects of errors/unsafe acts by individuals (usually frontline operatives) and they place emphasis on the psychological and behavioural aspects of humans (Chua and Goh, 2004). They do not explicitly facilitate the continual improvement of workplace safety management systems as they do not consider the role of organisation and management in the occurrence of accidents (Chua and Goh, 2004). Given the focus of individual theories of accident causation on individual factors (i.e. immediate accident causes) they are unhelpful in explaining how CPFs influence accident occurrence as CPFs have an underlying causal influence.

Systems models of accident causation highlight the role of the organisation and its systems in the occurrence of accident (Chua and Goh, 2004). They are concerned with the underlying causes of accident (which are usually latent/subtle), the induced proximate causes and the complex interactions between them. These models thus reinforce the multi-causal nature of accidents and they take a broader view of accident causation. Regarding system models of accident causation, the Constraint-Response and the ConCA models (Suraji et al., 2001; Haslam et al., 2005) in particular could be useful in helping to explain how CPFs influence accident occurrence as they highlight the causal influence of factors that are upstream of construction project procurement (e.g. decisions by client, designers and project management team) and by that provide the opportunity to address those factors early. The models thus drive home the message that accident prevention is not the sole responsibility of constructors but also other project participants whose decisions dictate the manner of the physical execution of projects. Being the result of pre-construction decisions by clients, designers and project management team, CPFs reflect the kind of underlying causal factors described by the Constraint-Response model as "distal factors" and the ConCA model as "originating influences". Manu et al. (2012), drawing on the systems view of accident causation, particularly the Constraint-Response model and the ConCA model, proposed a conceptual model of how CPFs influence accident occurrence. Arguably this model (illustrated by Figure 1) represents a useful step in shedding light on the mechanism by which CPFs influence accident occurrence.



Key

CPF: Construction project feature
PF: Proximate factor
Construction stage
Pre-construction stage
Path of accident causation
Causal interactions

Fig. 1. Conceptual model of the accident causal influence of CPFs (Adapted from Manu et al., 2012)

Based on the generic systems view that accidents are due to immediate causes of accidents triggered by underlying causes, the model proposes that CPFs influence accident occurrence through the inherent introduction of proximate causes of accidents into the construction phase of projects to give rise to accidents.

Manu et al. (2012) therefore likened CPFs to Reason's (1990) resident pathogens which are released by people who occupy a high position in the decision-making structure of an organisation. Subsequent to their release, CPFs (like resident pathogens) in turn determine the nature, extent and existence of proximate accident causes on site. The proximate causes are synonymous to the "proximal accident factors" in the Suraji et al. (2001) Constraint-Response model and the "shaping factors" in the Haslam et al. (2005) ConCA model. Also, based on the complexity and multi-causality of accidents which the systems view of accident causation captures as complex inter-causal relationships, the model again proposes that the accident causal influence of CPFs is marked by inter-causal relationships between CPFs and the proximate causes. Such inter-causal relationships could manifest in the form of a CPF or a proximate factor eliminating, mitigating or aggravating other proximate factors (Manu et al., 2012).

Despite the potential utility of the model in helping to explain how CPFs influence accident occurrence, its conceptual nature dictates that it is first verified empirically to ascertain its credibility as a sound explanation of how CPFs influence accident occurrence. To this end, this chapter presents an empirical verification of how CPFs influence accident occurrence through verification of the conceptual model.

Research Method

Due to the interpretive focus of the study (i.e. how CPFs influence accident occurrence) a qualitative inquiry was undertaken consistent with the direction of Fellows and Liu (2008). Seymour and Rooke (1995) have strongly advocated qualitative inquiry for construction management research. Seymour and Rooke (1995) explain that the utility of qualitative inquiry lies in the deeper understanding of the values and beliefs of others that can be derived by focusing on the points of view of individual practitioners. Although the conceptual model is a prior formulation, it essentially attempts to explain a phenomenon (i.e. how CPFs influence accident occurrence) and as such its verification by means of a qualitative inquiry is suitable. The use of qualitative inquiry in a process to verify a conceptualised view of a phenomenon in construction management research is not uncommon (see Tuuli and Rowlinson, 2010). In fact, Creswell (2009) notes that in other disciplines such as health science it is also common practice for researchers to use qualitative inquiry to verify a prior formulation such as theory. In terms of strategy of inquiry, the phenomenological approach was adopted (Creswell, 2009). This was to enable the exploration of the phenomenon of the accident causal influence of CPFs through the experiences of construction professionals who from their vast experience on project sites are able to relate with the H&S consequences of preconstruction decisions. Following the precedents of Haslam et al. (2005) and Choudhry and Fang (2008) regarding the use of interviews in construction accident causation studies, interviews, in particular semi-structured interviews, were also adopted as the data collection tool within the framework of the phenomenological strategy of inquiry. Following the application of this qualitative strategy, a credibility/validation check was also undertaken. Details of the check are presented later in the chapter.

Design of Interview

The proposed model has two key features: (1) path of accident causation (i.e. CPFs introducing proximate factors which cause accidents); and (2) causal interactions (i.e. inter-causal relationships between CPFs and proximate factors and also between proximate factors). In seeking verification of the model, the main objective of the interview was thus to explore the knowledge and experiences of experienced practitioners regarding the accident causal influence of CPFs and the systems view of accident causation with the intention of eliciting the two key features above. An interview schedule was used comprising a series of questions relating to: (1) how accidents are investigated within the practitioners' organisations; (2) the systems view of accident causation; (3) the H&S measures implemented by the practitioners' organisations on projects; (4) the accident causal influence of CPFs; and (5) the influence of pre-construction decisions by clients and project consultants (i.e. designers and project management team) in the occurrence of accidents. The practitioners were also asked to narrate accidents or near miss events which they had witnessed on projects in support of their views. There were no direct questions as to how CPFs influence accident occurrence as conceptualised in the model. Rather, the questions were indirectly posed and the two keys features were subsequently inferred from the responses. For instance, the practitioners were questioned as to whether the H&S measures they implement on projects are determined/influenced by the features of the projects. Overall, the questions brought to the fore the accident causal influence of CPFs and made it possible to extract relevant issues relating to the path of accident causation and the causal interactions between accident factors. The interviews were audio taped and on average took approximately 60 minutes.

Selection of Participants

Using the UK Kompass online directory, 50 UK contractors were randomly selected and sent letters to solicit participation in the interviews. In the invitation a request was made for a professional in construction management role (e.g. H&S manager, project manager, construction manager or site manager) to participate in the interview. H&S is a very sensitive subject in the UK due to the legalities surrounding it and for that matter obtaining participation in H&S research is difficult (see Gibb et al., 2002). Given this terrain, it was also deemed necessary to use industry contacts to assist with obtaining participation in the interviews.

Compared to quantitative research, qualitative research involves fewer participants/cases as the focus of qualitative research is not generalisation but rather the achievement of meaning of phenomena through the collection and analysis of rich data (see Creswell, 2009; Choudhry and Fang, 2008; Mason, 2010;). Whilst determining sample size in qualitative research is difficult, others have resorted to the use of saturation point: a point reached when the data does not return new codes (see Mason, 2010). As qualitative data collection and analysis can run concurrently, it is possible to ascertain the point at which data returns no new codes, and hence saturation. For instance, in Choudhry and Fang's (2008) construction accident causation study involving interviews, saturation was reached after 7 interviews. Other studies in which saturation was reached at an early stage include Guest et al. (2006). Guest et al. (2006) concluded that for studies with high homogeneity among the population even a sample of 6 interviews may be adequate to enable the development of meaningful themes and useful interpretations. In this study after 9 interviews, saturation was reached. However, because prior arrangement had already been made with 2 other practitioners, additional 2 interviews were conducted. The demographic information of the interviewees is given by Table 2. The participants are mainly contractor personnel in construction management roles and they have at least 10 years of construction experience which is an indication of adequate expertise in construction (Hallowell and Gambetese, 2010). Averagely, their years of construction experience (i.e. 26.27 years) is also respectable.

Analysis

To aid the analysis, Creswell's (2009) guide for qualitative data analysis was used. The analysis followed 5 main steps: transcribing of the audio interviews (i.e. verbatim transcription); organising and preparing the transcripts; iterative re-reading of the transcripts; coding of the transcripts; and generating themes. Creswell (2009) recommends that where a qualitative study seeks to verify a theory/prior formulation, coding should commence deductively (based on literature) and then complemented by inductive coding as guided by emerging information from the transcripts. This recommendation was followed. The systematic iterative re-reading and coding of the transcripts enabled the attainment of a profound understanding of each interviewee's view point and hence the extracting of issues relating to the accident phenomenon under investigation.

Table 2: Respondents' demographic information

No.	**Role of Participant***	**Years of experience in construction**
1	Construction H&S consultant	30
2	H&S manager of a medium-sized national B&C	10
3	Project manager of a large international B&C	34
4	Site manager of a medium-sized national B&C	20
5	H&S manager of a large international B&C	10
6	Senior site manager of a large national B&C	29
7	Civil engineer & director of a large international B&C	36
8	H&S of a large international B&C	20
9	Project manager of a large international B&C	42
10	Construction manager of a large international B&C	13
11	Project manager of a large international B&C	45

*B&C = Building and Civil Engineering Contractor. Annual turnover of medium-sized national B&C = circa £ 50 million. Annual turnover of large national B&C = circa £ 1 billion. Annual turnover of large international B&C = over £ 2 billion.

Findings and Discussion

The findings are presented and discussed below.

Accident Causation in Construction

The analysis showed that the occurrence of construction accidents is generally viewed by the interviewees to be the result of immediate causes which could be triggered by underlying causes. The responses of the interviewees also pointed that whereas immediate causes tend to be relatively obvious, underlying causes are much more difficult to identify when investigating the causation of accidents. For instance, regarding the role of underlying causes in accident causation and the difficulty in identifying such causes, interviewees made comments such as these:

> "*…Root causes are very important. One can have a fall from height. It might simply look like they slipped off a ladder but then, you start to question why the person slipped"* [H&S Manager].
>
> "*Immediate causes are usually fairly obvious…finding root causes in the first place is definitely the hardest bit*" [H&S Manager].

In addition to the basic path of accident causation i.e. from underlying causes through immediate causes, the interviews also revealed that accident causation is a complex phenomenon characterized by interrelationships between causal factors. For instance, an interviewee portrayed the complex and multi-causal nature of accident causation as:

> "*I think it is a very mixed picture. In some cases, you'd get causes that do influence each other…Definitely, things can definitely interact and increase the chances of an accident taking place without a shadow of doubt…"* [H&S Manager].

These findings are generally consistent with the systems view of accident causation and the systems models of construction accident causation by Suraji et al. (2001) and Haslam et al. (2005). In terms of accident investigations by the interviewees' organisations, it became increasingly evident that investigations do indeed try to trace the underlying causes. However, it also emerged from the interviews that the investigations focus on the underlying factors within the organisations' operations and not those factors which extend to the pre-construction stage. This is because, aside the difficulty in establishing causality by those factors, it was felt that they (i.e. the contractors) have no control or very limited control over decisions regarding those factors and hence the need to rather focus on investigating factors they can control.

How CPFs Influence Accident Occurrence

Regarding the accident causal influence of CPFs, the analysis confirmed that nature of project, method of construction, site restriction, project duration, procurement system, design complexity, level of construction, and subcontracting have accident implications as has been previously reported in literature (see Table 1). Commenting on some of these features, one interviewee for instance emphasised that:

> *"…A complex project brings more risk, a restricted site brings more risk, a tight duration brings more risk and a high rise also brings more risk but you've got to manage those risks by putting in place the right measures to mitigate those risks."* [Project Manager]

In addition to the above project features, another feature which emerged as having accident implications was *restriction of site locality*. This was drawn from a narrative of an accident and also from elaborations given by interviewees on a closely related project feature which is the restriction of site. The impact of the restriction of site locality is likely to occur as harm to a member(s) of public as it concerns working close to the public. Although it was acknowledged by the practitioners that the above project features have accident implications, an important view that also ran through the interviews was that it is really down to how the risk associated with these project features are effectively managed right from the early stage of a project. This underscores the significance of effective H&S planning right from the early stages of project procurement (Szymberski, 1997) and the importance of mechanisms such as the CDM Regulations.

The project features were considered as being underlying accident causal factors. An interviewee for instance referred to them as, "*…something that sits behind everything…they are underlying and quite deep underlying root causes*". The analysis further revealed that the project features are associated with certain inherent H&S issues which as a result make the project features have the potential to influence the occurrence of accidents. With regards to restriction of site locality which emerged from the interviews, it is associated with difficulty in traffic (pedestrian and vehicle) control around the site vicinity. The H&S issues are given in Table 3 and they are site-based. In the main, these H&S issues are similar to those that have been related to CPFs in the extant construction and H&S literature (see McKay et al., 2002; Wright et al., 2003; Hide et al., 2003; Anumba et al., 2006; Baiden et al., 2006; Ankrah, 2007; Hughes and Ferrett, 2008; Brace et al., 2009; HSE, 2009). With the CPFs being considered to be underlying/root causes with associated inherent H&S issues which are site-based, the interviews lend support to the first key feature of the proposed model: that CPFs introduce into the construction phase proximate causes of accidents which give rise to accidents.

Concerning the inter-causal relationships amongst project features and proximate accident factors espoused by the conceptual model, the interviews also showed evidence of such relationships. For instance, some interviewees were of the view that whilst design and build procurement does not guarantee improved buildability, it does offer the opportunity to improve buildability of designs due to contractor input in design.

> *"…Design and build gives you the opportunity to influence the design. I think the important thing with that is that a lot of construction companies may not actually realize they have that opportunity and so even if they don't have novated designers and they are their own designers, they might simply say we are not the designers, we'll subcontract the design, without realizing they have the opportunity to think about the designs, to review designs and say well hang on a minute we'll never be able to build that or that's going to be difficult to build safely or expensive to build"*[H&S Manager]

Haslam et al. (2005) in their study similarly reported this perception about design and build. This means that design and build offers the opportunity to reduce the difficulty in construction (i.e. the site-based H&S issue/proximate cause) associated with design complexity, and this provides an example of the possible inter-causal relations between some CPFs and the proximate accident factors introduced by other CPFs. Regarding inter-causal relationships between the various site-based H&S issues (i.e. the proximate causes) the analysis did not reveal specific examples. Nonetheless from the interviewees' general acknowledgement of possible inter-causal relationships between accident factors, the possibility of there being inter-causal relationships among the site based H&S issues in the process of accident occurrence cannot be discarded. Overall, the interviews also lend support to the second key feature of the model.

Table 3: CPFs and associated H&S issues

CPFs	**Associated H&S issues**	**Some Insightful Comments on the H&S issues**
Nature of Project	Uncertainty of hazards	*"With new build obviously, you're starting from the ground but with refurbishment you are working blindly really. You don't know what is behind that plaster board, do you?" [Site Manager]*
Method of Construction	Manual handling & Mechanical handling	*"For example the windows for this job arrived on site fully glazed… Lifting the windows by crane reduces manual handling risk but it introduces risk associated with operating a crane." [Site Manager]*
Site Restriction	Congestion	*"The separation of plant, workers, materials, and vehicles is more difficult on restricted site and so it's more dangerous to work on restricted sites." [Site Manager]*
Project Duration	Time-pressure	*"When the duration is tight, the workers are under pressure and when they are under pressure they'll cut corners if you allow them. As soon as time-pressure is introduced accidents can occur."[Site Manager]*
Procurement System	Difficulty in collaborative working	*"I'll say some of the collaborative early contractor involvement type of procurement helps us to think through problems and things in more detail." [Civil Engineer & Director]* *"It does pay dividend to be working with the design team months in advance before starting on site. And off-course through that you build a good relationship with the design team as well as some trust." [Project Manager]*
Design Complexity	Difficulty in building (i.e. buildability)	*"I think one of the key issues is for designers to understand that it might look very good on paper but someone has to deliver the design in operational terms." [Construction H&S consultant]*
Level of Construction	Working at height	*"The level of construction could influence accident occurrence because of working at height. I feel more confident and everybody feels more confident the lower they are working." [Site manager]*
Subcontracting	Fragmentation of workforce	*"One of the big challenges for the industry is the subcontract culture… it is not unheard of for a team to turn up on site and they don't even know who we are because they've been contracted by somebody who has been contracted by somebody." [H&S Manager]*

CPFs	Associated H&S issues	Some Insightful Comments on the H&S issues
Restriction of site locality	Difficulty in traffic (vehicle and pedestrian) control around site vicinity	*"When working in city centers you've got to be more aware of the public. For instance where we are now (i.e. Birmingham City Centre) there's about 10,000 people passing around every day. So that introduces some risks." [Project Manager]* *"Inner city jobs are usually more dangerous with H&S because they are tight. There's little of space. You have to time your deliveries, and getting stuff in and around the place." [Project Manager]*

Credibility/Validation check

Demonstrating credibility in qualitative research is important in establishing confidence in the findings and in that regard a number of checks have been suggested e.g. verbatim transcription of interviews (see Creswell, 2009). In this study, a further check that was applied was member checking/respondent validation (Silverman, 2006; Creswell, 2009). This involved a follow-up questionnaire survey of construction professionals which investigated the H&S impact of CPFs. An aspect of the survey was used to validate the interview findings, particularly the finding that CPFs are inherently associated with H&S issues (proximate accident causes) which are introduced into the construction phase. The survey yielded 184 valid responses (out of 1000 administered questionnaires) from UK construction professionals in construction management roles (e.g. H&S manager, project manager, site manager and construction manager). Altogether, the professionals have a respectable 16.30 years of experience in their roles, 24.31 average years of experience in construction and approximately 80 percent have over 10 years of experience in construction. Approximately 70% of the respondents are members of at least 1 industrial professional body (e.g. Institution of Civil Engineers, Institution of Occupational Health and Safety, Chartered Institute of Building, International Institution of Risk and Safety Management and the Royal Institute of Chartered Surveyors). Altogether the demographic information shows that the respondents are adequately experienced in the management of construction and H&S (see Hallowell and Gambetese, 2010).

Relying on their broad construction experience, the respondents were asked to rate the extent to which the H&S issues in Table 3 are common/prevalent within their associated CPFs. A 5-point scale (0 = not at all, 1 = low, 2 = moderate, 3 = high, 4 = very high) was used. The results are shown below in Table 4. Table 4 shows the mean ratings of the respondents. In order for the mean ratings to be interpreted with confidence, evidence of agreement amongst the respondents is important. The table therefore also shows single item inter-rater agreement indices (r_{wg}) which test for consensus amongst the respondents (James *et al.*, 1984). The estimated r_{wg} indices are evidence of significant consensus amongst the respondents. Approximation of the mean ratings to their nearest scale points confirms that the CPFs are inherently associated with the H&S issues as none of the mean ratings approximates to the zero point which would mean that a H&S issue is not at all common/prevalent within a CPF. Rather the H&S issues are common/prevalent within their associated CPFs to varying extents ranging from low to high.

It is argued in Silverman (2006) that in member checking/respondent validation where participants verify the findings of the research it generates more confidence in the credibility of the findings. The convergence between the results of the validation check and the findings drawn from the interviews thus lend confidence in the credibility of the interview findings and hence the soundness of the proposed model of how CPFs influence accident occurrence.

Table 4: Extent to which inherent health and safety issues (proximate causes of accidents) are common/prevalent within CPFs

Construction Project features (CPFs)	**Extent to which proximate cause of accident is common/prevalent within CPF**	**Medn.**	**Mode**	**Mean**	**Std. Dev.**	* r_{wg}	**Overall Assessment**		
							High (3)	**Moderate (2)**	**Low (1)**
Nature of project (New build, refurbishment & demolition)	Uncertainty of hazards within Refurbishment	3.00	3.00	2.7714	.93629	0.56	✓		
	Uncertainty of hazards within Demolition	3.00	3.00	2.9324	.94803	0.55	✓		
	Uncertainty of hazards within New work	2.00	1.00	1.6246	.73580	0.73		✓	
Level of construction (High level construction & low level construction)	Working at height within High-level construction (i.e. multi-level construction)	3.00	3.00	3.1832	.85076	0.64	✓		
	Working at height within Low-level construction (i.e. single-level construction)	2.00	2.00	1.9756	.89674	0.60		✓	
Subcontracting (Multi-layer & single-layer subcontracting)	Fragmentation of workforce within Single-layer subcontracting	2.00	2.00	1.7728	.72886	0.73		✓	
	Fragmentation of workforce within Multi-layer subcontracting	3.00	3.00	2.7273	.80241	0.68	✓		
Procurement system (Traditional, design and build, partnering, and management contracting)	Fragmentation of project team within Traditional procurement	2.00	2.00	1.8553	.74317	0.72		✓	
	Fragmentation of project team within Design and Build procurement	2.00	2.00	1.8109	.73153	0.73		✓	
	Fragmentation of project team within Partnering procurement	2.00	2.00	1.8198	.77830	0.70		✓	
	Fragmentation of project team within Management contracting	2.00	2.00	2.0225	.70703	0.75		✓	
Method of construction (Pre-assembly and traditional method)	Manual handling within Pre-assembly construction	2.00	2.00	1.7465	.77017	0.70		✓	
	Manual handling within Traditional construction	3.00	3.00	2.6614	.69753	0.76	✓		
	Mechanical handling within Pre-assembly construction	3.00	3.00	2.4021	.91827	0.58		✓	
	Mechanical handling within Traditional construction	2.00	2.00	2.3238	.72411	0.74		✓	
Project duration (Adequate duration and tight project duration)	Time-pressure within Tight project duration	3.00	3.00	3.1322	.67841	0.77	✓		
	Time-pressure within Adequate project duration	2.00	2.00	1.7843	.71232	0.75		✓	
Site restriction (Restricted site & Unrestricted site)	Site congestion within Restricted site (i.e. where footprint of facility covers most of the site area)	3.00	3.00	3.0472	.71876	0.74	✓		

	Site congestion within Unrestricted site (i.e. where footprint of facility covers a smaller portion of the site area)	2.00	2.00	1.5992	.68854	0.76		✓	
Design complexity (Complex design & simple design)	Difficulty in constructing within Complex design (i.e. design with intricate aesthetic qualities)	3.00	3.00	2.8957	.76707	0.70	✓		
	Difficulty in constructing within Simple design (i.e. design with simple aesthetic qualities)	1.00	1.00	1.4367	.65512	0.79			✓
Restriction of site locality (Restricted site locality & unrestricted site locality)	Difficulty in traffic control around site vicinity within Restricted site locality (e.g. city center location)	3.00	3.00	3.0732	.69869	0.76	✓		
	Difficulty in traffic control around site vicinity within Unrestricted site locality (e.g. outer city location)	2.00	1.00	1.6104	.75104	0.72		✓	

*Notes: r_{wg} indices > 0.14 are significant at $p < 0.001$ based on 10,000 simulation runs, group size of 184, and 5 response options (i.e. 5–point scale) (see Cohen et al. (2001)).

Conclusions

Whilst it is now evident that CPFs have a causal influence in accident occurrence through the inherent introduction of proximate accident factors, the study presented in this chapter has also indicated that the accident causal influence of CPFs could be marked by causal interactions between CPFs and the proximate accident factors. This causal interaction can reduce or increase the presence of the proximate accident factors. These findings lend empirical support and credence to the proposed model (i.e. Figure 1) of the mechanism by which CPFs influence accident occurrence. Contributing to earlier construction accident causation models, the model places the spotlight on features of construction projects from amongst other underlying causal factors in construction accidents and it explains how various CPFs acting collectively on a project contribute to the occurrence of accidents. As accident causation models are useful in devising and implementing accident prevention measures, the model could similarly be useful to pre-construction project participants during the early stages of projects. The model could serve as evidence based justification for encouraging pre-construction project participants to devise and implement accident prevention measures which can remove or ‘block’ the release of proximate factors introduced by CPFs. Also the knowledge of the existence of potential causal interactions between CPFs and the proximate accident causes could be a basis for pre-construction project participants to carefully consider the selection or avoidance of certain combinations of CPFs due to the effects some CPFs could have on the proximate factors associated with other CPFs. This could be very useful especially where due to certain project conception constraints, some CPFs are inevitable. Also, in terms of investigating accident causation on projects, the model could serve as a root cause analysis tool in helping to trace or probe the potential contribution of CPFs and hence the contribution of pre-construction project participants in accident occurrence. For instance if an accident investigation reveals the involvement of any of the H&S issues/proximate causes, further probing as to why those causes were involved could point in the direction of certain CPFs and hence the contribution of certain pre-construction project participants.

The study however has a limitation which provides a fertile ground for further research. Whilst this research has shown that there could be inter-causal relationships between CPFs and the proximate accident factors they introduce, the study does not provide insight into the extent to which various CPFs could increase or decrease the prevalence of proximate factors (e.g. can or to what extent can a procurement system increase or decrease the extent of time-pressure introduced by tight project duration?). Further research in this direction would provide additional insight that would strengthen the utility of the model for pre-construction H&S risk mitigation.

References

Ankrah, N.A. (2007), "*An investigation into the impact of culture on construction project performance*", PhD Thesis, University of Wolverhampton.

Anumba, C., Egbu, C. and Kashyap, M. (2006), *"Avoiding structural collapses in refurbishment - A decision support system"*, Suffolk, HSE Books.

Anumba, C., Marino, B., Gottfried, A. and Egbu, C. (2004), "*Health and safety in refurbishment involving demolition and structural instability",* Suffolk, HSE Books.

Baiden, B., Price, A. and Dainty, A. (2006), "The extent of team integration within construction projects", *International Journal of Project Management*, Vol. 24, No. 1, pp.13-23.

Brabazon, P., Tipping, A. and Jones, J. (2000), "*Construction health and safety for the new Millennium",* Suffolk, HSE Books.

Brace, C., Gibb, A., Pendlebury, M. and Bust, P. (2009), "*Phase 2 Report: Health and safety in the construction industry: Underlying causes of construction fatal accidents – External research",* Norwich, Her Majesty's Stationery Office.

Choudhry, R.M. and Fang, D. (2008), "Why operatives engage in unsafe work behavior: Investigating factors on construction sites", *Safety Science*, Vol. 46, No. 4, pp.566-584.

Chua, D. K. H. and Goh, Y. M. (2005), "Poisson model of construction incident occurrence", *Journal of Construction Engineering and Management*, Vol. 131, No. 6, pp.715-722.

Chua, D.K.H. and Goh, Y.M. (2004), "Incident causation model for improving feedback of safety knowledge", *Journal of Construction Engineering and Management*, Vol. 130, No. 4, pp.542-551.

Cohen, A., Doveh, E. and Eick, U. (2001), "Statistical properties of the rwg(j) index of agreement", *Psychological Methods*, Vol. 6, No. 3, pp.297-310.

Cooke, T. and Lingard, H. (2011), "A retrospective analysis of work-related deaths in the Australian construction industry", in *27th Annual ARCOM Conference on 5-7 September 2011 in Bristol, UK,* Association of Researchers in Construction Management, pp. 279-288.

Creswell, J.W. (2009), "*Research design: qualitative, quantitative, and mixed method approaches*", 3rd edn., Sage Publications, California.

Egbu, C.O. (1999), "Skills, knowledge and competencies for managing construction refurbishment works", *Construction Management and Economics*, Vol. 17, No. 1, pp.29-43.

Fellows, R. and Liu, A. (2008), "*Research methods for construction*". West Sussex, Blackwell Publishing,.

Gibb, A.G., Haslam, R.A., Gyi, D.E., Hide, S., Hastings, S. and Duff, R. (2002) ConCA-Preliminary Results from a Study of Accident Causality, in *Triennial Conference CIB W099, May 2002, Hong Kong*, University of Hong Kong.

Gibb, A.G.F. (1999), "*Principles in off-site fabrication*", Caithness, Whittles.

Gibb, A.G.F. (2001), "Standardization and pre-assembly-distinguishing myth from reality using case study research", *Construction Management and Economics*, Vol. 19, No. 3, pp. 307-315.

Groeneweg, J. (1994), "*Controlling the controllable: The management of safety*", 2nd revised edn. Leiden University, DSWO Press.

Guest, G., Bunce, A., and Johnson, L. (2006), "How many interviews are enough? An

experiment with data saturation and variability", *Field Methods,* Vol. 18, No. 1, pp. 59-82.
Hallowell, M. R. and Gambatese, J. A. (2010), "Qualitative research: application of the Delphi method to CEM research", *Journal of Construction Engineering and Management*, Vol. 136, No. 1, pp. 99-107.
Haslam, R.A., Hide, S.A., Gibb, A.G.F., Gyi, D.E., Pavitt, T., Atkinson, S. and Duff, A.R. (2005), "Contributing factors in construction accidents", *Applied Ergonomics*, Vol. 36, No. 4, pp. 401–415.
Heinrich, H. W. (1936), "*Industrial accident prevention*", New York, McGraw-Hill.
Hide, S., Atkinson, S., Pavitt, T., Haslam, R., Gibb, A., Gyi, D, Duff, R. and Suraji, A. (2003), "*Causal factors in construction accidents",* Suffolk, HSE Books.
Hinze, J. (1996), "The distraction theory of accident causation", in *Implementation of safety and health on construction sites - Proceedings of the First International Conference of CIB Working Commission W99: Safety and Health in Construction, 4-7 September, 1996 in Lisbon*, A. A. Balkema, Rotterdam, pp. 375-384.
Horbury, C. and Hope, C. (1999), "*The impact of procurement and contracting practices on health and safety - A review of literature",* Report RAS/99/02, Buxton, HSL.
HSE (2009), "Construction intelligence report: Analysis of construction injury and ill-health intelligence", Health and Safety Executive, Available online at http://s3.amazonaws.com/zanran_storage/www.hse.gov.uk/ContentPages/25543732.pdf (Accessed 1st January 2011)
HSE (2014), "*Health and safety in construction in Great Britain, 2014 - work-related injuries and ill health",* Health and Safety Executive. Available online at http://www.hse.gov.uk/statistics/industry/construction/construction.pdf (Access 22nd June 2015)
Hughes, P. and Ferrett, E. (2008), "*Introduction to health and safety in construction*", 3rd edn., Oxford, Elsevier Ltd.
James, L. R., Demaree, R. G. and Wolf, G. (1984), "Estimating within-group interrater reliability with and without response bias", *Journal of Applied Psychology*, Vol. 69, No. 1, pp.85-98.
Manu, P., Ankrah, N., Proverbs, D. and Suresh, S. (2012), "Investigating the multi-causal and complex nature of the accident causal influence of construction project features", *Accident Analysis and Prevention*, Vol 48, pp. 126-133.
Manu, P., Ankrah, N., Proverbs, D. and Suresh, S. (2013), "Mitigating the health and safety influence of subcontracting in construction: The approach of main contractors" *International Journal of Project Management*, Vol. 31, No. 7, pp. 1017 - 1026.
Manu, P., Ankrah, N., Proverbs, D. and Suresh, S. (2014), "The health and safety impact of construction project features", *Engineering, Construction and Architectural Management*, Vol. 21, No. 1, pp. 65 - 93.
Mason, M. (2010), "Sample size and saturation in PhD studies using qualitative interviews", *Forum: Qualitative Social Research*, Vol. 11, No. 3, Art 4.
Mayhew, C. and Quinlan, M. (1997), "Subcontracting and occupational health and safety in the residential building industry", *Industrial Relations Journal*, Vol. 28, No. 3, pp.192-205.
McKay, L.J., Gibb, A.G.F., Haslam, R. and Pendlebury, M. (2002), "Implications for the effect of standardization and pre-assembly on health, safety and accident causality-preliminary results", in *18th Annual ARCOM Conference, 2-4 September 2002, University of Northumbria.* Association of Researchers in Construction Management.
Perttula, P., Merjama, J., Kiurula, M. and Laitinen, H. (2003), "Accidents in materials handling at construction sites", *Construction Management and Economics*, Vol. 21, No. 7, pp.729-736.
Reason, J. (1990), "*Human Error*", Cambridge, Cambridge University Press.
Seymour, D. and Rooke, J. (1995), "The culture of the industry and the culture of research",

Construction Management and Economics, Vol. 13, No. 6, pp.511-523.
Silverman, D. (2006), "*Interpreting qualitative data: Methods for analyzing talk, text, and interaction*", London, Sage Publications Ltd.
Strategic Forum for Construction (2002), "*Accelerating change- A report by the Strategic Forum for Construction Chaired by Sir John Egan*", London, Rethinking Construction.
Suraji, A., Duff, A.R. and Peckitt, S.J. (2001), "Development of a causal model of construction accident causation", *Journal of Construction Engineering and Management*, Vol. 127, No. 4, pp. 337-344.
Szymberski, R.T. (1997), "Construction project safety planning", *TAPPI Journal*, Vol. 80, No. 11, pp. 69-74.
Tuuli, M.M. and Rowlinson, S. (2010), "What empowers individuals and teams in project settings? A critical incident analysis", *Engineering, Construction and Architectural Management*, Vol. 17, No. 1, pp. 9-20.
U.S. Bureau of Labor Statistics (2015), "National census of fatal occupational injuries in 2014", U.S. Bureau of Labor Statistics. Available online at http://www.bls.gov/news.release/pdf/cfoi.pdf (Accessed 9th October 2016).
Wright, M., Bendig, M., Pavitt, T. and Gibb, A. (2003), "*The case for CDM: better safer design-a pilot study*", Suffolk, HSE Books.