Knowledge Transfer for Occupational Health and Safety: Cultivating Health and Safety Learning Culture in Construction Firms

Meri Duryan, Hedley Smyth*, Aeli Roberts*, Steve Rowlinson** and Fred Sherratt****

* The Bartlett School of Construction and Project Management
University College London, London, United Kingdom

** University of Hong Kong, Hong Kong

*** School of Engineering and the Built Environment,
Anglia Ruskin University, Chelmsford, United Kingdom

Corresponding author:
m.duryan@ucl.ac.uk

Abstract

Within the last decades the incidence of workspace injuries and fatalities in the UK construction industry has declined markedly following the developments in occupational health and safety (OHS) management systems. However, safety statistics have reached a plateau and actions for further improvement of OHS management systems are called for. OHS is a form of organizational expertise that has both tacit and explicit dimensions and is situated in the ongoing practices. There is a need for institutionalization and for the transfer of knowledge across and along construction supply chains to reduce OHS risks and facilitate cultural change. The focus of this article is the factors that facilitate OHS knowledge transfer in and between organizations involved in construction projects. An interpretative methodology is used in this research to embrace tacit aspects of knowledge transfer and application. Thematic analysis is supported by a cognitive mapping technique that allows understanding of interrelationships among the concepts expressed by the respondents. This paper demonstrates inconsistency in OHS practices in construction organizations and highlights the importance of cultivating a positive safety culture to encourage transfer of lessons learnt from good practices, incidents, near misses and failures between projects, from projects to programmes and across supply chains. Governmental health and safety regulations, norms and guidelines do not include all possible safety issues specific to different working environments and tied to work contexts. The OHS system should encourage employees to report near misses, incidents and failures in a 'no-blame' context and to take appropriate actions. This research provides foundation for construction project practitioners to adopt more socially oriented

approaches towards promoting learning-rich organizational contexts to overcome variation in the OHS and move beyond the current plateau reached in safety statistics.

Keywords: Occupational Health and Safety, Safety Culture, Knowledge Transfer, Knowledge Management, Organizational Learning, Construction Industry.

1. Introduction

Organizational occupational health and safety (OHS) and issues of organizational learning and knowledge management (KM) have gained increasing attention in recent literature (Nesheim and Gressgår, 2014; Podgórski, 2010; Shereihiy and Karwowski, 2006; Wahlstrøm, 2011). Although studies exploring the application of KM principles in OHS across different industries (including aviation, mining, nuclear and construction) exist, they are fragmented and lack recommendations for practical application (Podgórski, 2010; Shereihiy and Karwowski, 2006).

The UK construction industry is a complex and safety-critical industry with a wide range of enterprises starting from sole-traders, small and medium enterprises to multi-nationals working on construction projects in long supply chains, under contract and sub-contract to a client (Office for National Statistics, 2018). This industry is not unique. Other sectors carry similar features such as oil and gas exploration infrastructure and chemical processing plants (e.g. Mearns and Yule, 2009; Vinodkumar and Bhasi, 2009). OHS management in the construction industry, which operates under pressure to deliver short-term results, is therefore a complex issue. This is particularly the case on the client-side of project and programme execution. In the construction industry every project is essentially

a temporary organization that engages various actors from different firms, which results in challenges in inter-project knowledge transfer (KT) and reuse. Establishing a culture of KT in construction firms is especially difficult due to its uniqueness, fragmented nature and the complexity of programme and project operations. What adds to complexity is the presence of subcultures in construction projects shaped by the groups of professionals who join project teams from other organizations across the supply chain (e.g. Auch and Smyth, 2010; Walker, 2015). People within different project teams and functional groups have different roles, develop different skills, work processes and may have different priorities and agendas. They might receive safety information from multiple sources but respond and act upon it in different ways, depending on the project team culture.

There are health and safety regulations, norms and guidelines in place (Shereihiy and Karwowski, 2006), however, they may not include safety guidance suitable for different working environments. Organizational learning of OHS will not be complete if it is based only on learning from generic safety guidelines and regulations provided by governmental bodies. Context related safety experience and cognitive skills of employees, alongside the synthesis of facts and physical experiences are crucial in attaining higher safety levels, encouraging innovative thinking and attracting new talent. Transfer of tacit knowledge that considers specific work contexts is especially important for risk management and hazard identification, particularly in safety-critical industries (Podgórski, 2010).

Learning theorists are very critical about the concepts of KT that isolate knowledge from practice (Brown and Duguid, 1991; Lave and Wenger, 1991;). Knowledge inevitably includes a degree of tacitness and cannot be fully documented. Lave and Wenger (1991) embraced the relational character of knowledge and view it as a process shaped by participation. In order to transfer the operational knowledge stored in ‘the heads’ of

individuals, organizations need to encourage social interaction based on trust and mutual understanding (Roberts, 2000; Shereihiy and Karwowski 2006). Mutual understanding around shared, for example beliefs and norms, as well as the substantive areas connected to OHS, such as wellbeing, social responsibility and ethical behaviour and actions.

Tacit knowledge can support shaping of appropriate habits and skills for OHS which will eventually contribute to reducing employees' unsafe behaviours. It can be transferred via narratives and stories (e.g. as texts, how-to videos, pictures) (Podgórski, 2010). Where there are phenomena and artifacts acting as barriers to knowledge transfer, cultivation of communities of practice (CoPs) across disciplines and organizations can be a way to overcome those barriers (Lave and Wenger, 1991). There are different mechanisms that can facilitate health and safety learning, however, there is a paucity of evidence regarding the successful usage of KM principles in managing OHS (Podgórski, 2010).

There is a shared understanding amongst academics and practitioners of the importance of organizational and cultural dimensions for facilitating KT (APQC, 2016; Davenport and Prusak, 1998; Szulanski, 2000; Senge, 1990). Organizational routines, organizational culture and informal KT and reuse have been defined as crucial for learning in and from projects (Bartsch et al., 2013; Mueller, 2015).

This paper is drawn from wider research which explored the policies, practices and experiences of OHS within the UK construction industry. Here, an exploration of the factors that facilitate KT on OHS in and between organizations involved in a number of construction projects has been drawn out. Empirical data gathered through interviews has been analysed to initially create a complex cognitive map (Figure 1), mobilized to demonstrate both the complexity of the findings and rigor in the analytical process.

Subsequently, a thematic mapping has been produced to provide a simplified visual tool able to clearly illustrate the interrelatedness of the key themes that surround the phenomenon of managing knowledge for OHS within the construction industry context (Figure 2). The findings demonstrate an inconsistency in OHS culture and the lack of a systematic approach to learning from incidents, failures and near misses in the UK construction industry. Considering the difficulties in capturing, codifying and transferring all possible OHS management scenarios, organizations need to cultivate a culture of continuous and proactive learning and KT through people-to-people communication between leadership teams operating in different levels of the organization and between the projects and operational functions.

2. Literature review

2.1 Knowledge Management in Organizational Context

KM is a relatively young discipline that has gained popularity within recent decades amongst both academics and practitioners. The vast majority of scientific papers on KM look mainly at information systems and the human dimensions (Jashapara, 2011).

Although the term ‘knowledge’ does not have a broadly accepted definition, in the field of business management it is considered as a “fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories, but also in organizational routines, processes, practices, and norms” (Davenport and Prusak, 1998, p. 5).

There are three levels of knowledge: individual, organizational and structural (Edvinsson and Malone, 1997). Individual knowledge (often tacit), resides in human minds. It is obtained through experience and is difficult to transfer to others. The term 'tacit' knowledge was first coined by Polanyi (1962, p. 4) as very personal knowledge: "we know more than we can tell". Tacit knowledge is "developed and internalized by the knower over a long period of time and is almost impossible to reproduce in a document or a database" (Davenport and Prusak, 1998, p. 70). Thus, consideration of human and social factors is crucial for knowledge flow through organizations.

Structural knowledge is formal (explicit), easy to access, codify and store in databases, reports, procedures and other organizational documents (Nonaka and Takeuchi, 1995). Organizational knowledge is a result of learning processes. According to Polanyi (1967) knowledge in organizations exists along a continuum between tacit and explicit knowledge. Nonaka and Takeuchi (1995) posit that innovation is a result of continuous interaction between tacit and explicit knowledge. The authors emphasize the importance of not only processing already existing knowledge but also creating new knowledge and using it in the organization. The Japanese model of organizational knowledge creation demonstrates four types of knowledge conversion: a) from individual tacit to group knowledge (socialization); b) from tacit knowledge into formal (explicit) knowledge (externalization); c) from segmented formal knowledge into one more effective form of explicit knowledge (combination) which can be distributed throughout the organization; and d) from formal (explicit) form of knowledge into personally applicable tacit knowledge (internalization), which represents the traditional notion of 'learning' (Nonaka and Takeuchi, 1995).

Considering that only part of tacit knowledge can be converted into explicit knowledge (Davenport and Prusak, 1998; Polanyi, 1962, 1967), and also that codification of tacit knowledge requires investment and may result in paying more attention to formal knowledge (Podgórski, 2010), it is important to have a system in place to manage both, tacit and explicit knowledge.

2.2 Occupational Health and Safety through the Lenses of Situated Learning Theory

According to Gherardi and Nicolini (2000, p. 333) occupational safety is a final result of a situated practice, "a 'doing' which involves people, technologies and textual and symbolic forms assembled within a system of material relations".

Knowledge plays a central role in implementation of an effective OHS management system (Dingsdag et al., 2008; Shereihiy and Karwowski, 2006; Törner and Pousette, 2009), especially in the construction industry (Hadikusumo and Rowlinson, 2004). There are governmental regulations, norms and guidelines, documented in explicit (passive) forms, that need to be followed (Shereihiy and Karwowski, 2006). However, those regulations do not include all possible safety issues that are specific to different working environments. Organizational learning of OHS will remain incomplete if it is based only on explicit knowledge as it is impossible to predict all possible scenarios. Different forms of tacit knowledge such as a safety engineer's experience, perceptual and cognitive skills, rules of thumb, intuition and synthesis of facts and physical experiences are crucial for providing safe working conditions (Shereihiy and Karwowski, 2006). Social interaction in the networks of practice is required to transfer that context-specific knowledge (Brown and Duguid, 2001; Roberts, 2000; Shereihiy and Karwowski, 2006).

Based on Situated Learning Theory (SLT), learning is "an integral and inseparable aspect of social practice" (Lave and Wenger, 1991, p. 31). SLT emphasizes agency and dynamic and interactive relations of agents with their environments. The key themes of SLT among others include collective sensemaking activities and development of "people's social and technical competencies and identities to function within the practice" (Sense, 2008, p 37). Lessons learnt contribute to safety only when put to work by people in situated practices in local settings. In this context, tacit knowledge, developed by knowers over a long period of time may be especially important for risk management and accidents' prevention particularly in high-risk industries (Podgórski, 2010).

Wiig (1997, p. 229) suggests KM initiatives must "rely on people-related mechanisms such as storytelling, CoP, and social networking". Situated learning involves peripheral participation in CoP (Lave and Wenger, 1991). The concept of CoP was introduced by Wenger (1998) as part of a broader conceptual framework on learning and has been widely acknowledged by academia and practice as a tool with high potential in facilitating knowledge exchange and reuse across organizational boundaries (APQC, 2016; Duryan and Smyth, 2018; Josserand, 2004; Wenger, 1998). CoP can facilitate KM at both, high and operational levels and can enable "a more agile response of knowledge needs and a strong governance model" (ICE, 2018, p.26).

It is widely acknowledged that a learning culture has a major role to play in cultivating safety culture within an organization (HSE, 2005; Shereihiy and Karwowski, 2006). There is no one-size-fits all model for OHS KM and the tendency to standardize safety practices restricts organizational learning (Guo, et al., 2015). Firms need to develop their own models of transferring tacit and explicit knowledge. Therefore, it is important for

organizations to cultivate an environment of continuous and proactive learning and knowledge transfer at all levels.

2.3 Knowledge Transfer for Occupational Health and Safety in Construction Firms

Organizational learning is a key strategic variable in project-based organizations (e.g. Bartsch et al., 2013). There are two levels of KM in construction firms: management of project knowledge and management of knowledge within individual firms (Kamara et all., 2003). KT can be defined as "the process through which one unit (e.g., group, department, or division) is affected by the experience of another" (Argote and Ingram, 2000, p. 151). Knowledge can be transferred through processes of socialization, education and learning (Argote and Ingram, 2000; Roberts, 2000). Smyth et al. (2019) posit that safety management systems are largely information-based, while knowledge management systems (KMS) in construction, albeit very partial, are disconnected from OHS at both formal and informal levels of operation. Therefore, KT in a construction context has still to be developed. A basis is examined below.

In some papers on KM, the terms knowledge sharing (KS) and KT are used interchangeably, however according to Tangaraja et al., (2016) the former is a subset of the latter. KS refers to knowledge exchange between two individuals, a sender and a receiver. Although KT incorporates people-to-people processes through personalization, it is not an entirely behavioral concept, as opposed to KS. KT encompasses both behavioral and non-behavioral features and can occur at different levels: individual, group, product line, department/division and organization (Paulin and Suneson, 2012).

In large infrastructure programs, knowledge is generated mainly outside the client and main contractor organizational boundaries. Considering that multiple organizations are involved in construction projects, KT across organizational boundaries at both, programme and project level and between the projects will require a degree of alignment of the organizational cultures. The capture of the information and knowledge on safety risks and hazards and its transformation into knowledge capital with further efficient KT within and amongst the organizations, can significantly influence problem solving and decision making on OHS. KT transfer leads to the integration of context-specific knowledge and there are variety of mechanisms that can support explicit KT (instructions, procedures) or tacit KT (CoPs, how-to videos, narratives, story-telling and online forums).There is insufficient evidence in the literature on successful usage of KM principles in managing OHS (e.g. Podgórski, 2010), therefore a gap exists in the literature on mechanisms to ensure KT works well in the OHS context.

According to the UK Health and Safety Executive (2008), it is important to achieve a critical mass of awareness to trigger behavioral change and worker engagement across organizations. This goes beyond the current emphasis upon information sharing, towards systematic application of the information as knowledge especially at programme and project management levels. Cross-functional and inter-project KT enables organizational learning, guided by leadership teams and conducted through effective interaction management. The management of main contractors and subcontractors need to develop a holistic approach to KM on OHS, viewing KM as a programme management capability (Duryan and Smyth, 2019).

Although there is still an overreliance on technological solutions for KM and KT in general, many organizations now realize Information Technology (IT) systems and platforms are

only tools that support the culture of learning (Davenport, 1998; Kamara et al., 2003). The ability of technology to support the transfer of tacit knowledge is restricted by the need for social interactions, and a relationship of trust and mutual understanding (Roberts, 2000). The forms of explicit KT are important, however, tacit knowledge, embedded in the workers' minds, is necessary for building trust and encouraging safe behaviours (Roberts, 2000; Shereihiy and Karwowski, 2006).

In high-risk organizations, learning of safety rules presented through stories is faster than via training or instruction. This is especially useful for new hires and young employees, who need to learn about the safety culture in the organization. According to Zierold (2016), for safety training to be effective in preventing injury especially in young workers, they must include videos, hands-on, and on-the-job demonstrations. Videos help to reframe OHS within a broader understanding of how work is done and significantly contribute to the development of safer and more effective ways of working (Lingard et al., 2015). Storytelling, or narratives, are considered a natural method of knowledge exchange (e.g. Podgórski, 2010). Stories are powerful artefacts that tell us about problems, solutions, informal rules and processes in organizations. Storytelling proved to be effective for simulation of rescue actions to train those responsible for rescue operations in the US mining industry (Vaught et al., 2006). Another method of communicating OHS messages to multilingual project teams is by images and videos for training and in-situ (e.g. Bust, et al., 2008).

Academics (Dalkir, 2005; Davenport and Prusak, 1998; Lave and Wenger, 1991; Szulanski, 2000) and practitioners (e.g. APQC, 2016) agree that the key challenge in facilitating KT and application lies in organizational and cultural dimensions. The culture of KT relates to the social perspective of systems thinking (Senge, 1990). At the same time,

the transactional and adversarial nature of the industry is known to fuel 'finger-pointing' behaviors that discourage project teams sharing mistakes and failure made on projects (Kamara et al., 2003). Support from senior management plays a crucial role in creating an environment for learning from past and current mistakes and failures without a fear of blame and in driving behavioral change (Carrillo, 2013; Duryan and Smyth, 2018; HSE, 2008; Kamara et al., 2003; Nesheim and Gressgår, 2014). Their commitment is crucial for the effectiveness of organizational safety initiatives (Clarke, 1999; Lingard and Rowlinson, 1997).

2.4 Workspace Culture that Enables Health and Safety

2.4.1 Organizational culture

The concepts of organizational culture and climate have been developed to understand social environments. According to a comprehensive definition by Schein (2004, p.1) organizational culture is "both a dynamic phenomenon that surrounds us at all times, being constantly enacted and created by our interactions with others and shaped by leadership behavior, and a set of structures, routines, rules, and norms that guide and constrain behavior". Based on Cox and Cheyne (2000), organizational climate is a temporal manifestation of culture that is reflected in the shared perceptions of the employees at a particular point in time. It lacks clear categorization and is subject to direct control (Jashapara, 2011).

Culture is the organizational mental model that specifies values, shapes patterns of interactions and influences behaviors, hence encouraging (or discouraging) employees to share knowledge and experience (Senge, 1990; Schein, 2004; Wamuziri, 2011). De Long and Fahey (2000) provide evidence that organizational culture creates norms regarding what is deemed 'right' and 'wrong' within the organization and influences how people

communicate and share knowledge. It has the potential to induce a shift from a transactional "knowledge is power" to the more transformational mental model of "knowledge sharing is powerful" (Dalkir, 2005).

2.4.2 Positive Health and Safety Culture

It is generally accepted that behavioral and social scientists have broadened and deepened understandings of OHS by studying 'safety culture' and 'safety climate' (Denison, 1996; Lee and Harrison, 2000). The concept of 'safety culture' is used to illustrate how organizational culture, among several other factors, influences health and safety behaviors (Antonsen, 2009; Edwards et al., 2013; Nordlof et al., 2017). As defined by HSE (2005), the term 'safety culture' can be used to refer to the behavioral and situational aspects of firms, while the term 'safety climate' should be used to refer to feelings, attitudes and perceptions of employees regarding safety within a firm.

Organizations with a positive 'safety culture' are characterized by shared perceptions of the importance of safety, by communications that are based on mutual trust and understanding, and by confidence in the efficacy of preventive measures (HSC, 1993). Organizations with a blame culture tend to "overemphasize individual blame for the human error, at the expense of correcting defective systems" (HSE, 2005). A blame culture discourages people from reporting incidents and near misses and prevents learning from past and current mistakes (HSE, 2005; 2008). Failures challenge norms and beliefs embedded in organizational DNA and promote greater introspection and analysis of what went wrong (Jashapara, 2011). In an 'open' cultural environment, employees pay more attention to the inconsistencies of the outcomes that may have been overlooked in the environment of 'blame'. Of course, major failures are to be avoided, especially in high-risk industries like construction, however, 'blame' can be replaced by accountability.

To cultivate a culture of learning and KT on OHS at all levels, not only in-depth analysis of incidents and near misses but also a good organizational bottom-up and top-down communication with the timely feedback is required (HSE, 2005). This implies that senior managers have a significant role to play in shaping organizational culture through the messages they convey and the way they behave under pressure (Schein, 2004; Wamuziri, 2011). Their positive safety attitudes and behaviors have a strong impact on work practices and on organizational safety performance (Clarke, 1999; Dahl and Kongsvik, 2018; Goh et al., 2018). Visibility of senior management's commitment to safety can be achieved through safety tours and briefings, open door policies for safety, safety statements and newsletters (HSE, 2005).

According to HSE Advisory Committee on the Safety of Nuclear Installations, OHS culture is defined as: "the product of individual and group values, attitudes, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management" (ACSNI, 1993). However, some scholars do not agree with generalizing this statement, especially considering that for some organizations, like nuclear industry or project-based industries that carry high operational risks, safety is a core value, while for the other organizations it is not (Roberts et al., 2012).

2.4.3 Health and Safety Culture in Construction

The UK construction industry with over 314,590 organizations (Office for National Statistics, 2018), is a complex and changing landscape, operating within high-risk operational environments. The industry is formed of a wide range of enterprises from small and medium to multi-nationals working on construction projects under contract and sub-

contract to a main provider (Office for National Statistics, 2018). Construction supply chains are more fragmented than other industries, as subcontractors themselves often subcontract some or all the work to others, creating long chains that can end at a sole trader. When such a project composition is considered alongside the dominant project culture in the organizations that manage such discontinuous and dissimilar projects, the complexity of the industry can be readily appreciated. Considering that project teams play a key role in organizational knowledge creation it is necessary to understand how they learn, interact and transfer knowledge. According to SLT the process of learning is contingent on social practices within the specific local contexts. Thus, it is important to ensure that there is a culture that encourages individual learning and knowledge sharing in projects.

In recent times, closer attention has been paid to the concept of OHS culture in the UK construction industry (Dingsdag et al., 2008; Sherratt et al., 2013). According to the report *Construction Statistics in Great Britain* (HSE, 2018), for the last five years the fatal injury rates remain at 1.64% per 100,000 workers. The main reasons for deaths are falls from height (47%) and injuries from being trapped by something collapsing or being struck by an object (12%). The rates of injuries and fatalities from falls in construction industry worldwide are alarming, even in countries where adequate fall protection and fall prevention measures are provided (Bunting et al., 2017). As estimated by HSE (2018), 58,000 cases of work-related injuries were registered across all industries in Great Britain between 2017 and 2018. In the construction industry alone, around 2.4 million working days were lost each year between 2015-2018 due to workspace injuries and illness (HSE, 2018).

Although there has been a significant decline in work related injuries and fatalities in the UK construction industry within the period 2000-2012, the rates of decline have slowed

(HSE, 2018), suggesting the industry needs a deeper analysis of the underlying causes of injuries and fatalities that lie in the behavioral or cultural domains (Goh, et al., 2018). Cultural change is necessary for construction organizations if they plan to bring about improvements in OHS performance (Wamuziri, 2011).

Construction projects are complex technologically and culturally as they are shaped by the groups of professionals from other organizations across the supply chain. There are underlying subcultures in construction organizations shaped by the groups of professionals "who bring their own culture to the table, even if all contributors are in-house to the client organization" (Walker, 2015, p. 161). 'Safety culture' and 'safety climate' in the industry are not necessarily aligned with each other due to the lack of shared understanding between firm level and project level. The lack of shared understanding, furthermore, can be attributed to the weak KMS, hence KT, between hierarchical levels.

Antonsen (2009, p. 184) posits that there are "different traits of larger organizational culture that can affect the organization's safety levels". In this context, some project teams and/or functional groups in construction may have a stronger focus on OHS than the others. Consonant with an interpretive perspective on organizational culture is SLT theorists' position that organizational learning is influenced by the social and cultural conditions, attitudes and behaviors of employees, and needs to be analyzed in the context of a larger organization (Lave and Wenger, 1991; Sense, 2008).

Differences are usually greater where the project teams are formed by different organizations across supply chains, which complicates building relationships of trust and cultivating a culture that encourages safe behaviors (Walker, 2015). Thus, robust OHS programmes and systems within a single enterprise may have little or no influence on

improvement in OHS across supply chain and in the industry. In order to bring changes across the fragmented supply chain and overcome variation in the OHS, there is a need for clarity concerning sharing accountability for the communicated information and knowledge for OHS among all actors. As KM linked to OHS is potentially transformational, the key point is about improving performance through a more socially oriented approaches towards learning and KT.

3. Methodology and Methods

The focus of this paper, which is drawn from wider research that explored the policies, practices and experiences of Occupational Health and Safety and Well-being (OHSW) in the UK, is on the factors that facilitate OHS KT in and between organizations involved in construction projects. The researchers focus their attention on organizational culture, where people are viewed as members of social systems with consideration of the dynamics of their interactions that influence KT.

An interpretative methodology was used in this research (e.g. Miles and Huberman, 2002), which is appropriate for a topic embracing tacit aspects of KT and application. Construction firms provide the unit of analysis in a case-based approach (e.g. Yin, 2009). The data collection process involved three phases: pilot interviews, a workshop, main interviews. The interviews were conducted with five types of organization: institutional, clients, main contractors (large international organizations), subcontractors and self-employed operatives. Representatives of the same organizations were invited to take part in the workshops."

The first phase of the research involved conducting pilot interviews with six representatives of three main contractors. This informed the second phase, the workshop with these and other organizational representatives. The data from the pilot interviews and the workshop were analyzed to identify the most relevant themes, single out most interesting companies to study, refine the interview questions for the third phase, the main interviews, and define the key directions for a wider research on OHSW that involved also questions around KM and KT practices for OHS.

This paper draws on a data set of 43 semi-structured interviews (phase three) undertaken with those responsible for OHS and those in other roles and functions who would be expected to engage with OHS directly or indirectly at different levels, from operatives to senior level management (see Table 1, Appendix). The main themes around which the questions for the wider research were designed are: Institutional Issues, Business Model, Well-being, Occupational Health and Safety, Operational issues, Recruitment and Churn. There were differences in the questions asked based on the types of organization. All themes include questions on KM and KT. For instance, one of the questions that helps to address the Business Model theme is:

To what extent is there a knowledge management system for OHS on your projects to support contractors and their supply chains? What form does it take?

a. How does it work between projects for OHS?
b. How is OHS knowledge transferred to the front-end in planning new projects?
c. How is OHS knowledge transferred to the execution stage for new projects?

All interviews were conducted in the UK, however not all firms are UK owned, and therefore, there is potential for generalization beyond national boundaries. Each interview lasted about 1,5 hours and was recorded. The interview transcripts, interviewers' notes and organizational reports were also examined for the presence of information about

organizational routines related to KT for OHS in and between multiple organizations involved in construction projects. The method used for data analysis was thematic. Thematic analysis used in this research was enhanced by a cognitive mapping technique that allows understanding of interrelationships among the concepts expressed by the respondents. A cognitive map is a two-dimensional directed graph that represents the issue from the perspectives of an interviewee. Cognitive maps have their roots in cognitive psychology and are a visual representation of the dynamic schemes of understanding within the human mind. The theory or personal constructs by Kelly (1955) proposes an understanding of how humans 'make sense of' their world by seeking to manage and control it (Eden, 2004).

Cognitive mapping techniques have gained traction in management science as a tool to stimulate creative thinking and problem solving. They facilitate understanding why a situation is problematic and what can be done about it (Eden, 2004). The map demonstrates inconsistency or contradiction in what individuals say, which can be the reason for perceived complexity of a problem situation. In qualitative research, cognitive maps are used to provide a structural representation of the complexity of a person's thinking (Miles and Huberman, 1994). The technique helps reduce the data to manageable segments and categorize salient concepts without losing the embedded meaning.

The concepts in the nodes are expressed in the interviewees' own language; and the meaning of every concept is contextual. The links between the nodes in the cognitive map represent logical implications between the concepts. According to Eden (2004) the bigger the number of concepts in a map, the more complex is the issue around which the interviews were conducted. The map enables the capture of key statements in a hierarchical

manner, able to demonstrate the implication links among them (Eden and Ackermann, 1998).

The limitation of the tool is that the process of mapping and analysis is time consuming and it is difficult for the person who was not involved in the research process to make sense out of the map. The larger and more complex is the map, the more difficult it is to see how the concepts are interrelated (Miles and Huberman, 1994). However, there are software tools available to enable the researchers deal with the complexity of the maps (e.g. Brightman, 2002). In this paper, the head, domain and centrality analyses of the merged map were conducted to identify the goals and key strategic directions as perceived by the respondents.

The heads of a map, the goal-type statements (desired or not-desired outcomes) are the concepts represented by the nodes that have only arrows going inside. They demonstrate the goals expressed in terms of final ends or effects (Eden and Ackermann, 1998). Domain (Table 2, Appendix) and centrality (Table 3, Appendix) analyses were used to identify the key issues in OHS KT. The nodes with complex domain (high density of links) are considered to be the potential key issues from the perspectives of the interviewees (Eden, 2004). By analyzing only immediate domain of the concept by itself, the wider context of the map is not considered. Centrality analysis (Table 3, Appendix) extends the domain analysis by considering also indirect links. It measures the complexity of the concept's implication chain (the greater the complexity, the more central is the concept), and allows a more accurate view of key issues. Concepts with the highest centrality scores usually strengthen the ideas expressed by concepts with the highest domain score. If a concept appears in both analyses it confirms its position 'at the core of a potential key issue' (Ackermann and Eden, 1998, p. 405). Those concepts, the emergent issues are the heads

of clusters, groups of concepts that are linked together and cover a specific area of the issue (schematic map, Figure 2). The links among the clusters indicate their interrelatedness (dotted arrows, Figure 2). These clusters can become the subjects for a deeper elaboration and are listed in Table 4 in descending order of importance.

4. Results and Analysis

The cognitive mapping technique helped to demonstrate both the complexity of the findings and rigor in the analytical process (Figure 1). It enabled structuring of the shared beliefs of all interviewees regarding KT for OHS. Figure 2 provided a schematic and more simplified map to demonstrate how the analysis and relevance of the findings were derived. The analysis of the map identified emerging issues, that interviewees believed would support achievement of the goal of improving OHS (Node 1, Figure 1). Concepts with the top fifteen highest domain and centrality scores (the key emergent issues) have been reported in the Table 4 (underlined nodes in Figure 1).

1.	Node 2: manage knowledge on OHS
2.	Node 6: design an effective KMS
3.	Node 37: continuously learn from the past incidents
4.	Node 22: cultivate a positive OHS culture
5.	Node 36: cultivate a culture of learning
6.	Node 8: transfer knowledge to execution
7.	Node 44: have a central OHS website
8.	Node 85: [client] learn with the supply chain
9.	Node 35: transfer knowledge on OHS
10.	Node 39: [client] collaborate with supply chain to minimize safety risks
11.	Node 72: move from 'having the right tools' to building a culture that will promote right behaviors
12.	Node 7: transfer knowledge to the front-end
13.	Node 4: ensure consistency in communicating changes in safety practices across all projects
14.	Node 56: help employees be more responsible for their own health and well-being

15.	Node 28: improve line managers' awareness on safety climate in their teams

Table 4. The key emergent issues (in descending order of importance)

The emerging issues from perspectives of the respondents are as follows: 'cultivate a positive OHS culture', 'cultivate a culture of learning' and 'manage knowledge on OHS' (Figure 1 & Table 4, nodes 22, 36 and 2 accordingly) directly contribute to achievement of the goal as perceived by the interviewees.

Overall, the factors that contribute to addressing the key emergent issues to ensure a better OHS performance, as perceived by the respondents, are:

- Clients' understanding of the importance of their role in facilitating collaboration across supply chains
- Transfer of invaluable collective knowledge internally and across the supply chains for effective identification of root causes of any inconsistencies or nonconformities within the OHS management system
- Cultivation and support of a culture that will: a) trigger behavioral change, b) eliminate blame in the corporate culture, and c) learn from not only best practice, but also from the past incidents, near misses and failures and bring about continual improvement.
- Implementation of behavioral change programmes that educate employees on taking responsibility for their own health and safety and wellbeing
- Senior management support and commitment to invest in KM for OHS
- Improved line managers' awareness on safety climate in their teams

- More efficient health and safety system that is aligned with KMS and is designed with consideration of the organizational culture

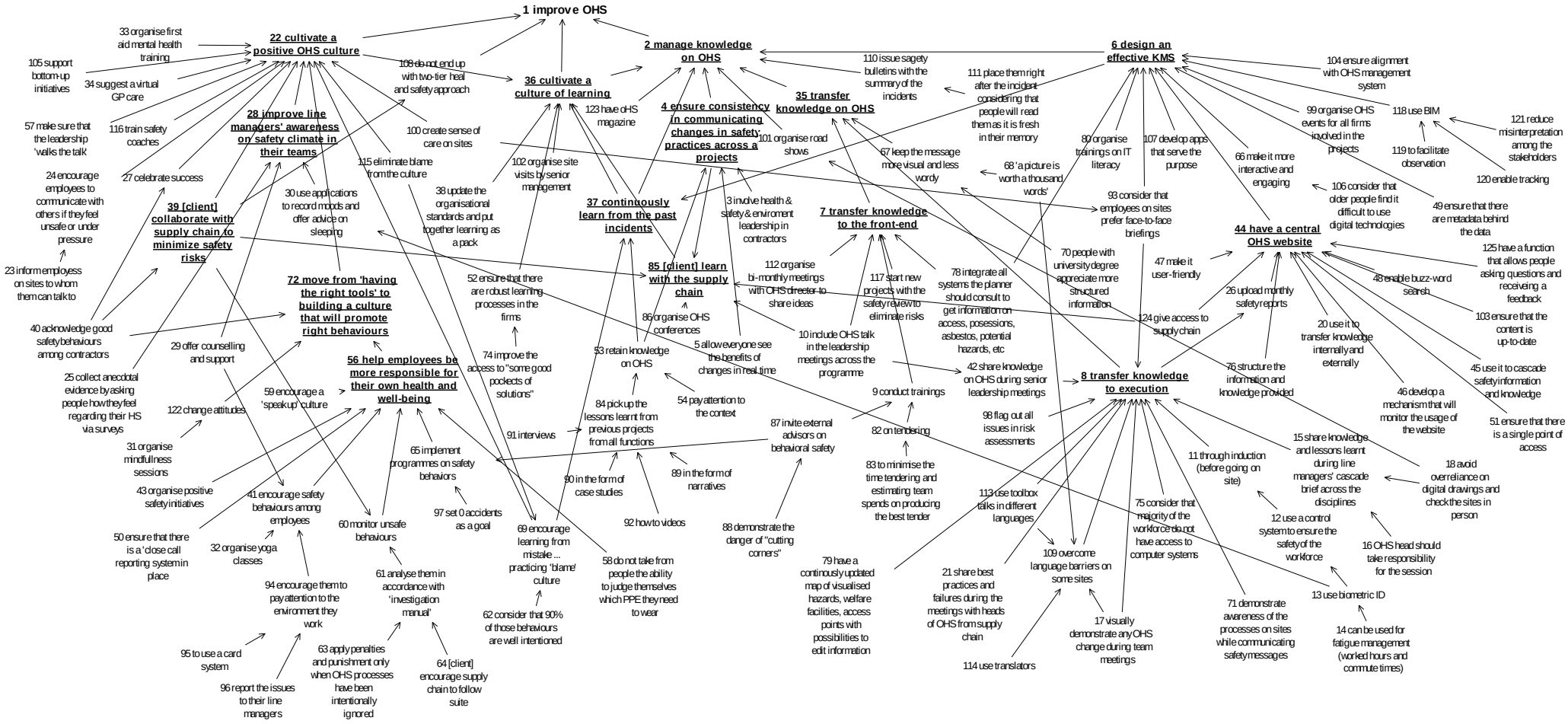

Figure 1 Merged Map (dotted lines represent the links to hidden nodes)

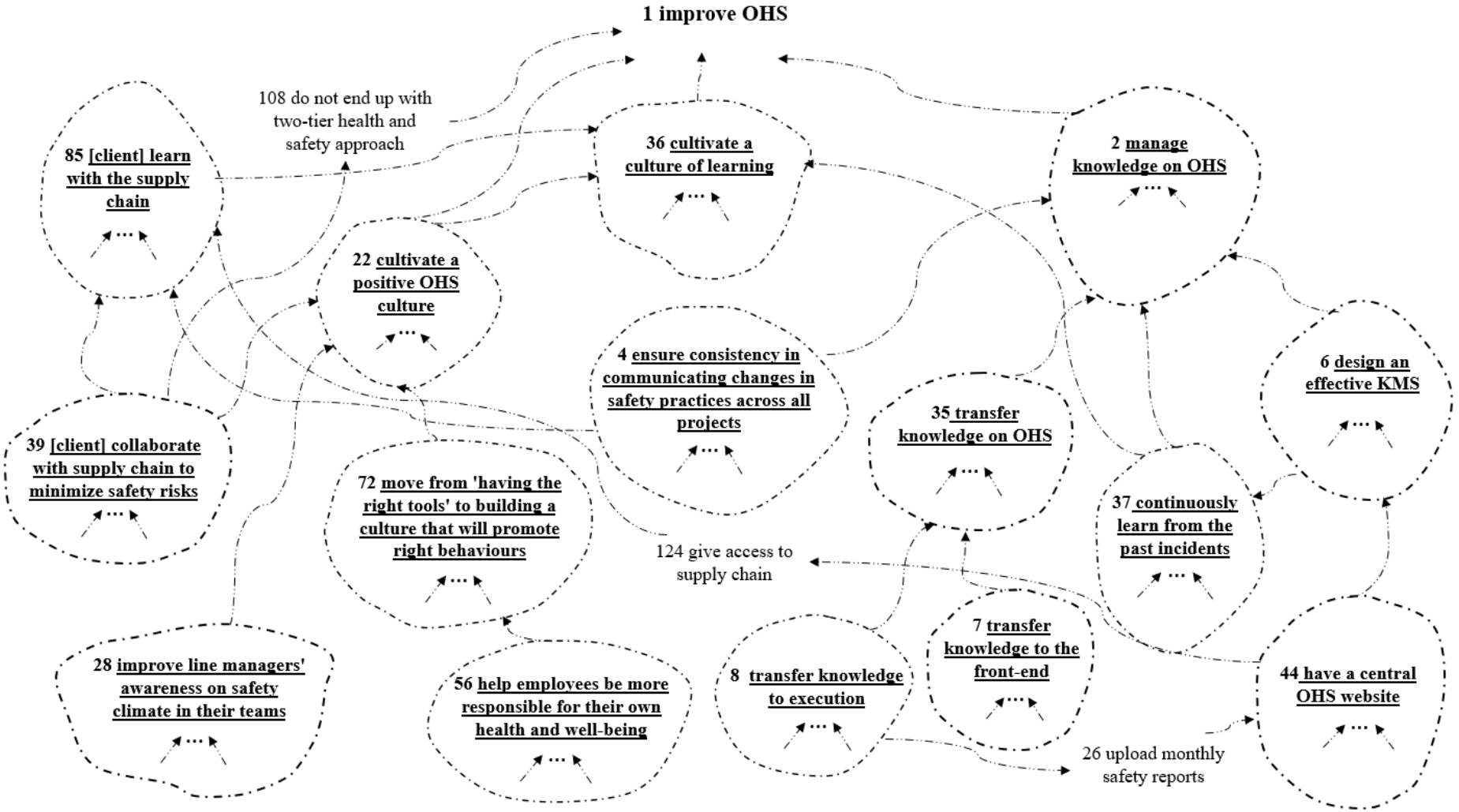

Figure 2 Schematic merged map (dotted lines represent the links to hidden nodes)

4.1 Organizational Culture that promotes H&S behaviors

The data revealed that there is no cultural uniformity in relation to OHS across fragmented construction industry supply chains. There is a lack of an agreed holistic view of OHS, which is often seen as the responsibility of individuals, mainly health and safety specialists. According to the Industry Expert and Chair of a Professional Body, the management of OHS in construction can be in part defined by the size of the construction firms involved. Large firms have stronger OHS approaches, competent health and safety professionals and internal KM systems that, however, are not aligned with OHS systems, which contributes to the differences in KT practice in the back office and at the front-line.

The respondents demonstrated a shared understanding of the importance of a positive culture for better health and safety performance and of its impact on managing knowledge for health and safety (node 2) through the culture of learning (node 36). Overall, respondents working in offices were more engaged in different health and safety improvement activities than people who worked on sites.

An awareness of the cultural differences between contracting organizations emerged during the interviews. The underlying subcultures in construction projects are shaped by professionals who bring with them not only their expertise, but also their culture towards health and safety behaviors (Auch and Smyth, 2010; Walker, 2015). Different subcultures, resources, organizational routines, disciplines and leadership styles, varying priorities and drivers all affect the consistency of implementation of the safety policies and procedures across projects. The larger the firm is the wider the variety of different health and safety practices (Nordlof et al., 2017). This can prevent the development of standardized approaches to OHS and requires an understanding of the informal routines.

Line managers have a big role to play in building trust and encouraging appropriate and aligned attitudes and behaviors in their teams (Dahl and Kongsvik, 2018; Goh et al., 2018; Nesheim and Gressgår, 2014). There was agreement among the interviewees that one of the key elements of a positive OHS culture is line manager's awareness of safety climate within their teams (node 28). The respondents from one of the sub-contractors noted that safety on sites is dependent on the management team working on that specific site, and less so on the company itself. Line managers are the ones who encourage safety behaviors through their own behavior, instructions, counseling and support. They can influence employee's negative intentions through consistent and systematic demonstration of their own commitment to safety (Goh et al., 2018).

Another factor that contributes to cultivation of OHS culture, from perspectives of the respondents, is moving from 'having the right tools to building a culture that will promote right behaviors' (node 72). The managing director of a main contractor (*International Contractor - II*, Table 1, Appendix) believes that to reduce safety risks and to encourage employees' discretionary behaviors, organizations need to invest in behavioral safety programmes. According to the HSE report (2008), it is important to achieve a critical mass of awareness to trigger behavioral change and worker engagement across organizations.

Employees' responsibility for their own health, safety and wellbeing (node 56) was recognized as another key element in ensuring cultivation of a positive OHS culture. Organizations provide training for their employees on sites but there are always people who take risks and ignore health and safety practices. All accidents, particularly severe ones, generally have a substantial element of contributory human behavior as people can make choices that lead to negative consequences. The OHS change programme manager of the infrastructure client organization (*Infrastructure – I*, Table 1, Appendix) argued that

individuals rely on the client organization to ensure their safety. They assume the working site is ‘a safety zone’ as everything is taken care of:

> *I think we have taken away the need to think. We produce all these processes and procedures and rules and do not encourage people to think about their safety and wellbeing. Health and safety and well-being carry behavioral element and we need to ensure that people understand that they are responsible for their lives.*

Behavior-based safety management systems have a considerable impact on improvement of safety performance across the construction industry (Lingard and Rowlinson, 1997). Overall there was a general consensus among the interviewees regarding the need to better understand behavioral factors that affect safety in construction. Positive safety culture is characterized by mutual trust and understanding that helps development of a shared mental model regarding the importance of preventive safety measures (HSC, 1993). Trust plays a crucial role in changing safety behaviors. When people see that they are trusted it encourages them to act responsibly to meet the expectations of the trustees (e.g. Törner and Pousette, 2009). Construction firms need to increase their employees’ ownership for safety by providing OHS training that considers the specifics of the workspace culture and includes tacit knowledge sharing. Storytelling can help in transferring knowledge in a way that is easily understood and remembered.

The OHS manager of the main contractor (*International Contractor - I*, Table 1, Appendix) emphasized the role of the client in shaping safety behaviors:

> *Those clients who take it seriously and take people through behavioral change programmes will succeed.*

Client organizations can set the OHS and also wellbeing tone and ethos across their supply chain by clearly stating their position and expectations to all parties involved. They have the power to undermine or strengthen a culture that will discourage or encourage appropriate health and safety behaviors in their main contractors (Guo, et al., 2015). That may eventually trigger cultural change in subcontractors.

'Blame' (node 115) in corporate culture is another challenge for the organizations that want to improve safety performance. According to the interviewees, 'blame' and 'macho' culture discourage raising concerns regarding fatigue, stress, and other health and safety issues. Some workers may prefer unsafe behaviors to "unmanly or weak" image (Guo et al., p. 136). This is especially dangerous on construction sites considering the limited power over resources and goals construction workers have there (i.e. pursuing intensive working to increase performance related pay and wishing to do an excellent job despite tight deadlines). Fatigued and stressed workers are more likely to have accidents and injuries due to the lack of ability to have a clear judgement on potential safety issues (HSE, 2008; Sherratt et al., 2013; Smyth et al., 2019).

The same OHS manager emphasized the role of the client in reducing or eliminating 'blame' in the culture and mentioned that organizations need to change the attitudes and then relevant safety behaviors will follow. Cultivation of a 'no-blame' culture in organizations is considered as one of the key factors that influence safety behavior on sites (Carrillo, 2013; HSE, 2005; Kamara et al., 2003). However, he posits that a lack of responsible allocation of responsibility and accountability or 'no blame' culture is dangerous as careless behaviors need to be addressed, especially in safety-critical industries like construction:

There is a need to shift from 'no blame' to 'just' culture because if there is no blame, there is no incentive to do things right.

More generally, a 'blame' culture tends to discourage people from reporting incidents and prevents learning from past and current mistakes. In order to develop a learning culture, the organization needs to introduce mechanisms that allow a deeper examination on what exactly has happened and what the issues are. 'Blame' must be replaced by 'accountability' (Jashapara, 2011).

Failures and mistakes occur on a daily basis and in order to develop a just and fair culture, the employees need to be treated with respect. Line managers' tendency to blame workers for accidents does not contribute to identification of root causes of accidents. Organizations need to develop mechanisms that allow a deeper examination of what exactly has happened and what issues were (HSE, 2008) to prevent accidents and injuries. Transfer of tacit knowledge is especially important for identifying root causes of any inconsistencies or nonconformities within OHS providing efficient ways of correcting those failures.

4.2 OHS and Organizational Learning

It was acknowledged by all respondents that a positive health and safety culture, which is a sub-facet of organizational culture, creates a favorable learning environment and supports OHS KM and KT. Noticeably, the concept 'manage knowledge on OHS' has the highest centrality score, which demonstrates consensus among the respondents on the importance of managing knowledge (in the absence of KM system) on health and safety for improvement of OHS performance (Table 4, also see Figure 1).

As demonstrated by the map, cultivation of the culture of learning directly contributes to KM on OHS (nodes 36 & 2, Figures 1&2). To sustain a culture of learning, organizations need to continuously learn from the past incidents (node 37), systematically update organizational standards (node 38), encourage senior managers' visits to construction sites and improve learning and collaboration across the supply chain to minimize safety risks (nodes 39 & 85).

Learning from past incidents is especially difficult in the construction industry, known for 'finger-pointing' behaviours that discourage learning in project teams (Kamara et al., 2003). Organizations prefer learning from success and have little or no tolerance towards mistakes and failures as people prefer not being associated with them (Jashapara, 2011). At the same time, learning from failures and mistakes may challenge existing norms and may "promote greater introspection and analysis of what went wrong" (Jashapara, 2011, p.65). It may encourage people to pay more attention to problems that may have been otherwise overlooked. Dangerous Occurrences, accidents and failures must be reported to HSE under RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations), even when no accident has occurred. The question remains as to whether reporting involves learning as well.

As the CEO of a main contractor (*International Contractor – II, Table 1, Appendix*) mentioned, systematic learning from incidents and near misses is crucial for safety culture in construction organizations. He also emphasized the importance of learning from other industries:

> *If being a mindful organization is what we strive to be, we need to embed the learning in what we do. The aircraft industry is a good example of learning from history.*

Learning and collaboration across supply chains was highlighted by the interviewees as an important contributing factor to developing a positive safety culture. The OHS manager of the infrastructure client (*Infrastructure – I,* Table 1, Appendix) acknowledged that some of its Tier 1 supply chain members have better OHS practices:

> *We organize a sustainability award ceremony for the supply chain. Based on the stories shared during the award, there are best practices to learn from our Tier 1 supply chain.*

However, there is a lack of mechanisms in place to learn from such practices. The other client (*Developer,* Table 1, Appendix) demonstrated better practices in collaboration and mutual learning by initiating regular safety, health and environment leadership team meetings with all contractors at an early stage of portfolio management. Any changes in safety practices, 'near misses' and failures are shared during those meetings. The contractors then take responsibility for cascading knowledge and information acquired in these meetings down to the project levels. Interestingly, the client also invites contractors who no longer work with it to the safety, health and environment meetings. The health and safety and security manager of the same client mentioned:

> *As a client, we recognize that we are in a powerful position where we can set the tone… We have got this chance to change things with our partners… The culture we are trying to build is that we look after each other.*

This implies that safety is certainly not a competitive variable. As the CEO of the main contractor (*International Contractor – II, Table 1*) said:

> *One thing the companies find easy to share information between each other, is health and safety, because they are certainly not giving anything away.*

This aligns with the ethical and moral requirements to minimize harm within any organizational operations, although a more cynical reason for this may be that high rates of injuries, near misses and fatalities in construction could cause more prescriptive industry regulation, which firms would like to avoid.

There was consensus among the interviewees on the leading role clients and main contractors play in shaping safety culture and behaviors and ensuring consistency across Tier 1 and Tier 2 supply chains. An electrical project engineer from one of subcontractors (*M&E*, Table 1) agreed:

> *It is important that a strong main contractor manages the relationships between the contractors and makes sure they do not end up with a two-tier health and safety approach.*

There was also a shared understanding among respondents on the importance of capturing knowledge on safety risks and hazards and transferring it to the project levels (node 35).

4.3 Knowledge Transfer to the front-end and execution stages of new projects

The interviewees talked about the transfer of knowledge on health and safety to the front-end in planning new projects (node 7) and to the execution stage for new projects (node 8). Overall, both the client and the supply chain members lacked coherent systems and procedures for developing KM capabilities at a program level, that is the management layer above the project level in order to transfer knowledge across projects.

Some of the respondents mentioned there is an established practice for safety review at the front-end of new projects to eliminate risks. Bi-monthly meetings with OHS

directors and the leadership meetings across the programme facilitate tacit KT on health and safety. However, this practice is unsystematic and inconsistent across all organizations and projects. As the OHS change programme manager from the client organizations (*Infrastructure – I*, Table 1) stated:

> *Transfer of health and safety lessons learnt is not built in the process of transfer to new projects. Managing programmes and projects here is very structured in terms of methodologies and processes. But there are no mechanisms for learning lessons on health and safety.*

According to the map's structural analysis, there are more consistent KT practices (where they are) during the execution stage of new projects (node 8, Figure 1). OHS knowledge is transferred during senior leadership meetings, during the meetings with heads of OHS from the supply chain, inductions and team meetings managers' cascade the brief across disciplines. The head of health and safety in a client organizations (*Infrastructure – I*, Table 1) stated knowledge is usually transferred in the middle or at the end of the project.

A positive safety culture requires effective top-down, bottom-up and horizontal communication on safety (HSE, 2005). Based on the interviews, the most popular way of cascading new knowledge or information on OHS to the sites, is through morning briefings. Bottom-up KT on health and safety issues on sites occurs through a card system that is further shared with the line manager. Operatives interviewed in one of the main contractors (International Contractor – III, Table 1) were satisfied with the feedback they received on their reports on safety issues. One of them mentioned that all safety and health issues are taken seriously, and the actions follow in a timely manner.

According to the feedback from the client organizations, the main issue with KT on OHS between the project and the firm levels is that the lessons are still in a project-specific silo and there are no mechanisms to transfer lessons across projects.

There was consensus among the interviewees on the importance of KT on changes related to OHS across different subgroups on sites in a timely manner to avoid accidents. H&S, Quality and Environment Manager from one of the main contractors (*International Contractor - III*, Table 1) said:

> *When people are not aware of the changes on time it may affect their health and safety and wellbeing as well. This is the biggest cause of the accidents or other issues. If they are notified on time they feel more secure and it also helps decision making, there is less chance for accidents.*

The CEO of a main contractor (*International Contractor – II, Table 1*) argued tacit knowledge tends to be ignored when it comes to functions. From his point of view, KT across functions cannot be mandated as people may end up with a 'ticking the box' exercise, fulfilling accountability requirements rather than reflecting on the lessons they have learnt. The problem is that freedom of thought is constrained. He posits that encouraging people to talk is more important than establishing an IT system to support communication.

The importance of tacit KT to the projects via people-to-people interaction was also emphasised by one of the OHS managers. He mentioned KMS do not serve the purpose and employees on sites are usually less informed on safety news and changes than in the offices:

'We created knowledge systems, management systems, intranets and communication systems that do not serve the purpose most of the time, because we are not reaching our front-line people, and that support should be targeted for them'

There are other challenges in KT to the execution stage related to language barriers on sites (node 109, Figure 1), most acutely in London. As HSEQ manager in a subcontractor (M&E) mentioned:

Language barrier poses a big issue because it can be very dangerous… There is one interpreter for every five people. The interpreter is often far away on site and they do not speak or even read in English so you may tell them something or correct something that they are doing in English and they will not understand.

According to Hughes and Ferrett (2016, p.72), the employees who have difficulties in understanding English, "may need to make special arrangements, which could include translation, using interpreters or replacing written notices with clearly understood symbols or diagrams". Lack of language proficiency and poor communication in new migrants, may lead to higher rate of occupational injuries. Additional efforts are required to ensure comprehension of health and safety messages by non-native speakers. The interviewees recommended translating the key health and safety messages to all languages used on sites and investing in the design of visual aids (how-to pictures and videos). According to research on health and safety learning in construction industry in Australia (Lingard et al., 2015), the main learning on OHS (know-how), which is difficult to verbalize and transfer via reports and guidelines, comes mainly from observing others.

4.4 Knowledge Management Systems

Investment in better KM and OHS systems in small and medium construction organizations is affected by the transactional approach to managing projects, which inhibits further safety improvements. Based on the responses, there are pockets of consistent practice in transferring information on OHS internally and across supply chain, however, KM systems, where present, were not linked to OHS systems (see also Smyth et al., 2019). Besides, an appropriate system for transferring safety information and knowledge is especially critical in smaller companies because of the lack of OHS competence (e.g. Aaltonen et al., 1996). Lack of time and lack of budget can significantly affect managerial decision making in relation to safety (Drupsteen and Hasle, 2014; Guo, 2015).

There are intranets, databases, websites and newsletters used for cascading explicit knowledge down to the project level. However, there are generic problems related to their structure, one-point access, user-friendliness, ease of search of appropriate information and modification and adjustment of OHS knowledge and information to meet the demands of different target groups. Information and knowledge transfer via Intranet and Internet media is considered to be passive, but it also does allow some forms of tacit knowledge exchange via interactive formats (i.e. video conferencing, online training, how-to videos).

It is also important to consider that the majority of the workforce on construction sites do not have access to the internet as they are not allowed to take their smartphones with them to avoid distractions that may restrict employees' ability to recognize and react to

hazards. Also, some employees do not engage with the IT systems for knowledge transfer.

Another respondent stated people are not able to find any information or knowledge shared online unless they know exactly what they are looking for:

> *There are too many databases with different information that "do not talk to each other". You cannot retain [knowledge] for the sake of retaining, one need to know what is going to be used and when. What one finds to be useful can be completely different to someone else, so the context is the key'.*

According to the respondents from contractors and subcontractors, there are cases when client organizations try to impose safety practices and equipment without investigating the real needs of people working on sites. OHS knowledge and information are needed at every level of organizations, but the type and content may be different. Large organizations have different health and safety information and knowledge needs than small ones. This requires more holistic approach to managing OHS knowledge and alignment between KM and OHS systems.

5. Conclusions and Recommendations

This study contributes to the current understanding of key enablers and inhibitors to KT on OHS across the UK construction organizations. Based on the analysis undertaken here, there is a shared understanding in the industry that knowledge is an important intangible asset that can assist in achieving better and more consistent safety performance. There is also an emphasis on KT through people-to-people communication, considering that some knowledge and experience on safety is context-

specific and is difficult to codify and transfer. Considering uniqueness and complexity of construction projects, organizational learning on OHS cannot be complete if it is based only on generic safety guidelines and regulations. Transfer of tacit knowledge that considers specific work contexts is important for better OHS performance.

The interviews with five types of organization revealed that there is no cultural uniformity in relation to OHS across fragmented construction industry. There are pointers towards less efficient OHS practices in small and medium firms. Large construction firms have stronger OHS approaches and more competent OHS professionals, however, where present, KM and OHS systems are not aligned and OHS lessons are still in project-specific silos. The findings of this research demonstrated that programme management, especially on the client-side, constrained KM on OHS across the supply chain. The client and the supply chain members lacked coherent systems and procedures for developing KM capabilities at a program level in order to ensure KT across projects. Internally, stronger systems between the firm and programme level and site operations are required to overcome variation in the OHS and to align KM and OHS systems.

The typical model for managing OHS in construction is a top-down approach that involves regulating employees' behavior through the enforcement of prescriptive rules and procedures. Top-down views on safety culture do not consider that different cultures may exist in a single organization. It is now generally recognized that the complexity of construction work requires a more holistic approach to OHS management that considers the interaction between the systems, procedures, workspace culture and the people in the organization. Active failures may lead to an accident, however there are less visible failures on the organizational side, more latent weaknesses, that should be given equal

attention to prevent accidents and injuries. The empirical work presented in this paper has been able to reveal the conceptual challenges and practical issues of applying KM and organizational learning principles, including KT. There is no 'one-size-fits all' model for OHS learning, and firms need to develop their own approaches for transferring tacit and explicit knowledge that meet their own organizational needs (Podgórski, 2010; Shereihiy and Karwowski, 2006). Learning from incidents should be embedded in the safety management system (Drupsteen and Hasle, 2014).

OHS culture remains weak and undeveloped within the industry. Besides, the presence of subcultures, hierarchically structured social relations and management by objectives inhibit implementation of a cohesive safety culture in construction firms. Due to the complexity of construction work not only do robust safety management strategies need to be developed, but also collective health and safety norms need to be established to guide people in their daily decision making. Management strategies and actions need to consider the traits of organizational culture that can affect efficiency of formal and informal OHS practices (Aaltonen et al., 1996; Roberts et al., 2012). When OHS strategies are aligned and integrated throughout an organization, they are seen by employees as a core company value. Organizations across supply chains need to engage in collaborative relationships that support KT. Informal structures (i.e. communities of practice) are equally important to understanding the culture of an organization, especially considering that existing subcultures can contribute by bringing different perspectives and views to safety problems. That data revealed that construction supervisors/line managers have a crucial role to play in the supply chain at a site level. They are often the fastest and most efficient channels for KT who can also influence the response to the safety message.

Tacit KT is predominantly a social process and cultivation of a culture of learning strongly depends on the quality of interactions between social actors. Intra- and inter-organizational routines are required to provide a crucial tie between different project-teams and to encourage tacit KT and reuse. For example, monthly meetings reviewing safety incidents need routines to embed the learning into the organization for future transfer.

Most incidents are combinations of organizational, cultural and human factors. Where relevant, the lessons learnt from past failures and incidents should be recorded and shared. An 'open' and blame-free 'positive' safety culture that enables responsible allocation of responsibility and accountability needs to be cultivated to encourage professionals to speak out when they spot risks and be empowered to stop work, if needed. Besides, sometimes workers do not report safety issues that didn't have serious consequences because they do not see that line managers are interested in knowing them (Drupsteen and Hasle, 2014). Within this context, studying examples of the role of CoPs, social networking, storytelling or narratives in improving OHS management can be particularly useful. These routines encourage learning, aid KT and improve practice where effectively implemented, which in turn will reduce near misses and other incidents.

According to HSE report (2006) construction workers tend to believe that accidents happen only to other people. This research demonstrated that there is growing recognition that OHS is not only the responsibility of all, including the management. Project leaders and safety professionals can still serve as a resource to the front-line employees but they should not be perceived as the only people responsible for solving safety issues. Construction firms need to increase their employees' ownership for safety

and sharing stories about the accidents on sites that had a life-changing impact on employees and their families who are going through pain and suffering, can send through a very powerful message and help others recognise their own vulnerability (HSE, 2006). .

Occupational safety can be defined as collective competence that following SLT, or Situated Learning Theory, is inseparable from organizational learning and collective sense-making. SLT theorists recognise the importance of personal experience and culture for learning and KT that involves ongoing reflection about current OHS practices and questioning of commonly held assumptions regarding existing systems and constantly searching 'what can be done better'. Safety practices to be successful need to be based on knowledge-based reasoning. Employees should rely on their own ability to act appropriately when dangers arise, considering that safety practices are context-specific.

Further research is needed to develop a conceptual model that will give a holistic view on the role of knowledge management (KM) and transfer (KT) for better OHS performance across construction supply chains. According to ICE Report (2018) there are industry sectors with well-established mechanisms for learning from failures and near misses. It might be useful to understand how their experience can be applied to a complex and safety-critical construction industry. Another interesting avenue to explore is what the construction industry can learn from other safety-critical industries, such as oil and gas exploration infrastructure and chemical processing plants, regarding cultivation of a learning culture that promotes inter-organizational KT across supply chain and triggers relevant safety behaviours (e.g. Mearns and Yule, 2009; Vinodkumar and Bhasi, 2009).

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Appendix

Type of Organization	Organization	Interviewee Role	Subtotals	Total
Institutional	Gov. and Former Professional Body	Industry Expert and Chair of Professional Body	1	3
	Industry Standards	Health and safety Principal Inspector	1	
		Health and Safety Inspector	1	
Clients	Infrastructure – I	OHS Change Programme Manager	1	8
		H&S Manager	2	
		Senior Procurement Manager	1	
	Infrastructure – II	Head of Commercial	1	
	Developer	Head of H&S	1	
		H&S&S Manager	1	
		Director	1	
Main Contractors	International Contractor - I	National Head of H&S	1	15
		Managing Director, Infrastructure	1	
		Health and Safety and Wellbeing Manager	1	
	International Contractor - II	CEO, UK	1	
	International Contractor - III	CEO	1	
		HSEQ Manager	1	
		Quality Improvement Manager	1	
		HR Manager	1	
		Pre-Construction Director	1	
		Operatives	4	
	International Contractor - IV	H&S Director	2	
		HSEQ Manager	1	
Subcontractors	M&E	HSEQ/Improvement Manager	1	
		Electrical Project Engineer	1	
		Technical Services	2	
		Site Engineer	1	
		Site Operative	1	

	Structural Steel	Group HSE	1	
		H&S/Environment Director	1	
		Commercial Director	1	
		Assoc. Commercial Director	1	
		Operations Director	1	
		H&S Advisor	1	12
Sub-subcontractors	Control Systems	Operative	1	
	Plumbing	Supervisor	1	2
Self-employed	Ventilation	Supervisor	1	1
Other contractors		Site Manager	1	
		Project Manager	1	2
			Interviewee Total	**43**

Table 1. Schedule of Organizations and Interviews

Domain Analysis		
1.	Node 22: cultivate a positive OHS culture	15 links around
2.	Node 8: transfer knowledge to execution	14 links around
3.	Node 6: design an effective KMS	13 links around
4.	Node 44: have a central OHS website	12 links around
5.	Node 2: manage knowledge on OHS	9 links around
6.	Node 36: cultivate a culture of learning	8 links around
7.	Node 56: help employees be more responsible for their own health and well-being	8 links around
8.	Node 7: transfer knowledge to the front-end	6 links around
9.	Node 85: [client] learn with the supply chain	6 links around
10.	Node 4: ensure consistency in communicating changes in safety practices across all projects	5 links around
11.	Node 37: continuously learn from the past incidents	5 links around
12.	Node 39: [client] collaborate with supply chain to minimize safety risks	5 links around
13.	Node 84: pick up the lessons learnt from previous projects from all functions	5 links around
14.	Node 109: overcome language barriers on some sites	5 links around
15.	Node 28: improve line managers' awareness on safety climate in their teams	4 links around
16.	Node 35: transfer knowledge on OHS	4 links around
17.	Node 41: encourage safety behaviours among employees	4 links around
18.	Node 53: retain knowledge on OHS	4 links around
19.	Node 69: encourage learning from mistake ... practicing 'blame' culture	4 links around
20.	Node 72: move from 'having the right tools' to building a culture that will promote right behaviours	4 links around

Table 2. Domain analysis of the map (the top 20 concepts in descending order of value)

Centrality Analysis		
1.	Node 2: manage knowledge on OHS	37from 82 concepts*

2.	Node 6: design an effective KMS	35 from 67 concepts.
3.	Node 37: continuously learn from the past incidents	31 from 71 concepts.
4.	Node 22: cultivate a positive OHS culture	31 from 54 concepts.
5.	Node 36: cultivate a culture of learning	30 from 62 concepts.
6.	Node 8: transfer knowledge to execution	30 from 58 concepts.
7.	Node 93: consider that employees on sites prefer face-to-face briefings	29 from 70 concepts.
8.	Node 44: have a central OHS website	28 from 54 concepts.
9.	Node 85: [client] learn with the supply chain	26 from 60 concepts.
10.	Node 35: transfer knowledge on OHS	26 from 58 concepts.
11.	Node 39: [client] collaborate with supply chain to minimize safety risks	24 from 52 concepts.
12.	Node 100: create sense of care on sites	23 from 58 concepts.
13.	Node 72: move from 'having the right tools' to building a culture that will promote right behaviour	21 from 45 concepts.
14.	Node 26: upload monthly safety reports	21 from 47 concepts.
15.	Node 7: transfer knowledge to the front-end	21 from 49 concepts.
16.	Node 4: ensure consistency in communicating changes in safety practices across all project	21 from 46 concepts.
17.	Node 56: help employees be more responsible for their own health and well-being	20 from 40 concepts.
18.	Node 78: integrate all systems the planner should consult to get information on access, possessions, asbestos, potential hazards, etc	19 from 48 concepts.
19.	Node 124: give access to supply chain	18 from 44 concepts.
20.	Node 28: improve line managers' awareness on safety climate in their teams	18 from 39 concepts.

* for the Node 2 cent score is 37 and the total number of concepts traversed is 82 (max band number is 7)

Table 3. Centrality analysis of the map (the top 20 concepts in descending order of value)