Critical factors for transferring and sharing tacit knowledge within lean and agile construction processes

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Abstract
Purpose – The purpose of the paper is to investigate the critical success factors (CSFs) associated with the effectiveness of transfer and sharing of tacit knowledge in lean and agile construction processes.

Design/methodology/approach – The study identifies ten CSFs that initiate the transferring and sharing of tacit knowledge. The CSFs are validated through quantitative study. This study recruited project managers, executives, consultants and other managers that are directly involved in the management of a construction project. It recruits the respondents those have background and experience from disciplines such as lean construction, agile construction, construction supply chain (CSC) and knowledge management in lean, agile and CSC. The data collected through self-administrative questionnaire are categorised as ordinal data to analyse in SPSS with frequency and Kruskal–Wallis H test, Spearman’s correlation analysis and a rank-order analysis is done to establish the level of importance of those factors.

Findings – Initially, “Trust between construction organisations” is identified as the foremost CSF. Moreover, other CSFs such as motivation, leadership capabilities, business strategies and organisational capabilities follow trust.

Originality/value – This is the first study that investigates and establishes the CSFs that are essential to initiate transferring and sharing tacit knowledge in a lean and in an agile construction processes.

Keywords Knowledge management, Organisational learning, Lean construction, Construction supply chain, Lean and agile construction process, Transferring and sharing tacit knowledge

Paper type Research paper

Introduction
Throughout the twenty-first century, our view regarding knowledge management (KM) Thomas (2013) has drastically changed (Reich et al., 2012). Over the past decade, construction projects have become more demanding in terms of process improvement (Egbru et al., 2005). Therefore, lean and agile processes are greatly considered to improve the efficiency of construction processes (Lin and Tserng, 2003). However, tacit knowledge transfer is neglected (Anumba et al., 2008). Consequently, some problems and challenges
indicated by researchers such as a lack of trust and commitment, a lack of, lack of efficient processes and a lack of standardisation. However, Alashwal et al. (2011) suggest that problems are either dependent or related to each other, such as a disunited supply chain (SC) is linked to the lack of integration and collaboration and insufficient KM systems. Construction supply chains (CSCs) are fragmented due to the lack of process integration and collaboration (Alashwal et al., 2011; Ribeiro and Fernandes, 2010; Hughes et al., 2002; Orange et al., 1994). Nevertheless, Taylor (2012) suggested that an inadequate KM system discourages process integration and collaboration in a CSC. Furthermore, Zhang (2012) suggests that the existing KM systems have failed to transfer and share tacit knowledge. That leads to lessened collaboration, a breakdown in trust between partners and inefficient process integration in CSCs (Hughes et al., 2002).

Even so, today, the UK construction sector, about three million employees jointly makes an immense brain-bank (Saini, 2015). BIS (2011a, 2011b) revealed that skill loss in the UK construction industry has not recovered since 1990’s downturn. The current recession reinforces the skill loss and leads to questioning of the capabilities of the UK construction sector (Baldauf and Hubbard, 2011). Now, the ongoing economic downturn continues to result in the stagnation of the construction industry’s growth in terms of skills, employment, innovation and business capabilities (Lomax et al., 2013). Moreover, construction of small- and medium-sized enterprises (SMEs) has seen the continuous downfall in skill enhancement. Therefore, deficiency in skills establishes itself as a negative efficiency in collaboration within a CSC. Kivrak and Arslan (2008) highlighted that KM brings productive collaboration in CSCs. However, only a handful of studies focused on KM in a CSC. Those studies focus only on KM either in lean or in an agile CSC. None of the studies focused on KM in both the lean and agile processes. Ribeiro and Fernandes (2010) expressed that joint application of lean and agile principles brings iterative development with a strong emphasis on SC partners in terms of skill advancement.

Still, the notion of transferring and sharing tacit knowledge in construction processes proceeded informally over the past decade. There is little empirical research within this area, especially in the context of KM in lean and agile processes. Transferring and sharing tacit knowledge is considered a critical task for managers involved in construction projects (Arif et al., 2015). That is because of the lack of understanding of how-to approach (to drive knowledge sharing) and the factors that drive the success of transferring and sharing tacit knowledge. A reason of that is the fragmented nature of construction industry and its low productivity (Xue et al., 2007), which remains characterised by adversarial practices and disjointed SC relationships (Briscoe and Dainty, 2005). The fragmentation process in traditional contracting practice further hinders the integration of construction knowledge among contractors (Nasrun et al., 2014).

The framework agreement (2011) set the growth objectives of construction sector but emphasised that these could only be achieved while sharing knowledge and acquiring skills. Vinodh et al. (2009) said, the construction industry requires an integrated approach to implementing lean and/or agile in a construction process. However, implementing lean and agile requires knowledge sharing approach. But lack of awareness and understanding of KM frameworks, specifically the transferring and sharing tacit knowledge remains a problem. Therefore, the lean and agile implementation within the construction processes is underperforming. One of the reasons for underperformance is that Tier 1 is forcing the lean implementation to Tiers 2 and 3 of a CSC (Aziz et al., 2016). The other reason is the unrealistic effort of implementing lean and agile on construction projects as a whole instead of process levels. Therefore, there is a lack of KC is performed at process levels. Resultant, 99 per cent of construction knowledge stays within the mind of people (Egbu et al., 2005).
Underpinning theories of lean (Sacks et al., 2009; Womack and Jones, 2003; Womack et al., 1990) and agile implementation (Abbas et al., 2008; Christopher and Towill, 2001; Owen and Koskela, 2006) suggests that both concepts work better if implemented for tiny advancements at process levels of a project. Therefore, it is important to study the transfer and sharing of tacit knowledge at construction process levels instead of project levels. This study sets out to define the critical factors that drive the transfer and sharing tacit knowledge in lean and agile construction processes.

**Lean and agile in construction**

Lean and agile are often described as two distinct manufacturing paradigms (Krishnamurthy and Yauch, 2007). In this context, lean as a principle is to add value to a construction process while relentlessly ruling out waste from each of the tasks within the current, following and related activities. On the contrary, agile as a principle add responsiveness to the current, following and related activities of a task and, in addition, increase responsiveness to the chain of processes. The basic understanding of agility defines the development of concepts and frameworks. In contrast, agility is used to “react” (Bredillet, 2013) and also to “act”. The meaning of agility depends on the context and relates to the role through a process (Saini, 2015). The term “react” is responding to the change and “act” is viewed as a decision-making framework.

Agility is often mixed up with flexibility as the definition of flexibility is similar to agility. Both are understood as “the ability to adapt to change”. However, there is a fundamental difference between agility and flexibility. In comparison, flexibility stands for one-off changes, and agility is a concept for continual change (Marc Werfs, 2013). That is why there are many definitions of agility exist. Some researchers view agility as philosophy. Alistair Cockburn’s defines “Agile implies being effective and manoeuvrable”. That means the agile process is the light enough to stays manoeuvrable and adequate enough to remain in the game (Abbas et al., 2008). Boehm (1988) gives a more practice-oriented definition:

> Agile methods are very lightweight processes that employ short loop cycles; actively involve users to establish, prioritise, and verify requirements; and rely on tacit knowledge within a team contrary to documentation (Abbas et al., 2008).

On the other side, the lean manufacturing system is often presumed as a mass production that cannot easily adapt to changing market conditions (Court et al., 2009). The agile paradigm is leant towards customisation and responsiveness to customer demand. Combining and integrating lean and agile principles have proven successful under uncertain conditions such as to increase customer satisfaction and decrease time and cost to market (Rahimnia and Moghadasian, 2010). The key characteristics of lean and agile methods are lean, flexibility and highly iterative development with a strong emphasis on stakeholder involvement (Ribeiro and Fernandes, 2010). However, lean and agile principles may be complementary to join one system to another, for instance, integrating lean manufacturing and agile SC. The adoption of “lean” and/or “agile” in construction processes is often known as the “lean and/or agile” construction process (Court et al., 2009). This combined approach contains the principles of lean and agile processes. Krishnamurthy and Yauch (2007) concluded that adopting both lean and agile principles in construction production process could be beneficial.

The benefits of integration of lean and agile within construction processes are for level schedule and to open up to opportunities to drive down costs. Separating the choice of either lean or agile process is presented through its attributes (Christopher and Towill, 2001) in Table I below. Selecting these attributes drives the choice of lean or agile process.
The attributes (Table 1) of lean and agile processes are adopted by the industries such as automobile, computing and clothing industries have benefitted from lean and agile SCs (Naylor et al., 1999). However, adopting just lean or agile principles as separate functions do not solve the existing problems such as a lack of integration, collaboration and partnering in SCs (Saini, 2015). This is because, lean principles are widely considered to reduce waste and lead-time in an SC (Sacks et al., 2009). On the other side, agile principles are merely considered as being more responsive to unpredictable demand and markets. Therefore, lean and agile principles require the collaboration of the stakeholders in any organisation (Owen and Koskela, 2006). In reality, implementing both the lean and agile processes produces better results (Christopher and Towill, 2001). Because a construction site is a combination of fabrication and assembly, then a building site should be considered as a manufacturing site that adopts lean and agile principles (Taylor, 2012; BIS, 2011a). Accounting above arguments, to bring efficiency in a CSC, both lean and agile should be implemented.

**Implementation of lean and agile in a construction supply chains**

In a recent study by BIS (2013), the CSC structure has a minimum of 50 to 70 (Tier 2) suppliers and sub-contractors. A CSC has a different level of vendors that are often categorised as Tier 1 (main contractors with a direct commercial relationship with clients), Tier 2 (sub-contractors with a direct contract with main contractors) and Tier 3 and beyond (sub-contractors and suppliers working for sub-contractors) (BIS, 2013).

Moreover, a CSC process mapping may be characterised by five main divisions: mega process, major process, sub-process, activity and task (Capgemini, 2004). A mega process is the top level of processes identified by an organisation (Figure 1). It is a combination of several major processes (Capgemini, 2004) that forms a core value chain for an organisation. It is a sub-division of a mega process and is a combination of several sub-processes. Furthermore, a sub-process is a compound of various activities. Moreover, an activity is a unit of work performed at one time with one mode of operation. An activity may have several work steps. Each work-step carried out to complete an activity is a task.

Lean is geared to improve the construction process and to develop innovative and sustainable construction (Sacks et al., 2009; Khalfan et al., 2007). Acquiring benefits of lean management, need implementing lean principles within the entire construction project and within the organisations involved in the project (Saini, 2015). Below Figure 1 is an outcome of the literature on lean and agile construction processes. This presents the implication of lean and agile within one mega construction process and its process levels. Organisations handling lean and agile construction projects must implement the lean and agile principles

<table>
<thead>
<tr>
<th>Attributes products/services</th>
<th>Lean</th>
<th>Agile</th>
</tr>
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<tbody>
<tr>
<td>Typicality</td>
<td>Commodities</td>
<td>Fashion</td>
</tr>
<tr>
<td>Demand</td>
<td>Predictable</td>
<td>Volatile</td>
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<tr>
<td>Variety</td>
<td>Low</td>
<td>High</td>
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<tr>
<td>Lifecycle</td>
<td>Long</td>
<td>Short</td>
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<tr>
<td>Customer drivers</td>
<td>Cost</td>
<td>Availability</td>
</tr>
<tr>
<td>Profit margin</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Contracts</td>
<td>Long-term</td>
<td>Immediate, short-term</td>
</tr>
<tr>
<td>Procurement policy</td>
<td>Material sourcing</td>
<td>Capacity Sourcing</td>
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<tr>
<td>Information enrichment</td>
<td>Highly desirable</td>
<td>Obligatory</td>
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<tr>
<td>Forecasting mechanism</td>
<td>Algorithmic</td>
<td>Consultative</td>
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<tr>
<td>Dominant cost</td>
<td>Physical cost</td>
<td>Marketability cost</td>
</tr>
</tbody>
</table>

**Table I.** Attributes for choosing lean or agile process

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Lean and agile construction processes

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on each aforementioned division (Saini, 2015; Capgemini, 2004) of an SC. Failure to use these principles leads to non-achievement of the project objectives, as all the SC processes are interconnected (Saini, 2015).

**Tacit knowledge concepts**

Tacit knowledge triggers unfold and combine through the interaction of mental and physical worlds. Tacit knowledge develops soon as a human being senses, visualise experience or observes a series of activities (Pathirage, 2007). Tacit knowledge is changing and updating with time and experiences of a source (Polanyi, 2009):

> Tacit knowledge is an embedded series of folded thoughts and point of views in a human’s mind, which are gained over the time by experience, learning, sensing, analysing, witnessing and observing a process or series of processes within the physical world (Saini, 2015).

Western philosophers have generally agreed that knowledge is “justified true belief” (Maier, 2007; Schwartz, 2006; McLean, 2004). Plato said, knowledge sensed by the eyes, the ears and from the whole body while interacting with the physical world (Markie, 2004). However, Aristotle criticised the fact that the knowledge of forms is always occasioned by sensory perception (Maier, 2007). The explicit and tacit knowledge are two fundamental dynamics that create knowledge. Individual acts as a principal agent who possesses and processes knowledge. Individual, group and organisational knowledge are three levels of knowledge creation.

Knowledge as an asset, the theory is ignored by most organisations. Those organisations still lack strategies and methods for managing knowledge (Thomas, 2013). Even by the mid-1980s, the importance of knowledge as a competitive asset was apparent. Tiwana (1999) said that Drucker warns that exploiting universally available knowledge is the only advantage left for organisations. Drucker describes knowledge as “the window of opportunity”. The 1980s also saw the development of systems for managing knowledge that relies on work done in artificial intelligence (Reimer and Karagiannis, 2008). However, expert systems, providing such concepts as “knowledge acquisition” (Issa and Haddad, 2008), “knowledge engineering” (Reimer and Karagiannis, 2008), “knowledge-based systems” (Arif et al., 2015) and computer-based ontologies (Thomas, 2013)
However, KM in the built environment mainly deals with the process of creating value from construction operations (Kivrak and Arslan, 2008). Valuable knowledge is available in different forms and media, such as brilliant ideas of experts, in operation procedures, reporting documents, databases and intranets. KM in the construction processes aims at efficiently and systematically collecting and sharing the experience and knowledge through web-based and intranet technologies (Chen and Zhang, 2014). This leads to reuse of information that minimises the time and cost of problem-solving and improves process quality during the construction phase of a construction project (Anumba et al., 2008). By sharing tacit knowledge, the same problems in the construction process do not need to be repeatedly solved (Kivrak and Arslan, 2008). However, a number of studies (presented in below Table II) originated different frameworks of KM and KC in construction processes. This study conducts a critical analysis to understand the relevance of those frameworks to transfer and share tacit knowledge in a construction process.

**Tacit knowledge within construction processes**
Below Table II presents the total numbers of studies those are relevant to the theme (transferring and sharing tacit knowledge) of this research. The relevance of this table is to

<table>
<thead>
<tr>
<th>Year</th>
<th>Study title</th>
<th>Author</th>
</tr>
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<tbody>
<tr>
<td>2015</td>
<td>Understanding knowledge sharing in Jordanian construction industry</td>
<td>Arii et al. (2015)</td>
</tr>
<tr>
<td>2011</td>
<td>A knowledge chain framework for CSCs</td>
<td>Konukcu (2011)</td>
</tr>
<tr>
<td>2011</td>
<td>A measurement framework for knowledge transfer in e-learning environment</td>
<td>Abdullah et al. (2011)</td>
</tr>
<tr>
<td>2011</td>
<td>Antecedents and consequences of inter-organisational knowledge transfer</td>
<td>Martinkenaite (2011)</td>
</tr>
<tr>
<td>2009</td>
<td>Analysis framework for the interaction between lean construction and building information modelling</td>
<td>Sacks et al. (2009)</td>
</tr>
<tr>
<td>2008</td>
<td>Knowledge transfer in developed-developing country interfirm collaboration – a conceptual framework</td>
<td>Narteh (2008)</td>
</tr>
<tr>
<td>2008</td>
<td>The interaction effects of lean production manufacturing practices, compensation and information systems on production costs: a recursive partitioning model</td>
<td>Koh et al. (2008)</td>
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<tr>
<td>2006</td>
<td>Knowledge Integration – a practice of knowledge management in small and medium enterprises</td>
<td>Jetter et al. (2006)</td>
</tr>
<tr>
<td>2006</td>
<td>Knowledge portal for addressing corporate sustainability issue: a conceptual framework</td>
<td>Renukappa et al. (2006)</td>
</tr>
<tr>
<td>2005</td>
<td>An agent-based framework for supply chain coordination in construction</td>
<td>Xue et al. (2005)</td>
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Table II. List of existing studies
interpret the inclusion and exclusion criteria of the most relevant studies in the field of transferring and sharing tacit knowledge in construction. However, most studies have only focused on effectively managing knowledge transfer and sharing within an organisation. Many of the studies listed below in Table II fail to quantify the CSFs to transfer and share tacit knowledge. Moreover, none of the study attempts to establish the CSFs specifically in construction projects and within the lean and agile construction processes. However, a few studies closely match with this study are by Arif et al. (2015), Martinkenaite (2011), Narteh (2008), Bou-Llusar and Segarra-Ciprés (2006), Lin and Tserng (2003) and Goh (2002). This study reviews those frameworks to understand the CSFs of tacit knowledge transfer and sharing in lean and agile construction processes.

Knowledge sharing in Jordanian construction industry. Arif et al. (2015) divided 14 factors into three main factors (trust, management and communication) of knowledge sharing in Jordanian construction industry. This study concludes, “Trust” as the most important factor for knowledge sharing. However, this study is limited to Jordanian construction and inter-organisational knowledge sharing, and there is no empirical basis for generalising.

An integrative framework. Goh (2002) emphasised that one means of driving information transferring and sharing is to encourage a problem-seeking and problem-solving culture within an organisation (Wong, 2005; Coakes and Clarke, 2005). Leadership, high trust and collaboration among employees are the three essential factors that influence problem seeking and solving. However, that framework is focused on the information sharing within an organisation. Goh’s study also establishes the organisational learning and knowledge transfer capabilities are essential for effective knowledge communication. This establishes that choice of knowledge recipient and identification of the type of knowledge to transfer are important factors underlying the knowledge transfer (Goh, 2002).

Project-oriented knowledge management framework in lean construction. Lin and Tserng (2003) presented that explicit knowledge is embedded within the project that comes from the activities. On the other hand, tacit knowledge is considered as non-activity and non-project knowledge. However, this rejects tacit knowledge should be developed within the activities within a process.

Construction supply chains for implementing knowledge management. Wong (2005) proposes 11 CSFs for implementing KM in SMEs. Those include leadership, motivation, business strategies, process and training of employees. However, this study fails to acknowledge the level of importance of each CSF. The main weakness of this study is the low number of respondents and only provides a preliminary indication of the appropriateness of these CSFs to implement KM in SMEs.

The framework of knowledge transfer. Narteh (2008) focuses on knowledge transfer within the inter-firm collaborations and especially within organisations based in developed or developing countries. Narteh’s framework claims to provide an in-depth discernment of the attributes of knowledge transferors and knowledge transferees. Additionally, this framework presents how knowledge transfer across firm’s border is influenced. In this, the framework identifies and suggests that organisationally embedded knowledge and cognitively or person embedded knowledge are the two original type of knowledge.

The framework of inter-organisational knowledge transfer. Martinkenaite (2011) emphasises that knowledge attributes, organisational attributes and inter-organisational dynamics are the enablers of inter-organisational knowledge transfer. These enablers of knowledge transfer are the valuable inputs that create the new knowledge. It claims that the further outcomes are the consequences of the inter-organisational knowledge transfer.
In conclusion of studies presented in Table III, this study identifies the main critical factors for transferring and sharing knowledge and KM are leadership, business strategies, trust, motivation, training and development of employees. The identified CSFs associated with KS in CSCs are given below.

**Discussion of critical success factors**

**Trust between organisation within a construction supply chain**

Trust as a critical success factor (CSF) leading the success or failure of construction projects is highlighted in both Egan (1998) and Latham (1998) reports. There are many definitions of trust based on the assumptions and based on the knowledge of the author. Trust increases order by reducing complexity (Weber et al., 2005). Trust is built upon the expectations that people have for others or themselves. McDermott et al. (2005) said, trust is the willingness to rely on the actions of others and being dependent and compromising to their actions. Later, Khalfan et al.’s (2007) research, entitled “Building trust in construction projects”, revealed three main factors of trust as honest communication (Arif et al., 2015), reliance and delivery of outcomes. Furthermore, Khalfan et al. (2007) said, people need to be open, willing to share knowledge to effectively transfer and share knowledge.

<table>
<thead>
<tr>
<th>Critical success factor</th>
<th>Supported reading</th>
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<tbody>
<tr>
<td>1 Trust between the organisations within a CSC</td>
<td>Arii et al. (2015), Lau and Rowlinson (2011), Lau and Rowlinson (2010), Khalfan et al. (2007), McDermott et al. (2005), Weber and Carter (1998)</td>
</tr>
<tr>
<td>5 Organisations within a CSC must have capabilities to share tacit knowledge</td>
<td>Manataki (2007), Schwartz (2005), Goh (2002), Tiwana (1999), Yusuf et al. (1999), Saad (1999), Orange et al. (1994)</td>
</tr>
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valuable information, being honest to reflect the real situation. Trust could only exist if this type of communication existed (Arif et al., 2015).

The study of Khalfan et al. (2007), Lau and Rowlinson (2011) and Ceric (2012) all mentioned the different levels of trust, e.g. inter-firm, intra-firm and interpersonal levels (Ceric, 2012) and strategic, multi-project, project and task level (Khalfan et al., 2007). This reveals that effective communication is required at all levels to drive trust in CSCs.

Weber et al. (2005) emphasised that face-to-face communication plays a major role in initiating trust and that leads to collaboration in an interpersonal relationship (Arif et al., 2015).

Motivation
Nonaka and Takuchi (1994) said that breaking down hierarchies in an organisation enables knowledge transfer. Studies such as Arif et al. (2015), Wong (2005) and Goh (2002) considers the motivation and the reward system are the factors that support and encourage knowledge transfer. Goh (2002) emphasised the qualities and capabilities of the recipients, and the characteristics of the knowledge source depend on motivation. Arif et al. (2015) and Goh (2002) also emphasised that poor transfer of knowledge is the result of lack of motivation, absorptive capacity and retentive capacity of a knowledge recipient.

Sharing and transfer of tacit knowledge requires “trust” between the individuals and organisations within the CSCs (Arif et al., 2015). The correlation between trust and motivation could be significant at the individual level but not at the organisational level, as the person’s motivation drives the exchange of information with trusted parties, (Weber et al., 2005). Ceric (2012) demonstrated that trust in construction is not driven by incentives. However, Weber et al. (2005) said that, to a greater extent, motivation and interests or own dependence drives the trusting-acts.

Leadership capabilities
Leadership support is an essential factor for the approach to building trust in construction (Khalfan et al., 2007). Moreover, senior management of construction organisations felt that policies to pursue trust should be driven from director’s level. Director’s level means the leadership and the role of leaders are essential to initiate sharing and transferring of knowledge. Because Egan (1998) reported that committed leadership is required to drive forward an agenda for improvement. Later, Anumba et al. (2008) said that knowledge sharing demands building trust through leadership. They also said that knowledge leadership is vital for the construction industry. They concluded that KM initiative in construction required compelling vision, leadership, coherent strategies and structures along with respect for people and the trust (Anumba et al., 2008).

Business strategies
The broad use of term “business strategies” can be equated with the development of a compelling and shared view of KM (Wong, 2005). Business strategies establish pre-implementation success factors of trust initiatives in interpersonal relationship and leadership (Khalfan et al., 2007; Arif et al., 2015; Wong, 2005). Business strategies must be aligned at inter-organisational level (Arif et al., 2015). This also requires the capacity building of the organisations and individuals to deliver and innovate (Al-Hawamdeh, 2002) trust to transfer and share knowledge among them. Wong (2005) stated that to drive the success of KM, clear and well-planned business strategies are required. However, Thomas (2013) argues that organisations still lack strategies to manage knowledge. Well-planned
KM strategies are essential to drive knowledge communication, trust and motivation and to build individual capability.

**Organisational capabilities**
Organisational maturity includes knowledge sharing in a construction process (Tiwana, 1999). Despite the identified importance, only a few studies have been initiated to examine the impact, maturity and importance of organisational capability (Keraminiyage, 2009) in construction processes. Organisational capability is a core competency that drives corporate wide learning processes and integrates diverse skills of people and streams of technologies (Yusuf et al., 1999).

**Individual capabilities**
Tacit knowledge comes from people and is hard to articulate (Polanyi, 2009). It is important to motivate and train individuals with the skills that develop communication at the interpersonal, inter-firm and intra-firm levels (Arif et al., 2015; Lau and Rowlinson, 2010). Individuals play a vital role in knowledge sharing with a construction process. The individual capability is connected to the ability of the person to share personal knowledge. Personal knowledge is the first form of knowledge by having information about someone or something (Kivrak and Arslan, 2008). Sharing personal knowledge leads to the development of procedural and propositional knowledge of a process (Polanyi, 2009). However, in the construction process, it is important to identify what type of tacit knowledge is to be shared (Saini, 2015; Rao 2012).

**Identification of process improvement opportunity**
Identifying a process improvement opportunity is a critical factor for a construction process. A process improvement opportunity should be aligned to key performance indicators (KPIs) of construction projects (Kagioglou and Cooper, 2012). Those KPI’s could include efficiency, financial performance and operational performance of a construction process (Maier, 2007). Until the construction managers know which processes need improvement, identifying the type of knowledge is specious (Alavi, 1999). Thus, to share knowledge in construction projects a process based view is required (Wong, 2005).

**Identification of type of knowledge to share**
As Polanyi (2012) stated, personal knowledge develops by being familiar with someone or something through the human senses. The human senses play a significant role in the development of personal knowledge (Polanyi, 2012; Pathirage, 2007), for example, someone does not know what “hot” is until it is sensed. Personal knowledge involves some propositional knowledge (Anumba et al., 2008).

Secondly, procedural knowledge is the second kind of knowledge, the knowledge of “how to do” something (Alavi and Leidner, 2001). Procedural knowledge evidently differs from propositional knowledge. For example, it is possible for someone to know what a computer and its components are but may not know the functionality of a computer. Using a computer involves processing the skills, which is different from just knowing a collection of facts.

Finally, propositional knowledge is the third form of knowledge and is the primary concern of philosophers. While defining facts behind an action both personal and procedural knowledge involves some propositional knowledge (Saini, 2015). However, Aarons (2005) argued that propositional knowledge itself do not provide either personal knowledge or procedural knowledge.
Identification of source of knowledge

Improving a construction process requires a context-specific knowledge from a source. The “source of knowledge” is cognitive/individually embedded tacit knowledge (Saini, 2015). The knowledge transfer framework (Narteh, 2008) emphasises the relationship factors when selecting partners is trust and interaction. The transfer processes that deal with the actual movement of knowledge are knowledge conversion (Konukcu, 2011), knowledge routing (Fischer, 2013), knowledge dissemination (Coakes and Clarke, 2005) and knowledge application.

Identification of recipient of knowledge

Capturing the tacit knowledge from a knowledge source, a “knowledge recipient” need the observation, absorptive, conversational, application, routing and explanation and dissemination capability (Goh, 2002). At the same time, these capabilities are equally important for the source of knowledge (Saini, 2015). However, this study suggests that the main source of knowledge should at least hold observational, communication and explanation capability. This is to observe (task and activities), articulate (new knowledge), communicate and explain new tacit knowledge to the recipient. A recipient needs explanation capability (Ishibuchi et al, 2009) as on the next stage of knowledge sharing, the recipient acts as the source of knowledge that requires explanation capability to transfer or share knowledge further in a construction process.

Methodology

Ten CSF’s have been identified in this review. The study adopts a systematic research methodology to investigate those CSFs through quantitative data analysis. As aforementioned, this research aims to investigate the CSFs associated with the effectiveness of transfer and sharing of tacit knowledge in lean and agile construction processes. The investigation demands the ontological grounds as this research is based on the personal knowledge that originates from the mental world (tacit knowledge). Similarly, an inquiry into construction processes (procedural knowledge) demands the investigation of personal knowledge to validate the main findings originated from the literature review.

The ontological stance of this research is leant towards constructivism because the understanding of the real world (in CSCs and lean and agile processes) changes in each organisation and the knowledge are constructed socially over the time. The other reason of choosing constructivism is that there can be multiple realities and have different schools of thoughts on each terminology of knowledge, CSC and lean and agile processes. Therefore, the ontological assumption for this study is constructivist that would authenticate multiple realities. Knowledge generated from interpretivist paradigm comprehends as socially constructed and subjective interpretations (Greener, 2008; Creswell, 2013). Therefore, this study considers interpretivist assumptions to test the hypothesis (Table IV) developed from main findings of CSFs through quantitative data.

This study collects the data through a survey questionnaire to understand the personal and procedural knowledge of respondents. This study captures personal and procedural knowledge of transferring and sharing tacit knowledge, lean processes and agile process within a CSC. Therefore, below facts are considered for recruiting the respondents.

A typical CSC consists three tiers (1, 2 and 3) (BIS, 2013). In this study, Tier 1 is termed for main contractors those have a first-hand commercial relationship with the client. Sub-contractors are termed Tier 2 suppliers those have a direct contract with the main contractor (Tier 1). Sub-contractors are termed Tier 3, those that have a direct relationship with Tier 2 and in some cases with Tier 1. Tier 3 sub-contractors also use other suppliers and other
sub-contractors. Therefore, many cases of construction delivery there is possible involvement of a fourth or even Tier 5. However, this study only focuses up to the Tier 2 level because of below facts with the connection to research objectives:

- This study concentrates on the CSFs of KC in a CSC and in the lean and agile construction process. Therefore, this study requires that respondents should have the knowledge and/or understanding of all four disciplines (KM, lean, agile and CSC process). This restricts the study to employ respondents who are directly involved in the KM, lean, agile and SC processes, which falls within Tiers 1 and 2 of CSCs.

- In construction, SC members beyond Tier 2 normally are not involved in implementing lean and/or agile within a construction process (Aziz et al., 2016). Beyond Tier 2 the manufacturers and suppliers are direct SC of Tier 2 suppliers those are never involved as direct stakeholders of a construction project (BIS, 2013).

- A report from BIS (2013) reveals only project managers, main contractors and the sub-contractors are the organisations and individuals who are directly involved in planning and execution of the construction process.

<table>
<thead>
<tr>
<th>Main question</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the level of criticality of success factors associated with the effectiveness of transferring and sharing tacit knowledge (a) in lean process (b) in agile processes?</td>
<td>The level of criticality of success factors associated with the effectiveness of transferring and sharing tacit knowledge (a) in lean process (b) in agile processes is high</td>
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<table>
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<th>Likert scale</th>
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<th>Data analysis technique/s</th>
</tr>
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<tr>
<td>Not critical</td>
<td>Ordinal</td>
<td>Reliability, frequencies, Kruskal–Wallis H test, Spearman’s correlation</td>
</tr>
<tr>
<td>Of little critical</td>
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<td></td>
</tr>
<tr>
<td>Moderately critical</td>
<td></td>
<td></td>
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<tr>
<td>Critical</td>
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<tr>
<td>Very critical</td>
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<table>
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<tr>
<th>Ranking 1 2 3 4 5</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trust between organisations in the CSC is highly critical success factor to transfer and share tacit knowledge (a) in lean process (b) in agile processes</td>
</tr>
<tr>
<td>2</td>
<td>Motivation in the CSC is highly critical success factor to transfer and share tacit (a) in lean process (b) in agile processes</td>
</tr>
<tr>
<td>3</td>
<td>Leadership capabilities of clients and main contractors is highly critical success factor to transfer and share tacit knowledge (a) in lean process (b) in agile processes</td>
</tr>
<tr>
<td>4</td>
<td>Business strategies are highly critical success factor aligned to transfer and share tacit knowledge (a) in lean process (b) in agile processes</td>
</tr>
<tr>
<td>5</td>
<td>Organisational capabilities are a highly critical success factor to transfer and share tacit knowledge (a) in lean process (b) in agile processes</td>
</tr>
<tr>
<td>6</td>
<td>Individual capability is highly critical success factor in (a) in lean process (b) in agile processes</td>
</tr>
<tr>
<td>7</td>
<td>It is highly critical that construction managers must identify the process improvement opportunity to transfer and share tacit knowledge (a) in lean process (b) in agile processes</td>
</tr>
<tr>
<td>8</td>
<td>Identification of type of tacit knowledge to transfer and share tacit knowledge (a) in lean process (b) in agile processes is a highly critical success factor</td>
</tr>
<tr>
<td>9</td>
<td>Identification of source of knowledge to transfer and share tacit knowledge (a) in lean process (b) in agile processes is a highly critical success factor</td>
</tr>
<tr>
<td>10</td>
<td>Identification of knowledge recipient to transfer and share tacit knowledge (a) in lean process (b) in agile processes is highly critical success factor</td>
</tr>
</tbody>
</table>

Lean and agile construction processes

Table IV. Question design and data analysis techniques
Due to the fragmented nature of construction industry and lack of skills and knowledge of aforementioned disciplines in Tier 3 contractors, manufacturers and raw material suppliers also restrict this study to employ respondents below the SC level named Tier 2.

Resultant this study recruited project managers, executives, consultants and other managers that are directly involved in every stage of managing a construction project. However, to fit the purpose of this research, the respondents should have background and experience in disciplines such as lean construction, agile construction, CSC and KM in lean, agile and CSC. Different data sources have been explored to understand and establish the sample size for this study.

Obtaining a large number of responses from the construction industry is challenging. On the other side, low sample sizes cast threatening uncertainties and raise questions on the strength of data collected (Root and Blismas, 2003). Hannan and Anderson (2007) said that a statistical analysis demands minimum 30 responses. However, some statistical analyses need about 100 responses. We observed (through statistical analysis) that from 2010 until 2015, a survey response rate from construction industry is 6.5 to 45 per cent, which calculates an average of 25.75 per cent response rate. Based on 25.75 per cent response rate, if a researcher requires minimum 30 responses, then target population is at least 120 respondents, and with a maximum requirement of 100 responses, the target population to be 400 respondents.

However, another dimension is used to determine the target population for this study. A logical, statistical analysis is conducted to calculate the target population while considering the overall population of the UK construction sector.

The data sources reveal that the employment size within the UK construction industry is about 2.9 million, and among them, 11 per cent are construction managers, directors and executives (BIS, 2014). Now the question is, out of that 11 per cent (which is 11 per cent of 2.9 m = 319 k) individuals, how many would have experience or understanding of working with lean, agile, CSC management and KM all four disciplines. Based on the facts drawn from above discussion, there is a high possibility that is finding respondents from such a background and experience have limitations. No such data are available that reveals the numbers. Therefore, industry experts are contacted to determine the approximate numbers. This reveals the possibility that merely a tiny proportion that is far less than 0.1 per cent individuals would have such experience. Therefore, this study has taken an optimistic approach to assume the target population is 0.1 per cent of 319 k = 319 individuals. Based on the 319 target population, the sample size is calculated 56 respondents with 10 per cent margin of error, 90 per cent confidence level and assuming the average response distribution of 50 per cent.

A target to employ respondents is considered for this study. An anonymous e-survey questionnaire is administrated, and the link is published in relevant websites that represent the community of practice groups in lean construction, agile construction, CSC and KM and/or KC in construction. In addition, about 250 emails were sent to the top hundred construction companies in the UK; 83 responses received that was 32.5 per cent higher than responses needed. That brings down the margin of error to 8 per cent and increase confidence level to 91 per cent. Moreover, as evident in hypothesis testing section, the asymptotic significance (p-value) is relevant to conduct the aforementioned statistical analysis. Because a link to e-survey was sent through different portals including emails, it is not viable to calculate the response rate. However, based on the estimated target population
of 319 individuals, response rate calculated is 26.01 per cent which is slightly above average than the industry average of 25.75 per cent.

Responses were received from managers and executives (industry experts with average experience of 15 years and above) and who have collective knowledge and understanding of KM, construction processes and CSC process (analysed through general questions). The overall experience of the respondents gave the research team confidence in the data and indicated that valid inferences could be drawn from this data. A high level of internal consistency for this data is calculated, as Cronbach’s alpha (α) is 0.766. The respondent’s experience is the basis for their response.

Questionnaire design and data analysis tools and techniques: To capture the tacit knowledge of aforementioned respondents, a hypothesis is developed for each CSF established earlier through the literature review. The level of criticality is set to “Critical” for each hypothesis.

The questionnaire is designed with five-point Likert scale to capture the views of respondents (Table IV). Below Table IV presents the main hypothesis and the questionnaire design through Likert Scale that produces data in ordinal scale (non-parametric). Having, the ordinal scale of data provided the opportunity to analyse in SPSS while running Frequency analysis (to understand the mean, median and mode statistics), Kruskal–Wallis H test to test the hypothesis and identify the asymptotic significance of data (against Mann–Witney because of more than two variables). In addition, Spearman’s correlation analysis to establish the correlation between CSFs (against Pearson’s correlation analysis because of not normally distributed data). The hypothesis for each CSF listed in Table IV is set to “highly critical” to test the hypothesis through mean, median (frequency and Kruskal–Wallis H test) and asymptotic significance (Kruskal–Wallis H test). That provided the opportunity to test the data in four dimensions (including literature review), and finally, an interpretive rank order analysis is performed to establish the essentiality of those factors based on the rank order.

Data analysis
Hypothesis testing
Given below Figure 2 is the data analysis resulting from this study. The frequency analysis and Kruskal–Wallis H test are based on non-parametric data analysis techniques. This table represents the CSFs as variables (V1 to V10) for presentation purpose.

The data analysis establishes that nine out of those ten CSFs observed to have the level of criticality is “High”. The only factor, organisational capabilities to transfer and share tacit knowledge is observed, as the degree of criticality is “Moderately Critical” in both lean and agile processes. The null hypothesis for (V2) is rejected in the lean process because the data are not statistically significantly distributed based on Kruskal–Wallis H test and resultant asymptotic significance (p-value) is calculated lower than (below < 0.05). Similarly, results are calculated for organisational capability (V5) and individual capability (V6) in agile processes, which reject the null hypothesis. However, frequency analysis for both the variables establishes that organisational capability (V5) is “Moderately Critical” to transfer and share tacit knowledge in agile processes.

Correlation between construction supply chains
The Spearman’s correlation analysis is run to identify the correlation significance among the CSFs, which enables transfer and share tacit knowledge in the application of both the lean and agile processes.
Correlation of CSFs to transfer and share tacit knowledge in both the (a) lean and (b) agile processes.

Correlation of construction supply chains in lean processes. The most significant correlation ($r_s = 0.775$) has been found between (V9) and (V10). This reflects that the identification of both the source and recipient of knowledge are essential CSFs.

The second highest and positive correlation coefficient ($r_s = 0.595$) is calculated between (V8) and (V9), and the third highest ($r_s = 0.585$) is between (V8) and (V10). Among the 45 correlations, a negative correlation is found between (V1) and (V9), calculated as ($r_s = -0.042$).

Correlation of construction supply chains in agile processes. In agile processes, the most significant correlation ($r_s = 0.719$) has been found between (V8) and (V10). This reflects that the identification of both the type of knowledge and recipient of knowledge are essential and are highly correlated CSFs.

The second highest and positive correlation coefficient ($r_s = 0.657$) is calculated between (V9) and (V10). This portrays that identification of both, the source and recipient of knowledge are also highly correlated CSFs.
The third highest significant correlation coefficient ($r_s = 0.651$) is found between (V8) and (V9). This reflects that the identification of both the type of knowledge and source of knowledge are essential CSFs to transfer and share knowledge in agile processes and are highly correlated with each other.

The fourth highest correlation coefficient ($r_s = 0.594$) is found between (V3) and (V4). This establishes that to encourage transfer and sharing tacit knowledge in agile processes leadership capabilities of clients and main contractors are highly correlated with business strategies. Moreover, the fifth highest positive correlation coefficient ($r_s = 0.499$) is recorded between (V3) and (V5). This establishes that, alongside business strategies (V4), leadership capabilities are significantly correlated with organisational capabilities (V5).

**Interpretive analysis of correlations between construction supply chains.** Figure 3 below exhibits the rank order among the CSFs from “Highest Correlated Coefficient” to “Lowest Correlated Coefficient”. The following three assumptions are made in respect to “highest to lowest” correlation coefficient of CSFs (V1 to V10) in lean processes. These assumptions are restricted to three based on (Rank 1-3) to avoid duplication and developing confusion interpreting presumptions.

**Interpretive correlation coefficient rank orders of construction supply chain’s: lean processes.**

(1) In Rank 1:
- In above Figure 3, CSF (V9) appeared three times, based on the highest correlation coefficient. CSF (V9) has a positive correlation coefficient with (V7), (V8) and (V10).
- Secondly, CSF (V1) has appeared two times and that have a positive correlation coefficient with (V2) and (V3).
- This establishes that identifying the source of knowledge (V9) is the first CSF, which highly required identification of the type of knowledge to transfer and share (V8) and, further, identification of knowledge recipient (V10). Similarly, trust among organisations (V1) required motivation to transfer and share tacit knowledge (V2) and leadership capabilities to encourage transfer and share tacit knowledge.

(2) In Rank 2:
- Following the Rank 1, CSF (V3) has a positive correlation coefficient with (V1), (V4) and (V6). This establishes the assumption that leadership capabilities (V3) demand aligned business strategies for transferring and sharing tacit knowledge between organisations (V4) and further requires capabilities of

<table>
<thead>
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<th>Frequency – Times</th>
<th>Rank</th>
</tr>
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<td>V9–3, V1–2</td>
<td></td>
</tr>
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<td>2</td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>V5 V9 V6 V7 V3 V9 V8 V7 V7</td>
<td>V7–4, V9–2</td>
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<td>V4 V3 V7 V10 V4 V7 V2 V4 V6 V4</td>
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<tr>
<td>5</td>
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<tr>
<td>6</td>
<td>V6 V8 V9 V5 V2 V4 V4 V2 V3 V3</td>
<td>V2–2, V3–2, V4–2</td>
<td></td>
</tr>
<tr>
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<td>V10 V10 V2 V1 V9 V8 V6 V3 V2 V2</td>
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<td>V8 V6 V10 V6 V8 V1 V5 V5 V5 V5</td>
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<tr>
<td>9</td>
<td>V9 V4 V8 V2 V10 V2 V1 V1 V1 V1</td>
<td>V1–4, V2–2</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Interpretive correlation coefficient ranking orders of CSFs in lean processes.
individuals to transfer and share tacit knowledge within the construction processes (V6).

(3) In Rank 3:
- CSF (V7) correlates with (V4), (V8), (V9) and (V10). This highlights that identification of process improvement opportunity (V7) is an essential CSF that relates to Rank 1 and Assumption (1) along with CSFs (V8), (V9) and (V10). This basis that before identifying CSF’s (V8), (V9) and (V10), it is necessary to determine the process improvement opportunity by managers (V7).

Interpretive correlation coefficient rank orders of construction supply chain’s: agile processes.

(1) In Rank 1:
- In above Figure 4, CSF (V10) has a positive correlation coefficient with (V7), (V8) and (V9) and (V3) has a positive correlation coefficient with (V4) and (V5). This establishes that identifying the recipient of knowledge (V10) is the foremost CSF. The frequency of highest correlation coefficient of V10 is three (3). This is highly correlated with the identification of process improvement opportunity (V7), type of knowledge to transfer and share (V8) and, further, identification of knowledge source (V9).
- Leadership capabilities of clients and main contractors (V3) appeared two times in rank one (Figure 4). Here, (V3) required business strategies aligned to transfer and share tacit knowledge (V4) and (V5) organisational capabilities to transfer and share tacit knowledge.

(2) In Rank 2:
- Following the (Rank 1, in Figure 4), CSF (V5) has a positive correlation coefficient with (V1), (V3), (V4) and (V6). This originates the assumption that organisational capabilities (V5) demands trust among organisations (V1), leadership capabilities of clients and main contractors (V3), aligned business strategies to transfer and share tacit knowledge (V4) and capabilities of individuals involved in construction processes (V6).
- Furthermore, capabilities of individuals (V6) requires identification of process improvement opportunity (V7) and nevertheless this requires identification of the type of knowledge to transfer and share (V8) and identification of the source of Knowledge (V10).

<table>
<thead>
<tr>
<th>Rank</th>
<th>V1</th>
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<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
<th>V7</th>
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<th>V10</th>
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<td>V9</td>
<td>V8</td>
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</tr>
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<td>3</td>
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<td>V8</td>
<td>V1</td>
<td>V1</td>
<td>V1</td>
<td>V7</td>
<td>V9</td>
<td>V3</td>
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<td>V7</td>
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<td>V3</td>
<td>V1–3, V4–2, V7–2, V10–2</td>
<td>Low</td>
</tr>
</tbody>
</table>

Figure 4. Interpretive correlation coefficient ranking orders of CSFs in agile processes.
In Rank 3:

- CSF (V1) is significantly correlated with (V3), (V4) and (V5). This pinpoints that trust among organisation within CSCs (V1) correlates with leadership capabilities (V3), business strategies (V4) and organisations capabilities (V5).
- Identification of process improvement opportunity (V7) significantly coefficient with, individuals involved in the construction process (V6) and identification of knowledge recipient (V10); this correlates with above assumption (2b).

Discussion

A strong relationship between lean and agile is seen through the literature review. Still, this study asks separate questions for lean and agile processes. This is because; existing literature (Court et al, 2009; Owen and Koskela, 2006) fails to establish that all construction processes are lean and agile processes. Even if it is determined, still, generalising CSFs in application to transfer and share tacit knowledge within a lean and agile construction process would require further investigation to generalise the lean and agile attributes. Therefore, the current understanding is that some processes are a purely lean process and/or purely agile process. Therefore, this study discusses lean and agile processes separately. On those grounds, this study also considers that asking a question about lean and agile would bring ambiguity and bias, which leaves the views of lean and agile (Leagile) thinkers ignored. Resultant, this would not justify the clear views of the dominant community of practice of lean and agile practitioners within the construction sector. Consequently, the results are not generalised and presented separately for lean and agile processes.

The first set of a question aimed to investigate the CSFs in the application of transfer and sharing tacit knowledge in lean construction processes and the second set aims on agile construction processes. To distinguish between these two processes (lean and agile) the statistical analysis has been performed separately.

In the lean process, the study establishes that identifying the source of knowledge is the foremost CSF, which requires to identifying the type of knowledge to transfer and share and further requires identification of knowledge recipient.

However, in agile processes, identifying the knowledge recipient is the first key CSF. This further requires identifying the process improvement opportunity followed by the type of knowledge to share and lastly identification of the source of knowledge.

Furthermore, in the lean construction process, trust among organisations is observed as the second CSF, which requires “motivation”, and further motivation is needed to identify the type of knowledge to transfer and share. However, motivation should be supported with leadership and organisational capabilities. On the contrary, in an agile process, leadership capabilities are the second most CSF, which requires business strategies aligned and further require organisational capabilities and trust among organisations. Motivation ranks three of agile process, which requires alignment with leadership and organisational capabilities. Both lean and agile processes require individual capabilities.

Implication of construction supply chains in lean and agile construction processes

The main goal of KM is to transfer and share tacit knowledge from one person to another to solve a specific problem or handle a particular task. The other goal of KM is to ensure that knowledge is available when required with the required speed and accuracy. Lin and Tserng (2003) stated that tacit knowledge could be reused to avoid repeating the same or similar mistakes in other projects. However, the transfer and share of tacit knowledge are based on the context-specific knowledge. That needs clear business strategy by project leaders (Trees
and Lemons, 2014). This also needs the identification of which type of knowledge requires an update. Afterwards, it requires identifying which process to update and finally identifying the source of the knowledge. Trees and Lemons (2014) highlighted that before transferring and sharing tacit knowledge, an organisation must define a strategy and identify a process to protect critical knowledge. Previous studies indicate that the first requirement of knowledge transfer is to set the control variables.

As pointed out in literature review and in rank-order analysis, below Figure 5 presents the variables that control initiation of transfer and share tacit knowledge are leadership capabilities, trust, motivation, business strategies, organisational capabilities and individual capabilities. Figure 5 below also exhibits the knowledge transfer and sharing process based on the data analysis of CSFs in lean and in agile separately. The data analysis establishes that identifying process improvement opportunity is significant before identifying the source of knowledge in a lean process. In an agile process, the source of knowledge is pre-known, but managers need to understand how that knowledge should be used to improve the process. As discussed in the literature review, both lean and agile processes have different attributes. Therefore, Figure 5 below shows that in an agile construction process, the predominant factor to identify is the recipient of knowledge. It presents that the knowledge is available beforehand to improve a process. This is because an agile process is having obligatory information enrichment and consultative nature of forecasting mechanism (Table I). Therefore, the results from both the lean and the agile are exhibited together in Figure 6.

A large number of published studies (Court et al., 2009; Mason-jones et al., 2000; Naylor et al., 1999; Sabri and Shaikh, 2010) suggest combining the lean and the agile principles to maximise the benefits. Figure 6 below exhibits the generalised results of implementing knowledge transfer and sharing in a lean and agile process. In this, the agile process can be taken as a stage two of knowledge transferring and sharing process. This is because the knowledge transfer and sharing in a lean process creates new insights. In Figure 6, identifying the recipient of knowledge is the point where lean and agile processes meet. In the lean process, knowledge sharing is driven through the identification of process improvement opportunity. Here, the problems that need attention are predefined, and knowledge sharing is needed (managers look for the source of knowledge) to overcome the problem. On the other side, in the agile process, readily available knowledge is shared to prevent potential problems.

Conclusion

Adopting just lean or just agile in construction process does not bring collaboration in a CSC. The lean principle aims to reduce waste and lead-time in a SC (Womack and Jones, 2003; Womack et al., 1990) and agility is merely considered as being responsive to unpredictable demands and markets (Christopher and Towill, 2001; Mason-jones et al., 2000). Both the lean and agile principles require the collaboration between the source and recipient of knowledge to create new knowledge. It is unjust to say that a CSC is entirely based on just lean or agile principles (Saini, 2015).

This study identifies the CSFs to facilitate the transfer and sharing of tacit knowledge in lean and agile construction processes. The investigation of the CSFs concludes with some interesting facts. The literature review finds that trust among organisations and individuals are to be the predominant CSF. However, above quantitative analysis demonstrates that in a lean process, identifying the source of knowledge is the leading and key CSF to determine the type of knowledge to transfer and share and to determine an appropriate knowledge recipient. However, in agile processes, the key CSF is determined to be the identifying of the
Implementing in Lean Construction Process

Control Variables
- Motivation
- Trust
- Leadership Capabilities
- Align Business Strategies
- Individual Capabilities

Knowledge Transfer and Sharing Process
- Identify Process Improvement Opportunity
- Identify Source of Knowledge
- Identify Type of Knowledge
- Identify Recipient of Knowledge

Feedback

Implementing in Agile Construction Process

Control Variables
- Leadership Capabilities
- Align Business Strategies
- Trust
- Organisational Capabilities
- Individual Capabilities

Knowledge Transfer and Sharing Process
- Identify Recipient of Knowledge
- Identify Process Improvement Opportunity
- Identify Type of Knowledge
- Identify Source of Knowledge
Figure 6. Implementing knowledge transfer and sharing in lean and agile construction process.
knowledge recipient. Furthermore, knowledge sharing in an agile process demands to identify the process improvement opportunities followed by the type of knowledge to share and, lastly, identification of the source of knowledge.

The literature review also concludes that leadership capabilities are the second most important CSF aligned with business strategies to initiate transfer and share of tacit knowledge. Trust between organisations is paramount. Moreover, quantitative analysis establishes that business strategies and individual capabilities are equally important factors. The standardised results from the literature review and the quantitative analyses conclude that identifying process improvements opportunity is the most predominant CSF, but there must be an equal consideration of trust, leadership capability, corporate strategies and motivation.

However, making a successful KM initiative within the lean and the agile processes, developing individual capabilities through training is essential to ensure the smooth transferring and sharing of tacit knowledge.

The study aims to provide a novel perspective to one of the most significant gaps in the literature of construction processes while developing a new literature of KM and framework (Figure 5 and 6) that establish that how tacit knowledge can be transferred and shared. This research establishes the CSFs associated with the effectiveness of knowledge sharing in lean and agile construction processes. The development of the framework (Figure 5 and 6) in this study fills the gap in existing literature and the lack of KM frameworks for transferring and sharing tacit knowledge. In addition, the study has potential to direct further research into effective communication to transfer and share tacit knowledge in construction and other industries.

In practice, at managerial levels (Tier 2 and above) of a CSC, this study provides a roadmap to remodelling existing policies concerning managing knowledge to facilitate construction project efficiency and collaboration and partnering among stakeholders of a construction project. In addition, this study has potential to urge Lean, Agile, KM and SC communities (in a variety of sectors) to rethink the role and importance of KC. The CSFs evolved from this study could also influence other closely related industries in terms of a knowledge transfer and sharing approach. Moreover, findings from the data analysis can lead to further research based on each hypothesis. In addition, the framework to transfer and share tacit knowledge can be further tested in practice and can be adopted in different contexts.

Nevertheless, to initiate knowledge communication in construction processes, there may be a certain set of individual capabilities that are required for the source and the recipient of knowledge. A study by Saini (2015) concludes that individuals (source and recipient of knowledge) require observational, knowledge application, absorptive, explanation, dissemination and conversational and routing capabilities. However, a successful KM initiative in lean and agile processes demands these skills through training and developing individual capabilities that ensure the smooth transferring and sharing of tacit knowledge. Therefore, this study has the potential to developing new literature on KM and establishing the ways of KC to transfer and share tacit knowledge. Hence, in terms of developing individual capabilities, this study can be taken as a guiding point for further research for essential skills and training needed for employees.

The study is limited to the UK construction sector, and thus, it cannot be generalised universally without further research in other countries and regions throughout the world. A similar study in another area or country might highlight a different set of CSFs for the transfer and sharing of tacit knowledge. Thus, it is important to attempt a sector-specific research and examine the findings of this study. The use of a survey questionnaire in the
areas of CSC, lean, agile and KM limited the scope of using a wider population for this study. Hence, perceptions of the broader population with a lower margin of error and high confidence level, need testing. Moreover, this study is limited to utilising experts who have knowledge and understanding of the lean, agile and KM principles in the construction process. The named CSF’s can be further analysed separately while taking this study as a starting point.

References


Coakes, E. and Clarke, S. (2005), in Coakes, E. and Clarke, S. (Eds), Encyclopaedia of Communities of Practice in Information and Knowledge Management, IGI Global.


Further reading


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