1. Introduction

The construction industry has long been criticised for being inefficient, wasteful, a high-risk/low-profit industry and “backward” in general when compared to some other major industries (London and Kenley, 2001; Teo and Loosemore, 2001; Woudhuysen and Abley, 2004; Assaf and Al-Hejji, 2006; Smyth, 2010). Many of those criticisms can be traced to the industry characteristics such as supply chain fragmentation (Vrijhoef and Koskela, 2000; Dubois and Gadde, 2002; Baiden et al., 2006), construction companies’ high sensitiveness to market conditions (Lo et al., 2007; Regat et al., 2010), lack of an industry-level strategic vision (Green et al., 2005; Love et al.,2005), low-entry barriers to the industry coupled with competitive tendering mechanisms and small profit margins (Rooke et al., 2004; Dikmen et al., 2010), and short-term and temporary organisational configurations (Pauget and Wald, 2013; Behera et al., 2015). Also, project management literature has displayed many examples of time overruns (Hwang et al., 2014; Arashpour et al., 2016), cost overruns (Nasirzadeh et al., 2014; Olawale and Sun, 2015), low productivity (Fulford and Standing, 2014), safety issues (Nieto-Morote and Ruz-Vila, 2011; Wang and Yuan, 2011; Demirkesen and Arditi, 2015), and quality problems (Zeng et al., 2007; Arashpour et al., 2017) in construction projects.

In the early 1990s, to improve the performance of the industry, some researchers advocated developing a production management perspective in construction project management practices through learning from the Japanese manufacturing industry (Koskela, 1992; Ballard and Howell, 1998; Tommelein, 1998; Gao and Low, 2014; Tommelein, 2015), which had attained a global competitive edge after Second World War by adopting certain production management techniques and principles explained under the term Lean Production System (LPS) (Womack et al., 1990; Fujimoto, 1999; Shah and Ward, 2007; Jasti and Kodali, 2015). In time, efforts associated with adapting the LPS techniques and principles into the construction industry and construction project delivery mechanisms were accumulated and called Lean Construction (LC) (Howell, 1999; Ballard and Howell, 2003; Tommelein, 2015).

In the UK, LC came under the spotlight with the Egan report, 'Rethinking Construction', which was produced in 1998 to address concerns raised by clients engaging services of construction companies (Egan, 1998). The aim of the report was to stimulate a change in the culture, style and management of the industry (Forbes and Ahmed, 2011). However, after the report, the dissemination of LC across the UK could not be realised as intended (Mossman, 2009; Sarhan and Fox, 2013). Around late 2000s, following grave criticisms for their project management performances, large public construction clients in the country experienced serious budget cuts and performance improvement targets by the government, which induced them to initiate efforts associated with instilling LC capabilities into their supply chains (Ansel et al., 2007; Chloe and Sue, 2012; Drysdale, 2013; Fullalove, 2013).

One of those large, civil projects clients is Highways England (HE), the organisation responsible for delivering, operating, maintaining and improving England's motorways and major roads. In 2016, HE announced a strategic plan to attain 250 million GB £ in savings in highways projects through LC between 2015 and 2020 (HE, 2016). This supply-chain level and strategic LC implementation initiative led by a powerful public client (HE) created a rare case for LC, which had not been implemented in the country's construction industry as intended. A major target in HE's LC strategy is to disseminate LC across Small-Medium Sized Enterprises (SMEs), companies operating with annual turnover not more than 50 million GB £ and with employees not more than 250 (DfBIS, 2012; EC, 2015). Despite constituting the largest group in construction supply chains (Morton and Ross, 2008), the exploration of LC in SMEs has been limited (Dainty et al., 2001; Barros Neto and Alves, 2007; Alves et al., 2009; Alves et al., 2012). The issue has been mainly discussed from the innovation and supply chain integration perspectives. Also, the literature on LC is mostly concerned with the production process, and to a lesser extent, the commercial side of LC implementations at specific projects or specific construction organisations. Beyond generic remarks, the lack of in-depth, sector-specific investigations (i.e. highways, rail, building, energy etc.) of LC in SMEs, covering supply chain characteristics in project governance, project procurement, training and process management is salient in the literature.

The research presented in this paper aims to explore two research questions;

(1) what are the current supply chain conditions defining how LC, a relatively new phenomenon for civil project management, is being implemented (current condition) and,

(2) how LC can be further promoted (future direction) in the highways supply chain from an SMEs perspective.

The research was sponsored by and conducted in cooperation with HE to inform future LC strategies in civil projects. Also, the findings are deemed contributing to the current understanding of LC in construction SMEs. In the rest of the paper, following a literature review on LC and construction SMEs, and an explanation of the highways project delivery context in the supply chain, the analysis and discussion of an explorative mixed-method study, involving 20 face-to-face interviews with highways managers and a comprehensive questionnaire survey with 110 responses on LC in highways SMEs, are presented.

2. Research background

2.1. Lean Construction and SMEs

LC presents a practice oriented research and development in construction management and construction projects, which are seen as temporary production systems, with an adaption of the LPS to the end-to-end design and construction process (Garnett et al., 1998; Howell, 1999; Koskela et al., 2002). LC advocates that some of the inherent construction industry problems like fragmented supply chains, strong focus on individual projects narrowing perspectives on general supply development, relationships between actors influenced by a culture of conflict, superficial supply chain integration practices, low-profit margins, frequent time and space conflicts in on-site production, low output productivity and quality, noncompliance between product design and on-site production, insufficient process and operations management perspective in on-site production, poor safety records, working in silos, and a slow-take up of innovation and change (Koskela, 1992; Shirazi et al., 1996; Vrijhoef and Koskela, 2000; Dainty et al., 2002; Dubois and Gadde, 2002; Green and May, 2005; Assaf and Al-Hejji, 2006; Segerstedt and Olofsson, 2010; Eadie et al., 2013; Behera et al., 2015; Tommelein, 2015; Howell et al., 2017) can be mitigated through learnings from the LPS.

The origins of the LPS are traced back to the innovations on the shop-floors of Japanese manufacturers, particularly at Toyota Motor Corporation, between the 1930s and the 1970s, which were first conceived as improvement opportunities inspired by the mass automotive manufacturing in the US (Monden, 1983; Shingo, 1986; Ohno, 1988; Fujimoto, 1999). Following Japan's successful post-war recovery and emergence as a global economic power, Japanese manufacturing techniques have been benchmarked by Western manufacturers since the 1970s (Drucker, 1971; Sugimori et al., 1977). Although the diffusion of the LPS had started in discrete manufacturing industries in the West in the 1980s, the publication of a business book, "The machine that changed the world" by Womack et al. (1990), fuelled a debate in both the practitioner and academic communities concerning the applicability of the Lean approach outside discrete, repetitive industries (Lyons et al., 2013). The start of discussions on the applicability of the LPS in the construction industry concurred with this broader diffusion period of Lean in other industries in the early 1990s. A recent market report by McGraw-Hill (2013) documented the positive effect of LC in attaining higher construction project performance and customer satisfaction, alongside challenges associated with lack of Lean knowledge and a limited understanding of LC by the industry. Similarly, after an in-depth study of ten building projects in the United States and Canada, Cheng (2016) concluded that Integrated Project Delivery (IPD), a relational contracting and partnering strategy, sets the terms and provides the motivation for collaboration and the process based LC techniques provide the means for construction teams to optimise their performance and achieve project goals, further highlighting the need to approach Lean in construction with a process and a supply chain management/ project governance perspective.

The basic principles of the LPS are frequently defined as (Lewis, 2000; Liker, 2004; Bhasin and Burcher, 2006; Dennis, 2016):

(1) continuously focusing on elimination of the process wastes (i.e. motion, delay, conveyance, correction, over- processing, inventory, over-production and knowledge) and lead-time compression,

(2) increasing production stability through Visual Management, 5S and Total Productive Maintenance (TPM),

(3) strandardising work through work design, cycle and *takt* time planning, layout and equipment design and standard operating sheets,

(4) just-in-time (JIT) production with continuous material and component flow, pull production with *kanban* cards and production levelling,

(5) batch size reduction,

(6) quality control at source with the *jidoka* principles and *poka-yoke* mistake proofing tools,

(7) ability to rapidly reconfigure production process and products through techniques like Single Minute Exchange of Dies (SMED),

(8) multi-functional work teams grouped in production cells,

(9) continuous improvement through *kaizen* circle activities, and

(10) long-term relations with supply chain for supply chain integration and development.

However, many LPS accounts reiterating those principal characteristics were criticised for explaining the LPS paradigm in an isolated fashion without taking strategic supply chain parameters and marketplace requirements such as demand characteristics or stock holding de-coupling points into account for the suitability of the LPS (Naylor et al., 1999; Christopher and Towill, 2000; Christopher et al., 2006). Mason-Jones et al. (2000), Olhager (2003), Bruce et al. (2004) and Agarwal et al. (2006) identified the distinguishing attributes of Lean supply, the system of purchasing and supply chain management required to best underpin the LPS, in which typical product is commodities, demand is predictable, product variety is low, product life-cycle is long, customer driver is cost, profit margins are low and dominant costs are physical costs. In Lean supply, beyond partnership, the entire flow from raw materials to consumer is considered as an integrated whole in which the interfaces between stages are seen as artificial, resources, information and know-how are often shared by creating a network of suppliers to build a common understanding and learning (cross-enterprise collaboration), a common management culture are built across the supply chain, and the effects of costs associated with less than perfect execution of a sub-process are not limited to the location of the execution (Lamming, 1996; MacDuffie and Helper, 1997; Vitasek et al., 2005; Myerson, 2012; Jasti and Kurra, 2017).

In the construction industry, according to Green and May (2005), LC deployments can be categorised into three levels with increasing degree of sophistication; (1) process based LC deployment efforts to reduce waste, variability, information deficiencies and to support production and process flow and stability through some specific LC principles and techniques, (2) arrangements to eliminate adversarial relations and to increase integration in construction supply chains, and (3) a strategic change in the overall project governance toward partnering. Similarly, the Lean Construction Institute (LCI) (2017) defines LC implementation in construction as a triangle with the following edges; (1) Lean techniques at the operational level (operating systems), (2) Integrated Project Delivery (IPD) strategies (commercial) and (3) transformational change (organisational), mostly concerned with strategic decisions.

Currently, most of the discussions on LC deployments are around the process based deployments as per Green and May's (2005) and the LCI's (2017) definitions. The main LC principles at this level are (1) elimination of the process wastes (Terry and Smith, 2011; Koskela et al., 2013), (2) effective management of the value stream (Garnett et al., 1998), (3) maintaining a continuous and reliable flow of the production and process elements (Koskela et al., 2002), (4) pull-based project planning and control (Ballard, 2000), (5) just-in-time delivery of materials and components (Pheng and Chuan, 2001), and (6) instilling a continuous improvement culture (Lapinski et al., 2006). Those underpinnings inspired by the LPS principles led to the adoption of some operational techniques and practices in LC like the collaborative and pull-based construction production planning and control framework – the Last Planner System (Ballard and Howell, 1998; Priven and Sacks, 2016; Viana et al., 2016), *takt*-planning and work structuring (Tsao et al., 2004), Visual Management (Tezel and Aziz, 2017), the 5S (Stehn and Höök, 2008), pull production control using *kanban* cards (Arbulu et al., 2003; Khalfan et al., 2008; Ko and Kuo, 2015), quality at source and *andon* light boards (Kemmer et al., 2006), Single Minute Exchange of Dies (SMED) (Filho et al., 2005), *poka-yoke* mistake proofing systems (Tommelein, 2008), cell production units (Mariz et al., 2013), Value Stream Mapping (Yu et al., 2009), Target Value Design (Zimina et al., 2012) and Continuous Improvement Cells (Miron et al., 2016). The Last Planner System is almost the only method specifically developed for the construction industry. There is evidence that many Lean techniques developed in the manufacturing context under the LPS work well in the construction context with some adaptation.

To commercially underpin the LC techniques and to liken the construction project procurement and supply structure to Lean supply, the IPD type relational project procurement has been suggested (Matthews and Howell, 2005; Kent and Becerik-Gerber, 2010; Lahdenperä, 2012), which practically corresponds to the commercial leg in LC deployments as per Green and May's (2005) and the LCI's (2017) definitions. In IPD, main construction project supplying organisations act as an integrated unit through inter-contracts among each other based on proportional profit/risk sharing as a compensation and incentive mechanism while delivering a turnkey or design-build type construction project (American Institute of Architects, 2007; Kent and Becerik-Gerber, 2010; Lahdenperä, 2012; Mesa et al., 2016). However, IPD is subject to various barriers in the industry such as the unwillingness of the industry to change its traditional supply and procurement methods (cultural), issues associated with selecting compensation and incentive structures commensurate to the unique characteristics of project suppliers (financial), liability and insurance issues (legal), and ownership, liability and interoperability concerns in the integrated use of technology to achieve collaboration (technological) (Kent and Becerik-Gerber, 2010; Ghassemi and Becerik-Gerber, 2011; Rached et al., 2014). The degree of IPD diffusion in construction remains still low, with IPD mostly being adopted in the procurement of complex, fast-track construction projects (NBS, 2015; Mesa et al., 2016).

Many of the criticisms for the current LC implementation discussions are based on the assertion that they largely overlook some macro factors like the industry's business and economic context, market and supply dynamics, industry culture and its overall governance (Green 1999; Barros Neto and Alves 2007; Alves et al. 2012; Wandahl, 2014; Cano et al., 2015). Shortly, the amount of strategic and supply chain focused LC implementation discussions have remained relatively narrow when compared to the discussions focusing mostly on the production process, and to some extent, the procurement side of LC implementations, which are more concerned with specific project cases and their conditions rather than supply chain system characteristics in different construction sectors. Therefore, while conducting a LC deployment research, beyond some specific LC techniques or mantras, it was deemed necessary to take the less-investigated overall industry and sector context, and project governance structure into account, particularly when the object of study is a supply chain, not some particular construction organisations or projects.

The following macro factors regarding LC deployments in construction were identified;

(1) Project governance and supply chain management: fragmentation, sub-contracting and lack of top management support (Johansen and Walter, 2007; Mossman, 2009; Sarhan and Fox, 2013; Zanotti et al., 2017),

(2) Project delivery systems: commercial, design, procurement and contractual issues (Rooke et al., 2007; Sarhan and Fox, 2013; Cano et al., 2015; Pasquire et al., 2015a),

(3) Training issues: culture and human attitudes, lack of LC knowledge/ understanding and educational issues (Alarcon et al., 2005; Jørgensen and Emmitt, 2008; Sarhan and Fox, 2013; Cano et al., 2015; Pasquire et al., 2015b) and

(4) Process: lack of process and customer focus (Alarcon et al., 2005; Leong and Tilley, 2008; Wandahl, 2014; Sarhan and Fox, 2013; Zanotti et al., 2017).

As for LC deployments at SMEs, unlike the manufacturing industry (Achanga et al., 2006, Panizzolo et al., 2012; Zhou, 2016; Antosz and Stadnicka, 2017), research investigating Lean in SMEs in the construction industry has remained scarce. However, the importance of SMEs in construction is increasing, particularly in developed economies, where many large contractors prefer not to retain permanent staff and outsource construction activities to smaller companies, acting more like project management or project integrating organisations (Morledge and Smith, 2013; Farmer, 2016). The increasing presence of SMEs renders it imperative to better understand issues around Lean deployment and SMEs. Some of the general arguments around LC at construction SMEs have been that (1) SMEs are more prone to variations in the economy; therefore, they do not have spare resources to invest in innovation

(Alves et al., 2009; Poirier et al., 2015), (2) the common lack of trust between SMEs and their larger clients as a hindering factor for partnering for LC (Briscoe et al. 2001; Björnfot and Torjussen, 2012), (3) competent LC deployments should integrate SMEs into the process, reducing the transaction costs of all parties; not only large contractors' (Miller et al., 2002; Mills et al., 2012), (4) a general lack of belief that there are mutual benefits in supply chain integration practices and other business improvement initiatives like LC (Holt et al., 2000; Dainty et al., 2001; Upstill-Goddard et al., 2016), and (5) the need for large clients' active support in terms of know-how and resources to develop capabilities in innovative approaches in SMEs (Ferng and Price, 2005; Alves et al., 2009; Mills et al., 2012; Gledson and Phoenix, 2017).

2.2. Project management and Lean Construction in the highways sector

In England's highways sector, since 2009, LC as a strategy has actively been championed by HE, the main client of the supply chain, who is able to influence the strategic directions (e.g. LC deployment) of its service providers (Ansel et al., 2007; Drysdale, 2013; HE, 2016). HE first promoted LC through engagement and contractual configurations with some large-sized main contractors (Tier 1s) and some specialised sub-contractors operating in key delivery areas like soil works, paving/surfacing or traffic management (large Tier 2s) (Chloe and Sue, 2012; Drysdale, 2013; Fullalove, 2013). Those large Tier 2s are almost on par with Tier 1s in terms of their annual turnovers and employee numbers.

HE is using prime contracting with Tier 1s as its main project delivery method (Fernie et al., 2001; Gosling, 2015). In that contractual configuration, a small number of Tier 1s form long-term partnerships with HE and large Tier 2s for the delivery of a series of projects. HE commonly imposes a cap contract price, from which deviations in the form of price overruns or savings are shared between Tier 1s and HE to supposedly incentivise Tier 1s to make operational cost savings and to encourage the deployment of LC at the same time. Alongside this, HE is contractually imposing the use of some LC techniques like the Last Planner System (known as Collaborative Planning in the UK) (Daniel et al., 2017) or Visual Management (Tezel and Aziz, 2017) in its contracts with Tier 1s. Also, Tier 1s and large Tier 2s are monitored by HE for their LC maturity (Nesensohn et al., 2015). This active LC agenda drew consultants into the supply chain. Those consultants work collaboratively with Tier 1s and large Tier 2s on their LC efforts and offer LC trainings.

In this equation, SMEs are employed by Tier 1s, often for short terms on the minimum price basis with fixed-priced contracts (Waara and Bröchner, 2006). Additionally, because of the current project delivery system, SMEs are rarely in direct contact with HE for their LC or other process improvement efforts, which are mostly shaped and directed by their Tier 1 clients. Due to the nature of work, SMEs have to execute their on-site operations in short working windows in coordination with other SME, large Tier 2 and Tier 1 organisations to avoid extended traffic disruptions. SMEs constitute the largest group in the supply chain (Morton and Ross, 2008) and given this context, one of the strategic targets of HE for LC is to effectively disseminate LC across the whole highways supply chain, primarily including SMEs (Abbot and Aziz, 2015; Tezel et al., 2017).

Given the findings from the literature review, the research is justified as follows:

- As explained in Section 2.1, although LC becomes a strategic priority in the UK's civil sector, LC implementation discussions are mostly on process and LC techniques, and to a lesser extent, on commercial arrangements, with lesser attention to macro project management factors,
- The existing LC discussions are mostly on specific companies or projects with lesser attention to sector-level analyses,

- Also, little has been identified as to LC implementations at construction SMEs, whose importance is increasing in the construction industry,
- Moreover, client-led, large-scale LC implementation efforts in construction supply chains are relatively recent phenomena. Given the scarcity of empirical research on LC at SMEs and sector-specific (e.g. civil, building, energy etc.) analyses, the cooperation with a powerful public client, HE, which promotes and directs the LC initiative in its supply chain, presents an opportunity to better understand the current LC condition and future LC direction (necessities) for SMEs in civil projects for both academic and practical reasons.

As different supply chain roles may have different perceptions and opinions as to the current condition and future directions for LC at SMEs (Dainty et al., 2002; Huin, 2004; Khalfan and McDermott, 2006; Cheng et al., 2010; Turner et al., 2010; Marcelino-Sádaba et al., 2014), to increase the validity and generalisability of the research, and to further explore those different perceptions and opinions, the current condition and future direction statements were investigated over two hypotheses:

Hypothesis 1:

- H_0: The distribution of current LC condition agreement for SMEs is the same across the three types of companies (SMEs, Large Tier 2s and Tier 1s) in the highways supply chain.
- H_1: The distribution of current LC condition agreement for SMEs is not the same across the three types of companies in the highways supply chain.

Hypothesis 2:

- H_0: The distribution of future LC direction agreement for SMEs is the same across the three types of companies (SMEs, Large Tier 2s and Tier 1s) in the highways supply chain.

- H_1: The distribution of future LC direction agreement for SMEs is not the same across the three types of companies in the highways supply chain.

For the validity and generalisability, the null hypotheses (H_0) are expected to be retained (H_0 is not rejected) in general at a certain confidence level. However, the difference in opinions or where the distributions for the current condition and future direction statements significantly differ (H_0 is rejected) may present interesting insights into the varying approaches to the LC at SMEs issue by the main supply chain roles.

3. Methodology

With the fundamental aims of identifying the current condition parameters and the future direction for LC implementation factors at highways SMEs, a mixed-method study of exploratory nature, involving interviews and a survey questionnaire, was designed.

3.1. Interviews

Following a literature review on LC and SMEs, 20 senior managers (4 from HE, 5 from Tier 1s, 4 from large Tier 2s, 7 from SMEs) form England's highways construction supply chain were interviewed face-to-face for circa 45 – 60 minutes between December 2015-May 2016 (see details of the interviews in Table 1). The interviews were semi-structured and open-ended. The primary advantages of open-ended interviews are that that they can provide more detailed information on a subject matter than survey studies and their potential to reveal rich-insights for exploratory research (Rapley, 2001; Berg, 2004). The interviewees were identified in collaboration with HE under a purposive sampling strategy from managers actively engaging with the LC implementation in highways projects. The involvement of HE was deemed effective both in reaching and accessing the interviewees, as well as securing an interview time slot with them, as the interviewees were mostly senior managers of their organisations with quite schedules. Particular attention was given to interviewing managers from all the supply chain roles, from the client (HE) to SMEs, in order to capture a more complete picture of the issue, which is as an important aspect for interview reliability (Miles and Huberman, 1994; Shao and Müller, 2011). Also, to further increase interview reliability and validity, the interview protocol was reviewed by peers and supervisors, and the data and the analysis were linked to the existing literature as much as possible (Miles and Huberman, 1994; Shao and Müller, 2011). A shortlist of possible interviewees was produced first. Each interviewee on the shortlist was contacted initially to explain the aims and objectives of the research. Subsequently, 15 days later, a reminder was sent.

Two open-ended questions were asked during the interviews; the current condition of and future directions of LC for SMEs. The responses were voice-recorded, transcribed and grouped into 31 current condition and 40 future direction statements. The 31 current condition statements were further grouped into 5 project delivery, 8 process, 3 training, 8 project governance and 7 supply chain management related statements. The 40 future direction statements were further grouped into 7 project delivery, 7 process, 8 training, 8 project governance and 10 supply chain management related statements.

No	Interviewee management role	Experience in the sector	Organisation's role in the supply chain	Main operational area	Lean construction background (years)
1	Senior Manager	More than 20 years	SME	Civil Works	<5
2	Senior Manager	More than 20 years	SME	Civil Works	<5
3	Senior Manager	More than 20 years	SME	Telecommunication Works	<5
4	Senior Manager	More than 30 years	SME	Telecommunication Works	<5
5	Senior Manager	More than 30 years	Tier 2 (Large Contractor)	Aggregate/ Surfacing	>5, <10
6	Senior Manager	More than 20 years	Tier 2 (Large Contractor)	Aggregate/ Surfacing	>5, <10
7	Senior Manager	More than 20 years	Tier 1 (Large Contractor)	General Contracting/ Project Management	>5, <10
8	Senior Manager	More than 30 years	Tier 1 (Large Contractor)	General Contracting/ Project Management	>5, <10
9	Senior Manager	More than 20 years	Tier 1 (Large Contractor)	General Contracting/ Project Management	>10
10	Senior Manager	More than 30 years	Tier 2 (Large Contractor)	Traffic Management	>5, <10

11	Senior Manager	More than 30 years	SME	Civil Works	<5
12	Senior Manager	More than 20 years	Tier 2 (Large Contractor)	Surfacing	>5, <10
13	Senior Manager	More than 20 years	Tier 1 (Large Contractor)	General Contracting/ Project Management	>5, <10
14	Senior Manager	More than 30 years	Tier 1 (Large Contractor)	General Contracting/ Project Management	>10
15	Senior Manager	More than 20 years	SME	Electrical Works	<5
16	Senior Manager	More than 20 years	SME	Surfacing	<5
17	Senior Manager	More than 20 years	Client (HE)	Lean/ Process Improvement Department	>10
18	Senior Manager	More than 30 years	Client (HE)	Lean/ Process Improvement Department	>10
19	Senior Manager	More than 30 years	Client (HE)	Lean/ Process Improvement Department	>10
20	Senior Manager	More than 20 years	Client (HE)	Lean/ Process Improvement Department	>10

Table 1. Profile of the interviewees.

3.2. Survey questionnaire

To validate, rank and perform further analyses on the statements, a questionnaire survey was designed due to its ability to cover large number of respondents, its cost effectiveness and for a higher generalisability of results (Arditi and Gunaydin, 1997; Oyedele, 2013). Concerns associated with validity and operationalisation of the statements (how concepts/ statements are represented and measured) were mitigated by using a pilot survey and statistical Cronbach's alpha reliability test (Johnson and Duberley, 2000; Geoghegan nad Dulewicz, 2008; Oyedele, 2013). The questionnaire includes the 31 current condition and 40 future directions statements on a Likert-type scale of 1 to 5, where 1 represents ‘strongly disagree’ and 5 represents ‘strongly agree’ for the current condition statements and 1 represents ‘not important’ and 5 represents ‘very important’ for the future direction statements.

After the first draft of the questionnaire, a pilot study was conducted with the aim of testing the level of ease at which respondents would be able to complete the questionnaire. The pilot study examined the clarity of the language, the appropriateness and the logic of the questions, the layout, the degree of depth, the ease of navigation and user friendliness of the whole questionnaire. Additionally, it also gave the opportunity to ask the respondents if there were other statements beyond the ones in the final questionnaire. The pilot study involved 12 senior managers (with the highways sector experience more than 20 years) from 4 Tier 1 companies, 4 large Tier 2 companies and 4 SMEs. Although no additional statements were required to include in the final list, the companies recommended re-wording some of the questions. These suggestions were implemented in the design of the final questionnaire.

HE’s database was used to pinpoint relevant managers to send the questionnaire to, who are familiar with both the context in which SMEs operate and the current LC efforts in the highways supply chain. This kind of purposive sampling strategies in survey studies can be necessary to obtain relevant results when investigating innovative, emerging or niche phenomena (Adams, 1997; Tongco, 2007; Winch et al., 2012). The questionnaire was sent electronically. Of the outgoing 289 surveys, 110 responses were collected between June – October 2016 with 38% response rate, which is acceptable in academic studies (Baruch, 1999; Barlett et al., 2001). Among the respondents, 49 managers are from Tier 1s (45% of the respondents), 43 managers are from SMEs (40% of the respondents), 13 managers are from large Tier 2s (11% of the respondents) and 5 managers are from consultants (4% of the respondents). 67 of the respondents are senior managers (61% of the respondents), 35 of the respondents are middle managers (32% of the respondents) and 8 managers are junior managers (7% of the respondents) (see details of the respondents in Table 2). It is not surprising that many of the respondents are from large Tier 1s as the LC imitative in the supply chain was first initiated by Tier 1 companies. The questionnaire was analysed using the SPSS (Statistical Package for the Social Sciences) software. The research process can be seen in Figure 1

Supply chain role	**Years of experience**				
Management role	0 - 10 years	10- 20 years	20 - 30 years	more than 30 years	Grand Total
Consultant	1	2		2	5
Middle Manager	1	1			2
Senior Manager		1		2	3

Tier 1	12	19	8	10	49
Junior Manager	8				8
Middle Manager	3	15	3	2	23
Senior Manager	1	4	5	8	18
Large Tier 2	7	1	3	2	13
Middle Manager	6	1			7
Senior Manager	1		3	2	6
SME	3	17	17	6	43
Middle Manager		2	1		3
Senior Manager	3	15	16	6	40
Grand Total	23	39	28	20	110

Table 2. Profile of the survey respondents.

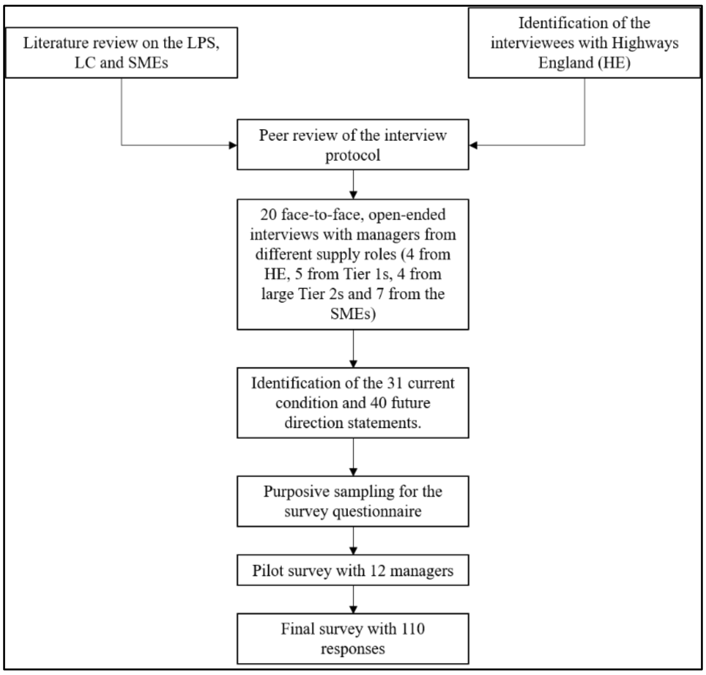

Figure 1. The research process.

4. Analysis of data

4.1 Interview results

First, the initial transcription and coding of the 20 voice-recorded interviews were completed. Following this, the screening of the transcriptions for topic relevance of the large-data set of more than 100000 words was executed, as despite giving rich insights, open-ended interviews tend to content large amount of irrelevant data as well (Auerbach and Silverstein, 2003). With the relevant data in hand, the response patterns of the interviewees were investigated by grouping similar responses (Miles and Huberman, 1994) under 5 main group headings (e.g. project delivery, process, training, project governance and supply chain) identified from the macro-factors in Lean implementations and SMEs as outlined in *Section 2.1* from the investigations of Alarcon et al. (2005), Johansen and Walter (2007), Rooke et al. (2007), Jørgensen and Emmitt (2008), Leong and Tilley (2008), Mossman (2009), Sarhan and Fox (2013), Wandahl (2014), Cano et al. (2015), Pasquire et al. (2015a) and Pasquire et al. (2015b). This kind of theory grounding forms one of the fundamental approaches in qualitative data analysis (Dillon and Taylor, 2015). The interview analysis comprises of two subsequent steps;(1) the transcribed sentences were reviewed and grouped by those 5 main group headings, (2) similar statements initially grouped under similar group headings were identified, analysed and grouped once more under one representing statement to narrow down the size of the findings. Those second statements were used in the pilot survey study for further relevance and clarity check. In the end, the responses were summarised into 31 current condition and 40 future direction statements under 5 main headings to be used in the survey questıonnaire (see Table 3 and Table 4).

Regarding the current condition, the interviewed SME managers were found mainly complaining about the lack of SME focus and direct support and collaboration culture for LC in the supply chain. The SME managers also underlined the high potential of SME organisations in achieving innovation and improvement at the process level. The managers provided some suggestions for future directions. The interviewees from large Tier 1s and Tier 2s agreed on the condition that the LC focus had been on their organisations in the supply chain. They, however, expressed their desire for SMEs to take more risks and initiative for LC within their organisations. The interviewees from larger organisations also validated that they formed partnerships only with a few, specialised and larger subcontractors and chose their SME service providers by mostly the conventional way (low-price) and on temporary basis. The interviewees from the client organisation admitted that the LC focus had been on large organisations and expressed their desire to diffuse LC into SMEs. The managers also discussed some practical barriers and future plans as to further LC diffusion across SMEs in the supply chain.

The interview findings agreed well with the generic LC implementation factors identified in *Section 2.1* and those factors were used as the basis for the interview grouping in this study. However, the interview findings also reflect and elaborate on some specific conditions of the highways supply chain as explained in *Section 2.2*, which gave the study a sector-level focus too. To facilitate the analysis and the reporting, each statement was assigned a code. All the codes for the current condition statements start with *CCLC*, whereas all the codes for the future direction statements start with *FDLC*. Then following a hyphen, the initials of the group name the statement belongs to and the statement's number in the group are written (e.g. *CCLC-D1* – the first project delivery related statement of the current condition statements) (see Table 3 and Table 4).

No	**Current condition of LC (CCLC) at SMEs**	**Code**
	Project Delivery (D)	
1	The level of LC deployment is not an important, direct parameter for SMEs to win future contracts at the moment.	CCLC-D1
2	Commercial (contract) teams at HE and the Tier 1s put up various barriers for further LC deployment at SMEs.	CCLC-D2
3	SMEs start working generally on a short notice without much earlier preparation for a project.	CCLC-D3
4	The contracts between Tier 1s and SMEs are mostly conventional unit price or lump sum contracts, which does not incentivise innovation much.	CCLC-D4
5	Many construction and maintenance performance issues stem from the initial design. However, generally SMEs have a little say on the design phase of projects at the moment.	CCLC-D5
	Process (P)	
6	SMEs currently give support to the LC practices led by Tier 1s (i.e. Collaborative Planning). They don't have much going on within their own organisations in terms of LC.	CCLC-P1
7	SMEs generally have to work on short windows on site (limited time of work not to interrupt the traffic). This hampers some LC efforts.	CCLC-P2
8	Due to lack of a complete systems thinking, some improvements made by an SME (i.e. asphalting) can put extra workload or pressure on other(s) (i.e. Traffic Management) within the same project.	CCLC-P3
9	The use of BIM as an enabler for data/ information flow between SMEs and Tier 1s is very limited.	CCLC-P4

10	The application of specific LC techniques (i.e. Collaborative Planning) is not standardised enough and generally differs from one organisation/project to another.	CCLC-P5
11	SMEs work under time and cost pressures and cannot spare enough time and resources to actually improve their processes using LC.	CCLC-P6
12	Some LC techniques (i.e. Collaborative Planning, Visual Management etc.) have been applied fragmentarily as opposed to part of a holistic Lean Production System.	CCLC-P7
13	Even though not very systematic or labelled as "Lean", SMEs have been already doing process improvement in their daily activities.	CCLC-P8
	Training (T)	
14	The current LC training mechanisms just cover the basic Lean concepts and are not continuous.	CCLC-T1
15	SMEs generally do not have an internal LC training mechanism.	CCLC-T2
16	The external training mechanisms run by the consultants and Tier 1s are the main formal training mean for LC for SMEs at the moment.	CCLC-T3
	Project Governance (PG)	
17	The focus of HE for LC has been mostly on Tier 1s and large Tier 2s to date.	CCLC-PG1
18	Rather than practical benefits, currently, the main motivation for SMEs for LC is HE's and Tier 1s' lean impetus ("If you are not doing lean, you are not working for us").	CCLC-PG2
19	There should be an objective and SME specific LC deployment evaluation (assessment) mechanism.	CCLC-PG3
20	HE's and the Tier 1s' work procedures and specs are too rigid and bureaucratic for the more flexible SMEs to make process improvements through LC.	CCLC-PG4
21	SMEs are mostly cash sensitive and working on little profit margins; therefore, are looking for hard evidence and incentives for LC for further deployment at their organisations.	CCLC-PG5
22	I feel LC has been rushed and pushed on the organisations from top without much deep understanding.	CCLC-PG6
23	Companies want to implement LC quickly and through the imposition of top management (top-down). Actions are implemented in several projects at once..	CCLC-PG7
24	Knowledge retention for LC is problematic. When a key personnel leaves a company/project, Lean knowledge is mostly lost as well.	CCLC-PG8
	Supply Chain (SC)	
25	Currently, there is no effectively working SME led innovation group(s) that support(s) each other's improvement activities or knowledge base in the supply chain.	CCLC-SC1
26	I feel there is a lack of a real top-management support (buy in) for LC.	CCLC-SC2
27	Strategic alliances and supply-chain integration for LC are limited.	CCLC-SC3
28	Risk aversion is too high for LC in the supply-chain.	CCLC-SC4
29	The current allocation of funds and resources for LC in the supply chain is not enough.	CCLC-SC5
30	The current Lean knowledge is superficial and limited in the supply chain.	CCLC-SC6
31	The cooperation between the organisations in the supply chain to drive LC is limited.	CCLC-SC7

Table 3. Current condition of LC at highways SMEs

No	Future direction for LC (FDLC) at SMEs	Code
	Project Delivery (D)	
1	Forming longer term alliances with Tier 1s will help SMEs adopt LC.	FDLC-D1
2	Earlier engagement with SMEs for projects will help them better design and improve their processes.	FDLC-D2
3	SMEs should have a say in the design stage to better execute their process improvement and LC efforts.	FDLC-D3
4	The current conventional unit price or lump sum contracts between Tier1s and SMEs should be replaced with more risk/benefit sharing contractual mechanisms for better incentivisation for LC at SMEs.	FDLC-D4

5	Aligning commercial teams with LC teams at HE and Tier 1s.	FDLC-D5
6	Longer term contracts involving Tier 1s and SMEs.	FDLC-D6
7	The current tendering mechanism at Tier 1s should better support innovation (i.e. LC practices).	FDLC-D7
	Process (P)	
8	Improving systems thinking in which different SMEs support each other's' Lean improvement efforts in a project.	FDLC-P1
9	Lean techniques should be extended to the maintenance/ operations phase after construction.	FDLC-P2
10	There is a need to improve the use of BIM at SMEs to support a better information flow.	FDLC-P3
11	LC efforts should be extended to the design phase.	FDLC-P4
12	There is a need for an increased standardisation in the execution of specific Lean techniques (i.e. Collaborative Planning or Visual Management) in the supply chain.	FDLC-P5
13	Value based decisions and prioritising innovations are necessary to implement some Lean techniques in short working windows.	FDLC-P6
14	As opposed to top-down, bottom-up practices for LC stemming from the workforce should be given more importance.	FDLC-P7
	Training (T)	
15	Training for LC, getting consultants on board and employing dedicated LC managers are costly for SMEs. Tier1s and HE should provide more support in those matters.	FDLC-T1
16	SMEs should develop on their in-house training for LC.	FDLC-T2
17	SMEs should better understand the Lean terms like value, waste and flow.	FDLC-T3
18	HE's "Lean Tracker" (an online database where LC records are kept and shred openly with the supply chain) could be improved to be more user-friendly and better promoted for SMEs to digest and learn from successful LC implementations in the supply chain.	FDLC-T4
19	The current LC training mechanisms should be extended to cover more advanced LC topics for SMEs and be more frequent (continuous).	FDLC-T5
20	Going beyond the LC tools, training SMEs and the supply chain for the strategic deployment of LC.	FDLC-T6
21	We need to raise the awareness on how different LC techniques are linked to each other and work as a complete system.	FDLC-T7
22	Joint training mechanisms for LC for SMEs and Tier 1s led by HE.	FDLC-T8
	Project Governance (PG)	
23	Instead of going through Tier 1s (large contractors), SMEs would benefit from more direct contact/ engagement with HE for their LC efforts.	FDLC-PG1
24	There is a need for SMEs to improve their current skills and expertise on LC.	FDLC-PG2
25	There is a need for SMEs to clearly see the business case (benefits) for LC.	FDLC-PG3
26	The number of innovative, successful pilot LC implementation projects should be increased for SMEs.	FDLC-PG4
27	HE should get more SME managers on board at their LC dissemination events.	FDLC-PG5
28	HE should expand the capacity of its LC department.	FDLC-PG6
29	Tier 1s should also improve their management style to be more supportive to SMEs for LC.	FDLC-PG7
30	Extended modularisation and standardisation (off-site) in the design phase to support LC efforts.	FDLC-PG8
	Supply Chain (SC)	
31	More academic collaboration and research/implementation focusing on LC and SMEs.	FDLC-SC1
32	LC related lessons learned, best practices, cases should be better captured, retained and communicated for future highways projects.	FDLC-SC2
33	The competencies and teachings of LC consultants in the supply chain should be better monitored/ regulated.	FDLC-SC3
34	Overall organisational support and commitment for LC should be increased in the supply chain.	FDLC-SC4

35	Increasing benchmarking efforts for LC against other sectors and countries.	FDLC- SC5
36	Supporting SMEs to form innovation driving and sharing work groups among each other.	FDLC- SC6
37	There is a need for SMEs to change their work culture for LC for more information share with each other (adverse competition).	FDLC- SC7
38	A strategic long-term focus for LC should be developed at SMEs.	FDLC- SC8
39	The view or evaluation of objective third parties (other than HE, Tier 1s, SMEs, Lean consultants, Lean proponents or dissents) are needed for the supply chain.	FDLC- SC9
40	Coordination and collaboration in the supply chain should be increased to make innovation in the short working windows.	FDLC-SC10

Table 4. Future direction for LC at Highways SMEs

4.2 Questionnaire results

4.2.1 Reliability and non-parametric tests

A Cronbach's alpha coefficient of reliability should be calculated when using Likert scale in a questionnaire to determine the internal consistency of the questionnaire (Field, 2005; Nunnally and Bernstein, 2007; Oyele, 2013). The aim here is to confirm whether the criteria and their associated Likert scale are actually measuring the construct they were intended to measure. Since Cronbach's alpha coefficient is usually between 0 and 1; as a rule of thumb, George and Mallery (2003) suggest that a value of 0.7 or more is acceptable. The overall Cronbach's alpha coefficients for the *CCLC* questions and for the *FDLC* questions were calculated as 0.904 and 0.921 respectively, demonstrating a good reliability and internal consistency of majority of the questions.

To confirm that all the criteria are actually contributing to this internal consistency, the second columns of Table 5 and Table 6 labelled “Cronbach's alpha if item deleted” are further examined. According to Field (2005), if a question is not contributing to the overall reliability and therefore not a good measure of the construct, its associated Cronbach's alpha coefficient would be higher than the overall coefficient (0.904 for *CCLC* and 0.921 for *FDLC*). This higher value implies that if the criterion is deleted, the overall reliability of the whole data would improve (Field, 2005). Only *CCLC-P8* was calculated as a poor construct as shown in bold in Table 5.

After checking reliability of the questionnaire, it was essential for this study to examine whether the *CCLC* and *FDLC* parameters were perceived similarly or differently by the respondents' supply chain roles (i.e. Tier 1s, Large Tier 2s and SMEs). Consultant organisations were excluded from the analysis due to their very small respondent number.

Since the data were not drawn from a particular probability distribution, normal distribution is not assumed and there are three distinct groups, the non-parametric test of Kruskal–Wallis were used on the three supply chain role groups. The null hypothesis (H_0) is that there are no differences in the perception of the respondents among the groups with regards to their supply chain roles. At 95% confidence interval, when the Kruskal-Wallis significance values shown in Table 5 and Table 6 are smaller than 0.05, the null hypothesis is rejected, meaning there is a statistically significant difference in the perception of the corresponding question by the different supply chain roles. The null hypotheses investigated in Table 5 and Table 6 under the Kruskal-Wallis column are as follows:

H_0: The distribution of current LC condition agreement is the same across the three types of companies (SMEs, Large Tier 2s and Tier 1s) (Table 5),

H_0: The distribution of future LC direction agreement is the same across the three types of companies (SMEs, Large Tier 2s and Tier 1s) (Table 6)

The result shows that the respondents were in general agreement in terms of their perception of all the *CCLC* questions, with the exception of four current conditions (*D3, P8*, *PG8* and *SC5*). With 11 disagreements as to the importance of the future directions (*D1, P2, P3, P4, P7, T1*, *T4, PG6, PG8*, *SC3* and *SC10*), there seems to be a greater discord in the *FDLC* questions.

4.2.2 Central tendency

Median values generally better represent central tendency than mean values for Likert-scale questions (Field, 2005; Coakes and Steed, 2009). Therefore, median values for each *CCLC* and *FDLC* questions were calculated (see Table 5 and Table 6). The dominant median score in both types of questions is 4, which indicates 'Agree' for the *CCLC* questions and 'Important' for the *FDLC* questions. From the central tendency of the data, it can be inferred in general that the respondents found the current condition statements mostly accurate and the identified future directions for LC at SMEs mostly important. The central tendency of the data validates the interview findings.

4.2.3 Current condition and future direction indices

In order to be to rank the findings, to understand the degree of agreement on the current condition (*CCLC*) and the degree of importance for each future direction statement (*FDLC*), a current LC condition (*CCI*) and a future direction index (*FDI*) in % were calculated. Similar indices were used by different researchers for similar purposes (Chan and Kumaraswamy, 2002; Spillane et al., 2011; Oyedele, 2013):

$$(\mathrm{CCI}) = \left(\frac{\sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{CCLC_i}}{NS}\right) \times 100\% \quad (1)$$

$$(\mathrm{FDI}) = \left(\frac{\sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{FDLC_i}}{NS}\right) \times 100\% \quad (2)$$

where $CCLC_i$ and $FDLC_i$ are the ratings given by (i^{th}) respondent ranging from 1 to 5; i= 1, 2, 3.......N; N is the total number of respondents for that particular statement, which is 110; and S is the highest possible agreement rating, which is 5. The ranks within the groups and the overall ranks for each *CCLC* and *FDLC* statement were identified (see Table 5 and Table 6). The descriptive statistics of the *CCI* scores (mean=75.1, standard deviation = 5.7, kurtosis =

0.07 and skewness = -0.38) indicate the current condition statements were mostly agreed by the respondents with the scores concentrating around the mean. The descriptive statistics of the *FDI* scores (mean=76, standard deviation = 7.4, kurtosis = -0.68 and skewness = -0.25) indicate that although the distribution is flatter than *CCI* (negative kurtosis), the future direction statements were also mostly found important by the respondents (negative skewness – clustering around the higher end).

	Reliability[a]	Central tendency	Kruskal-Wallis test			Current LC condition index (CCI) and rankings		
Current LC condition	Cronbach's alpha if item deleted	Median	Chi-square	Sig.[b]	H_0[c]	CCI (%)	Ranking within the group	Overall ranking
Delivery								
CCLC-D5	.902	4	1.242	.537	Not Rejected	86.4	1	1
CCLC-D4	.901	4	1.996	.369	Not Rejected	79.0	2	7
CCLC-D3	.898	4	7.380	.025	*Rejected*	77.9	3	10
CCLC-D2	.900	4	3.370	.185	Not Rejected	77.3	4	13
CCLC-D1	.900	4	4.192	.123	Not Rejected	74.0	5	19
Process								
CCLC-P8[d]	**.905**	4	14.153	.001	*Rejected*	81.6	1	3
CCLC-P4	.902	4	4.228	.121	Not Rejected	80.5	2	5
CCLC-P2	.900	4	2.651	.266	Not Rejected	80.0	3	6
CCLC-P7	.898	4	.102	.950	Not Rejected	78.7	4	8
CCLC-P5	.901	4	.850	.654	Not Rejected	77.1	5	14
CCLC-P1	.902	4	.176	.916	Not Rejected	73.1	6	22
CCLC-P3	.900	4	1.222	.543	Not Rejected	72.8	7	23
CCLC-P6	.899	4	2.896	.235	Not Rejected	67.8	8	28
Training								
CCLC-T2	.898	4	.884	.643	Not Rejected	81.0	1	4
CCLC-T3	.904	4	3.658	.161	Not Rejected	77.4	2	12
CCLC-T1	.903	3	.083	.959	Not Rejected	68.7	3	26
Project Governance								
CCLC-PG1	.902	4	1.491	.475	Not Rejected	85.3	1	2
CCLC-PG4	.902	4	.048	.977	Not Rejected	78.4	2	9
CCLC-PG5	.900	4	1.021	.600	Not Rejected	76.6	3	15
CCLC-PG3	.902	4	.092	.955	Not Rejected	73.8	4	20
CCLC-PG2	.899	4	1.191	.551	Not Rejected	73.3	5	21
CCLC-PG8	.900	4	6.192	.045	*Rejected*	72.2	6	24
CCLC-PG7	.903	3	5.960	.051	Not Rejected	68.4	7	27
CCLC-PG6	.900	3	1.559	.459	Not Rejected	62.4	8	31
Supply Chain								
CCLC-SC1	.899	4	5.016	.081	Not Rejected	77.7	1	11
CCLC-SC7	.901	4	4.887	.087	Not Rejected	76.0	2	16
CCLC-SC5	.903	4	11.130	.004	*Rejected*	75.7	3	17
CCLC-SC6	.902	4	1.883	.390	Not Rejected	75.2	4	18
CCLC-SC3	.899	4	.445	.800	Not Rejected	71.8	5	25
CCLC-SC4	.898	3	.382	.826	Not Rejected	66.2	6	29
CCLC-SC2	.902	3	4.815	.090	Not Rejected	63.8	7	30

[a] Overall Cronbach’s alpha = 0.904
[b] Significant at 95% confidence interval= 0.05

[c] H_0: The distribution of current LC condition agreement is the same across the three types of companies (SMEs, Large Tier 2s and Tier 1s)
[d] The statement's associated Cronbach's alpha coefficient is higher than the overall coefficient. Hence, not a good construct.

Table 5. Current LC condition at SMEs and associated statistical analysis

	Reliability[a]	Central tendency	Kruskal-Wallis test				Future LC direction index (FDI) and rankings		
Future LC direction	Cronbach's alpha if item deleted	Median	Chi-square	Sig.[b]	H_0[c]		FDI (%)	Ranking within the group	Overall ranking
Delivery									
FDLC-D2	.919	5	.035	.983	Not Rejected		90.2	1	1
FDLC-D3	.918	5	4.117	.128	Not Rejected		87.6	2	2
FDLC-D1	.920	4	8.736	.013	Rejected		86.4	3	3
FDLC-D6	.920	4	1.073	.585	Not Rejected		85.8	4	4
FDLC-D7	.918	4	.738	.691	Not Rejected		82.7	5	8
FDLC-D5	.919	4	5.185	.075	Not Rejected		81.3	6	10
FDLC-D4	.919	4	2.206	.332	Not Rejected		66.0	7	36
Process									
FDLC-P4	.919	4	8.811	.012	Rejected		85.1	1	6
FDLC-P7	.918	4	18.021	.000	Rejected		78.9	2	17
FDLC-P6	.918	4	4.390	.111	Not Rejected		78.5	3	18
FDLC-P1	.918	4	4.228	.121	Not Rejected		73.6	4	26
FDLC-P5	.919	4	.919	.631	Not Rejected		73.5	5	27
FDLC-P2	.919	4	27.584	.000	Rejected		70.0	6	32
FDLC-P3	.918	4	15.674	.000	Rejected		69.3	7	33
Training									
FDLC-T1	.920	4	7.702	.021	Rejected		80.2	1	13
FDLC-T7	.919	4	1.119	.571	Not Rejected		77.7	2	19
FDLC-T8	.919	4	.632	.729	Not Rejected		77.5	3	20
FDLC-T3	.918	4	3.983	.136	Not Rejected		75.3	4	25
FDLC-T4	.920	4	9.315	.009	Rejected		72.5	5	28
FDLC-T6	.917	3.5	4.743	.093	Not Rejected		70.6	6	29
FDLC-T5	.918	3	.187	.911	Not Rejected		68.7	7	34
FDLC-T2	.920	4	.279	.870	Not Rejected		66.9	8	35
Project Governance									
FDLC-PG3	.920	4	.202	.904	Not Rejected		85.5	1	5
FDLC-PG7	.918	4	.020	.990	Not Rejected		81.6	2	9
FDLC-PG2	.919	4	1.549	.461	Not Rejected		81.0	3	11
FDLC-PG4	.919	4	4.872	.088	Not Rejected		79.6	4	15
FDLC-PG5	.917	4	2.353	.308	Not Rejected		79.3	5	16
FDLC-PG1	.920	4	4.486	.106	Not Rejected		76.2	6	22
FDLC-PG8	.919	4	12.607	.002	Rejected		76.0	7	23
FDLC-PG6	.918	3	10.764	.005	Rejected		64.0	8	38
Supply Chain									
FDLC-SC2	.919	4	1.631	.443	Not Rejected		84.2	1	7
FDLC-SC10	.919	4	9.214	.010	Rejected		80.8	2	12
FDLC-SC4	.919	4	3.503	.173	Not Rejected		79.8	3	14
FDLC-SC8	.918	4	.347	.841	Not Rejected		77.3	4	21
FDLC-SC6	.918	4	.530	.767	Not Rejected		75.6	5	24
FDLC-SC7	.918	4	1.641	.440	Not Rejected		70.4	6	30
FDLC-SC3	.920	4	9.088	.011	Rejected		70.2	7	31
FDLC-SC5	.917	3	2.517	.284	Not Rejected		64.7	8	37
FDLC-SC9	.919	3	5.929	.052	Not Rejected		62.7	9	39
FDLC-SC1	.919	3	2.415	.299	Not Rejected		60.9	10	40

[a] Overall Cronbach's alpha = 0.921
[b] Significant at 95% confidence interval= 0.05
[c] H_0: The distribution of future LC direction agreement is the same across the three types of companies (SMEs, Large Tier 2s and Tier 1s)

Table 6. Future LC direction for SMEs and associated statistical analysis

4.2.4 Correlation analysis

To investigate the level of correlation between the future direction (*FDLC*) statements, a Spearman's rho correlation matrix was calculated (see Table 7), as homoscedasticity, linearity and normal distribution of the data were not assumed (Field, 2005; Coakes and Steed, 2009). In the matrix, the cells highlighted in black indicate a high correlation (Spearman's correlation coefficient > 0.5) (i.e. between *T5* and *T6* and *SC7* and *SC8*) and the cells highlighted in grey indicate a moderate correlation (0.3 < Spearman's correlation coefficient < 0.5). Many of the correlations were found significant at 95% (*) and 99% (**) confidence (two-tailed). The correlation analysis was performed to identify what future direction items should be treated and considered in connection with what other future direction items for further LC diffusion across highways SMEs.

FDLC	D1	D2	D3	D4	D5	D6	D7	P1	P2	P3	P4	P5	P6	P7	T1	T2	T3	T4	T5	T6	T7	T8	PG1	PG2	PG3	PG4	PG5	PG6	PG7	PG8	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10
D1	1																																							
D2	.3**	1																																						
D3	.2*	.3**	1																																					
D4	.2**	.1*	.2**	1																																				
D5	.2*	.0	.0	.1	1																																			
D6	.3**	.2**	.2**	.2*	.2*	1																																		
D7	.2**	.1	.2**	.1	.3**	.3**	1																																	
P1	.2**	.2**	.3**	.3**	.0	.1	.3**	1																																
P2	.0	.0	-.0	.1	.2**	.0	-.	.1	1																															
P3	.0	.0	.1	.2**	.1	.0	.1*	.1*	.4**	1																														
P4	.1	.2*	.2**	.2**	.2**	.1	.1	.2*	.2**	.2**	1																													
P5	.0	.1	.2**	.1	.0	.0	.1*	.3**	.1	.3**	.1*	1																												
P6	.2**	.2*	.2*	.3**	.2*	.2*	.2**	.4**	.2**	.1*	.4**	.3**	1																											
P7	.0	.0	.2*	.2**	.2**	.2**	.2**	.2**	.3**	.3**	.2**	.1	.3**	1																										
T1	.3**	.3**	.3**	.1	.0	.1	.1	.2**	-.0	.0	.0	.2*	.1	-.0	1																									
T2	.1	.1	.2**	.2*	.0	.0	.0	.3**	.2**	.2**	.3**	.1	.2*	.1	0.1	1																								
T3	.2*	.1	.1*	.1	.2*	.0	.1*	.3**	.3**	.3**	.3**	.3**	.3**	.2**	.3**	.1	1																							
T4	.0	.1	-.1	.1	.1*	.0	.2*	.3**	.1	.1	-.0	.1	.1	.3**	.0	-.0	.1	1																						
T5	.1	.2**	-.0	.2*	.2*	-.0	.1	.2**	.3**	.2**	.0	.2**	.2*	.3**	.2*	.1	.2*	.4**	1																					
T6	.2**	.1	.1*	.2**	.3**	.1	.4**	.3**	.1*	.2**	.2**	.2**	.3**	.4**	.1	.2**	.3**	.1	.5**	1																				
T7	.1	.2*	.2*	.1	.2**	.1	.3**	.2**	.1	.2**	.3**	.2**	.1	.3**	.1	.1	.3**	.1	.3**	.4**	1																			
T8	.2*	.1	.2**	.2**	.1	.1	.3**	.2**	-.1	.0	.1	.1	.2**	.2**	.1	.1	.0	.0	.1	.2*	.1	1																		
PG1	.4**	.3**	.3**	.3**	.1	.3**	.2*	.2**	.0	.1	.1	.1	.2**	.0	.3**	.2*	.1*	.0	.1	.2*	.2*	.1*	1																	
PG2	.2**	.0	.0	.2*	.1	.0	.1*	.1	.1	.0	.1*	.1*	.3**	.1	.2**	.0	.3**	.1*	.1	.2**	.0	.1	.0	1																
PG3	.3**	.1	.2*	.0	.2**	.3**	.4**	.2**	-.1	-.0	.1	.0	.1	.1	.1	.0	.0	.2*	.0	.1*	.1	.2**	.0	.1	1															
PG4	.1	-.0	.2*	.2**	.2*	.0	.2*	.2**	.1*	.1	.3**	.3**	.2**	.2*	-.0	.1	.3**	.0	.1	.3**	.2**	.3**	.1	.1	.1	1														
PG5	.2*	.2**	.2*	.3**	.1	.2*	.3**	.3**	.1	.2**	.2*	.2**	.3**	.3**	.3**	.2*	.3**	.2**	.2**	.4**	.2**	.2**	.3**	.3**	.2**	.2**	1													
PG6	.0	.1	.2**	.1	.1	-.0	.0	.1*	.2*	.3**	.1	.1	.2*	.3**	.0	.2**	.2*	.2**	.2*	.3**	.2**	.2*	.1	.1	.1	.2*	.3**	1												
PG7	.3**	.2**	.2**	.2*	.4**	.2*	.3**	.2**	.1	.0	.1	.2**	.3**	.2**	.0	.1	.1	.0	.3**	.4**	.2**	.2*	.3**	.2*	.2*	.2**	.3**	.2*	1											
PG8	.0	-.0	.1	.1	.2*	.1	.1	.1	.2**	.3**	.1	.1	.2*	.2*	.0	.1	.1	.1	.0	.1	.1	.1	.0	.0	.1	.2**	.2**	.2*	.1	1										
SC1	.0	.2*	-.0	.3**	.1	-.0	.1	.1*	.2**	.4**	.1	.1	.2**	.2*	.2*	.2*	.1	.3**	.3**	.3**	.1	.1	.0	.2**	-.0	.0	.4**	.4**	.1	.1	1									
SC2	.2**	.0	.1	.2**	.4**	.3**	.2*	.1	.1	.1	.2*	.1	.2**	.3**	.1	.0	.2*	.2*	.2*	.2**	.2*	.3**	.2*	.1	.2**	.2**	.3**	.2**	.3**	.3**	.1	1								
SC3	.0	.1	.0	.0	.0	-.0	.1	.1	.0	.1	-.0	.1	.0	.2*	.0	-.1	.0	.1	.2*	.2**	.1	.2*	-.0	.0	.1	.2**	.1	.3**	.1*	.0	.1	.2**	1							
SC4	.2*	.0	.1	.2**	.2**	.0	.2**	.2**	.2*	.2**	.2*	.3**	.3**	.2**	.0	.2*	.3**	.2**	.3**	.2**	.1	.3**	.1	.4**	.3**	.4**	.3**	.3**	.2*	.2**	.2**	.1	.1	1						
SC5	.1	.2**	.2*	.3**	.0	.1	.2**	.3**	.4**	.4**	.1*	.3**	.2**	.3**	.2*	.3**	.2**	.1*	.3**	.3**	.2**	.1	.2**	.1	.0	.2*	.2*	.3**	.2*	.1	.3**	.0	.1*	.2*	1					
SC6	.2*	.2**	.3**	.2**	.1	.1	.1	.3**	.0	.1	.4**	.2**	.4**	.1*	.1	.3**	.2**	-.0	.1	.2**	.2**	.3**	.2**	.0	.2*	.5**	.2**	.1	.2**	.0	.1	.1	.1	.3**	.2**	1				
SC7	.1	.1	.1	.4**	.0	.0	.1	.2**	.2*	.2*	.3**	.2**	.3**	.3**	.1	.2**	.3**	.0	.2*	.3**	.1	.3**	.2*	.1	-.0	.3**	.2**	.1	.2*	.1	.2*	.1*	.1	.2*	.3**	.3**	1			
SC8	.1	.1	.2**	.2**	.1*	.3**	.3**	.2*	.1	.1	.3**	.3**	.4**	.2**	.2*	.2*	.2**	-.0	.1	.2**	.1*	.3**	.2*	.3**	.2*	.2**	.3**	.0	.2**	.2*	.0	.2*	.1	.2**	.2**	.2**	.5**	1		
SC9	.1	.1	.0	.2**	.0	.0	.1	.2**	.2*	.2**	-.1	.2*	.0	.2**	.2**	-.0	.1	.2**	.2**	.2**	.0	.2*	.0	.1	.1	.0	.2*	.2*	.1	.0	.3**	.2*	.3**	.1	.3**	.0	.2*	.1	1	
SC10	.2*	.1	.1*	.2*	.3**	.1	.3**	.1	.1	.1*	.2**	.0	.1	.3**	-.0	.0	.1*	.0	.0	.2**	.2**	.3**	.0	.0	.2*	.2**	.2**	.2*	.1*	.1	.1	.3**	.17	.1	.1	.2*	.3**	.3**	.1	1

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

Table 7. Spearman correlation matrix for the *FDLC* statements

5. Discussion

5.1 Current condition of LC at SMEs

With the minimum current LC condition index (*CCI*) score of 62.4% (Table 5), it can be inferred that the respondents mostly agreed with and validated the identified statements associated with the current LC condition at SMEs (*CCLC*). The top 5 most agreed statements by their overall *CCI* rankings (Table 5) in decreasing order are *D5, PG1, P8, T2* and *P4*, which denote

- SMEs' current inability to affect the design phase,
- the focus of HE being on Tier 1s and large Tier 2s for LC,
- SMEs already doing some process based improvements even though not labelled "LC",
- lack of in-house LC training mechanisms at SMEs and
- the limited use of Building Information Modeling (BIM) as an enabler for LC and information flow.

On the other hand, the 5 least agreed statements are *PG7*, *P6*, *SC4*, *SC2* and *PG6*, which denote

- a haste in the current LC implementations,
- lack of resources for LC at SMEs,
- risk aversion being too high for LC in the supply chain,
- lack of top management support and
- LC being pushed from top without much understanding.

The lack of supply chain integration with SMEs comes to the fore in the findings (Naoum, 2003; Cheng et al., 2010; Meng, 2010), which results also in SMEs' inability to affect and participate in product design. Establishing that integration between product design and production elements is key in LC practices for better product value and effective production system design on-site (Koskela et al., 1997; Zimina et al., 2012). Additionally, the client's engagement with SMEs for LC was found limited. SMEs seem to be dependent on their large clients to develop on their LC skill and capabilities. The respondents also highlight SMEs' ability and need to make process improvement and innovation to some extent to survive in the highly competitive construction market (Hardie and Newell, 2011). However, the nature and structure (whether a system innovation or incremental/ ad-hoc) of this process improvement need to be investigated with respect to LC (Slaughter, 1998). The lack of in-house training mechanisms at SMEs further indicates their reluctance in committing to the LC agenda, which validates the literature indicating that SMEs do not see mutual benefits in such improvement efforts as LC (Holt et al., 2000; Dainty et al., 2001; Upstill-Goddard et al., 2016). BIM, as a LC enabler (Sacks et al., 2010), has not penetrated enough into SMEs' operations yet as identified by Abuelmaatti (2014) andPourier et al. (2015).

The current LC agenda has been driven in the supply chain since the late 2000s (Ansel et al., 2007; Drysdale, 2013; HE, 2016); therefore, it is not something alien to the supply chain and they do not seem to agree much on that LC has been hastily implemented. Similarly, the lack of top management support and top-down push of LC, which were identified as important barriers for LC implementations in the literature (Sarhan and Fox, 2013; Ward, 2015; Zanotti et al., 2017), could find relatively less ground as to the current LC condition at SMEs. The respondents do not strongly agree with the lack of resources at SMEs for LC, which was identified as a barrier for LC at construction SMEs by Harper and Bernold(2005) andAlves et al. (2012).. The unexpected nature of this finding can be attributed to the respondents' high return-on-investment expectation from LC and their confidence in its potential to change the current civil project management. Also, the size of SMEs considered by the respondents could be relatively bigger (medium-sized enterprises) that may more easily allocate the necessary resources for LC than small or micro-sized enterprises. The interview and questionnaire design did not further group SMEs by their sizes. Although, those general views for the LC adoption in the supply chain are promising, they seem to be in partial disagreement with the interview findings and the literature, and therefore, their reasons and motives need further investigation.

In Table 5, there is a statistically significant difference in their current condition views across the different supply chain actors on these statements;

- SMEs start working generally on a short notice without much earlier preparation for a project.
- Even though not very systematic or labelled as "Lean", SMEs have been already doing process improvement in their daily activities.
- Knowledge retention for LC is problematic. When a key personnel leaves a company/project, Lean knowledge is mostly lost as well.
- The current allocation of funds and resources for LC in the supply chain is not enough.

Larger SME clients do not agree much on SMEs being caught unprepared for projects, as identified from the interviews, they tend to perceive that SMEs' job scopes are narrower and therefore, they can prepare for projects more rapidly. Hence, the difference. SMEs' capability of innovation was underlined frequently by the interviewed SMEs managers. The statement was also highly agreed by all the respondents in general. However, respondents from larger organisations do not seem to agree that strongly on that capability, indicating a difference in perception in SMEs' current innovation form and capacity. Respondents from larger organisations seem also in partial disagreement with the lack of resources and the problems associated with LC knowledge retention statements at SMEs for LC. Again, this may be related to the size of SMEs considered by the respondents being relatively large (medium-sized enterprises) with better monetary and managerial capabilities than smaller enterprises.

5.2 Future direction for LC at SMEs

With the minimum future LC direction index (*FDI*) score of 60.9% (Table 6), it can be inferred that the future direction statements (*FDLC*) were found mostly important by the respondents. Therefore, all the statements should be given attention to. The top 5 most important statements for the future by their overall *FDI* rankings (Table 6) in decreasing order are *D2, D3, D1, D6* and *PG3,* which reflects the high importance given to project delivery related action items (Rooke et al., 2007; Sarhan and Fox, 2013; Cano et al., 2015; Pasquire et al., 2015a) by the supply chain for the dissemination of LC across highways SMEs. However, according to the Kruskal-Wallis test (Table 6), there is a greater variation in the given importance to *D1* (forming longer term alliances with SMEs for LC) across the different supply chain roles. The full consensus towards developing a LC capability at highways SMEs seems to be around

- earlier engagement,
- higher certainty,
- better ability to affect the design phase, and
- that the SMEs' need to see the business case for LC.

In line with this finding, the importance of certainty, alliances and creating an environment of mutual benefit in project-based construction supply chains to penetrate working strategies (e.g. LC) was highlighted repeatedly in the literature (Dainty et al., 2001; Naoum, 2003; Bresnen, 2007; Eriksson, 2010; Meng, 2010). LC deployment in highways projects is not an exception in that sense. Considering a move towards an IPD type project delivery mechanism and other supply chain integration strategies will be helpful (Lu and Yan, 2007; Kent and Becerik-Gerber, 2010; Baiden and Price, 2011). Relational procurement strategies can also set the commercial base for improved BIM use across the supply chain (McAdam, 2010; Porwal and Hewage, 2013), which was found currently limited from the study.

In Table 6, the 5 least important action items for the future are SC1, SC9, PG6, SC5 and D4, which denote;

- More academic collaboration focusing on LC and SMEs,
- Obtaining the view or evaluation of objective third parties,
- HE should expand the capacity of its LC department,
- Increasing benchmarking efforts for LC,
- Replacing the current traditional contractual mechanisms with more risk/benefit sharing contractual mechanisms

Although the respondents gave higher importance to establishing earlier engagement, better job certainty and longer-term alliances for the diffusion of LC across SMEs, replacing the current traditional contractual mechanisms were found of a lesser priority, which highlights the importance of a mind-set change over a change in mere contractual mechanisms, supporting the desire of the interviewed SME managers in developing a collaborative culture between larger organisations and SMEs in the supply chain. However, it should be noted that long-term alliances and partnerships should be firmly supported with commercial arrangements by a proportional risk/ award sharing mechanism (American Institute of Architects, 2007; Kent and Becerik-Gerber, 2010; Lahdenperä, 2012; Mesa et al., 2016).

As seen in Table 6, the views as to the importance of the future direction statements vary more greatly than the current condition statements and there is statistically significant difference in the given importance to the future direction statements *D1, P4, P7, P2, P3, T1, T4, PG8, PG6, SC10 and SC3* across the different supply chain actors. Therefore, sector leaders and policy makers for LC at SMEs should pay greater attention to consensus seeking, if those statements are to be strategic action items in the future.

The high level of inter-correlation identified form the Spearman’s correlation matrix (Table 7) underlines the complexity and interrelatedness of the issue. Furthermore, beyond the dominant process focus in LC discussions, it calls for a broader, more holistic view to LC deployment practices and research, validating the claims by Green (1999), Barros Neto and Alves (2007), Alves et al. (2012), and Sarhan and Fox (2013). In particular, the positive and statistically significant correlation between

(1) *PG1* (SMEs' need for a direct engagement with HE) and the delivery related statements *D1, D2, D3, D4* and *D6,*

(2) *T3* (SMEs' need for a better understanding of LC basics) and the process related statements *P1, P2, P3, P4* and *P6,*

(3) *SC4* (the need for increasing organisational commitment and support for LC) and the project governance related statements *PG2, PG3, PG4, PG5* and *PG6,*

(4) *T1* (SMEs' need for LC training and learning support) and the delivery related statements *D1, D2* and *D3,*

(5) *SC1* (More academic collaboration to develop a LC capability) and the training related statements *T1, T2* and *T3,*

(6) *SC5* (Increasing benchmarking efforts for LC) and the process related statements *P1, P2, P3*, and

(7) *SC8* (Developing a long-term focus for LC) and the process related statements *P4, P5* and *P6* suggests treating those future directions together.

The top 10 ranked current condition and future direction statements can be seen in Table 8. The ranking shows the top agreed current condition statements by the supply chain and the top most important future direction items (action items) for the promotion of LC in SMEs to validate the current condition and to prioritise the future strategy.

No	Most agreed current condition of LC statements
1	Many construction and maintenance performance issues stem from the initial design. However, generally SMEs have a little say on the design phase of projects at the moment.

2	The focus of HE for LC has been mostly on Tier 1s and large Tier 2s to date.
3	Even though not very systematic or labelled as "Lean", SMEs have been already doing process improvement in their daily activities.
4	SMEs generally do not have an internal LC training mechanism.
5	The use of BIM as an enabler for data/ information flow between SMEs and Tier 1s is very limited.
6	SMEs generally have to work on short windows on site (limited time of work not to interrupt the traffic). This hampers some LC efforts.
7	The contracts between Tier 1s and SMEs are mostly conventional unit price or lump sum contracts, which does not incentivise innovation much.
8	Some LC techniques (i.e. Collaborative Planning, Visual Management etc.) have been applied fragmentarily as opposed to part of a holistic Lean Production System.
9	HE's and the Tier 1s' work procedures and specs are too rigid and bureaucratic for the more flexible SMEs to make process improvements through LC.
10	SMEs start working generally on a short notice without much earlier preparation for a project.

Table 8. Top 10 *CCLC* statements

No	**Most important future direction for LC statements**
1	Earlier engagement with SMEs for projects will help them better design and improve their processes.
2	SMEs should have a say in the design stage to better execute their process improvement and LC efforts.
3	Forming longer term alliances with Tier 1s will help SMEs adopt LC.
4	Longer term contracts involving Tier 1s and SMEs.
5	There is a need for SMEs to clearly see the business case (benefits) for LC.
6	LC efforts should be extended to the design phase.
7	LC related lessons learned, best practices, cases should be better captured, retained and communicated for future highways projects.
8	The current tendering mechanism at Tier 1s should better support innovation (i.e. LC practices).
9	Tier 1s should also improve their management style to be more supportive to SMEs for LC.
10	Aligning commercial teams with LC teams at HE and Tier 1s.

Table 9. Top 10 *FDLC* statements

5.3. Implications to project management

Under the light of the findings, the following important practical implications and suggestions should be considered by project managers in order to diffuse LC at SMEs in their supply chains:

- Realising that implementing LC at SMEs requires more than process or Lean techniques and tools related know-how or training. It needs to be supported by long-term alliances and collaborative contractual arrangements with shared profits/risks. IPD type arrangements, which can address SMEs' requirements for earlier engagement and better project certainty, should be considered.
- As an extension to these collaborative contractual agreements, SMEs should be given the opportunity to give input in the design phase for better design constructability and to align their site production systems and project management efforts with product design.
- Under collaborative contracts, SMEs should be introduced to BIM process and be encouraged to invest in BIM as a tool to support better information flow in LC efforts.
- Large, powerful clients in construction supply chains (like Highways England) should directly engage with SMEs for their LC efforts, particularly for issues around project delivery (see Table 7).
- Larger SME clients should give support and encourage SMEs to develop their in-house LC training mechanisms. The scope of this support can range from sharing training materials, involving SME managers in their larger clients' in-house LC training sessions to embedding LC consultants in SMEs on the account of larger SME clients. Also, those larger clients should be aware of the fact that SMEs potentially develop innovation without "doing LC" in their project management efforts and support them in capturing and standardising those innovations.

- SMEs need to clearly see the business case for LC. Mechanism in capturing and disseminating LC benefits for SMEs should be developed in supply chains. For this purpose, under the leadership of larger clients, liaison groups for LC at SMEs and databases for LC improvement records for specific projects or supply chains can be formed.
- Remarks like SMEs' not having necessary resources for LC or LC is being pushed to them in haste without much preparation should be checked, validated and approached with caution, as their relevance for LC at SMEs were found comparatively lower in this study.
- Project managers should review their existing LC techniques and tools for their correctness, completeness and integration with each other, as fragmented and partial implementation of those tools and techniques were captured. In parallel with this, their LC training content should also be reviewed.
- Larger SME clients should review their internal mechanism and commercial units to support the LC improvements by their SME subcontractors.
- SMEs need to better understand the basics of the LPS and LC, particularly while taking process related actions for LC (see Table 7).
- While striving to increase organisational support and commitment for LC, project managers need to consider and take action for project governance related issues (see Table 7).

6. Conclusions

The focus of this exploratory study is on understanding (a) the current condition of and (b) the future direction for the LC deployment initiative in a civil projects (highways) supply chain from an SMEs perspective. Going beyond the usual process level discussions on LC, the current condition and future direction for LC at highways SMEs were identified and detailed from 20 interviews and the literature, and classified into project delivery, process, training, project governance and supply chain related groups. The initial findings were validated and further investigated by using a questionnaire survey with 110 responses.

The current condition of LC at SMEs highlights some major negative factors before LC deployment in SMEs, the most agreed of which are a) a short term relations structure, (b) competitive tendering mechanisms, (c) fragmentation, (d) problems in engaging with SMEs for LC, (e) their inability in affecting product design and (f) issues with convincing SMEs to deploy LC by demonstrating the business case on mutual benefits. The identified capacity of SMEs in doing operational innovation is promising in that sense. The supply chain however, does not strongly agree that (a) LC has been pushed hastily from top with proper managerial support and (b) SMEs lack necessary monetary and managerial resources for LC deployment and LC knowledge retention.

In line with the current conditions, the identified future directions hold responsibilities for each supply chain actor. While SMEs need to improve their LC understanding and know-how by (a) developing their own in-house training mechanisms, (b) forming innovation driving and sharing work groups, (c) doing benchmarking and in general, (d) adopting LC practices more in their operations, their larger clients are expected to develop (a) a long-term perspective with SMEs (b) help SMEs increase their level of business certainty and (c) help SMEs see the business case for LC. IPD-type partnering strategies can be considered. As the leading actor and the main client in the supply chain, HE (a) needs to review and audit its current project delivery mechanisms, (b) its engagement with SMEs for LC, (c) the adaptation of and the level of standardisation in more popular LC techniques (e.g. Last Planner, Visual Management) and (d) the current LC training content and structure in the supply chain. The supply chain gives higher priority to project delivery related arrangements in the future for the dissemination of

LC in highways SMEs. The correlation analysis of the future direction items also revealed that there are many future direction items that are significantly correlated and can potentially be treated together.

Although the study aims to draw a general picture of the issue, it is also possible to investigate LC deployment with regards to each classification group (i.e. project delivery, process, training, project governance and supply chain) in more detail from a civil or highways project management perspective (e.i. Daniel et al., 2017; Tezel and Aziz, 2017). As the deployment of LC is gaining momentum, investigating the success factors for LC in civil projects and their supply chains will present another research opportunity. Larger data sets may give way to explorative analyses like factor analysis or clustering. Also, deploying some LC techniques in civil SMEs within a design science or participative research effort will yield rich insights on LC at SMEs. Additionally, it will be useful to further group SMEs into medium-sized, small-sized and micro-sized enterprises to obtain a greater understanding of the issue. The lack of the further grouping of SMEs is a shortcoming of this research. The study also highlights the importance of keeping a sector-specific perspective in supply-chain level investigations in construction project management (e.g. housing, commercial building, civil/ infrastructure, energy). Therefore, similar studies can be conducted under different construction sector contexts.

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