A FRAMEWORK FOR TRANSFERRING AND SHARING TACIT KNOWLEDGE IN CONSTRUCTION SUPPLY CHAINS WITHIN LEAN AND AGILE PROCESSES

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Dedication

I dedicate this piece of work to my Mother Kaushalya Devi, Father Shri. C. L. Saini, my lovely wife Shalu and sons Lovish and Rayensh.

Certificate of Originality

This thesis is submitted under the University of Salford rules and regulations for the award of a PhD degree by research.

The researcher declares that no portion of the work referred to in this thesis has been submitted in support of an application for another degree of qualification at this, or any other university or institution of learning.

Mandeep Saini……………………………(Signed)

……………………………………………(Date)

List of Abbreviations

BIM	Building Information Modelling
CSC	Construction Supply Chain
CSCs	Construction Supply Chains
EoS	Economies of Scale
ERP	Enterprise Resource Planning
IBM	International Business Machines Corporation
JIT	Just in Time
KBV	Knowledge Based View
KC	Knowledge Communication
KDRM	Knowledge Driven Research Methodology
KM	Knowledge Management
KS	Knowledge Sharing
KT	Knowledge Transfer
NASA	National Aeronautics and Space Administration
PBOs	Project Based Organisations
PhD	Doctor of Philosophy
PPP	Public-Private Partnership
RBT	Resource Based Theory
RBV	Resource Based View
RM	Research Methodology
SC	Supply Chain
SMEs	Small and Medium Size Enterprise(s)
TK	Tacit Knowledge
TPS	Toyota Production System
TQM	Total Quality Management
UK	United Kingdom

Definitions in this Study

The operational definitions used in this study are presented below in alphabetical order

i. **Agile as a principle** is to increase responsiveness of each of the current, following and related activities within a task and, furthermore, in the processes that integrate with others.

ii. **Capability in this context** refers to the capacity of individuals and firms to deploy resources in terms of sharing and transferring tacit knowledge.

iii. **Capacity in this context** is the capability of individuals and firms to perform the sharing and transferring of tacit knowledge to produce efficiency within the processes.

iv. **Challenges in this context** is a call for the essential factors whose absence hinders the sharing or transference of tacit knowledge.

v. **Construction Supply Chain** is to integrate and add value to key business processes from the original suppliers to end user and, furthermore, to add value to a product or service that is being delivered to the end user.

vi. **Construction Supply Chains** is a combination of multi-organisational supply chains, whereby several supply chains jointly establish a mega supply chain.

vii. **Contribution in this context** is the role played by tacit knowledge to bring about efficiency (a) in Lean, (b) in Agile and (c) in Construction Supply Chain Processes.

viii. **Critical Success Factors** in this context are the necessary factors whose absence hinders the effectiveness of the transference and sharing of tacit knowledge.

ix. **Efficiency in this context** is to enhance the skilfulness of a supply chain to reduce waste and effort in order to make it responsive.

x. **Knowledge Management** is the process of identifying, transferring and effectively sharing tacit knowledge to support other processes, wherever and whenever required.

xi. **Lean as a principle** is to increase the value of a business process while relentlessly eliminating waste from each of the task within the current, following and related activities.

xii. **Principle in this context** is a basic generalisation rule or rule of law concerning a natural phenomenon or the function of a complex system that is accepted as true and that can be used as a basis for reasoning or conduct.

xiii. **Process in this context** is a series of tasks and activities within (a) Lean, (b) Agile and (c) the Construction Supply Chain (such as brick laying, painting, roof laying

xiv. **Tacit Knowledge** is the point of view in the human mind which is gained over time by experience, learning, sensing, analysing, witnessing and observing a process or series of processes in the physical world.

ABSTRACT

Fragmentation in the UK construction sector is hindering knowledge production which leads to low levels of productivity. For decades, several unproductive initiatives have been deployed in an effort to increase partnering and collaboration between construction supply chains. Despite these efforts recent studies highlight that the UK construction sector needs to consider the process-based view seriously with the application of knowledge communication and specifically the transferring and sharing of Tacit Knowledge within the supply chain, if performance improvements are to be achieved.

In this study, a three-stage framework for transferring and sharing Tacit Knowledge within Construction Supply Chains is developed to bring collaboration and partnering, and to improve efficiency in Construction Supply Chains and in the application of Lean and Agile. Relevant and associated literature about knowledge management, supply-chain management and Lean and Agile thinking within construction supply chains is investigated in different dimensions.

The study highlights some unique and fresh findings in terms of transferring and sharing of Tacit Knowledge. In addition, a novel research processes' model "Knowledge Driven Research Methodology" is developed and applied to define a worthy research methodology for this study.

To validate the factors extracted from the literature review and the conceptual framework, a systematic research methodology is adopted to collect quantitative data through a survey questionnaire. Moreover, data is analysed with frequency, the Kruskal-Wallis H test and correlation analysis and with interpretive analysis, to highlight the taxonomic relations among the findings based on the propulsive coefficients, and to identify and establish the rank of the foremost and following factors. Through the results from the data analysis, the conceptual framework is modified and then further validated through the expert interviews.

The study concludes with a validated framework and establishes the fact that, if the transferring and sharing of tacit knowledge is initiated within construction processes, it will bring collaboration and partnering and increase efficiency among construction supply chains. The most estimable part of this study is that it brings forward several tiny and major contributions to the existing knowledge for Literature, academia, policy makers and practitioners.

Keywords: Construction Supply Chains, Knowledge Management, Tacit Knowledge, Transferring and Sharing Tacit Knowledge, Lean and Agile Construction

1 INTRODUCTION OF THE RESEARCH

1.1 Introduction

This chapter introduces the research work as well as outlines the content of the work presented in rest of the thesis. The aim of this chapter is to provide a detailed overview of the research. It describes the background, research aim, objectives, questions, justification and gives an overview of the extensive literature review undertaken which provided a thorough understanding of the research area and a conceptual framework for the Transfering and Sharing of Tacit Knowledge in Construction Supply Chains in the context of Lean and Agile principles.

1.1.1 Background to this Study

The United Kingdom (UK) construction industry consists of over 280k firms (contracting, services and products) employing over 2.93 million people (10% of total UK employment) in a multitude of roles (BIS, 2013d). The construction sector is defined as a sector which embraces construction materials and products, suppliers and producers, building services manufacturers, providers and installers; contractors, sub-contractors, professionals, advisors and construction clients and those relevant organisations which build, operate and refurbish buildings (BIS, 2012). In a 2013 publication the composition of construction industry was defined (BIS, 2013d) as incorporating (i) construction contracting, (ii) construction-related professional services, and (iii) construction-related products and materials. BIS (2013) also stated that the construction industry is known as one of the knowledge-based value-creating industries. However, the fragmented nature of Construction Supply Chains (CSCs) has a negative impact on the construction industry and construction projects. Within the construction sector at least 99.9% of firms are Small and Medium Enterprises (SMEs) and, of those, about 70% employ no more than one person (BIS, 2013d).

As a critical barrier to change, fragmentation can inhibit knowledge creation and this canlead to a low level of productivity (Oragne et al., 2005; Egbu, 2006; Alashwal et al., 2011). Some the recent researchers (such as Baldauf & Hubbard, 2011; Lynagh, 2011; Brewer & Johnson, 2004) suggested that an integrated and collaborative Supply Chain approach and developing knowledge transfer and a sharing approach within a project would be helpful in reducing the impact of fragmentation in construction supply chains. The study of Forgues et al. (2009) has suggested that collaboration within supply chains as a major factor that will as assist in preventing the negative impact of fragmentation. The study proposed three main approaches for encouraging collaboration: practices, integrated teams and integrated design processes (Alashwal et al. 2011). However, such approaches face many challenges due to the embedded nature of the fragmented construction supply chain. Furthermore, Alashwal et al. (2011) revealed the reason why fragmentation occurs, when the number of SMEs increases and of large firms decreases. In February 2014, in the construction industry, 37% of organisations were more likely than average to have reduced employment (BIS, 2013d). Another analysis carried out for BIS (2013) by E S Harris (2013) reveals that main contractors may be directly managing around 70 sub-contracts in which 70% of contracts are below £10k (BIS, 2013d). Alashwal et al. (2011) emphasised that this is the clear evidence of the scale of fragmentation in the construction industry. The Egan, Latham & BIS reports suggest that SMEs hold an important position in the construction industry. However, individuals SMEs may hold specialised skills and knowledge in one of the aspects of CSC but do not necessarily hold the skills of transferring and sharing knowledge. As the result, the knowledge of an SME does not contribute to improve efficiency in a CSC. Thus, the problem consists of communicating knowledge within the CSC and, more importantly, in the transfer and sharing of tacit knowledge with others. A lack of this would result in developing a highly fragmented and un-collaborated supply chain.

Different knowledge-based and process-based solutions such as Lean and Agile processes have been proposed during the past to overcome the problem of the negative impact of fragmentation. Lean construction is a production management-based approach to project delivery; it is a new way of designing and building capital facilities (Sacks et al., 2009). The application of Lean production management to manufacturing caused a revolution. The objectives of the Lean production systems are to maximise value and minimise waste within specific techniques and apply those techniques to form a project-based production system (Childerhouse et. al., 2003). Lean Construction is particularly useful in complex, uncertain, and quick projects. The Lean principles are to increase the quality of work and products, increase value by eliminating waste and increase flow through the process. On the contrary, Agile Thinkers contended that the agile paradigm has values that can enhance the business capability of SMEs. However, very few construction SMEs are aware of the agile paradigm (Ribeiro & Fernandes, 2010). Owen et. al., (2008) observed that the agile concept has considerable potential in the pre-design and design phases in CSC but that there are significant hurdles to its adoption in the construction phase. There could be more to offer in the construction sector than the application of "Agile" such as pull demand and the customisation of products (Naim and Barlow, (2003) cited by Ribeiro & Fernandes, (2010)). Agility stresses different values to Lean, typically, learning, rapid configuration and change. This study considers the distinct perspectives of Lean Thinkers and Agile Thinkers to investigate the application of Lean and Agile principles to CSCs and to analyse the capability of these to increase efficiency.

On the other hand, Briscoe & Dainty, (2005), Khalfan et al., (2007) and Sanderson & Cox, (2008) observed that the construction industry requires a blended approach. Furthermore, following on after Vrijhoef & Koskela (1999), Chen & Paulraj (2004) suggested that a well-integrated approach required an efficient CSC. Briscoe & Dainty (2005) argued "The UK construction industry remains characterised by adversarial practices and disjointed supply relationships. Commonly, construction clients appear to distrust their main contractors, who in turn maintain an arm's length relationship with their subcontractors and suppliers." In CSCs, the projects are a series of sequential and predominantly unconnected operations. The individual players have a very little stake in the long-term success of the project and no commitment to it. A well-integrated approach involves clients, designers, main contractors and sub-contractors working together as a unified team, rather than as a disparate collection of unrelated organisations.

It is against this backdrop that this study examines the reasons for the fragmentation of CSC, resulting from a series of inter-linked causes. The literature review revealed that the main reason for the fragmented nature of the construction industry is the absence of knowledge (tacit knowledge) transfer and sharing practice within construction processes, within the CSCs and, furthermore, within entire construction projects. However, this study does not reject the views of Lean and Agile thinkers but reveals the potential of Lean and Agile processes working together with the application of knowledge communication (specifically the transfer and sharing of Tacit Knowledge) to improve the construction process at the individual task, activity, sub-process and, furthermore, at the mega process levels.

1.1.2 Research Need and Justification

The critical analysis of the literature highlighted that the construction industry needs to consider the process-based view seriously with the application of both Lean and Agile principles. Furthermore, it requires Knowledge Communication within Lean and Agile processes if the desired supply chain performance is to be improved.

There has been a considerable amount of skill loss in the sector since 1990s downturn and the industry still has not recovered (BIS, 2012). Unfortunately, the UK construction industry is now experiencing the ongoing economic recession, leading to the stagnation of the construction sector and its growth in terms of employment, innovation, business capabilities and exports (BIS, 2013a). On top of that, the current recession is augmenting the skill loss and leading to a questioning of the capabilities of the UK construction sector (Baldauf & Hubbard, 2011). Additionally, recently, BIS (2013c) revealed that there is a lack of awareness in the seeking of skills and expertise. Moreover, construction SMEs has seen the continuous lack of response in, skill enhancement of workforce and lack of increase turnover by exploiting skills. Also, there has been a lack of reducing costs by increasing the efficiency of workers, of developing and launching new inventions and employing more staff, also a lack of increasing leadership capabilities and the number of experts, revealed by BIS (2011, 2013a, 2013b, 2013c, 2013d, 2014); HM Government (2010) and Rhodes (2012).

Earlier, the Latham (1994), Egan (1998, 2002) Wolstenholme (2004) and BIS reports all emphasised CSCs' development while integrating teams, integrating processes, quality and capability development and skills' development. However, there has been a general absence of awareness, understanding and research into the roles and contributions that Knowledge Management (KM) plays in collaboration and in the integrated approach in CSCs and in Lean and Agile process as well as in the importance and efficiency of CSCs. The latest reports by BIS in 2012 and 2013 revealed that construction organisations do not have adequate awareness about the availability of knowledge and support from government in terms of skills' development.

Moreover, this study identifies that construction organisations also have a lack of capability and awareness to improve the modern products and construction processes. Based upon the data provided by BIS since 2010 until to date, in terms of business capabilities, there was a downfall of 17% in the improvement of new product and services. There has been a lack of initiative in process improvement since 2010 and growth has been recorded as being constant. However, the UK construction SMEs predicted in 2012 only 64% companies aim to grow in next 2 to 3 years, compared to 78% companies aiming to grow in 2010. “Aim to Growth” requires motivation to encourage intellectual capital growth and corporate strategy needs to be aligned with the business strategy. The “Aim to Growth” of SMEs has seen 14% downfall since 2010.

In addition, there is paucity of empirical research within this area, especially in the context of KM in Lean and Agile processes. There are several problems and challenges indicated by researchers such as a lack of trust and commitment, a lack of Public-Private Partnerships (PPP), a lack of efficient processes and a lack of standardisation. However, Alashwal et al. (2011) and Taylor et al (2012) suggested that problems such as a disunited supply chain, a lack of integration and collaboration and insufficient KM systems are either dependent or related to each other. The fragmented nature of the CSC is due to the lack of process integration and collaboration (Alashwal et al., 2011; Hughes, Hillebrandt, Greenwood, & Kwawu, 2002; Orange et al., 1994; Ribeiro & Fernandes, 2010). Nevertheless, London & Kenley, (2001); Khalfan & McDermott, (2007); Alashwal et al. (2011) and Taylor et al. (2012) suggested that a lack of process integration, partnering and collaboration within the CSC is because of insufficient KM systems. Furthermore, studies have shown that the existing KM systems have failed to transfer and share tacit knowledge from source (Zhang, 2012). This leads to inactive collaboration, a lack of trust between partners and inefficient process integration in CSCs (Hughes et al., 2002, Guo 2012). Consequently, a lack of collaboration and integration establishes itself as a negative influence in the fragmentation in CSCs. It is due to a lack in the skills of transferring and sharing tacit knowledge. KM and skills are required in construction companies to enable them to integrate within the SC efficiently, as observed by Kivrak & Arslan (2008) and Maqsood et al. (2003).

Numerous research projects have started during the last decade in this domain. Some researchers have worked on knowledge transfer in Inter-firm Collaboration and Inter-organisational Knowledge Management and Knowledge Communication (Transfer &

Sharing). Moreover, some have worked on Knowledge Management in Lean construction. Still, none of the research claims to understand and develop the best practice for knowledge transfer and share in Lean and Agile processes to improve the efficiency of the construction supply chain. A few recent frameworks of KM have been found during the literature review, but none of them focuses on the transfer and sharing of Tacit Knowledge in the context of both the Lean and Agile processes to bring about collaboration in CSCs.

It is acknowledged that the construction sector is suffering from a lack of skills and requires knowledge sharing practice to enhance skills. A CSC could involve several hundred large, small and medium organisations (Tier 1, 2, and 3). Such organisations bring a lower level of knowledge transfer and sharing capabilities to advance and accomplish lean and agile processes. Moreover, these different levels of capabilities define how they can recognise the concerns of CSC efficiency in order to enhance the skills. There is an essential need to bring collaboration and partnering within CSCs. In addition, because of that, there is a need to understand the applicability and importance of the Transfering and Sharing of Tacit Knowledge in CSC and Lean and Agile principles. Moreover, most importantly, there is a need to develop a framework, which could help in understanding how to initiate the transfer and sharing of tacit knowledge in CSCs and within Lean and Agile Processes. Therefore, this study explores and investigates the following topics in greater depth.

1) The reasons for fragmentation in CSCs
2) The importance of KM in CSCs
3) The performance of Lean and Agile processes in terms of bringing about collaboration and partnering among CSCs.
4) The contribution of KM in the application of Lean and Agile thinking in CSCs
5) The challenges that hinder the effective transfer and sharing of Tacit Knowledge in CSCs
6) The critical success factors associated with the transfer and sharing of tacit knowledge in CSCs
7) Individual and organisational capability to transfer and share knowledge.

1.1.3 Aim & Objectives of this Study

Having identified and justified the need for this research, this study defines the following aim and objectives.

1.1.1 Aim

The aim of this study is to develop a framework for the transfer and sharing of tacit knowledge within the context of Lean and Agile processes and to improve the understanding and awareness of Tacit Knowledge in Construction Supply Chains.

1.1.4 Objectives

- To critically review the concepts of Knowledge Management, Supply Chain Management and Lean and Agile processes in general and specifically within Construction Supply Chains.

- To examine the contribution of Tacit Knowledge in the application of Lean and Agile principles within Construction Supply Chains.

- To investigate and document the challenges associated with the effective Transfer and Sharing of Tacit Knowledge through the application of Lean and Agile principles in Construction Supply Chains.

- To identify the critical success factors associated with the effective Transfer and Sharing of Tacit Knowledge in Construction Supply Chains through the application of Lean and Agile principles.

- To develop and validate a knowledge communication framework that improves the level of efficiency in Construction Supply Chains through the application of Lean and Agile thinking.

1.1.5 Research Questions

- What are the main contributions of Tacit Knowledge in the application of Lean and Agile principles within Construction Supply Chains?

- What are the challenges associated with the effective Transfer and Sharing of Tacit Knowledge through the application of Lean and Agile principles in Construction Supply Chains?
- What are the critical success factors associated with the effective Transfer and Sharing of Tacit Knowledge in Construction Supply Chains through the application of Lean and Agile principles?

1.1.6 Scope of study

The scope of this research is limited to the development of a Knowledge Communication framework to initiate the effective transfer and sharing of Tacit Knowledge within the context of Lean and Agile processes. In addition, this framework is intended to improve awareness and understanding of KC in CSCs within the UK construction sector.

In a horizontal scope, this study analyses the wide range of KM frameworks for the transfer and sharing of Tacit Knowledge. This provides an in-depth view of the topic area and enhances the insight into what it takes to transfer and share Tacit Knowledge. This also establishes the tools and techniques of knowledge communication and develops the theory about how knowledge communication can bring collaboration and partnering within Lean and Agile processes and in CSCs.

This study is limited to the UK and to the construction projects and will be restricted to KM, SCM, Lean and Agile concepts.

1.1.7 Novelty and uniqueness of this study

As there is a paucity of research within the area of Knowledge Transfer and Sharing in CSCs within the context of Lean and Agile processes, this study brings a framework to initiate knowledge communication among individuals and organisations.

The study brings novelty into the literature of Tacit Knowledge by exploring cross-disciplinary literature to establish why tacit knowledge is hard to articulate and what it takes to share. The uniqueness of this study is in the investigation of the literature and in the data analysis through multi dimensions to develop the framework. Moreover, this study brings together literature on KM, SC, and Lean and Agile thinking and reveals several interesting facts and findings.

The study also brought a novel and functional Knowledge Driven Research Methodology (KDRM) Model to define the research methodology based on the research objectives. The uniqueness of the research is to improve the awareness and understanding of KM in CSCs in order to develop a framework and a set of guidelines in the context of Lean and Agile principles.

1.1.8 Structure of this Thesis

The research structure presents the organisation of the research into chapters and sections corresponding to the research objectives. Below is given the complete structure of this research.

Chapter (2) Critical Analysis of Literature: This chapter focuses on the judgmental review of relevant and related literature to fulfil the aim and objectives of this study. Based on the first objective of this research, this chapter covers four sections.

Section (1) of the Literature Review Chapter (2) focuses on the UK construction sector to identify existing trends, and to highlight problems within the sector and the perceptions on growth within the sector. Afterwards, this then focuses on the present supply chain issues within the construction sector at both the industry and project levels. The literature reviews include The Latham Report, The Egan Report and The Wolstenholme Review etc from the 1990s until the present date. Moreover, in conjunction with these reports, this review investigated the BIS reports, HMRC reports and published journals and other literature from 2007 until 2014. The analysis focused on identifying the problems and success factors required to achieve growth in the sector. This analysis provides a solid base forfurther analysis for the forthcoming sections in the literature review.

This section aimed to investigate and identify the objectives listed below.

- To identify the role and the importance of the construction sector in the UK economy.
- To identify perceptions on the growth of organisations in the construction sector.
- To identify and highlight the current problems related to the construction sector.
- To identify and evaluate the factors which hinder the growth of the UK construction sector.

Moreover, this section concentrates on analysing the CSC and its classic and current trends. In this section, it evaluates the role of the supply chain and its importance within the sector. Furthermore, it identifies the complexity of, and the problems within, the Construction Supply Chain. This section aims to investigate and analyse the literature of the supply chain in general, and on the literature on the construction supply chain, specifically with the aim to identify, investigate, and highlight the objectives listed below.

- To identify the role and pinpoint the importance of the construction supply chain.
- To evaluate the structure and the complexity of the construction supply chain.
- To identify the main attributes of the performance of the construction supply chain.
- To identify the factors which hinder the effectiveness of the construction supply chain.
- To identify the existing approaches to increasing the efficiency of the construction supply chain.

Section (2) of the Literature Review Chapter (2) focuses on reviewing relevant and related literature on the application of Lean and Agile principles in CSCs. This section discusses the literature on Lean and Agile principles and its application in the SC and specifically in CSCs. In addition, this section identifies the problems and challenges associated in the application of such principles. This chapter seeks to identify the main principles and processes of Lean and Agile thinking and their implications on Construction Supply Chains. This section investigates and identifies and highlights the objectives listed below.

- To explore and evaluate lean thinking and its principles.
- To evaluate the application of lean thinking and its principles in construction.
- To explore and evaluate agile thinking and its principles.
- To evaluate the application of agile thinking and its principles in construction.
- To analyse and evaluate the application of lean and agile thinking within construction processes.

Section (3) of the Literature Review Chapter (2) focuses on exploring the literature on Knowledge Management, knowledge, types of knowledge, school of thoughts and perceptions of Knowledge Management and analysing the application of Knowledge Management in Construction Supply Chains. In this section, Knowledge Communication and its tools and techniques used to convey Tacit Knowledge and the problems which exist in transferring and sharing Tacit Knowledge are critically analysed based on the objectives listed below.

- To evaluate distinctive perceptions of Knowledge and its Management in general
- To identify and evaluate the different tools and techniques of Knowledge Communication in general and, specifically, in the context of Tacit Knowledge
- To highlight the factors that hinder the effectiveness of Knowledge Communication in the context of Tacit Knowledge
- To analyse and evaluate the application of Knowledge Management, Knowledge Communication and Tacit Knowledge in Construction Supply Chains in the context of Lean and Agile Processes.

Section (4) of the Literature Review Chapter (2) focuses on to identifying and evaluating the critical success factors associated with effective Knowledge Transfer and Sharing within CSCs in the context of Lean and Agile Processes. Its objectives are given below.

- To evaluate the existing frameworks which transfer and share Tacit Knowledge within Construction Supply Chains, specifically in the context of Lean and Agile processes.
- To identify and highlight the critical success factors associated with effective Knowledge Sharing and Transfer within the Construction Supply Chain in general and, specifically, in the context of Lean and Agile processes.

Section (5) Conceptual Framework

In this chapter, the conceptual framework is developed based on the findings from the literature review.

Chapter (3) Research Methodology

This chapter concentrates on establishing and justifying the appropriate methodology for this research. Accordingly, the following objectives are set out for this chapter and structured as follows:

- To evaluate methodological framework and research philosophies and to establish the basis for identifying the applicable philosophical assumptions for this research
- To evaluate the applicability of research approaches based on the defined research objectives
- To evaluate and highlight the most suitable research techniques to establish the methodological stand of the research
- To evaluate and define appropriate data collection and data analysis tools and techniques for this research

Chapter (4) Data Analysis Tools and Techniques

This chapter investigates and defines the data analysis tools and techniques. It also focuses on the design of the survey questionnaire and the interview questions. The purpose of this section is to consider all the aspects of the data collection questionnaire design and data analysis. This chapter aims at answering the following questions.

- What is the scope of this research in recruiting respondents?
- Who can answer the questions?
- How big is the population of prospective respondents in this research?
- What are the potential difficulties in collecting data from the construction sector?
- How many survey responses are required for undertaking the data analysis for this research?
- What data analysis tools and techniques are appropriate in this study?
- How are the survey questions designed and why?

Chapter (5) Quantitative Data Analysis

This chapter focuses on the data analysis of the quantitative data gathered through a survey questionnaire. IBM SPSS qualitative data analysis software was used to analyse the data while running Reliability (Cronbach's Alpha), Descriptive (Frequencies), Non-parametric (Kruskal-Wallis H Test) and Correlation Analysis and Interpretive Rank Order Analysis

Chapter (6) Modification of Framework This chapter concentrates on the modifying of the conceptual framework based on the findings from data analysis in chapter (5).

Chapter (7) Validation of Framework

Through quantitative data analysis, this chapter focuses on validating the framework and on identifying its applicability to construction processes, as well as its potential applicability to other industries.

Chapter (8) Conclusion and Recommendations

This chapter presents the conclusion and recommendations from this study; it also establishes the study's contribution to research, its limitations and emerging fields for future research.

2 CRITICAL ANALYSIS OF LITERATURE

2.1 Background

2.1.1 Introduction

This chapter focuses on the critical review of the relevant and related literature to fulfil the aim and objectives of this study. This chapter is presented in five sections, focused on the research objectives. This first section conducts an investigation of the potential challenges associated with the effective transfer and sharing of Tacit Knowledge within construction supply chains. The second section focuses on exploring and identifying the application of Lean and Agile principles in construction processes. The third section establishes the application of knowledge management in construction supply chains and its application in conjunction with Lean and Agile thinking. The fourth section explores and establishes the critical success factors associated with the application of knowledge management within Lean and Agile processes and, finally, the fifth section focuses on developing a conceptual framework based on the preliminary findings from section one to four.

This section discusses and critically analyses the UK construction sector and the problems associated with the CSCs with the help of the current (from 2010 until date), less recent (1990 until 2010) and classical (before 1990s) literature available. The problems and challenges currently existing in Construction Supply Chains are identified and discussed.

This investigation adopts a systematic research methodology to define the challenges discovered through the literature review. Firstly, the literature is explored to identify the leading challenges within the construction sector. Afterwards, it identifies the main reasons and causes which provide the major challenges. Moreover, these challenges are critically analysed to establish the factors which hinder performance improvement in CSCs. Finally, it defines a total number of six challenges. Nevertheless, it identifies and establishes fifteen positive correlations among those challenges.

In this section, this study lays down that a 'lack of understanding of the importance of the transfer and sharing of tacit knowledge' and a 'lack of trust between organisations, are the most dominant challenges which hinder the transfer and sharing of tacit knowledge within construction supply chains. The other four factors are also found to be challenging and support the predominant challenges.

2.1.2 The UK Construction Sector

In January 2014, the Office of National Statistics estimated the UK construction output to measure its role within the UK gross domestic output. It accounted for about 6.3% of the total GDP in 2013. In July 2013, the Department of Business and Innovation Skills (BIS) stated that, since the recession of 2008, the construction sector has been disproportionately affected. However, s newspaper article by Allen (2013) claimed that, in 2013, the UK construction output showed the highest growth since 2007.

In 2007, the construction sector accounted for 8.9% of the UK's Gross Value Added (GVA) but, by 2011, the sector's contribution had decreased to 6.7%. Later, in early 2012, the construction contracting industry returned to recession for the third time within five years, (BIS 2013a).

Many researchers (such as Baldauf & Hubbard 2011; BIS 2011; HM Treasury 2012; Lynagh, 2011) also blamed the recession for this decreasing percentage. Baldauf & Hubbard (2011) observed that the key problem in 2011 with the construction industry was currency inflation, rising international competition and the loss of skills in UK construction industry.

It is a truism of economic analysis that construction whiles only a small part in the economy at around 7% of GDP (in 2011), can contribute a strong push in getting out of a recession. Output contracted 0.5% quarter-on-quarter, limiting the annual seasonally adjusted growth to 2.8% in 2011 (Lynagh, 2011). At November 2013 construction, output had fallen by 4.0% (£395 million) when compared with October 2013 (ONS 2014). However, in comparison, providing a longer-term picture, construction output had gone up by 2.2% when comparing November 2013 with November 2012.

The global construction sector is suffering from the financial crisis of 2008. However, BIS, (2013a) has observed a major decline in US, UK and European construction sectors. That notwithstanding, the BIS report suggests that, in comparison with Europe and other developed countries, the UK construction sector has got export opportunities within emerging markets such as Brazil, Russia, India and China (BRIC) (as observed by Baldauf & Hubbard, 2011). However, ONS, (2014) expressed theconcerned that the UK construction sector has no adequate export capability. The BIS report highlights that "*the UK firms which export* *generally tend to be larger, have higher absorptive capacity of 'Know How' (Tacit Knowledge) and are more likely to be engaged in research and innovation activities*” (BIS 2013a). In the UK, only 6% of small and medium-size companies were exporting (BIS 2013a).

In 2013, The Research by BMG for BIS revealed the barriers and strategic challenges of exporting for UK SMEs. The research highlighted that the total population of UK construction SMEs in 2012 was 907,195. This is the highest number compared to other industries, with an employment size of 12% of the UK employment in 2012. The construction industry has a recorded a 1.2% downfall in employment since 2010.

Furthermore, the UK construction sector had 74% family run businesses in 2010; the number reduced to 72% in 2012. Among them, only 2% of the companies are considered as social enterprises in 2012 after a 50% downfall since 2010.

In terms of business capabilities, there is a downfall of 17% in the improvement of new products and services (BIS, 2013b). Process improvement remains constant in the construction sector. However, the UK construction SMEs estimated that in 2012 only 64% of companies aim to grow in the next two (2) to three (3) years, compared to the 78% of companies that has such an aim in 2010. “Aim to Growth” requires motivation, intellectual capital growth and corporate strategy to be aligned with the business strategy, and it has seen a 14% downfall since 2010.

Furthermore, data from BIS (2013b) highlights the growing perception of a link between “employing more staff” and “increasing leadership capabilities." On the other hand, perceptions of the growth factors as considered by construction SMEs have seen an increase in the negative awareness of the skills of the workforce by minus (-) 4%, and of increased turnover by exploiting skills by minus (-) 11%. Moreover, reducing costs by increasing the productivity of workers is recorded as minus (-) 10%, developing and launching new products as minus (-) 14%, and exports as minus (-) 7%. Although construction SMEs contributes greatly to the construction industry, this sector lacks the awareness and support to improve construction productivity, innovation and capabilities, and to increase and exploit the skills of workforce (BIS, 2013b and ONS 2014).

A large number of the UK SMEs show concern about a lack of financial support but the lenders and commercial authorities contend that the investment is available. However, the survey revealed that 38% of SMEs do not meet the lenders' criteria. However, the report claims that 68% of SMEs obtained all the finances they needed in 2012. The report also contends that a vast amount of support is available to SMEs but only less than 50% of businesses received the support or advice. Also, about 40% of SMEs in England and Wales seek, and rely on, accountant firms for business growth advice and information, while 15% or less of business seeks advice or information from consultants or business advisors.

The BIS (2013b) report also suggests that construction SMEs' growth has fallen since 2010, mainly business capabilities have seen the worst fall, and the processes have not seen any improvement in the last five years. Based on the facts of 199's recession, Baldauf & Hubbard (2011) showed concern and suggested, "The construction skills on all levels and of all disciplines were lost in previous recessions, with large numbers not returning, often through choice. In particular, it has been suggested that the industry did not truly recover its skills base from the recession of the 90s."

The BIS (2013b) report highlights the other reason for skill loss in construction companies is because SMEs are seeking advice and information in the wrong place and are avoiding easily available expert advice from the government and designated authorities.

The other report by BIS, (2013a) highlights that the main driver for long-term growth is increasing export activities. However, the factors and areas of concern in increasing exports are:

- People and Skills' enhancement: The report showed concern that there has been a substantial fall in apprenticeship completions in construction-related industries in the last three years.
- Innovation Capabilities: compared with other industries, construction has a low level of innovation, measured by R&D.
- Access to finance: The evidence shows that construction-contracting SMEs face more difficulties then other SMEs in accessing finance from banks.

- Supply chain development: The sector is characterised by a high level of fragmentation. Construction Supply Chains require contractor's engagement and continuing involvement, strong relations and collaboration with suppliers.

In 2011, the framework agreement (FA) for the construction sector set growth objectives but emphasised that these could only be achieved while sharing knowledge and acquiring skills. Acquiring skills and developing SME's knowledge base with key contacts can assist with understanding of the construction sector and can influence on business performance.

However, the serious issue within the UK construction industry is the traditional way of thinking of businesses and the disunity of the industry (Alashwal et al., 2011; Chen & Paulraj, 2004; London & Kenley, 2001).

At the same time, the UK construction industry has a large number of privately (family) owned companies (BIS 2013b) and is thought to be more disconnected in comparison with its major competitors such as in Germany or France (BIS 2013a). A relatively high proportion of self-employment in the UK elevates the fragmentation in the UK construction industry and brings a towering number of small and micro businesses. The study of Forgues et al. (2009) put forward collaboration as the major factor in reducing the impact of fragmentation. Forgues et al. (2009) proposed three main approaches to encourage collaboration: practices, integrated teams and integrated design process.

Moreover, Taylor et al. (2012) Taylor, Jarvenpaa & Keating (2012) Chen & Paulraj (2004), Blake & Croot (2004) and London & Kenley (2001) revealed several problems within the UK construction industry, such as taxation, Knowledge Management, industry fragmentation, supply chain and procurement issues. However, the major concern seems to be the fragmented nature and the traditional approach in the industry. Alashwal et al. (2011) observed that industry-level fragmentation occurs when the number of small and medium-sized enterprises increase and the number of the large firms decrease. In this situation, enterprises usually have no significant market share and are unable to influence considerable outcomes for the industry and unable to establish intra-firms networks (Langford and Male, 2001; Gonz'alez et al., 1998; Winch, 2010; Garcia, 2005; Vlies and Maas, 2009).

The construction industry requires an integrated approach (Briscoe & Dainty, 2005; Jørgensen & Emmitt, 2008; Vinodh et al., 2009). Furthermore, the literature suggests a well-integrated approach requires an efficient supply chain. Briscoe & Dainty (2005) said, “The UK construction industry remains characterised by adversarial practices and dis-jointed supply relationships. Commonly, construction clients appear to dis-trust their main contractors, who in turn maintain an arm’s length relationship with their subcontractors and suppliers. Projects are treated as a series of sequential and predominantly separate operations where the individual players have a very little stake in the long-term success of the resulting building or structure and no commitment to it.” The argument by Briscoe & Dainty, (2005) indicates that the integration of processes and products is required to ensure that better value can be delivered to the client (Latham (1994) and Egan (1998)). This approach involves clients, designers, main contractors and subcontractors working together as a unified team, rather than as a disparate collection of separate organisations.

An efficient supply chain is one of the essential elements to integrate the fragmented construction sector (BIS, 2013a, Briscoe & Dainty, 2005; Sanderson & Cox, 2008). Briscoe & Dainty (2005) pointed out some of the Construction Supply Chain issues, such as “CSCs only exist in the duration of a project”. Where maintenance services are part of the contract, the supply chain can theoretically remain in existence during the life of the project. Furthermore, CSCs on larger projects typically involve hundreds of different small companies supplying materials, components and a wide range of construction services.

The other problem is the reliance of the construction industry on a disconnected and predominately subcontracted workforce. This increases complication within the supply chain and creates barriers for integration.

2.1.3 Highlighted Problems of the UK Construction Sector

Since the early 1990s, there has been a widespread increase in concern relating to 'value for money'. This is particularly true for the UK construction industry which has a long history of failing to satisfy the expectations of many of its clients. In 1974, the National Economic Development Office (1974) suggested that nearly one in five clients was dissatisfied with the service they had received from the industry. In 1998, Egan Report also highlighted growing dissatisfaction and the underachievement of the construction industry.

The initiatives introduced over this period acknowledged changing the way the industry worked. These reviews include The Latham Report "Constructing the Team" (1994), The Egan Report "Rethinking Construction" (1998) and The Egan Report, Accelerating Change (2002). Each report encouraged the industry to make improvements and address key issues. Those reports also contended that driving efficiency and greater client involvement and collaboration would help the sector's competitiveness.

The Latham Report "*Constructing the Team*" is always considered to have made an outstanding contribution to the development of collaborative approaches to project delivery (BIS 2013c). The report focuses upon the fragmented nature of the industry as a major factor contributing to the poor communication between all parties working within a construction project (Kagioglou & Cooper 2012). The Latham and Egan reports have identified the need for improvements in the construction industry in a number of areas. Among them, one is the the creation, utilisation and effective implementation of processes both at a strategic and operational level (Kagioglou & Cooper 2012). Moreover, Hope (2012) said that the Latham and Egan reports highlighted that the requirement of outsourcing causes more emphasis on developing SC relationships. As the result, an explosion of research has gone into SCM.

The Egan Report in 1998 highlighted the main issues within construction sectors were client dissatisfaction and the underachievement of the sector. The report focuses on the scope for improving the quality and efficiency of UK construction (Kagioglou & Cooper 2012). The report gave five key drivers for change namely, Committed Leadership, being Customer Focused, Integrated Processes, a Quality Driven approach, and Commitment to People (Egan 1998). The report also emphasised that the fragmentation of the UK construction industry inhabits performance improvement. Egan (1998), in addition, said that fragmentation in construction has its strength and weakness. On the positive side, it provides flexibility to deal with a high variable workload and, on the negative side, the extensive use of sub-contracting has increased adverse contractual relations.

Moreover, Orange et al. (1994), considered fragmentation as a problem within the construction industry and documented it as being a critical barrier to change since it is seen as a major factor in the poor communications between parties working together on construction projects. Orange et al. (1994) emphasised, “The construction industry is organisationally complex and highly fragmented with more than 95% of companies being small to medium-sized enterprises. In addition, the construction industry suffers from supply chains and relationships that are both dynamic and transient as a direct effect of the temporary nature of construction projects, resulting in a poor communication structure.”

In 2002 the Egan Report “Accelerating Change” set out demanding targets for the construction industry which had not been seen since the earlier report “Re-thinking Construction” four years previously. Some of the key targets included:

- By the end of 2004, twenty percent (20%) of construction projects (by Value) to be undertaken by **integrated teams**.
- To increase supply chains by 50%, by the end of 2007
- To develop and implement strategies to **recruit and retain** 300,000 **qualified** people in the industry, by the end of 2006.

The report addressed key issues such as people, leadership, supply chains’ integration and product focus issues.

After almost two decades since the Latham and Egan reports emphasised such issues to-date the situation is not much improved.

Egan (1998) also discussed and suggested collaboration in CSCs but on a series of projects as a long-term relationship tool. However, based on some of the real-world examples (by Briscoe & Dainty, 2005) establishing long-term SC relationships do not commonly work in the construction industry. Supply chain collaboration requires core elements such as ‘trust, shared vision and long-term commitments’ that encourage ‘contracting parties to change their adversarial relationships to a more cooperative, team-based approach’ (Taylor et al., 2012).

The Wolstenholme Review (2008)**,** ‘Never Waste a Good Crisis’ concluded that the construction industry had made a little progress against the Latham (1993, 1994) and Egan (1998 and 2002) targets and identified a range of actions needed to drive the performance improvement of construction industry. The report’s themes such as the construction business model, capability and delivery were highly relevant to the supply chain agenda (BIS 2013c).

A report by Construction Industrial Strategy in 2013 revealed that results from SC interviews presented that the implementation of recommendations from the Egan and Latham reports has had an impact on behaviour within the supply chain. However, it is not clear what clients have benefited from the change. Moreover, there is plenty of evidence that the construction industry has become more adversarial and less integrated because of the current downturn (BIS 2013c). The report identified a series of actions that should be taken jointly by the Government and the industry to harness the potential of the supply chain to improve performance and productivity within the UK construction industry.

The actions are:

- Promoting an agenda of change at all levels of the supply chain
- Developing the quality and capability of site management staff to drive performance improvement through supply chain interaction
- Better alignment of the construction industry in the supply chain, in procurement and in risk transfer practice
- Encourage procurement practice for the early engagement of sub-contractors
- Capability development throughout the supply chain
- Developing an emphasis on the supply chain in cost-led procurement
- Promotion of effective practice for change management
- Promotion of awareness of all sources of waste in construction industry, not just physical waste
- Development of a commercial exchange model recognising that small businesses are a fundamental part of the UK construction industry.

In contrast, since the 1990s, the Egan, Latham, Wolstenholme and BIS reports have all emphasised Construction Supply Chain development while integrating teams, integrating processes, and promoting quality and capability development and skills' development. However, other scholars also have some other views on developing the Construction Supply Chains and reducing the impact of fragmentation in CSCs.

Recently, Alashwal et al. (2011) and Hope (2012) have presented similar views and have suggested several factors which may reduce the negative impact of fragmentation and hence facilitate knowledge sharing and transfer. These factors are: good knowledge management, encouraging partnering, and utilising design and build contracting methods. On the other side, the question put forward by Orange et al. (1994) concerns who will be taking the ownership of knowledge and who will be having access. A major problem within the construction industry is the fragmented nature whereby companies only have a relationship with the sub-contractors during the life of a project.

There is a requirement for clients and partners to build trust and relationships at the early stage of a project and during the project (Brewer & Johnson, 2004). Briscoe & Dainty (2005) and Vrijhoef & Koskela (2000) also suggested having and building trust between the trading partners. Warren & Rhodes (2006) hve given the example of car manufacturing and how the manufacturer developed trust and relationships with the suppliers and achieved success in Le-agile manufacturing. However, again it is possible to build long term relationships in car manufacturing but it is hard to maintain within project basis construction as the fragmented nature of the construction industry makes it difficult to build trust among the trading partners/contractors. Secondly, they work on a project basis with the result being that it is hard to maintain trust and relationships with trading partners or subcontractors after the completion of the project.

2.1.4 Construction Supply Chains

Supply chain management (SCM) is a 21st century global operation strategy for achieving organisational competitiveness (Gunasekaran & Ngai, 2004). The concept of the ‘supply chain’ is generally recognised as the flow of information, physical distribution, and the capital used to deliver products and services from raw materials to the customers (Walker and Alber, 1999). The first supply chain model is attributed to Forrester (1961) and was originated by the Toyota Production System (TPS) to reduce the inventory with the Just-in-Time (JIT) approach. SCM started to make its presence in mid 1980s after Houlihan (1984) introduced SCM theory in the field of logistics (Lamming, 1996). However, for over a decade and half, the SCM literature has shown a confusion of terminologies and definitions (New, 1997). Some of these include: combined purchasing strategy, supplier integration, supply based management, buyer-supplier partnership, supplier alliances, supply chain synchronisation, network supply chain, value added chain, logistic integration, Lean chain approach, supply network, value stream, etc. (Dyer et al., 1998; Nassimbeni, 1998; Tan et al., 1998; Ellinger, 2000). While each term addresses elements of the phenomenon, typically focusing on the immediate suppliers of an organisation, SCM is the most widely used (but often abused) term describing this process (Tan, 2001).

After 1992, Christopher Martin is considered one of the pioneers of the logistics and supply chain movement, influenced by the value-chain concept of Porter (1985) and London & Kenley (2001). SCM has often been associated with the management of the physical distribution of products from raw materials through manufacturing processes to the ‘point of sale’ for the product (London & Kenley 2001).

The Council of Supply Chain Management Professionals (CSCMP) defines SCM as follows: “SCM comprehends the planning and management of entire activities elaborate in sourcing and procurement, transformation and complete logistics management actions.” Moreover, it further embodies coordination and partnership with channel partners which can be suppliers, third-party service providers, and customers. In reality, SCM amalgamates supply and demand management inside and beyond companies. SCM’s foremost motive is to link the major business functions and business processes within and across companies into a well-integrated and rich business model. However, researchers (uch as Koçoğlu et al., 2011; Martínez-Olvera, 2008; Rezgui et al., 2011) have concluded that KM plays an important role in developing a collaborative supply chain. Lambert and Cooper (2000) identified the components of a supply chain such as planning and control, product flow and information flow facility structure etc.

In a supply chain the components such as the workflow activity structure, the organisational structure and the communication and information flow structure rely on other supporting managerial components such as management methods, power, the leadership structure, risk, the reward structure, culture, and attitude (Lambert & Cooper, 2000). The lack of planning and control further relies on information flow. A lack of adequate KM and information flow in supply chains has created fragmented process and operations (Zhang, 2012). To meet the requirements of improved CSC and client satisfaction, the organisations in CSC should encourage knowledge sharing (Briscoe & Dainty, 2005; Zhang 2012).

When considering other sectors such as electronics and automobiles or the e-commerce industry, a fragmented supply chain could offer opportunities for SMEs (Lall et al., 2004). Having many suppliers gives flexibility in outsourcing and increased competitiveness among subcontractors. Fragmentation is not a new phenomenon; nor is outsourcing. Both go back to the beginning of the industrial revolution or even predate it (Lall et al., 2004). For example, the Android market is highly fragmented, and the fragmentation is growing rapidly, but in this type of market fragmentation does not challenge market growth, innovation and the expansion of SMEs according to a recent report by PC Magazine (Albanesius, 2013).

In the construction sector, because of having project based organisations and one-off projects, disconnected supply chains have challenged the managerial components (Lambert & Cooper, 2000) of supply chains and the integration and partnering among the subcontractors, which results in short term relationships and a lower level of trust among sub-contractors and contractors on a project basis. Some researchers have suggested, to reduce the negative impact of fragmented supply chains, developing a productive information system (Caballero et al., 2012). Moreover, Caballero et al. (2012) and Guo (2012) have all agreed that CSC integration and collaboration requires good communication between organisations and efficient KM systems.

In reality, the CSCs are the most complex supply chains, in comparison with other sectors (Cheng, et al., 2010). Typically, CSCs are a combination of several multi-organisational supply chains of Project-Based Organisations (PBOs) which collaborate to achieve the same objectives in order to fulfil the client's demand (Cheng et al., 2010). However, these project-based organisations only collaborate until the project is finished, mainly on projects with a short life cycle (Arditi et al., 2000). PBOs are considered highly flexible in collaborating with other PBOs on a new project (Egbu et al., 2005; Khalfan & McDermott, 2007). A Construction Supply Chain consists of several different suppliers, consultants, designers, contractors and other organisations. Those organisations have their own supply chains which join for a specific project for a short time until the project finishes.

A typical CSC can combines hundreds of construction firms including, Project Managers, Main Contractors, Architects, Quantity Surveyors, Structural Engineers, M & E Engineers, Sub-Contractors and Component manufacturers. Construction projects typically involve tens and hundreds of companies supplying materials, components, and a wide range of construction services (Cheng et al., 2010). The figure below (2-1) is a simplified example of a construction project supply chain given by RICS (2011). In reality, a CSC is much complex than is shown in figure below (2-1).

In this figure, the supply chain shows three levels, the first level have Information flow, orders and schedules at the project manager, main contractor and finance level who are in communication with the client / end user. The second level, architects, quantity surveyors and engineers communicate with the project managers and the sub-contractors communicate with the main contractors. In the second level, the supply chain manages the flow of suppliers materials, production and deliveries. Moreover, only a one-way communication is shown at all levels of the supply chain.

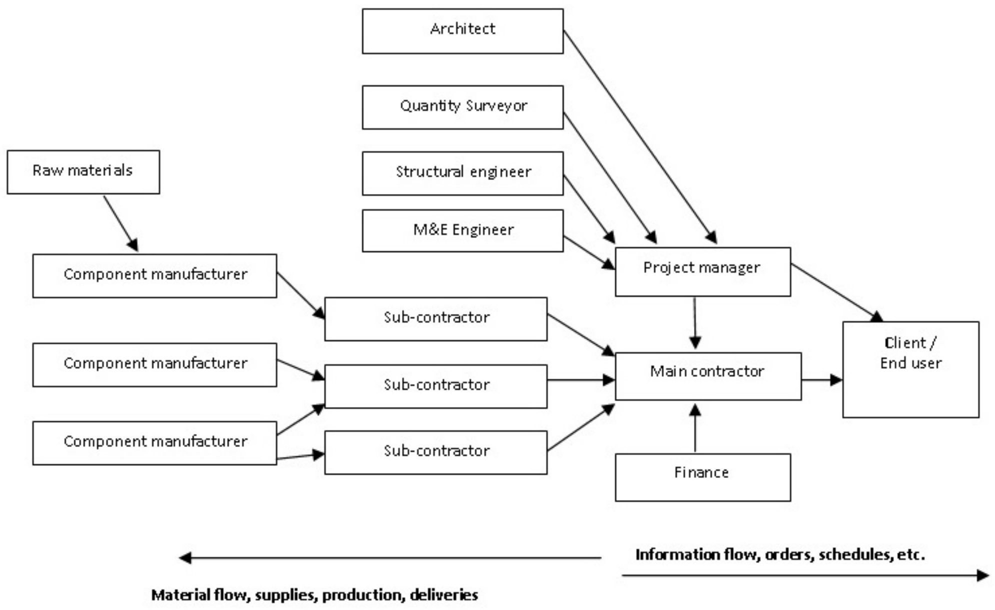

Figure 2-1: The Construction Supply Chain

Source: RICS (2011)

One-way communication in supply chains increases fragmentation and results in a supply chain incapable of adding value.

Finally, the investigation of the relevant and related literature revealed that CSC is a combination of multi-organisations in a supply chain. The planning and management of supply chains require the proper specification of the participating members and identifying their relationships to one another (Cheng et al., 2010). This task is especially challenging in the construction industry because CSCs are complex in structure and are often composed of a large number of participants who work together in a project-based temporary manner (Cheng et al., 2010).

2.1.5 Construction Supply Chain Structure

In a recent study by BIS (2013c), the CSC structure has a minimum of 50 to 70 (Tier 2) suppliers and sub-contractors. The analysis revealed at least three tiers in CSCs, from Main Contractors (Tier 1), to the sub-sub-contractors (Tier 3). When Tier (1) and Tier (2) contractors are involved in a large number of transactions the SC becomes more fragmented for the contractors involved in the main delivery. Moreover, the first two tiers (Tier 1 and Tier 2) are mainly engaged in management activities such as procurement, and the third Tier (3) delivers most of the construction activities. There is limited research into supply chain formation, specifically in the UK construction industry. Research has also shown that there are only a few standard methods or frameworks for representing the supply-chain structures. Lambert & Cooper (2000) proposed supply chain mapping using three primary attributes namely:

- Supply Chain Members
- Structural Dimensions
- Type of business processes

Another supply chain model framework, suggested by the Global Supply Chain Forum (GSCF), gives eight key business processes, which include:

1. Customer Service Management
2. Supplier Relationship Management
3. Demand Management
4. Order Fulfilment
5. Product Development

6. Manufacturing Flow Management
7. Product development and Commercialisation, and
8. Returns Management

The proposed frameworks for supply chain development may vary because of the characteristics of various manufacturing sectors and the characterisation of management functions. For example, in the construction sector, the majority of companies are SMEs which often do not have a clear understanding of function units (Cheng et al., 2010). The recent report by BIS (2013) and the small business survey reveal that the majority of construction companies (that is, 72% in 2012) are family run businesses and in around 20% of businesses are less than five years old. Moreover, an average of 29% of businesses do not have a work address and work from home. Construction SMEs employ on average 12 employees and most of them work on a project basis.

Based on the facts that arose from the survey by BIS (2013), a supply-chain model framework that requires the interaction of cross business functions units may not be suitable for Construction Supply Chain modelling.

To standardise, measure and improve the Supply Chain, the Supply-Chain Council in 2008 put forward another framework, the “Supply Chain Operations Reference” (SCOR). The SCOR modelling framework depends on five key supply chain processes, Plan, Source, Make, Deliver and Return and is structured into four process levels. The first three levels, ‘Scope, Strategies and Steps’ are claimed to be applicable across industries but the fourth level 'Activities’ can be industry specific. SCOR does not describe every business process or activity (SCOR, 2008). For instance, it does not address issues such as research and technology development, or product development. It only assumes, but does not address, the presence of quality, information technology or administration (SCOR, 2008). SCOR is a generic SC operation reference model, to use for fabricating various Supply Chains (Cheng et al., 2010).

SCOR (2008) presents five main attributes of a supply chain performance matrix, namely:

Reliability: A customer-focused approach which addresses the ability to perform tasks as expected. This focuses on the predictability of the outcome of a process. The typical matrix of reliability is on-time, at the right quality and quantity.

Responsiveness: A customer-focused approach which describes the speed at which tasks are performed, such as, cycle time or Takt-Time (a term in Lean Manufacturing).

Agility is a customer-focused approach that describes the ability to respond to external influences and the ability to change, for example, to manage fluctuating demand, labour issues, downtime, etc.

Costs: The internally focused attribute which describes the cost of operating the process. This includes labour, materials’ transport and operational costs.

Assets Management efficiency: This describes the ability to utilise assets. This is mainly an internally focused attribute aimed at reducing inventory and outsourcing.

These SC performance matrix attributes may vary from one process to another. For example, in the Knowledge Management process, within a supply chain, will consider knowledge as an asset or knowledge as stock. In this situation, the performance of assets’ attributes may describe the ability to utilise the knowledge asset and the growth in knowledge asset and stock. Due to its structural levels and characteristics, SCOR is the most suitable framework for CSCs. It allows the modelling of the supply chain design and the relationship of processes in an arranged way. Moreover, the performance measurements’ attribute mainly focuses on the customer and generates value.

Unlike the other frameworks discussed earlier, the SCOR framework has four levels of supply chain development. The fourth level of development is unique for each organisation. Therefore, this formation fits best with CSCs on the (component and material manufacturers’) supplier’s supplier side.

However, there is a growing realisation that CSC’s performance can be improved by adopting Lean, Agile or Le-agile approaches (Court et al., 2012). Lean thinkers (Pheng & Fang, 2005; Owen & Koskela, 2006, and Sacks et al., 2009a, 2009b) suggest that CSCs could have the ability to perform better by adopting the lean approach. On the other side, agile manufacturing supporters have observed that a CSC needed to be responsive. Moreover, adopting agility would help CSCs deliver value to the client (Court et al., 2012; Ribeiro & Fernandes, 2010 and Khalfan et al., 2007). A third community of practice has highlighted the areas of improvement that can be achieved by using Lean and Agile processes in CSCs. In addition, it suggests, obtaining the benefits of both the Lean and Agile processes in order to reduce the negative impact of fragmentation (Court et al., 2012; Rahimnia & Moghadasian, 2010; Sanderson & Cox, 2008).

2.1.6 Associated Challenges and Reasons for Underperformance of Construction Supply Chains

Based on above literature review, the challenges and reasons for the under-performance of the construction sector is explored below in the context of considering fragmentation as the preliminary factor which hinders collaboration and partnering within CSCs and further hinders the transfer and sharing of Tacit Knowledge.

2.1.6.1 Fragmentation in the Construction Sector

The construction industry is generally categorised by high fragmentation and low productivity (Xue et al., 2007). The construction industry remains characterised by adversarial practices and disjointed supply chain relationships (Briscoe & Dainty, 2005).

The main reason for having hundreds of organisations involved within the construction process is that about 99% of the UK construction industry is made up of small and medium firms (ONS, 2014). This problem is intensified by the fact that the construction process typically involves several specialised disciplines such as Architects, Quantity Surveyors, Structural Engineers, M & E Engineers and Sub-Contractors (Caballero et al., 2012). This originates the practice of sub-letting the sub-contractors firms for a construction project. A study by Wu (2009) concluded that the sub-letting practice within construction is often more profitable for construction firms. Having said that, the fragmentation in the construction industry does enable small firms to contribute and survive in the sector. However, the construction sector is still struggling to respond to change and to increase the performance of the CSCs (Xue et al., 2007). Despite the benefits of having fragmented supply chains, the literature also suggests some of the drawbacks of having a fragmented construction sector.

Fragmentation within the design, fabrication and construction functions leads to cost, time and quality-related issues. This later develops into unnecessary liability claims and other issues such as a lack of integration, collaboration and coordination between various functions and leads to poor communication.

The table below (Table **2-1**) shows a list of supporting factors/challenges which jointly increase the problem of fragmentation while supporting the main and sub-causes of the disintegrated CSCs. However, this list of supporting factors is not exhaustive; there could be many more supporting causes in each discipline of organisational level and others at the CSC level.

Table 2-1: List of factors/challenges supporting the main and sub-causes of fragmented Construction Supply Chains.

Factors/Challenges supporting fragmentation of CSCs	**Supported Reading**
Large number of small and medium companies	(Arditi et al., 2000; Blake et al., 2004; Sanderson & Cox, 2008; Coakes & Clarke, 2005; BIS, 2011)
Lack of skills and knowledge of collaboration and partnering	(BQF, 2013; Guo, 2012; Love, Irani & Edwards, 2004; Martinkenaite, 2011; Suresh & Egbu, 2006)
Traditional way of working/lack of business knowledge	(Arditi et. al., 2000)
Lack of funds to support organisational growth	(BIS, 2011; BIS, 2013b; Brigitta, 2012)
Short lifecycle of construction projects	(Arditi et. al., 2000; Race et. al., 2012; Rezgui, Boddy, Wetherill & Cooper, 2011; Scavarda, 2006)
Lack of awareness of Knowledge Management	(Alavi, 1999; Alavi & Leidner, 2001)
Lack of support available to small and medium firms	(BIS, 2013a; Lehtimäki et al., 2009; Adetunji, 2005)
Lack of awareness in seeking support	(BIS, 2013b)
Lack of learning capabilities	(Tsai, 2001; Baets, 2005)
Lack of decision making knowledge	(Baets, 2005; BIS, 2011; Adetunji, 2005; Sigala, 2008)
Lack of organisational strategies for competitive advantage	(Maier, 2007)

2.1.6.2 Suggested Ways of Resolving the Negative Effect of Fragmentation

In 2004 the report “Partnering in Practice” (Brewer & Johnson, 2004) by Price Waterhouse Coopers and HM Treasury Standardisation of PFI Contracts Version (3) suggested that CSCs should be structured in a way to enhance Public-Private Partnering. The report believed that there is a real need to define and communicate better to enhance partnering and collaborative working for PPPs. It also emphasised that partnering allows the public sector to combine its skills and resources with those of the private sector. The report concluded with the three types of potential partner grouping in the Construction Supply Chain.

- Bilateral Partnering: Applies between the client and the main contractor
- Multi-party Partnering: Applies between the client, main contractor and key sub-contractors.
- Supply Chain Partnering: This applies between all the parties (main contractors, sub-contractors and sub-sub-contractors) excluding the client.

This report presented the following key determinants in the success of choosing supply chain partners:

- Contractor’s willingness to engage in a partnering relationship
- Contractor's previous experience of partnering
- Contractor’s understanding of the client business and the project objectives
- Contractor's ability to work together at personal and team level
- Effectiveness of management and governance in supporting the partnership and building the relationship
- Contractor's ability to demonstrate “Value for Money” (VFM)

Extensive studies in the construction sector and on its supply chains and Lean and Agile thinking shows that there is a general lack of awareness and understanding about the roles and contributions that Knowledge Management (KM) plays in collaborative and integrated approaches to CSCs and Lean and Agile processes and the importance of the efficiency of CSCs. There is a paucity of empirical research within this area, especially in the context of KM in Lean and Agile processes. There are several problems and challenges indicated in studies, such as a lack of trust and commitment, a lack of Public-Private Partnerships (PPP), a lack of efficient processes and a lack of standardisation.

Recently, Alashwal et al. (2011) and Taylor et al. (2012) considered problems such as the disunited supply chain, the lack of integration and collaboration and insufficient KM systems and whether they are either dependent or related to each other. They also observed that the fragmented nature of CSCs is due to a lack of process integration and a lack of partnering and collaboration (Alashwal et al., 2011; Ribeiro & Fernandes, 2010; Hughes et al., 2002 and

Orange et al., 1994). However, Taylor et al. (2012), Alashwal et al. (2011), Khalfan & McDermott (2007) and London & Kenley (2001) argued that a lack of process integration and a lack of partnering and collaboration in the CSC is because of insufficient KM systems. The literature on CSCs suggests that the existing KM systems fail to transfer and share Tacit Knowledge.

Furthermore, the existing literature argues that KM and skills are required in construction companies to enable them to integrate within the CSC efficiently (Kivrak & Arslan, 2008; Maqsood et al., 2003). Moreover, Alashwal et al. (2011) suggested that the negative impact of fragmentation is reduced by developing a knowledge sharing approach in a CSC. The problems in CSCs are caused by a lack of transferring and sharing tacit knowledge and results in developing wasteful KM systems (Alashwal et al., 2011). In addition, an incompetent KM system enhances the lack of trust and commitment among the stakeholders. This leads to inactive collaboration, a lack of trust in the partners and inefficient process integration in CSCs (Hughes et al., 2002; Guo 2012). These studies consider that a lack of partnering, collaboration and integration are the negatives outcomes of fragmentation in CSCs. This is because of a lack of skills and awareness of knowledge communication.

. The interrelationship between the main and sub-causes of fragmentation in CSCs, it’s supporting factors and challenges are documented in the table below (Table 2-2). Each section in this table spotlights the challenges that hinder the transfer and sharing of tacit knowledge in CSCs.

Table 2-2: The Inter-relationship of the main and sub-causes of fragmentation in CSCs and the supporting factors and challenges

Challenges	Causes	Supporting factors/challenges
Section (1) Fragmented Supply Chains	<u>1-A</u> Lack of Partnering and Collaboration	• Large number of small and medium companies • Lack of skills and knowledge of collaboration and partnering • Lack of motivation • Lack of trust and commitment • Short project lifecycle
	<u>1-B</u> Lack of Process Integration	
Section (2) Lack of Effective Knowledge Management Systems	<u>2-A</u> Lack of Trust and Commitment	• Lack of support available to small and medium firms • Lack of awareness in seeking support • Lack of learning capabilities • Short project lifecycle • Short term supply chain relationship
	<u>2-B</u> Lack of Motivation	• Lack of human resource capabilities • Lack of organisational strategies • Lack of reward system
Section (3) Inefficiency in transferring and sharing tacit knowledge	<u>3-A</u> Lack of Knowledge Transferring and Sharing capabilities	• Lack of organisational capabilities • Lack of learning capabilities • Lack of awareness of gaining competitive advantage through KM • Lack of financial resources • Lack of awareness in seeking support • Lack of awareness of Knowledge Management
	<u>3-B</u> Lack of Awareness of Knowledge Transferring and Sharing	

Based on the findings given in table (2-2) figure (2-2) below *(see large image in appendix 2)* presents the interrelationship between the problem and the causes of fragmentation in the construction sector. This presents the list of supporting factors/challenges (taken from Table 2-2) which jointly encourage fragmentation while also endorsing the main and sub-causes of the disconnected CSCs. For example, in section (1) of table 2-2, the fragmented CSCs have two supporting causes (1-A) lack of partnering and collaboration, and (1-B) lack of construction process integration in CSCs. The supporting factors of these causes which leads to the fragmented nature of CSCs are: lack of skills, lack of trust, lack of motivation, short term SC relationship, etc. Similarly, sections (2 and 3) of table 2-2 have sub-causes and supporting factors that leads to fragmentation in CSCs.

However, due to the nature of this study, the list of supporting factors is restricted to those that arguably hinder the transfer and sharing of Tacit Knowledge in CSCs.

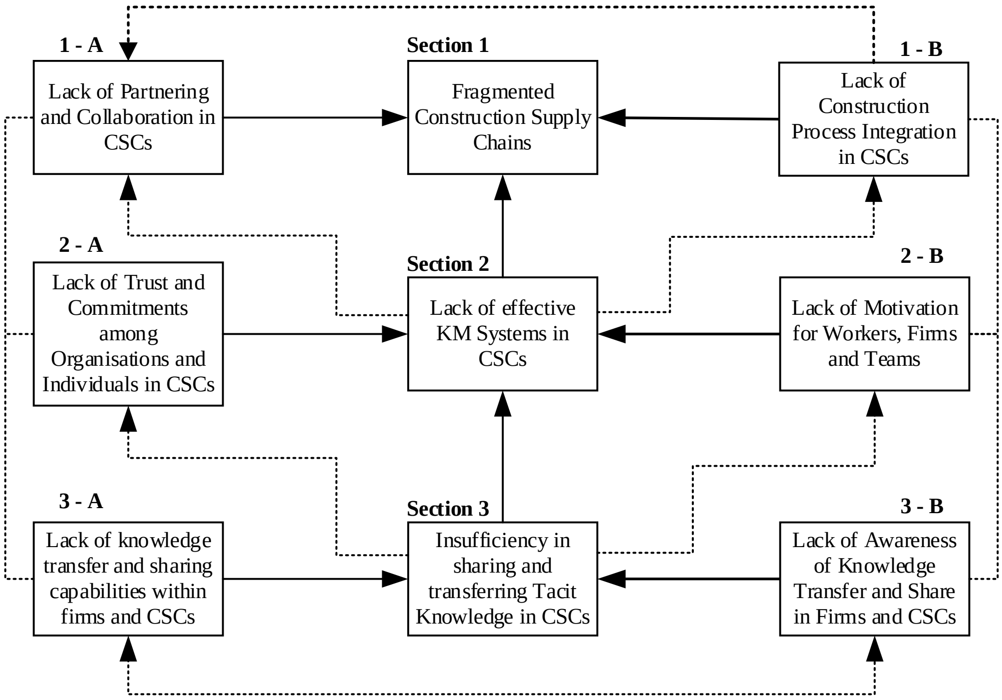

Figure 2-2: Problem, Causes and their interrelationship in the fragmented Construction Supply Chain

Source: Based on literature from Carroll & Burton (2012); Alashwal et al. (2011); Khalfan & McDermott (2007); London & Kenley (2001)

The above figure (figure 2-2) exhibits the causes of the fragmented nature of construction supply chains and the interrelationships between them. The figure is broken down into three sections, namely 1, 2 and 3. Section (1) shows the major problem as being the disunited nature of CSCs. The disconnected nature of CSCs is an effect of the causes (1-A and 1-B) shown within the section (1). Lack of partnering and collaboration and lack of process integration in a CSC supports and leads to fragmented CSCs. These causes are the direct causes of fragmentation but are also supported by the third principal cause of section (2), Lack of effective Knowledge Management Systems (KMS).

In section (2), the foremost cause is the lack of KMS in CSCs which in itself is an effect of two sub-causes, namely: lack of trust and commitment among organisations (2-A) and lack of motivation (2-B) to share knowledge. The main cause of section (2), supported by section (3), is inefficiency in transfer and sharing tacit knowledge. This is further supported by the sub-causes, namely, the lack of knowledge transferring and sharing capabilities (3-A) and the lack of awareness of knowledge transferring and sharing in CSCs (3-B).

2.1.7 Summary

This study highlights that the negative impact of fragmentation in the construction sector is supported by several sub-causes. A critical analysis of the literature led this study to the root causes such as the lack of collaboration and the lack of process integration within CSC. These causes preserve the negative impact of fragmentation. Furthermore, the study highlights that collaboration and partnering within CSCs is led by a lack of knowledge management systems. This is also supported by a lack of trust between organisations and lack of motivation among organisations and individuals. In this study, the following six main challenges were found to hinder the transfer and sharing of tacit knowledge in CSCs.

1) A lack of understanding of the importance of the transfer and sharing of Tacit Knowledge
2) A lack of trust among organisations in Construction Supply Chains
3) Insufficiency of motivation within organisations in Construction Supply Chains
4) The short term supply chain relationship among partners in Construction Supply Chains
5) Contractors have a traditional way of doing business
6) The fragmented nature of the construction sector

This study shows that many of the challenges are inter-related. For instance, the lack of motivation to transfer and share tacit knowledge is led by the lack of awareness of knowledge transferring and sharing in CSCs. Similarly, the lack of partnering and collaboration in CSCs is led by the lack of trust and commitment among organisations and, furthermore, could be affected by the lack of motivation.

The preliminary study within this section found that the foremost challenge that hinders the transfer and sharing of tacit knowledge is the fragmented nature of the construction sector. The negative impact of fragmentation appears to be affected by the supporting causes listed in Table **2-1** and the relationships between the problem, causes and supporting factors are analysed in Table **2-2**. Surprisingly, this literature review reveals a few interesting themes, which support the main challenges, such as the lack of skills in the construction sector (BQF, 2013 and Guo, 2012), the lack of adequate support to grow (BIS, 2011, 2013b; Schulz, 2012) and the lack of learning capacity and capabilities (Baets, 2005; Tsai, 2001). Mostly, previous studies have suggested that there is a gap in knowledge communication, especially in transferring and sharing tacit knowledge within CSCs. For these reasons, this study establishes that an effective knowledge transfer and sharing approach would help to bring enhanced collaboration and partnering between organisations and, consequently, increase the efficiency of CSCs

2.2 Application of Lean and Agile Principles in Construction

2.2.1 Introduction

This section critically reviews the relevant and related literature concerning Lean and Agile Thinking and their application in Construction Supply Chains. This section further identifies and discusses the literature on Lean and Agile principles and their application in Supply Chains and specifically in Construction Supply Chains, and the problems and challenges associated with their application. This section seeks to identify the main principles and processes of Lean and Agile thinking and their implications in Construction Supply Chains.

CIRIA (2013) defined "Implementing Lean in Construction as the construction industry, its clients and its supply chain, were under pressure to deliver 'more for less'. Lean practice is fast becoming a pre-requisite of its supply chains." This section observes that many construction organisations, and their clients, are participating or exploring Lean thinking as a way of delivering value.

2.2.2 Lean and Agile Thinking

2.2.2.1 Lean Thinking

Lean thinking is the term used to refer to the reduction of non-value added activities such as physical waste, operations and equipment (Muri, Mura and Muda) within work procedures in order to enhance process flow and add value as well as delivering what the customers want. Historically, Lean was initiated based on the flow concept, and on the value concept which was cultivated by the quality movement and subsequently merged with Lean (Sacks et al, 2009). CIRIA (2013) defined Lean as a term that relates "to a proven way of doing business, entirely focused on maximising customer value through the relentless elimination of all forms of process waste and ensuring that value-adding activities are completed in the most efficient and time-effective manner."

The Toyota Production System (TPS) defined seven (7) types of waste namely, Defects, Inventory, Processing, Waiting, Motion, Transportation and Over production. According to Womack (2006), these types of waste can be removed without the need to coordinate with larger organisations. Consequently, Womack defines that people working within the process can just eliminate the waste from a production process.

The roots of Lean principles can be found within history, ever since the Venetian Arsenal introduced floating assembly lines of boats to a standard design. This was the first known example of flow in history. Later, in the 1780s the French army ordnance introduced the concept of interchangeable parts. This concept means that the parts are standardised to a nearby fit for almost any similar device to ensure a quick assembly of new products.

John Krafcik defined the term “Lean” in 1987. John was a young researcher in the MIT International Motor Vehicle Programme. For many Lean is the set of tools used to reduce waste (Muda). John Krafcik, Jim Womack, Daniel Jones and Daniel Roos took the term from a book called The Machine that Changed the World (Womack et al., 1990).

Lean is the concept of efficient manufacturing or operations which grew out of the Toyota Production System in the early 20th century (Womack & Jones, 2003; Womack et al., 1990). It is based on the philosophy of defining value from the customer’s viewpoint and continually looks at improving the way in which that value delivers, by eliminating every use of resources that is wasteful, or that does not contribute to the value goal (Ibbitson & Smith, 2010). This continual improvement of processes requires the involvement and empowerment of every member of staff at every level. The Kaizen (Japanese word for small improvements) is one of the philosophies of the Lean that tends to make small improvements in a process. However, the western world perceives Kaizen as a way of thinking and of asking self-questions frequently such as how and why. It centres on finding a better way of doing things for continuous improvement.

2.2.2.1.1 Application of Lean Principles in Construction

Lean construction is a new way of managing work over the life of a project. It is not a productivity improvement programme (Sacks et al., 2010). Lean construction is a production management-based approach to project delivery; it is a new way of designing and building capital facilities (Sacks et, al., 2009). The application of Lean production management to manufacturing caused a revolution. The objectives of Lean production systems are to maximise value and minimise waste within specific techniques and to apply those techniques to form a project-based production system (Childerhouse et al., 2003). Lean Construction is particularly useful on complex, uncertain and quick projects. The Lean principles given in Table 2-3 below are based to increasing the quality of work and products, increasing value by eliminating waste and increasing flow through the process.

Table 2-3: Lean principles and their application in construction

Lean Principles	Application of Lean principles in construction
Value	This is to specify the value of a process/product from the standpoint of the end customer. In construction value-adding could be the activities which transform material or information in something that the customer would be prepared to pay for. Non-value added activities are those that do not add value to anything.
Value Stream	Is to identify all the activities that expose waste between the activities within the Value stream and eliminating whenever possible those steps that do not create value. The value stream exists both on-site and across the organisations that supply raw materials and finished products for the construction project. This is used to identify all types of waste in a process.
Flow	Normally in manufacturing products, flow is through workstations. In construction, flow represents the flow of material within or between companies.
Pull	This is to deliver all raw materials, finished products, labour, and information to the customer exactly when it is needed. Delivering materials on Just-in-time is the approach to eliminate the excess inventory holding on site. Pull helps to eliminate wastes such as over-inventory and waiting.
Problem Solving	To solve the problems in Lean construction is a joint effort by partners. Problems needs solving to avoid waste such as waiting, re-manufacturing and defects.
Developing Partners	Both in Lean construction and Lean manufacturing supply chain partners need to be developed to work jointly to add value while reducing the waste and improving the process. Developing partners could help to eliminate waste such as waiting, motion, transportation, over inventory and defects.
Perfection (Continuous improvement)	Is to continuously improve the processes through collaboratively identifying and removing waste until a state of perfection is reached in which flawless value is created with no waste.

Source: modified after CIRIA(2013); Sacks et al. (2009a); Pheng & Fang, (2005)

There have been many Lean principles suggested specifically for Lean construction. In construction, Lean is an operational excellence strategy that enables better changes. Kaizen, in Japanese, means ‘change for good’ and is the basic philosophy of Lean. However, the Lean process is slow and steady, instead of quick and vague (Dombrowski et. al, 2012). The Japanese believe that Lean principles are a persistent pursuit of the elimination of waste whereby waste means any activity that adds no real value to the product or service. Moreover, the Japanese view Lean as not only eliminating waste to increase the value, but also as increasing the speed of the processes (to increase flow). Pheng & Fang (2005) presented eleven Lean principles naming them the modern-day Lean construction principles. However, these Lean principles relate to the main aim of Lean principles to increase the value, and to increase flow and uninterrupted improvement. Additionally, Sacks et al. (2009) said that, as in the Toyota Production System, the focus in Lean construction is on the reduction of waste, the increase of value for the customer, and continuous improvement. Moreover, Sacks et al. (2009) considered four types of Lean principles focused upon an analysis of the interconnection of Lean and BIM. Those four principles were philosophy, process, people, partners and problem solving. The philosophy principle was given little consideration in this research as Sacks et al. (2009) said that philosophy is not related to BIM. They concluded with four processes' areas namely, flow process, value generation process, and problem-solving, as well as developing partners. In addition, the continuous improvement principle was considered as embedded within the flow process. However, according to Pheng & Fang (2005), continuous improvement or quality management should be seen as a separate process.

Based on the above analysis of literature, Table 2-4 and Figure 2-3 below have been developed to establish the interpretation of the communal characteristics and correlations of Lean principles.

Table 2-4: Collective Characteristics of Lean Principles

Lean Principles	**Characteristics**	**Supported Reading**
To Remove Waste from Processes	Lean is improves the process while removing unwanted activities (waste) from it.	(CIRIA, 2013; Manrodt & Vitasek, 2005; Conboy & Fitzgerald, 2004; Egan, 1998)
To generate value in processes	Removing waste to generate and add value to the process	(Rooke & Sapountzis, 2010; Womack & Jones, 2003)
To enhance material and information flow in processes	Removing unwanted activities & enhancing material and information flow within a process	(Pheng & Fang, 2005; Bratić, 2011; Krishnamurthy & Yauch, 2007)
To increase efficiency in the decision-making process	Material and information flow increasing efficiency in the decision-making process	(Bratić, 2011; Love et al,. 2004a; Michell et al,. 2012; Sacks et al., 2010)
To continuously improve processes	Keep removing unwanted activities from a process continuously to improve the entire process	(Sacks et al., 2009; CIRIA, 2013; DeMin, 2007; Sacks et al., 2010)

The potential correlations amongst the lean principles are shown in Figure 2-3 below. Based on the interpretations gained from the literature review concerning lean principles and their characteristics as given in Table 2-3, there are a total number of nine (9) correlations found among five (5) principles. These correlations demonstrate two-way linkers coded as Correlation 1 to Correlation 9 (C1 to C9) and Lean Principles are given the codes V1 to V5 for presentation and explanation purposes. The potential correlations are explained below and these will be tested during the data analysis.

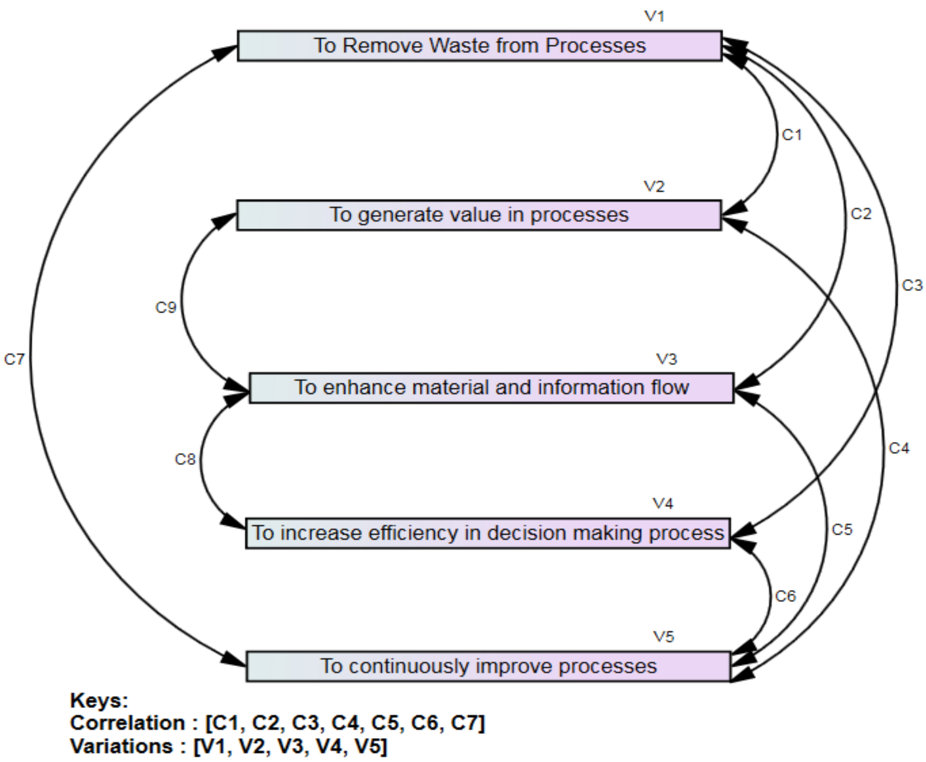

Figure 2-3: Potential Correlations among Lean Principles

Source: Original

(C1): Remove Waste (V1) ← to → (V2) Generate Value: Removing waste (unwanted activities) generates value through a process while reducing the cost of each activity and the time taken to perform the process. In other words, removal of waste from a process would help to generate value in it.

(C2): Remove Waste (V1) ← to → (V3) Enhance Material and Information Flow: This correlation indicates that removing undesired activities from a process enhances the flow of material and information, for example, the removal of a process that hinders the flow within construction processes would enhance the flow of material and information.

(C3): Remove Waste (V1) ← to → (V4) Increase Efficiency in the Decision-Making Process: Removing unwanted activities from a process increases efficiency in the decision-making process because it provides a clearer understanding while enhancing the information flow.

(C4): Generate Value (V2) ← to → (V5) Continuous Improvement**:** To generate value would require continuous improvement in a process while removing waste and enhancing the flow of material and information whilst also eliminating the activities that hinder the value generation process.

(C5): Enhance Material and Information Flow (V3) ← to → (V5) Continuous Improvement: Enhancing material flow while removing unwanted activities from a process and keeping on doing it will continuously improve the process and vice versa. **(C6):** Efficient Decision Making (V4) ← to → (V5) Continuous Improvement**:** An efficient decision-making process can continuously improve other processes and vice versa.

(C7): Continuous Improvement (V5) ← to → (V1) Remove Waste**:** Removing unwanted activities from a process will improve the process, but continuous improvement is required to eliminate the waste from the whole process.

(C8): Increase Efficiency in Decision-Making Process (V4) ← to → (V3) Enhance Material and Information Flow**:** If the decision-making process is efficient, then reducing unwanted activities in a process will enhance the material and information flow.

(C9): Enhance Material and Information Flow (V3) ← to → (V2) Generate Value: Enhancing material and information flow to generate value in a process.

The above interpretive correlations give an understanding of the working and unique characteristics of Lean principles. The main principle of Lean thinking is to remove waste (unwanted activities) from processes. Other principles of Lean are often dependent on waste reduction and providing limited efficiency to an SC and, especially, to a set of multiple SCs within a construction project. In short, adopting Lean thinking in CSCs would help to reduce waste from processes and, consequently, to reduce cost and lead-time; rather than to bring efficiency to the entire construction supply chain from start to finish.

In support of this view, there have been many arguments that applying Lean does not provide a standalone solution to bringing efficiency to a SC process. As discussed earlier, a SC also requires Reliability, Responsiveness and Agility (SCOR, 2008) in the processes and activities. Moreover, Lean Principles do not offer collaboration and partnering, customisation or responses to change and uncertainty. However, by applying Agile thinking in combination with Lean would help to gain desired outcomes (Court et al., 2012; Ribeiro & Fernandes, 2010; SCOR, 2008 and Khalfan et al., 2007). To validate this view, further analysis of the literature is required to explore agile thinking and its application to CSCs.

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2.2.2.2 Agile Thinking

Historically, agile thinking is a method and approach to software development. It has its roots back in the 1950s within the National Aeronautics and Space Administration (NASA) and later within the International Business Machines Corporation (IBM) (Abbas et al., 2008). The appearance of Agile methods has been most noticeable in supply chain thinking since the end of 1999, since Childerhouse et al. (2003); Christopher & Towill (2001) and Mason-Jones et al. (2000) viewed it as a viable method to improve supply-chain performance. However, in fact, many of the “Agile ideas” have been around since the 1950s. There are different angles in which to look at agility. Some people think of agility as a concept to exploit opportunities (Werfs, 2013). Thes differences in the basic understanding of agility define how concepts and frameworks are developed. In contrast, agility is used to *‘react’* (respond to change) (Bredillet, 2013) and at the same time to ‘*act’*. The meaning of agility is context dependent and relates to its role throughout a process. The term ‘react’ is mainly to respond to change and ‘act’ is often viewed as a decision-making framework.

Agility is often confused or mixed up with flexibility, and with dynamic abilities. The definition of flexibility is “the ability to adapt to change”. The definition is similar to that for agility. However, there is a fundamental difference. Flexibility refers to one-off changes and agility is a concept for continual change (Werfs 2013). This is why so many definitions of agility exist. Some researchers continue to define agile as a philosophy. Alistair Cockburn’s definition is “Agile implies being effective and manoeuvrable. An Agile process is both light and sufficient. The lightness is a means of staying manoeuvrable. The sufficiency is a matter of staying in the game” (Abbas et al., 2008). Boehm (1988) gives a more practice-oriented definition, "In general, 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). However, the proponents of agility at the Iaccoca Institute of Lehigh University (USA) have defined it as “A manufacturing system with extraordinary capabilities (Internal capabilities: hard and soft technologies, human resources, educated management, information) to meet the rapidly changing needs of the marketplace (speed, flexibility, customers, competitors, suppliers, infrastructure, responsiveness)”. A manufacturing system shifts quickly and requires speed and responsiveness between product models or between product lines. Therefore, this requires a real-time response to customer demand (Yusuf et al., 1999). Furthermore, they have given the key attributes of agile organisations, see Table 2-5 below.

An Agile method follows four values, Adaptive, Iterative, Incremental and People Oriented (Abbas et al., 2008).

1) **Adoptive:** an agile method welcomes change in activities and processes. It takes feedback from the previous activities or processes to improve the further activities and processes (Basu & Wright, 2010; Crispin & Gregory, 2009).
2) **Iterative:** is an agile method that means providing and obtaining feedback (Crispin & Gregory, 2009) while repeating the process until it achieves the main objective. In each loop, the process is developed, tested and improved until it develops a new and efficient process. This is a similar method to Deming's continuous improvement cycle of Plan-Do-Check-Act.
3) **Incremental:** this method works in combination with the Iterative method. This improves each process or activity to develop a new form or functionality of a process. This delivers the fresh functionality to next process to get the feedback (Raschke, 2010).
4) **People Oriented:** in agile methods, people are the primary drivers of project success. Key characteristics of agile methods are Lean, flexibility and highly repetitive development (Raschke, 2010; Abbas et al., 2008) with a strong emphasis on stakeholder involvement (Ribeiro & Fernandes, 2010). Therefore, there is a need to develop a team to determine the best way to handle the work process. Agile methods emphasise in-person communications (sharing tacit knowledge) within the team and with the customer (Crispin & Gregory, 2009) who is closely involved throughout the development process instead of utilising documents (explicit knowledge).

Some researchers who have criticised the traditional methods have suggested alternative approaches which are actually agile viewpoints such as the response to change, customer involvement and a customer centric approach. Agile methods have proven successful in increasing customer satisfaction and decreasing time and cost to market under uncertain conditions (Ribeiro & Fernandes, 2010).

According to Henderson-Sellers (2006), "Agility is a persistent behaviour or ability of a sensitive entity. This exhibits flexibility to accommodate expected or unexpected changes rapidly. It follows the shortest time span, uses economic, simple and quality instruments in a dynamic environment. In addition, it applies updated prior knowledge and experience to learn from the internal and external environment."

Table 2-5: Key Attributes of an Agile Organisation

Process Domain	Key Attributes
Integration	• Concurrent execution of activities • Enterprise integration • Information accessible to employees
Competence	• Multi-venturing capabilities • Developed business practice difficult to copy
Team Building	• Empowered individuals working in teams • Cross functional teams • Teams across company borders • Decentralised decision making
Technology	• Technology awareness • Leadership in the use of current technology • Skill and knowledge enhancing technologies • Flexible production technology
Quality	• Quality over product life • Products with substantial value-addition First-time right design • Short development cycle times
Change	• Continuous improvement • Culture of change
Partnership	• Rapid partnership formation • Strategic relationship with customers • Close relationship with suppliers • Trust-based relationship with customers and suppliers
Market	• New product introduction • Customer-driven innovations • Customer satisfaction • Response to changing market requirements
Education	• Learning organisation • Multi-skilled and flexible people • Workforce skills' upgrades • Continuous training and development
Welfare	• Employee Satisfaction

Source: Modified after Yusuf et al. (1999)

2.2.2.2.1 Application of Agile Principles in Construction

'Agile' construction has been taken up by some construction researchers who have argued that 'Lean' practices and benchmarking are essential ingredients in achieving the target of a real cost reduction of 30% (Graves, 2000; London & Kenley, 2001). The Agile paradigm has values that can enhance the business capability of SMEs. Very few constructions SMEs are aware of the agile paradigm as stated by Ribeiro & Fernandes, (2010). Owen et al. (2008) observed that the agile concept has considerable potential in predesign and design but that there are significant hurdles to its adoption in the construction phase. There could be more to offer in the construction sector other than the application of "Agile" such as pull demand and the customisation of products (Naim and Barlow, (2003) cited by Ribeiro & Fernandes, (2010)). Agility stresses different values to Lean, typically learning, rapid configuration and change.

Moreover, Hansson et al. (2006), Gunasekaran and Yusuf (2002), Sharifi, and Zhang (1999; 2001) have argued that the key attributes of an agile organisation (see Table 2-5) are: flexibility, speed, Leanness, learning and responsiveness. Flexibility is the ability to respond to change and Leanness accentuates lower cost, reduced timeframes and quality production, as observed by Hansson et al. (2006). Agility also involves flexibilities of several sorts, and includes the capability to do unplanned, new activities in response to unforeseen shifts in market demands or to unique client requirements (Sharifi and Zhang, 1999; 2001). Agility conveys the ability to change operating states in response to uncertain market conditions (Gunasekaran and Yusuf, 2002). Adopting agility in the construction business process could emphasise performance improvements in the areas of responsiveness, product customisation (made-to-order), shorter new-product development lead times, reduced waste and costs, and efficient turning up and down of unproductive operations. Based on the above analysis of literature Table 2-7 and Figure 2-4 below have been developed to establish the collective characteristics of Agile principles. Table 2-6 presents the key principles of agile methods.

Table 2-6: Key Agile Principles

Principles	Supported Reading
Response to change and uncertainty	(Christopher, 2000; Conboy & Fitzgerald, 2004; Gunasekaran, 1999; Yusuf et al., 1999; Raschke, 2010; Bredillet, 2013)
High Customisation	(Christopher & Towill, 2001; Bredillet, 2013)
Synthesis of diversity	(Conboy & Fitzgerald, 2004; Bredillet, 2013)
Integrated process through project lifecycle	(Gunasekaran, 1999; Yusuf et al., 1999; Conboy & Fitzgerald, 2004; Crispin & Gregory, 2009; Raschke, 2010)
Empower teams to make decisions	(Conboy & Fitzgerald, 2004; Crispin & Gregory, 2009; Basu & Wright, 2010; Raschke, 2010)
Collaborative approach between stakeholders	(Conboy & Fitzgerald, 2004; Crispin & Gregory, 2009; Basu & Wright, 2010; Raschke, 2010)
Provide continuous feedback	(Abbas et al., 2008; Basu & Wright, 2010; Bredillet, 2013; Conboy & Fitzgerald, 2004)

Table 2-7: Collective Characteristics of Agile Principles

Principles	**Characteristics**	**Supported Reading**
To enhance the responsiveness of activities in SC processes	Enhanced responsiveness in the SC process is in addition to a high level of efficiency, quality and smooth operations (Basu & Wright, 2010).	(Hooper et al,. 2001; Gunasekaran & Ngai, 2005; Krishnamurthy & Yauch, 2007; Olhager, 2010; Raschke, 2010)
To bring collaboration and partnering in construction processes	Agile is to bring Face-to Face communication which introduces collaboration and partnering in the manufacturing process. (Crispin & Gregory, 2009)	(Dove, 1999; Basu & Wright, 2010; Ribeiro & Fernandes, 2010)
To empower teams to take efficient decisions	Implementing other Agile principles brings people together to make efficient decisions about process (Crispin & Gregory, 2009; Basu & Wright, 2010).	(Conboy & Fitzgerald, 2004; Crispin & Gregory, 2009; Basu & Wright, 2010; Raschke, 2010)
To integrate processes throughout the project	Agile principles should be implemented in the whole process to integrate intra-enterprise and inter-enterprise and with each other (Bredillet, 2013).	(Gunasekaran, 1999; Yusuf et al., 1999; Conboy & Fitzgerald, 2004; Crispin & Gregory, 2009; Raschke, 2010)

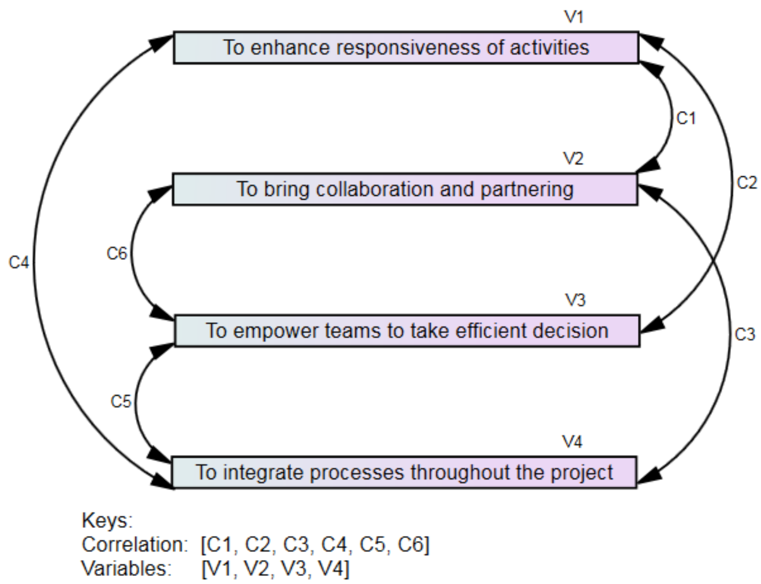


Figure 2-4: Potential Correlation among Agile Principles

Source: Original

Originating from the analysis of the literature, figure 2-4 presents a total number of six (6) correlations among the four (4) variables (Agile principles). These correlations require testing at the data analysis stage of this research.

In correlation C1 (between V1 and V2) it is interpreted that, to bring the responsiveness of activities, there is a need to bring collaboration and partnering into the agile processes. However, in correlation C2 (between V1 and V3) it is interpreted that, to bring the responsiveness in the activities within the construction process, teams need to be empowered to make efficient decisions. Nevertheless, in correlation C3 (between V2 and V4) to bring collaboration and partnering in an agile process, there is a need to integrate the process throughout the project. Moreover, correlation C4 (between V1 and V1) indicates that, to enhance responsiveness, is important to integrate processes throughout the project.

Based on this analysis, correlations C1, C2 and C4 are independent correlations among agile principles, but correlations C3, C5 and C6 are dependent and, most importantly, are supportive correlations to achieve agility in a construction process.

2.2.3 Lean and Agile in Construction Processes

Process is a specific ordering of work activities across time and place, with a beginning, an end, and clearly defined inputs and outputs. Processes are the structure by which an organisation physically performs necessary activities to produce value for its customers.

In Figure 2-5 below, a simplified series of a business process is presented. In this series Input #1 of the process #1, produce Output #1. In the second step, Output #1 becomes Input #2 for the process #2 and Outputs #2. This process continues throughout the chain. In reality, each process can have several inputs and more than one output.

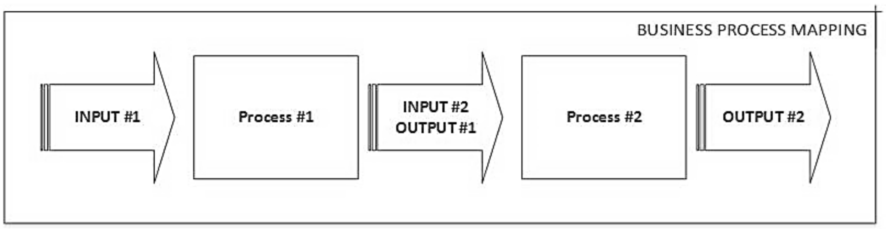


Figure 2-5: Lean and Agile Process Mapping

Source :Capgemini (2004)

The process mapping is characterised by five main divisions, Mega Process, Major Process, Sub Process, Activity and Task. The different divisions of a mega process is exhibited in figure 2-6 below.

A mega process is the highest level of processes identified by an organisation. It is a combination of more than one major process (Capgemini, 2004). A mega process usually forms a core value chain for an organisation. A major process is a sub-division of a mega process and is a combination of several sub-processes and a sub-process is a combination of several activities. An activity is a unit of work performed by one job function at one time with one mode of operation. Each activity can have several tasks. A task is a work step performed to complete an activity.

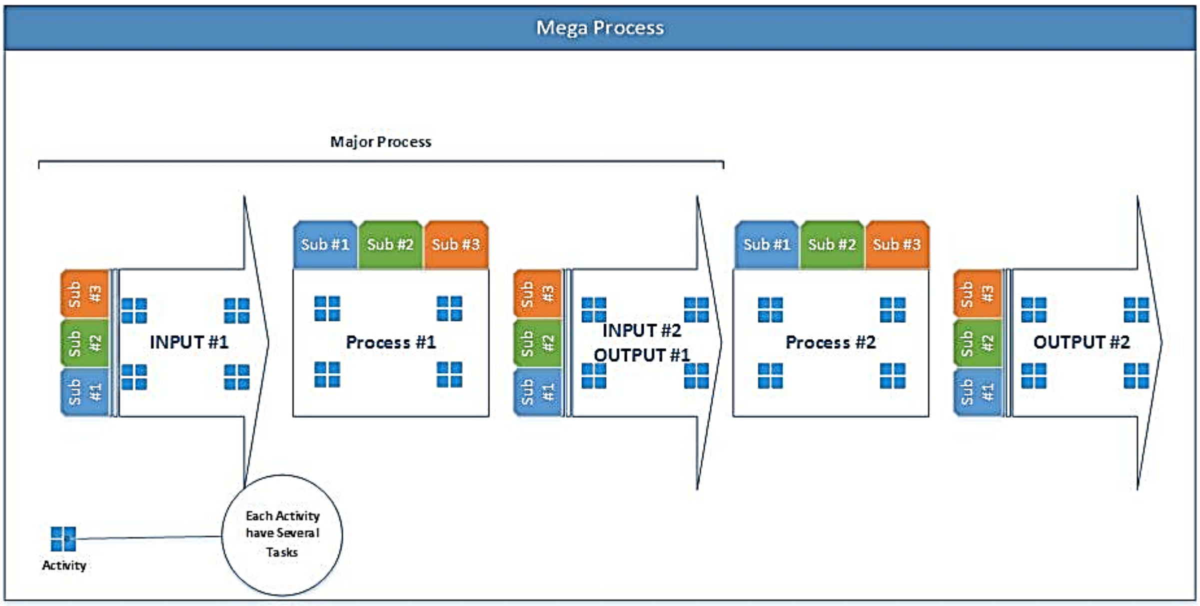


Figure 2-6: Lean and Agile Process Hierarchy

Source: adopted and modified from Capgemini (2004)

A Lean process is a series of processes that works on Lean principles heading towards one goal in order to add value to the self and following processes and across the whole set of manufacturing processes (Jørgensen & Emmitt, 2008; Koh, et al., 2008). In a Lean process the focus is on improving each task in order to make it Short, Straighten, Shine, Standardise, and Sustain (the 5Ss of Lean) and to reduce waste (Womack & Jones, 2003).

Unneeded tasks need to be removed such as excessive motion involved in a task (Womack & Jones, 2003). If tasks within an activity are subsequently improved, it adds value to the activity. In addition, a group of improved activities brings value to the sub-process and afterwards to the major-process and, at the end, to the mega-process levels (Lin & Tserng, 2003).

In reality, Lean construction is not just to remove waste from the construction process or to make standardised material to use in construction projects. Lean is mainly to improve the construction process and to develop innovative and sustainable construction. To get the benefits of Lean management, the Lean principles require implementation within the entire construction project and within the organisations involved in the project. Lin & Tserng (2003) said that Lean construction is a new way of managing work over the life of a project instead of a productivity improvement programme. It is a production management-based approach to project delivery. Furthermore, Lin & Tserng (2003) concluded that a good construction project management could generate both tacit and explicit knowledge through a construction project. Moreover, such a management can reuse explicit knowledge to avoid similar mistakes in the future projects. On the other hand, tacit knowledge can be used to improve the know-how experience at the individual task level and at the further activity level. Figure 2-7 below is modified to show the simple lean supply chain of a construction project. In this figure, there are two sets of supply chains.

In supply chain #1, the supply chain is mainly concerned with Tier 3 suppliers that are often SMEs in CSCs. In addition, supply chain #2 is concerned with the main supply chain of the construction project with Tier 1 (main contractors) and Tier 2 (sub-contractors) suppliers. However, Figure 2-8 is an outcome from the literature on Lean and Agile construction processes and CSC. This presents the implication of Le-agile within one organisation and its process levels. Organisations handling Le-agile construction projects must implement the projects using Lean and Agile principles on each level through a mega process, major process, sub-process, and activity and task levels. Failure to employ these principles will lead to non-achievement of the stated goals/objectives, as all the departments in the organisations are interconnected.

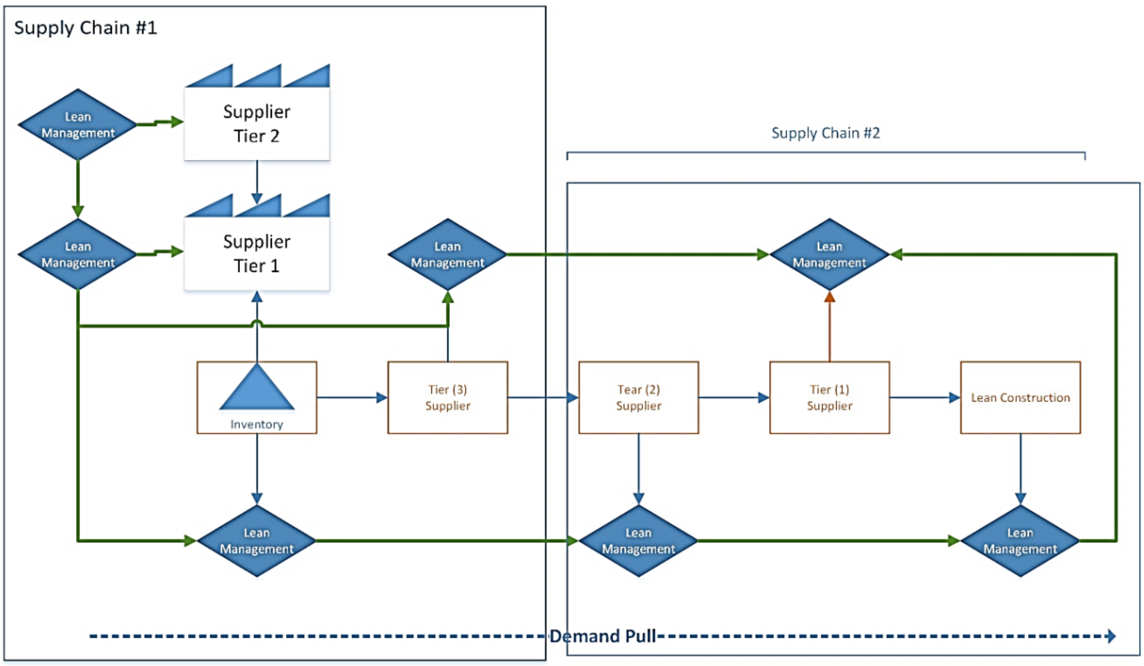


Figure 2-7: Lean Construction Supply Chain

Source: adopted and developed from Capgemini (2004) and Lin & Tserng, (2003)

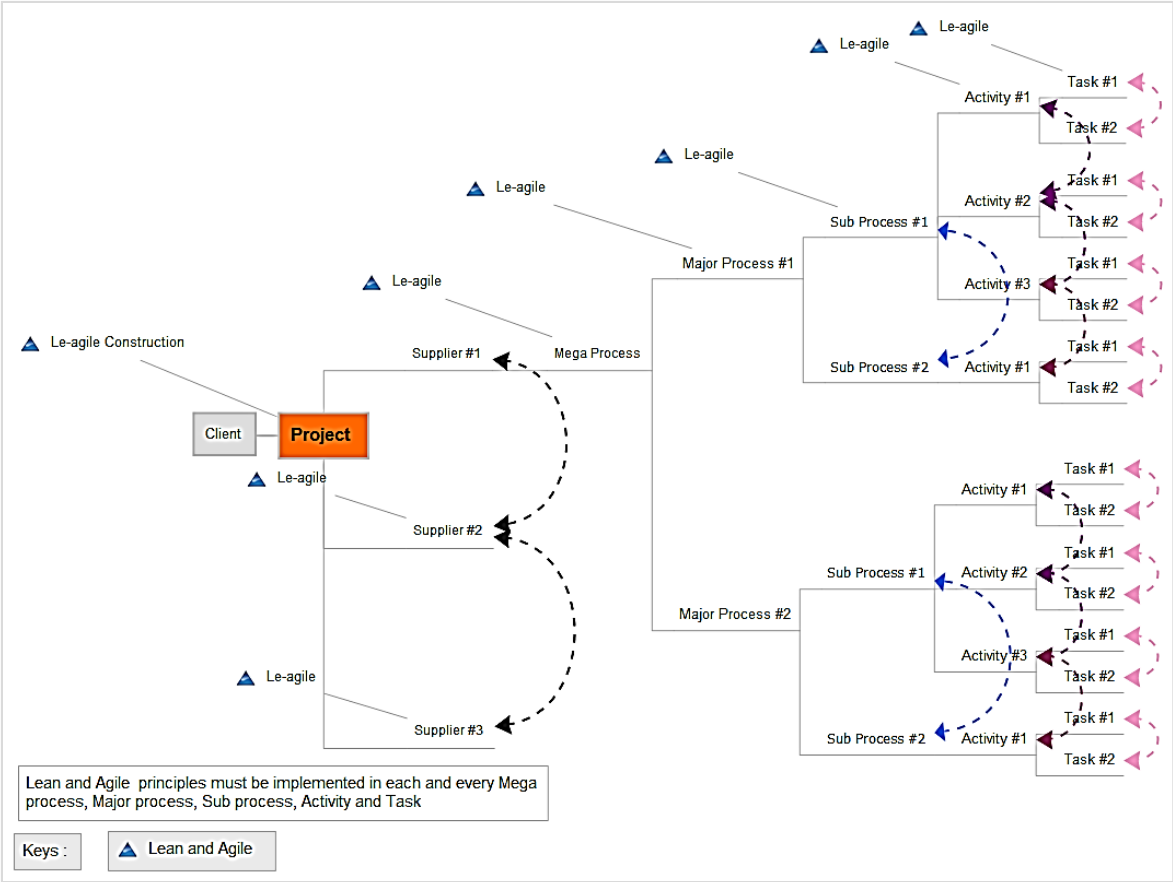


Figure 2-8: Actual Lean and Agile Construction Supply Chain

Source: Developed from Jørgensen & Emmitt (2008); Rooke & Sapountzis (2010); Christopher (2000)

2.2.4 Application of Le-agile Principles in Construction

The Le-agile principle has proven successful in increasing customer satisfaction and decreasing time and cost to market under uncertain conditions. The key characteristics of Le-agile methods are Lean, flexibility and highly iterative development with a strong emphasis on stakeholder involvement (Ribeiro & Fernandes, 2010). However, Lean and Agile principles may be complementary in the sense that they can join one system to another, for example, integrating Lean Manufacturing with an Agile Supply Chain. The linking of “Lean" and “Agile” processes is often known as the “Le-agile” process (Court et al., 2012). This combined approach contains the principles of Lean and Agile processes.

The integration of Lean and Agile processes in supply chains can thereby adopt a Lean approach upstream. To enable a level schedule and the opening up of an opportunity to drive down costs while simultaneously still ensuring that downstream should have an agile response that is capable of delivering to an unpredictable change. Table 2-8 below presents the benefits of adopting the Le-agile approach.

In this table (table 2-8attributes which are linked to Lean or Agile Supply highlight some of the main attributes of CSC, which distinguish the choice of either Lean or Agile supply. Initially Christopher and Towill (2001) suggested the integration of those attributes.

The choice of these attributes leads to the choice of Lean or Agile supply. For instance, the construction project which uses Lean supply is more viable for commodities where the demand forecasting is predictable and cost is the main customer-driven factor. To keep the cost down these types of commodities are often mass-produced and often the number of the suppliers is low. The product and services can be outsourced while building a long-term relationship with suppliers to get the benefit of Just-in-Time (JIT) and the vendor managed inventory Lean supply is the best approach to reducing the cost.

On the other hand, services or materials that are required in low quantities can be purchased locally, where the demand is unstable and derived by availability. For instance, a building with 100 flats could have a minimum of 100 customisation opportunities for builders such as the customisation required for a variable demand of 20 different types of beds and 25 distinctive types of bathroom fittings.

Table 2-8: Attributes for choosing Lean or Agile Supply

Attributes Products/services	**Lean Supply**	**Agile Supply**
Typicality	Commodities	Fashion
Demand	Predictable	Volatile
Variety	Low	High
Lifecycle	Long	Short
Customer drivers	Cost	Availability
Profit Margin	Low	High
Contracts	Long Term	Immediate, Short term
Procurement Policy	Material Sourcing	Capacity Sourcing
Information enrichment	Highly desirable	Obligatory
Forecasting Mechanism	Algorithmic	Consultative
Dominant cost	Physical Cost	Marketability cost

Source: compiled from Christopher & Towill (2001, 2002).

Some of the well-known SC examples of using the Le-agile concept are from different industries. These industries include the automobile, computing and clothing industries and these have been proven to obtain the maximum benefit from Le-agile SCs. The literature also emphasises and proves that having an efficient KM model is an essential part of these SCs. KM in a Le-agile supply chain has been proven to gain advantage from the many efficient Economies of Scale (EoS), from Enterprise Resource Planning (ERP), project planning, shorter lead time, and better relationships and partnering among suppliers.

2.2.5 Summary

This section establishes that, adopting just Lean or Agile principles as separate functions in CSCs, does not solve the existing problems such as a lack of integration, collaboration and partnering in supply chains. Lean principles are widely considered to reduce waste and lead-time in a supply chain. However, Agile principles are merely considered as being more responsive to unpredictable demand and markets as Lean and Agile principles require collaboration and partnering of the stakeholders in any organisation. In reality, implementing Lean and Agile processes both together produces better results. The examples from other industries such as clothing and automobile reveals that Lean and Agile processes both embed in each other and should not be considered as different paradigms or functions. However, in CSCs, it will be unfair to say that Lean or Agile principles are the only approaches to bringing efficiency into CSCs. At the same time, Lean principles are only successful when they are implemented with Agile principles in the SC to bring agility/flexibility and responsiveness.

In addition, Ballard & Howell (1998) categorised different types of construction projects such as job shops, batch flow, line flow and continuous flow. Any construction project could contain a different set of manufacturing flows or, at the same time, include many flows. Ballard & Howell (1998) observed that a construction site is a combination of fabrication and assembly. Industrialisation initiatives advocate simplifying site construction to final assembly and testing in order to shift as much work as possible into shop conditions in order to undertake it much more efficiently. Arguably, if a construction site is a combination of fabrication and assembly then a construction site should be considered as a manufacturing site based on Le-agile principles. The above literature defends the aim of Le-agile principles to create a responsive CSC. This further requires collaboration, partnering and the integration of processes to add value to the CSC. Studies have shown that, without effective KM and knowledge sharing tools and techniques, neither Lean nor Agile principles would perform effectively to develop an efficient CSC. This literature review puts forward the following findings.

- Implementing Lean and Agile principles as separate functions do not produce the desired results in CSCs.

- Lean and Agile processes must be implemented together as being embedded in each other to bring integration, collaboration and partnering in CSCs.
- To bring about efficiency in CSCs, Lean and Agile processes requires further integration with knowledge sharing tools and techniques.

The next section explores the literature on knowledge and knowledge management to establish and find the answer to questions such as why is KM so important for construction processes? What role does it play and how?

2.3 Application of Knowledge Management in Construction

This section explores and investigates the literature on knowledge, knowledge management and types of knowledge. Moreover, it investigates how to establish the role and application of knowledge and knowledge communication and knowledge management within construction supply chains. In addition, it explores the current schools of thought on knowledge and classical and modern perception of knowledge. This section investigates and identifies the answers to the questions below.

- Why should knowledge management be applied in construction?
- What role does it play?
- Why is knowledge management important for construction supply chains and Lean and Agile processes?
- Why the transfer and sharing of Tacit Knowledge is is significant in CSCs?
- What are the reasons that hinder the articulation of Tacit Knowledge?

This section puts forward that adopting just Lean or agile concepts in CSCs does not solve the existing problems such as integration, collaboration and partnering in supply chains. The application of knowledge management and especially knowledge communication plays a substantial role in enhancing the efficiency of Lean and Agile thinking in construction processes.

2.3.1 Knowledge Management

The phrase "KM" provides a technological base for managing knowledge. An association of companies in the USA started the Initiative for Managing Knowledge Assets in 1989. KM-related articles began appearing in journals such as Sloan Management Review, Organisational Science, Harvard Business Review and others, and the first books on organisational learning and KM were published, for example, Senge's "The Fifth Discipline." However, the roots of KM have traces back to the late 1960s and the early 1970s in Anglo American literature such as the article by Zend (1969) on "*Management of the Knowledge Organisations*." This discussion was not directly about Knowledge Management. It was about managing knowledge organisations. However, the term KM originated roughly two decades ago in the 1990s. In simple terms, KM is the capturing, coding and sharing of information within organisations or between a set of multi-organisations. Although, there is no single accepted definition, Devenport (1994) has given the most cited definition of KM. It defines "*Knowledge Management is the process of capturing, distributing, and effectively using knowledge*."

Intuitively, Knowledge Management is “any process or practice of creating, acquiring, capturing, sharing and using knowledge, wherever it resides, to enhance learning and performance” (Scarborough et al., 1999). Knowledge Management is vital for efficiency in project delivery and in improving organisational competitiveness. Knowledge Management also promotes innovation and business entrepreneurship, helps in handling change, and empowers employees (Egbu et al., 2005)

Having undertaken a literature review on Knowledge and Knowledge Management, this study defines Knowledge Management as:

“Knowledge management is a process of identifying, transferring and effectively sharing knowledge to support other processes, wherever and whenever required.”

The works of Nonaka & Takuchi, Devenport, Koeing and Stewart influences this definition.

Since the birth of the concept of KM, it has been widely used in the consultants’ community. Koenig (2012) observed that the consultants’ community offered KM as a product after gaining expertise in the Internet. In addition, Koeing, stated, the enthusiasm for intellectual capital in the 1980s primed the pump for the recognition of information and knowledge as essential assets for any organisation. Similarly, Nonaka and Takuchi (1995) contended that knowledge resources are the only assets of an organisation. Furthermore, Koeing (2012) argued that KM is needed to make information and data available to the stakeholders through portals and with the use of content management systems. Content Management, sometimes known as 'Enterprise Content Management', is the most immediate and obvious part of KM. Nevertheless, Stewart (1997) added “Knowledge has become the primary ingredient of what we make, do, buy and sell. As a result, managing it, finding and growing intellectual capital, storing it, selling it and sharing it; becomes the most important economic task of individuals, business and nations.” Fink & Disterer (2005) argued that the most valuable knowledge is believed to be closely tied to the person who developed it, is mainly transferred by direct person-to-person contact; the approach is therefore called a “personalisation” approach (Hansen et al., 1999). Later this section discusses the personalisation view of knowledge development.

2.3.2 Schools of Thought on Knowledge Management

There is a shortage of agreement about the definition of what is KM. Every person has their own view on defining knowledge. There are two main Communities of Practice (CoPs) of knowledge viewers in the modern world which are IT Dominant and Business Dominant CoPs. The IT dominant viewers often look on both knowledge and information as similar concepts. They view information as knowledge. The IT dominant community believes that KM is a technological discipline and is an IT system, and tools are the key elements of KM.

On the other hand, the Business dominant group usually differentiates knowledge into tacit and explicit knowledge, whereby tacit knowledge is expertise (know-how) rooted in practice and sometimes seen as intuitive and context-specific knowledge. The group regards explicit knowledge as less valuable than tacit knowledge. Explicit knowledge is codified, found in documents and manuals and available for access. The Business dominant group contends that IT systems are not effective tools for tacit KM. Business dominant group considers Tacit Knowledge as the main source of competitive advantage.

2.3.2.1 Positivist school of thought

The positivist school of thought expresses that the observation of objective reality drives knowledge (Schwartz, 2005). This school argues that knowledge is gained from the observation of an objective reality thus distinguishing between an observing subject and an observed object (Maier, 2007). A major aspect of positivism is the division between object and subject. According to Baets (2005), positivism considers that knowledge exists independent to the human being, “the knower” who uses it, learns it and transfers it.

2.3.2.2 Constructivist school of thought

Constructivism claims that the construction of knowledge is in the minds, thus it is not objective (Schwartz et al., 2005). This, therefore, challenges the notion of an objective reality (Maier, 2007). This school explains how the construction of knowledge occurs in a human being when information is exposed to existing knowledge that has been developed by experience. Constructivism has an implication for the tacit knowledge theory; experiments, and collaborative and task based learning and teaching.

2.3.2.3 Critical rationalist school of thought

The critical rationalist school of thought develops the judgmental theory to challenge the traditional theory. This matures without the reality of society and the real function of science. It develops an argument that all our knowledge is tentative and must be open to empirical falsification (Maier 2007).

2.3.2.4 Empirical school of thought

Empiricism is based on the assumption that knowledge can be created solely from experiences; on the other hand it contends that mathematics and sciences create undoubted truth (Schwartz, 2005). This means that any hypothesis requires testing by experiment or observation (Creswell, 2013). Even the base of knowledge gained from the senses is upon the evidence of senses. Such a thought was represented by Thomas Hobbs and later represented by Bertrand Russell who called it “Logical Atomism” or “logical holism” meaning logical facts. In simple words, every instance in this world has logic behind it which can be analysed (Maier, 2007; Baets, 2005). John Locke has been seen as the leading philosopher of British Empiricism. Some philosophers associated with empiricism include Francis Bacon, Aristotle, Thomas Hobbes and Robert Boyale.

2.3.2.5 Social constructivism school of thought

Social constructivism means that the construction of knowledge is in communal (social) settings. In this, one or more group construct knowledge for each other. This tends to form a challenge for “positivist” measurement (Schwartz, 2005). This falls in the Constructivist school of thought. Originally such a thought was quoted by Thomas Hobbes based on his recall of Francis Bacon's work.

2.3.2.6 Pragmatist school of thought

Pragmatism is concerned with the local reality of experience. It develops and represents the philosophy that the function of thought is to act as a tool for prediction, action and problem solving, rather than to describe, represent or mirror reality (Maier, 2007; Coakes & Clarke, 2005).

2.3.3 Predominant views of Knowledge Management

There are three predominant views of Knowledge Management which are Information Based, Technology Based and Culture-Based Views. There has been major confusion on these views since they emerged (Alavi, 1999; Alavi & Leidner, 2001).

2.3.3.1 Information Based view of Knowledge Management

In terms of the information-based perspective, Knowledge Management is about characteristics of information, such as readily accessible information, real-time information, and actionable information. Studies (by Alavi 1999; Alavi & Leidner 2001) reveal “in terms of the information perspective, several managers mentioned their view that KM was concerned with reducing the overload of information by “filtering the gems from the rocks." However, other scholars view KM as a means of keeping track, not so much of knowledge itself, but of tracking down the person who holds the knowledge (Alavi, 1999).

2.3.3.2 Technology Based view of Knowledge Management

In terms of the technology-based perspective, KM is a combination of different systems (including data warehousing, enterprise wide systems, executive information systems, expert systems, and the intranet) and various tools (e.g., search engines, multi-media, and decision making tools) (Alavi, 1999). Baets (2005) said that, in practice, a technology-driven development of Knowledge Management, often fails.

2.3.3.3 Culture Based view of Knowledge Management

The culture based view of knowledge management is concerned about the implications for change management. It represents to develop a culture of continuous and collective learning of organisations for intellectual property cultivation. In Alavi, (1999)'s view, the cultural based view of KM requires ability to convince people to volunteer their knowledge. Furthermore, this demands the ability to organisations to share their knowledge with other organisations. A major cultural shift would be required to change the construction workers attitudes and behaviour so that they willingly share their knowledge. However, that requires a long-term investment to align the cultural, managerial and organisational elements for knowledge management. However, since individuals and organisations in a CSC have short-term supply chain relationships and traditional ways of working, it is highly challenging to bring a major cultural shift in a short lifecycle of a construction project.

2.3.4 Knowledge

Humans' activity is unconvincing without knowledge, (Anumba et al., 2008). It is obvious that without creating, accumulating, sharing and applying knowledge, no human civilisation would have existed. Even though the term KM emerged just a couple of decades ago, this does not mean that KM processes did not exist earlier (Anumba et al., 2008). Furthermore, Anumba et al. emphasised that there are many classical examples such as building the pyramids, the steam engine, etc. which means that knowledge processes have a rather long history.

Today, knowledge is not a resource such as labour, capital and land. However, Drucker (1969, 2000) considers knowledge as the only meaningful resource, as knowledge is what makes a new society unique. Toffler (1990) backed-up Drucker's contention, proclaiming that knowledge is the source of the highest quality power and the key to power shifting (sharing) that lies ahead. Toffler (1990) believed that knowledge is the ultimate replacement of resources. Drucker (1993) said that a worker who knows how to put knowledge to productive use is a key asset to an organisation.

This study defines knowledge as follows.

"Knowledge is the only intellectual asset of a person, which is gained by sensing and experiencing the justifiable series of events of the physical world over a period of time."

This definition is influenced by the literature and the work of Francis Bacon, Thomas Hobbs, Cartesian, Plato, Peter Drucker and Peter Senge, is discussed later in section 2.3.10 of this chapter.

2.3.4.1 Background of Knowledge

The knowledge process has rather a longer history than a merely a couple of decades (Anumba et al., 2008). Therefore, this research explores the history of KM in the context of managing, capturing, sharing and transferring knowledge.

The phrase "scientia potentia est" (Knowledge is Power) originated with Sir Francis Bacon in 1557, The phrase was written in the 1558 by Thomas Hobbes (the rationalist doctrine of natural law), who was secretary to Sir Francis (Thomas, 2013).Later, Thomas Hobbes stated “there be two sorts of knowledge, whereof the one is nothing else but the sense, or knowledge original and remembrance of the same; the other is called science or knowledge about the truth of propositions, and how things are called, and is derived from understanding” (Quoted by Tonnies, 1928).

Thomas Hobbes also stated “Science is the knowledge of consequences, and dependence of one fact upon another” (cited by Leviathan (1651), ed. Macpherson (1968, 183)).

Other important challenges to what knowledge is were highlighted in the 17th and 18th centuries when philosophers such as Descartes, Leibnitz and Locke challenged the ideas of knowledge as faith and developed ideas of knowledge as accurate, provable facts, while other philosophers such as Hegel and Kant defined knowledge as divergent meaning or justified true beliefs. Since the 19th century, many different philosophical schools of thought have emerged, and they have all tried to pin down their views.

“Which brings you the ‘knowledge about the self’ is knowledge” (Rawat, 2009). The true knowing of knowing is the self (A phrase from the Upanishads, the ancient books of India). Thes statements define ‘Self’ as an individual identity that holds knowledge in his/her brain.

2.3.4.2 What is self-knowledge?

“The wise sees knowledge and action as one" (Bhagavad Gita). This phrase from ‘Shrimad Bhagavad Gita’ means, for wise people, the knowledge which is actionable.

Self-knowledge is the knowledge of the inner-self of one. Self-knowledge is not belief, but it comes from the belief of the mental or physical world or a combination of both. “We just know what we experience” (Rabolu, 2000). This means the knowing of something simply comes from experiencing the physical world. There are three key ingredients of self-knowledge, Personal, Procedural and Propositional knowledge, which combine and make self-knowledge.

2.3.4.3 Personal knowledge

Personal knowledge is the first form of knowledge by having information about someone or something (Coakes & Clarke, 2005; Kivrak & Arslan, 2008). This is the kind of knowledge that a person claims to have when he/she says things like “I know classical music.” Arguably, personal knowledge comes only with being familiar with someone or something. In order to know something a person needs to be familiar with the something. The human senses play a significant role in personal knowledge, for example someone does not know what hot is, until it is sensed. Personal knowledge involves some propositional knowledge. In fact, knowing what hot is seems to involve knowing a significant number of propositions about it. However, personal knowledge involves more than the knowledge of propositions about something.

2.3.4.4 Procedural knowledge

Procedural knowledge is the second kind of knowledge, the knowledge of how to do something (Alavi & Leidner, 2001). An example is the person who claims to know how to drive, he/she is not simply claiming that he/she understands the theory involved in driving activities (Tiwana, 1999c). The person is claiming that actually he/she possesses the skills involved that makes him/her able to drive. This type of knowledge clearly differs from propositional knowledge. In an example, it is possible for someone to know what a computer is, what a keyboard is and what a mouse is. It is possible that a person knows all the theory behind these items but does not know how to use them. In this example of knowing, using a computer involves processing the skills to use a computer, which is different from just knowing a collection of facts.

2.3.4.5 Propositional knowledge

Propositional knowledge is the third form of knowledge. It is the knowledge of facts. This type of knowledge is the primary concern of philosophers. This knowledge is used to find and define facts behind an activity or process. Personal and Procedural knowledge both seem to involve some propositional knowledge. Still, propositional knowledge is not enough to provide either personal knowledge or procedural knowledge (Aarons, 2005).

The three kinds of knowledge jointly make up the knowledge of the inner self. In contrast, the theory of knowledge by Plato and Gettier puts forward the three main pillars of knowledge, namely, Belief, Truth and Justification. This tripartite of knowledge contends that if someone believes something with justification, and it is genuine, then someone knows it, otherwise not.

Belief is the first condition of knowledge according to the tripartite theory; if a person does not believe in something it means the person does not know it, even if the person has excellent reasons for believing that it is actual.

Truth is the second condition of knowledge. According to the tripartite theory, if something is known, then it must be truth; if it is not true, then it does not constitute knowledge (Coakes & Clarke, 2005). It does not matter how strong the belief is. The third condition of knowledge is justification. It is not enough to believe something to be true. One must have a good reasoning and an authentic justification for the belief.

However, Gettier (1963) rejected the tripartite theory of ‘Justified true belief’ with the example of the stopped clock and the sheep in a field. The examples showed that knowing can be the belief and a matter of luck at the point of time one experiences something. In Gettier’s cases, the tripartite theory’s three conditions for knowledge are satisfied, i.e. in which a person does have a justified true belief, but in which there is no knowledge. The existence of such cases shows that there is something more in knowledge than having justified true belief. That is why the tripartite theory of knowledge appears to be wrong. Gourlay (2002) indicated that, as per Gettier’s theory, one can know a proposition only if:

- That proposition is true
- One believes the proposition
- One’s belief is justified
- One’s belief is not based on any false assumptions

2.3.5 Sources of knowledge

2.3.5.1 Empiricism

Empiricists hold that our senses or our experiences drive all of our knowledge. As per the empiricism theory, experience is the primary importance that constitutes knowledge (Baets, 2005; Coakes & Clarke, 2005). Firstly, Classical empiricism is a rejection of unlearned, inborn knowledge or concepts (Alavi, 1999). John Locke (considered as one of the first of the British empiricists, following the tradition of Francis Bacon) said that a person is born with a blank mind and that mind acquires information by experiencing the physical world. Secondly, radical empiricism holds that all of someone’s knowledge comes from the senses (Alavi, 1999). Thus, it is impossible to talk about something that has not been experienced by someone yet. In this case, the statements that are not tied to one’s experiences are, therefore, meaningless. Finally, moderate empiricism holds the view tha,t in some cases, the senses do not create our knowledge (Markie, 2004).

2.3.5.2 Rationalism

Rationalists hold the view that reasoning drives at least some of our knowledge; moreover, that reason plays an important role in the acquisition of all of our knowledge (Wickramasinghe, 2005) (Schwartz, 2005). Rationalism also argues that the human mind is not born in a blank state. It contends, even before a human experience of the physical world, there are some pre-known things such as the faculty of language. The rationalists argue that there may be some truths that are not known by birth, but can be worked out independently while experiencing the world, such as logic or mathematics or ethical truths (Coakes & Clarke, 2005). Rationalists may argue that some truths are grounded within experience. Experience alone may not drive those truths (Markie, 2004). For example, two people may observe the same object yet reach contradictory views as to its beauty or ugliness. This shows that the senses cannot present artistic qualities to someone, but rather these are overlaid onto experience by reason. Similarly, people do not observe the cause, but simply see one event followed by another. The mind provides the idea and the former event causes the second event. To identify the facts about this theory by empiricists and rationalists requires the exploration of a question to find answers and modern views about how a brain works to create and share knowledge.

2.3.6 How a brain works to create and share knowledge?

Athene's Theory of Everything (2011) revealed that the human brain is a network of approximately 100 billion neurons. Different emotions create different neutral connections that bring about different emotions. In addition, depending on which neurons get stimulated, certain connections become stronger and more efficient, while others may become weaker. This is what is called neuro-plasticity (Boumaaza, 2011).

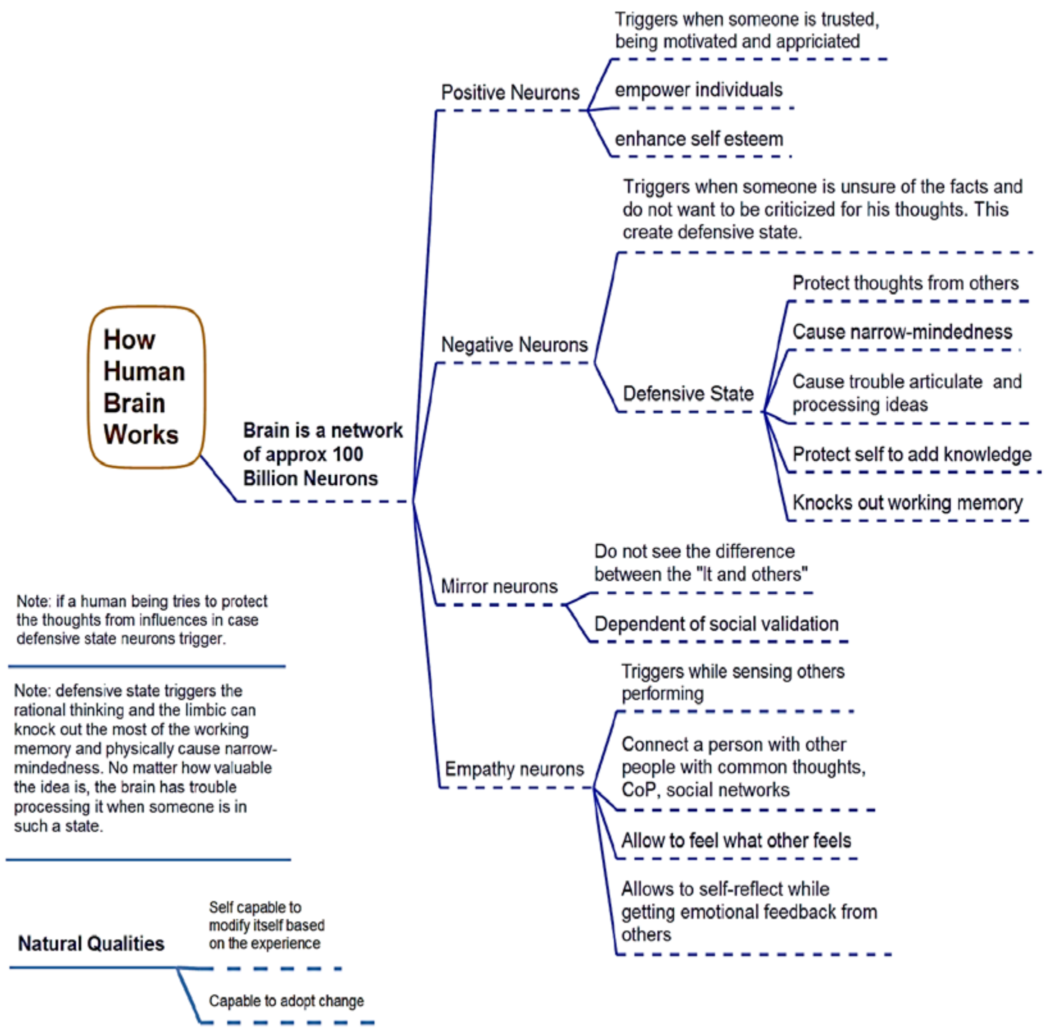


Figure 2-9: How the Human Brain Works?

Source: adopted from Athene's Theory (2011)

For example, someone who trains to be a musician will create stronger neutral connections that link the two halves of the brain in order to be musically creative. Training creates talent or skill. For instance, Rudiger Gamm (The Famous Human Calculator) who was the self-administrated 'hopeless student' who used to fail at basic maths, went on to train his abilities and become a famous human calculator (Boumaaza 2011).

As per the Athene's Theory, (2011), whatever human beings do at any time, this physically modifies the brain to become better at it. Moreover, being self-aware can greatly enrich the life experience of one (Leysen, 2011). However, when a human being feels that their thoughts need protection from the influence of others, in such a case, the specific defensive neurons trigger a defensive state.

Similarly, if someone's opinions were confronted with differences, the defensive neurons try to ensure the survival of the one in these situations.

This type of defending state triggers rational thinking and the limbic system can knock out the working memory and physically cause narrow-mindedness. No matter how valuable the idea is, the brain has trouble processing it when someone is in such a state. Relating to this research narrow mindedness causes difficulty in the articulation of thoughts (Tacit Knowledge) or ideas and further makes it hard to present thoughts among others.

However, when someone feels that views and thoughts are being appreciated the defensive chemicals decrease in the brain. This makes the person feel empowered and increases self-esteem. In relation to this study, the motivation of employees, teams and management is important in the sharing of knowledge with others, which will make them feel empowered and enhance their self-esteem. People tend to participate more in teamwork if they are motivated (Belbin, 2012).

Moreover, Athene's theory explains that social psychology often looks at basic human needs, to fit in the normative social influence. The reason for being socially dependent is that the mirror neurons do not see the difference between it and others. Ramachandaran (2013) said that is why a human being is dependent on social validation and is in a state of constant duality of his/her thoughts to know how one sees him/herself and how others see him/her. This is one of the reasons why social science research requires social validation. It is because a researcher cannot see the difference in his/her research about multiple realities. However, others can see the difference, based on their own experiences.

For instance, specific empathy neurons activate when a human experiences an emotion or performs an action. The same neurons trigger off when someone else is performing the activity. This is why the person starts acting or imagining as he is performing. The person feels as if he/she was performing the action him/herself. These empathy neurons connect a person with other people, allowing to the emotion of what the other is feeling, and science neurons respond to imagination. A person can experience emotional feedback from others as if it has come from others. This system allows self-reflecting. Connecting with other people develops common schools of thought, CoPs and social networks.

2.3.7 Development of Schools of Thought in the Human Brain

The left hemisphere of the brain creates the belief system which maintains the sense of continuity throughout the life of a person (Boumaaza 2011). Based on Athene's theory, Bacon, Hobbs and Aristotle suggest that new experiences get folded into the pre-existing belief system within the mental world. However, it simply denies those experiences if they do not fit with the pre-existing belief system. The right hemisphere of the brain does the opposite. In addition, it challenges the left hemisphere. On the other hand, if the belief is too strong, then the right hemisphere does not succeed. That belief in something is the form of the school of thought.

As per Athene's theory "This world is a grand scheme of things" whereby human minds are connected with each other and make a grand network of human minds. The statement indicates that humans are born with the tendency of being social and building social communities. This is because of the requirement for social validation of beliefs. However, negative neurons create the defence system if thoughts are not appreciated but are criticised. This leads a person to disconnect from the social world and leads that person to protect his/her thoughts and not to reveal them. This is also the cause of mental depression. However, if thoughts are appreciated and given the right guidance, then the positive neurons trigger and fight against the defensive state to break the barriers. This is why motivation at work is considered as an important factor increasing productivity. Many researchers (Mclean, 2002; Rooke & Sapountzis, 2010; Yu et al. 2010) and others contend that knowledge is socially constructed.

In last few centuries, human investigations have focused greatly on scientific matters. One example is Einstein's law of relativity: time and space is the same fabric. In 2012 Professor Brian Cox gave a lecture at the University of Manchester on Albert Einstein's 'Time and Space' theory supporting Gettier's example that at any point of time if something has been experienced by many they will all have a different perception, views and explanations of the experience, based on their time footprints. This example indicates the reasoning for social validation of social science research to generalise the results and contends that there could be multiple realities of a hypothesis or experience.

Ramachandaran in his book "Phantoms in the Brain," stated that the human body and the physical world is created within the mind. Even pain and senses come from the mind. This is down to individuals, how they accept the surroundings. This statement relates to the theories of Bacon, Hobbs, Aristotle, Einstein and others that both the physical and mental worlds interact with each other and constitute tacit knowledge.

2.3.8 Types of Knowledge

2.3.8.1 Tacit Knowledge

The findings in the literature on KM gives many different views on tacit knowledge, but the most modern and reliable definitions are presented below.

“Tacit knowledge is deeply implicit in everyone's actions and experiences, as well as in the ideals, values, and emotions that they embrace or exhibit” (Egbu et al., 2005).

“Tacit knowledge is understanding, capabilities, skills and the experiences of individuals; often expressed in human actions in the form of thoughts, points of view, evaluation and advice; generated and acquired through past experiences, individuals, and repositories; utilized for the benefit of individual and organisational development” (Pathirage et. al., 2013).

However, this research defines tacit knowledge as:

“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.”

As the mental and physical world interacts with each other, tacit knowledge triggers, unfolds and combines as soon as a human being senses, visualises experience, or observes a series of activities. Tacit knowledge does not remain constant but changes and updates with time and experiences of a source.

In terms of tacit knowledge, the human brain functions in a similar way to a computer system, the new experiences fold in the memory system with the older experiences being folded and preserved in an archive or repositories. However, the archived knowledge is readily available with a simple search. According to the Athene’s theory, the embedded knowledge in a human brain is unfolds, while triggering the most related neurons when one experiences something and has a strong belief that what is happening is true.

Observing, sensing and experiencing an action requires a strong connection between experience and embedded knowledge. This makes a human capable of visualising a clear understanding about the action.

2.3.8.2 Implicit knowledge

Personal knowledge is tactic knowledge. According to Polanyi, all knowledge has tacit components and there is nothing between tacit and explicit. He contended that there is not something amenable for conversion (Polanyi, 2012; Polanyi, 2009). However, a later focus of tacit knowledge on a particular subject or topic is called implicit knowledge (Carter & Rogers, 2008). Implicit Knowledge defines a knowledge that is not explicit (Bergeron, 2003). WordWeb online dictionary defines Implicit Knowledge as “Implied though not directly expressed; inherent within the nature of something." This definition gives the view that implicit knowledge is a form of tacit knowledge which is not expressed promptly but observed from the nature of something. However, there is a subtle difference between Implicit Knowledge and Tacit Knowledge. Scholars presume that implicit is un-codified knowledge but has the potential of codification. On the other hand, tacit knowledge may well be impossible to codify. In other words, implicit knowledge is that which has not been put together either by expressions, concept development and assumptions, which leads to principles. Since Polanyi (1969), the literature of implicit knowledge is not widely mentioned, even though Grant (2007) defends and argues that Polanyi never talked about implicit knowledge and that his work is vastly misinterpreted.

Implicit knowledge is more about knowing "how" to do something, but some as this may be hard to describe explicitly. However, the definitions given above it can be said that, with a careful observation of something or someone, tacit knowledge can be extracted but it remains implicit as it could not possibly be explicated.

2.3.8.3 Explicit knowledge

Explicit knowledge is the form of knowledge which is, or can be, articulated, expressed and recorded as words, numbers, codes, mathematical or scientific formulae and musical notations. This knowledge is easy to communicate, store and distribute and is the knowledge found within books, the Internet and other visual or oral means. Explicit knowledge can be transmitted readily across individuals in a formal and systematic manner (Egbu et al., 2005). Moreover, explicit knowledge is opposed to tacit knowledge. It is viewed as coded tacit and implicit knowledge which can be transferred, shared and communicated (Smith, 2001).

Concerning CSCs, Lean and Agile Principles, explicit knowledge is not considered as a priority. However, explicit knowledge is used to support business functions, developing process and for many other enhancements. At the same time, tacit knowledge is the prime priority of organisations. Moreover, construction organisations consider tacit knowledge as a main resource (see section 2.1.6).

2.3.9 Different Forms of Tacit Knowledge

2.3.9.1 Personal Knowledge

Personal knowledge relates to a particular individual based on experiences. This type of knowledge is associated with human biology. This combines the body, mind and soul of a person. This is often considered as tacit knowledge (Inkpen, 2014). However, personal knowledge can also be gained by reading or studying explicit knowledge (Yu et al., 2010).

Knowledge from a body represents the human sense functions, in which the knowledge is gained by the human senses such as touch/feel, smell, view, taste and sound. The knowledge from the mind represents the articulation and calculations of epistemology and psychology, which come from the experiences of the mental or physical world (see section 2.3.10). Knowledge of the soul represents the human sense of right and wrong and functions as a social being.

2.3.9.2 Organisational Knowledge

Organisational knowledge is the collective knowledge of people, processes and technology (Khalfan & McDermott, 2007). The people represent the workers who function within the organisational standards and culture. The process is the people's learning process that functions within the KM process framework of an organisation (Anumba et al., 2008). Here, technology provides the tools for techno-learning and sharing information and explicit knowledge (Narteh, 2008).

2.3.9.3 Collective Knowledge

Collective knowledge is the combination of the personal and organisational knowledge in which a human being involves personal knowledge with other people, KM standards, process and technology.

2.3.10 Classical Schools of thought of knowledge

Different people have different views on the KM perspective. Various schools of thought have been reviewed in the literature. For example, Sir Francis Bacon has his view of "Knowledge is Power." Later, his assistant Thomas Hobbs gave his view that knowledge can be of two types, one which is nothing else but the sense and the second is science or knowledge of proposition. This section explores and critically analyses the various perceptions of knowledge within the classical schools.

2.3.10.1 The Cartesian perspective of knowledge

In the Cartesian view about the world, philosophy is a thinking system that embodies knowledge that is expressed in its way. The Cartesian perspective views the mind as a very separate thing from the body but realises that they interact with each other. This has given dualism (a philosophy of mind) that positions the cognitive phenomenon that some aspect of mind and body is not identical. According to this Dualism philosophy, the mental phenomenon does not have an extension to space and materials do not think. This corresponds with the philosophy of Rene Descartes (1641) that the mind is a not a physical substance and there are two kinds of substance, mental and physical. Aristotle's works expresses similar views.

2.3.10.2 Descartes' perspective of knowledge

In Descartes view of Cartesian's philosophy, he said that there are two types of forms, mental and material. In the mental world, mind or soul does not follow the nature of law. However, he argued that the mind interacts with the material world (body). This defends the theory of interactionism that the mind closely engages with the body in a way where mental beliefs, states and desires casually interact with the physical world. In contrast, this view defends the philosophy of Thomas Hobbes that there are two types of knowledge, one from the sense and the other coming from the truth of propositions.

2.3.10.3 Plato's perspective of knowledge

Plato originated the concept of "justified true belief" and states that in order to know that a given proposition is real, one must not only believe the relevant true proposition, but one must also have justification for doing so. Plato, in his dialogues, captured and elaborated the thoughts of his mentor Socrates (Thampi, 2005), and Plato's view were an influence on the future development in epistemology. He argued that knowledge is distinguished from mere belief by the knower having an account of the object of her or his true belief. However, later Edmund Gettier challenged the theory of 'justified true belief'. Afterwards, some scholars rejected the Plato's view.

More explicitly, Plato himself argued that knowledge is always proportional to the ground from which it is gained. Later, he also argued that conceptions derived from the impressions of sense can never give the knowledge of true being. Plato said it can only be obtained by the sole activity within itself and with dialectics as the instrument for the process, leading us to knowledge about forms and following the greater form of the good and first instance of science.

2.3.10.4 The Aristotelian perspective on knowledge

The writings of Aristotle have proven to be fertile ground for uncovering the foundations of KM (Schwartz, 2005). Aristotle focused on practical and technical reasons. Aristotle presented five virtues of thought which can be mapped to the levels of knowledge in the Nicomachean Ethics (Schwartz, 2005).

- **Episteme**: is factual or scientific knowledge. It is pure knowledge such as mathematics and logic. Episteme comprehends the knowledge of cause and effects, and deductions.
- **Techne**: is skills-based technical and action-oriented knowledge. It deals with the physical world that changes over time or process. In Aristotle's view, a practitioner can pass technical knowledge to a student. It is a type of knowledge that is acquired and is encapsulated to reuse.

- **Phronesis**: is the experiential self-knowledge or practical wisdom based on experience. It deals with action and getting things done. In Aristotle's view, it can be gained through hands-on training and experiencing action. Moreover, this type of knowledge can only be shared through actual mutual experience. In terms of KM, phronesis lead us to the direction of simulation and forms of experimental presentations.
- **Nous**: Intuition: Nous not only embodies the intuitive side of knowledge, it also subsumes a large part of what we have come to refer to as tacit knowledge. Aristotle viewed nous as a manner in which one can become aware of primary principles. As per Schwartz (2005), when observing the relation between intuition and tacit knowledge, the first approach is to attempt to externalise tacit knowledge through intervention and representation methods. The second approach is to identify the owner of the tacit knowledge in an efficient and effective manner. However, intuition emerges from practical knowledge and technical knowledge. Tacit (Nous) knowledge cannot be acquired by IT management systems. Social network mapping tools can discover and classify it.

2.3.10.5 John Locke's perception of knowledge

The theory of empiricism is also called the theory of knowledge (Locke, 1823). This states that knowledge comes from sensorial perception (Connolly, 2014). According to Locke, the human is born with a blank mind and from birth it collects knowledge via the sensory perception. Empiricism is the philosophy of science which requires evidence. The fundamental part of scientific methods is that all hypotheses and theories must be tested against observation of the natural world. This should not rely upon prime reason, intuition and revelation.

2.3.10.6 Polanyi's perception of knowledge

The most important work of Polanyi (1958) is on Personal Knowledge which is widely cited for a positivist account of science. Polanyi's view of tacitness is that it is something personal. It is an ability or skill to resolve problems or to do something that is based on a person's own experience. Polanyi claims that knowledge relies on personal judgements. He also contended that, no matter how the knowledge is formulised, it relies upon commitments of the person. Therefore, this study rules that personal experiences come from the physical world while integrating subsidiary awareness and focal awareness. Later in his other book, 'The Tacit Dimension', (1966) Polanyi wrote more about knowing instead of knowledge. He contended that 'we can generally know how to do things without even knowing or without being able to articulate to others.' Recently Grant (2007), revisited Polanyi's work and found that since the 1950s until the present date his work is often misunderstood. He argued that Polanyi's work reflects that tacit knowledge is highly personal and is on how individuals can gain knowledge and share it. Moreover, in his work, Polanyi did not suggest that tacit knowledge cannot be transferred. Rather he suggested that some kind of knowledge has a limited capability to transfer. Grant (2007) concluded that Polanyi's work is 23% misinterpreted within the fifty-two (52) most cited papers.

2.3.11 Modern Schools of thought of Knowledge

This study looked at modern Schools of thoughts of knowledge. The literature from a number of authors such as Peter Drucker, Peter Senge, Devenport, Koing, and Nonaka & Takuchi have been the main focus throughout this study.

2.3.11.1 Peter Drucker's view of Knowledge

Peter Drucker coined the concept of "Knowledge Worker" in his 1959 book "The Landmarks of Tomorrow." Since then, knowledge-based work has become increasingly important in businesses worldwide. Drucker (1969) re-emphasised the "knowledge worker" in his book "The age of discontinuity: a guideline of our changing society." In 1989 in the book "The New Reality" Drucker emphasised networks in general. In addition, he stressed the growing importance of information and explicit knowledge as organisational resources, (Coakes & Clarke, 2005). Later in the book "The New Society of Organisations" (1992) and in "Post-Capitalist Society (1993) he advanced the notion that tacit knowledge should be considered a key resource for competitiveness and performance as knowledge is the fresh embedded value proposition of workers in the post-industrial economy (Coakes & Clarke, 2005; Suresh & Egbu, 2008).

2.3.11.2 Peter Senge's view of Knowledge

On the other hand Peter Senge (1990) looked into the "Learning Organisations". He looked into the five disciplines of system thinking, personal mastery, mental methods, shared vision and team learning (Mason et al., 2005). Senge's work places strong emphasis upon the articulation of knowledge and linguistics. Furthermore, Senge (1992) talks about the 'dialogue' that takes place between employees by way of sharing knowledge within learning organisations (Bellarby & Orange, 2005). Since then, there is a wide recognition of the growing importance of organisational knowledge and this is accompanied by concern over how to deal with exponential rises in the amount of available knowledge and in increasingly complex products and processes.

2.3.11.3 Mixed modern views of knowledge

Western philosophers have generally agreed that knowledge is 'justified true belief'. Plato said that knowledge could only be obtained by the physical world, which can be sensed by the eyes, the ears and from the whole body. On the other side, Aristotle criticised the fact that the knowledge of forms is always occasioned by sensory perception. The two forms of knowledge creation, explicit and tacit knowledge, have the key dynamics of knowledge creation. An individual is the principal agent who possesses and processes knowledge. There are three levels of knowledge creation, individual, group and organisational knowledge. Business knowledge, generally, is of two types:

Firstly, codified knowledge/explicit knowledge: which can be written down, transferred, and shared. It is definable and can be protected by the legal system. Tangible knowledge, which can be seen and sensed by touch, is merely readily available to use.

Secondly, Tacit knowledge: which knows how, and is, by nature, difficult to describe. It can be demonstrated but rarely codified, and resides with its holder. It gets transferred through demonstration and on-the-job training. It is the form of knowledge which stays in the mind of individuals and can be hard to capture or articulate in works or explanation, especially if it is related to complicated knowledge such as art which cannot be specified in details and cannot be transferred by perception (Polanyi, 2009). In this form of knowledge, sometimes, the individual himself/herself may not know that he/she has the knowledge.

The distinction between these two types of knowledge is relevant because each must be managed differently. However, KM in the construction phase mainly deals with the process of creating value from construction operation and organisation towards company knowledge. Valuable knowledge is available in different forms and media, in the brilliant ideas of experts, in operation procedures, and in documents, databases, intranets, etc. However, KM in the construction phase of projects aims at effectively and systematically collecting and sharing the experience and knowledge about the project using web-based and intranet technologies.

The reuse of information and knowledge minimises the learning processes from past projects, reduces the time and cost of problem solving, and improves solutions' quality during the construction phase of a construction project. By sharing experience and knowledge, the same problems in the construction phase do not need to be solved repeatedly.

By the mid-1980s, the importance of knowledge as a competitive asset was apparent, even though the classical economic theory ignores knowledge as an asset and most organisations still lack strategies and methods for managing it (Thomas, 2013). Tiwana (1999) said that Drucker warns that no industry or company has a natural advantage or disadvantage; the only advantage it can possess is the ability to exploit universally available knowledge. He describes knowledge as "the window of opportunity." The 1980s also saw the development of systems for managing knowledge that relied on work done in artificial intelligence and expert systems, providing such concepts as "knowledge acquisition," "knowledge engineering," "knowledge-based systems" and computer-based ontologies.

2.3.12 Resource Based and Knowledge Based View of Organisations

The knowledge-based view (KBV) of firms has received increasing attention. A relatively unexplored area is knowledge transfer in project-based organisations (PBOs). The construction project is a one off mega process where several PBOs rely upon combining expertise from several internal and external parties in order to deliver their own capabilities. The problem is the difficulty of transferring knowledge over projects due to the unique character of projects. Moreover, the short-term perspective and partnerships among the PBOs make it harder to develop new knowledge in projects with parties in the CSCs. The CSCs consists of suppliers, clients and governmental institutions.

2.3.12.1 Resource Based View of Knowledge

The resource-based view (RBV) framework indicates that firms with valuable, rare and inimitable, organisational and non-substitutable resources (VRIO and VRIN) have the potential to gain competitive advantage (Barney, 1991). A sustainable competitive advantage (e.g. in terms of low costs/prices, better service, faster delivery, innovativeness) can be described as the development in the RBV. Within the RBV, knowledge is gaining increasing attention as an important source of competitive advantage (Amit & Schoemaker, 1993; Grant, 1996). The resource-based perspective has an intra-organisational focus and argues that performance is a result of firm-specific resources and capabilities (Barney, 1991; Wernerfelt, 1984).

One of the most recent studies (Acedo, Barroso and Galan, 2006) analyses the so-called resource-based theory (RBT) and identifies three main trends co-existing within the RBV, including some representative works from the dynamic capability perspective (Teece, Pisano, and Shuen, (1997) cited by Schwartz (2005), the knowledge-based view (KBV) and the relational view. From the RBV, clearly, firms have the potential to provide enduring competitive advantage when they are unique and not readily substitutable (Peteraf, 1993). Moreover, a significant source of the creation of inimitable value-generating resources lies in a firm's network of relationships (Gulati, Nohria & Zaheer, 2000). Gnyawali and Madhavan (2001) distinguished four sets of arguments why resources in external networks are important for a firm. Firstly, relationships in a network are potential conduits to inside resources held by connected actors. Secondly, external economies (i.e. capabilities created within a network of competing and cooperating firms) often complement firms' internal resources. Afterwards, the rate of return on internal resources is determined by how well structured the firm's network is. Nevertheless, a firm's position within a network contributes to its acquisition of new competitive capabilities. In this context, a firm is especially interested in the knowledge flows (next to asset flows and status flows) as a consequence of a firm's network.

2.3.12.2 Knowledge Based View (KBV)

In the KBV, the primary goal of a firm is the application of existing knowledge for the production of goods and services (Grant, 1996). KBV can be considered a subset of the RBV. A person within the firm is a source of unique advantage. Integration of the knowledge of individuals in the production process of goods and services rests on their abilities (Grant, 1996). An important issue in KBV is the transfer of knowledge and the difficulty of such transfers (Nonaka, 1994; Szulanski, 1996).

The KBV approach considers firms as bodies that generate, integrate and distribute knowledge (Narasimha, 2000; Miller 2002). The ability to create value is not based as much upon physical or financial resources as on a set of intangible knowledge-based capabilities. Knowledge and skills give a firm competitive advantage, because it is through this set of knowledge and skills that a firm can innovate fresh products and processes, or improve existing ones more efficiently and/or effectively (Nonaka & Takeuchi, 1995).

According to the KBV, competitive success is governed by the capability of organisations to develop new knowledge-based assets that create core competencies (Pemberton and Stonehouse, 2000). Fundamental to the KBV of a firm is the assumption that the critical input in production and the primary source of value is knowledge (Grant, 1996).

2.3.13 Knowledge Communication

The efficient and effective transfer of experiences, insights and know-how among different experts and decision makers as a prerequisite for high-quality decision making and co-coordinated, organisational action (Eppler, 2006) is called knowledge communication.

(Eppler 2006) defined, it thus: "knowledge communication as the (deliberate) activity of interactively conveying and co-constructing insights, assessments, experiences, or skills through verbal and non-verbal means."

The exchange of know-how, know-why, know-what and know-who through persons or media-based interaction is called knowledge communication. Knowledge communication has two main aspects, knowledge transfer and knowledge sharing. Knowledge transfer through interpersonal communication or group conversations is one of the principal tools of knowledge communication, for example, an engineer who discovered how to master a difficult manufacturing process needing to convey the method to other engineers. Similarly, project managers/leaders need to present their results to upper management and share their experience of past projects in order to assess the potential on new projects.

The main focus of knowledge communication is on that between experts and decision makers. However, knowledge communication can be between experts and co-workers and between inter-organisational teams. Knowledge communication and the type of knowledge communication depends on the nature of the process and the type of knowledge. According to Gupta (2014) knowledge communications require two main mechanisms: (a) the formal integrative mechanism of organisations, and (b) the intensity of the communication between them.

Knowledge communication differs in terms of what knowledge is to be transferred and how it is to be communicated (Eppler, 2006). Moreover, the process of knowledge communication requires more shared interaction between decision-makers and experts because both sides merely have a fragmented understanding about an issue and, consequently, can gain a complete comprehension by interactively aligning their mental models. This means that when knowledge is communicated between experts and decision makers, they create a context-specific knowledge that can be used to create fresh perspectives or acquire new skills (Eppler, 2006).

2.3.13.1 Communicating Tacit Knowledge

Pursuits of tacit, explicit and self-knowledge, self-renewal and innovation are timeless, endless and relentless. Knowledge transfer refers to the exchange of knowledge between units within a firm (internal transfer) or between different firms (external transfer) (Bou-Llusar & Segarra-Ciprés, 2006). Bou-Llusar & Segarra-Ciprés distinguish different kinds of internal transfer (such as between departments or units within an organisation) and external transfer (such as strategic alliances, joint ventures, acquisitions, and so on) (Bou-Llusar & Segarra-Ciprés, 2006). In addition, Bou-Llusar & Segarra-Ciprés (2006) said that knowledge transfer includes different applications depending on the characteristics of transferred knowledge. Authors such as Ghoshal & Barlett (1988) and Kogut & Zander (1995) have focused on the transfer of technology and product innovation, whereas others such as Darr et al. (1995) and Kostova (1999) have focused on the transfer of organisational practices. In any case, the objective of knowledge transfer is to facilitate the flows of knowledge within the firm or between collaborating firms. However, a knowledge transfer approach to innovation in Lean construction requires a robust process and organisational structurewhich supports the enhancement of knowledge transfer. Nonaka and Takuchi (1994) said that breaking down hierarchies in an organisation enables knowledge transfer. t Organisations with many hierarchies create bottlenecks for knowledge transfer and knowledge become sticky at the place of origin. Some researchers such as Ghoshal (1998) consider a motivation and reward system is the major factor for supporting and encouraging knowledge transfer. Some researchers such as Goh (2002) emphasised the qualities and capabilities of the recipients and the characteristics of the knowledge source. Goh (2002) also emphasised that a recipient's lack of motivation, absorptive capacity and retentive capacity can result in poor transfer of knowledge.

2.3.13.2 Tools and Techniques of Communicating Knowledge

"KM tools, in a sense, are the "face and place" as well as the "nuts and bolts" of knowledge in the 21st century workspace" (Rao, 2012). Rao also highlighted that knowledge management is not just about technology but, in today's age, it is a technology-driven communication and information production.

Very often, the term 'knowledge management tool' is seen as being within information technology (IT) tools. "Knowledge management (KM) tools are both IT and non-IT tools required to support the sub-processes of KM such as locating, sharing and modifying knowledge" (Egbu, Anumba & Carrillo, 2005). KM tools are a combination of Technology and Management techniques and are not simply information management tools (Egbu et al., 2005). As per - Egbu et al.'s analysis of KM techniques and technologies, knowledge techniques require strategies for learning and for involving of people. Egbu et al. suggested that the techniques such as brain storming, CoP, in-person interactions, recruitment and training were much more affordable in comparison with technology such as data and text mining, GroupWare intranets/extranet, knowledge bases and taxonomies/ontologies. However, other tools such as paper, pen or video capturing can also be used to support KM.

Additionally, Suresh & Egbu (2008) identified that the most commonly used tools/techniques in the construction industry for knowledge mapping are casual, conative, concept, knowledge flow, mind/idea, perceptual, process, semantic and social mess maps. However, their study reveals that some tools have high robustness and low cost but their impact is either medium or low. Other tools with low and medium robustness also have same impact and adaptability. The impact and adaptability of most knowledge mapping tools and techniques were found to be average and low. Suresh & Egbu concluded that construction organisations have not adopted off-the peg knowledge mapping software solutions because they do not offer value addition. Organisations rely on other techniques such as meetings, briefing notes, seminars, coaching and newsletters.

Based on these studies by Rao (2012); Anumba et al. (2008); Suresh & Egbu (2008), this study focuses on non-technological tools in KM. The reasons behind choosing non-technological tools are: firstly, it has been established that part of an organisation's knowledge stock cannot be codified because it is tacit and embedded in its people (Kogut and Zander, 1992). The people may be the company's own employees or experts hired elsewhere who possess such knowledge. Narteh (2008) said that any knowledge transfer process must involve core personnel within the organisation who are familiar with the knowledge in question or people hired from outside with same knowledge bases in order to transfer such knowledge. Knowledge transfer and sharing between people requires socialisation. Even capturing and sharing knowledge is a kind of social science research because of the involvement of the people who require social validation for any type of knowledge being captured.

Moreover, at the individual level, knowledge is created via cognitive processes such as learning, while social systems (i.e., groups) generate knowledge through collaborative inter-actions (Smith & Lyles, (2003) cited in Schwartz (2005)). The factors which take part in the knowledge creation process within an organisation may come either from internal or external sources. Tacit knowledge mainly requires interactive and collaborative techniques (such as in-person meetings, training, storytelling) to capture it instead of technology. However, it uses some kind of technology to support knowledge creation, capturing, coding or sharing processes (Rao, 2012) such as recording devices, emails, forums, etc.

2.3.13.3 Problems in Communicating Knowledge

In a process development initiative, KM is best applied in times of stable processes and as a follow-on to a reengineering effort, not as a parallel process (Bergeron, 2003). Moreover, Bergeron said that many KM initiatives fail because KM is performed in parallel with reengineering initiatives.

There are several barriers in communicating tacit knowledge. The problems in knowledge communication include topics such as inter-departmental knowledge transfer, professional communication, decision-making, communication technology, or the nature of expert knowledge (Eppler 2006). Eppler suggested three main criteria relating to the knowledge communication problem.

Firstly, the concept has to be closely related to the problem of interpersonal and professional knowledge transfer. Secondly, the concept has to describe the major impact of the quality of knowledge transfer and, thirdly, the concept has to be influential. The key concepts given by

Eppler (2006) are, Absorptive Capacity, Argumentation, ASK problem, Cassandra Problem, Cognitive Biases, Common Knowledge Effect and Communication Biases.

Absorptive capacity: the knowledge recipient must have absorptive capacity. A limited ability of a recipient to grasp the knowledge from source based on a lack of prior knowledge would lead to inefficient knowledge communication.

Argumentation Fallacies: In this barrier, Eppler (2006) put forward argumentative traps such as begging the question, over-generalizing, appealing to false majorities or artificial expertise.

Ask problem: this type of problem occurs when a recipient does not have the knowledge of what question to ask. The recipient should have reasonable knowledge about the topic before asking the question.

Cassandra Syndrome: This problem occurs when recipients do not give much weight or attention to an expert’s warning, just because they have many other important problems or they do not think that the warning is appropriate.

Cognitive Biases: This bias is reasoning. This brings a tendency to think in certain ways and adds differences in the standard of judgements. Therefore, this knowledge may not be interpreted or used.

Common Knowledge Effect: The tendency within a group to focus merely on commonly shared knowledge rather than on newly discovered knowledge from the expert (source).

Communication Biases: This is a bias when knowledge is manipulated through means of communication, the personal characterisation of the audience and situational factors.

2.3.14 Application of Tacit Knowledge in Construction

Historically, capital, raw materials and labour have been considered more valuable than creating and applying knowledge. The information age and the knowledge revolution have caused problems for people and organisations (Smith, 2001). From the construction industry point of view, the study of tacit knowledge is usually, but not necessarily, concerned with the area that has come to be known as KM. The capturing of tacit knowledge has been noted as being fundamental to KM. It has been noted that “through 2001, more than 50 percent of the effort to implement KM will be spent on cultural change and motivating knowledge sharing,” which Casonato and Harris (1999) have predicted as including the more effective utilisation of tacit knowledge.

Ninety percent of the knowledge is embeded and synthesised in people's heads in any construction organisation (Wah, 1999b; Bonner, 2000a; Lee, 2000). However, most organisations do not have a corporate budget for the sharing or transferring of tacit knowledge. However, it is tacit knowledge that plays a key role in leveraging the overall quality of knowledge (Quinn et al., 1996; Wah, 1999; Goffee and Jones, 2000).

Generally, KM practices aim to draw out the tacit knowledge people have, what they carry around with them, what they observe and learn from experience, rather than what is usually explicitly stated. In the construction industry, collaborative KM is of particular importance as it addresses the issue of capturing knowledge within teams/groups of workers (Dave & Koskela, 2009). People have always passed their accumulated knowledge and commercial wisdom on to future generations by telling stories about their thoughts, work and experiences. Now, as in the past, people use in-person and ''hands-on'' methods to convey their "'know how" or tacit knowledge to others (Hansen et al., 1999)

In firms that appreciate the importance of KM, the organisational responsibilities of staff are not focused on the narrow confines of traditional job descriptions (Broadbent, 1998). The implementation of a KM system should be treated equally as important as core systems such as Enterprise Resource Planning, Document Management or Design and Estimating within construction organisations (Dave & Koskela, 2009).

"We know more than we can say" is a popular phrase heard at KM conferences and quoted in the many KM blogs. It is quoted to encourage attending to tacit knowledge, rather than exclusively focusing on explicit knowledge. However, those quoting the phrase rarely go beyond referencing it to Polanyi, providing little explanation or reasoning for why, if we know it, we cannot just write it down. This study confronts that KM is not about writing down "what we know" or "know how." KM is to share "what we know" or "know how" with others, in a way whereby the knowledge holder (Source) and the knowledge seeker (Recipient) both add value to the context-specific knowledge which is being shared. Moreover, in construction projects, the Knowledge Management cycle (Lin & Tserng 2003b) gives five phases of KM namely, Knowledge Acquisition, Knowledge Extraction, Knowledge Storage, Knowledge Sharing and Knowledge Update. The whole KM cycle involves new knowledge to be identified, extracted from the source, stored in a way to be shared with others and updated continuously to reuse in the future. However, knowledge must be transferred from the source to recipients to be able to collaborate and innovate with an aim of developing an efficient KM cycle.

2.3.15 Application of Tacit Knowledge in CSCs in the context of Lean and Agile Processes

Existing problems such as integration, collaboration and partnering in supply chains cannot be solved by adopting just Lean or Agile principles in concept. The Lean principle is widely considered to reduce waste and lead-time in a supply chain. On the other hand, agility is merely considered as being responsive to unpredictable demands and markets. Lean and Agile principles both demand the collaboration and partnering of stakeholders in order to create value for client. Similarly, in the matter of CSCs it will be unfair to say that a CSC is entirely based on just Lean or Agile principles. However, the Lean principle is only successful in construction when the CSC is Agile and responsive and works together with Lean principles.

As established earlier in this study, the primary goal of KM is to transfer tacit knowledge from one person to another, in order to enable the one who needs the knowledge 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. The relationship between KM in construction and Lean construction is shown in Figure 2-10. Lin & Tserng (2003) stated that, in a construction project life cycle, tacit knowledge and explicit knowledge can be created based on the knowledge and experience generated from the project. Tacit knowledge particularly can be reused for other current and future projects to avoid repeating the same or similar mistakes. Furthermore, in below figure (2-10) Lin & Tserng, (2003) also emphasised that tacit knowledge and explicit information combined should be considered as company assets which jointly makes a KM system which can be applied in a Lean construction project. This results in reducing cycle time, reducing waste, and increasing output in the project and are the main advantages of the application of KM in Lean construction.

Nevertheless, the application of KM in CSCs and Lean or Agile processes is entirely based on the type of process and the type of knowledge to be applied to enhance the effectiveness of a process. There have been several KM frameworks and models suggested during the past. However, no perfect match has been found which enhances CSCs in the context of Lean and Agile processes. Hadrich & Maire (2005) suggested that the design of KM initiatives requires modelling perspective concepts for Processes, Persons, Products and Productivity tools. They also suggested the application of knowledge in the Process-Oriented and Activity-Oriented perspective which requires defining the motive of knowledge (process or activity oriented) the goals (defining functions and knowledge oriented actions) and the conditions (defining tasks and operations) to apply KM in processes and activities.

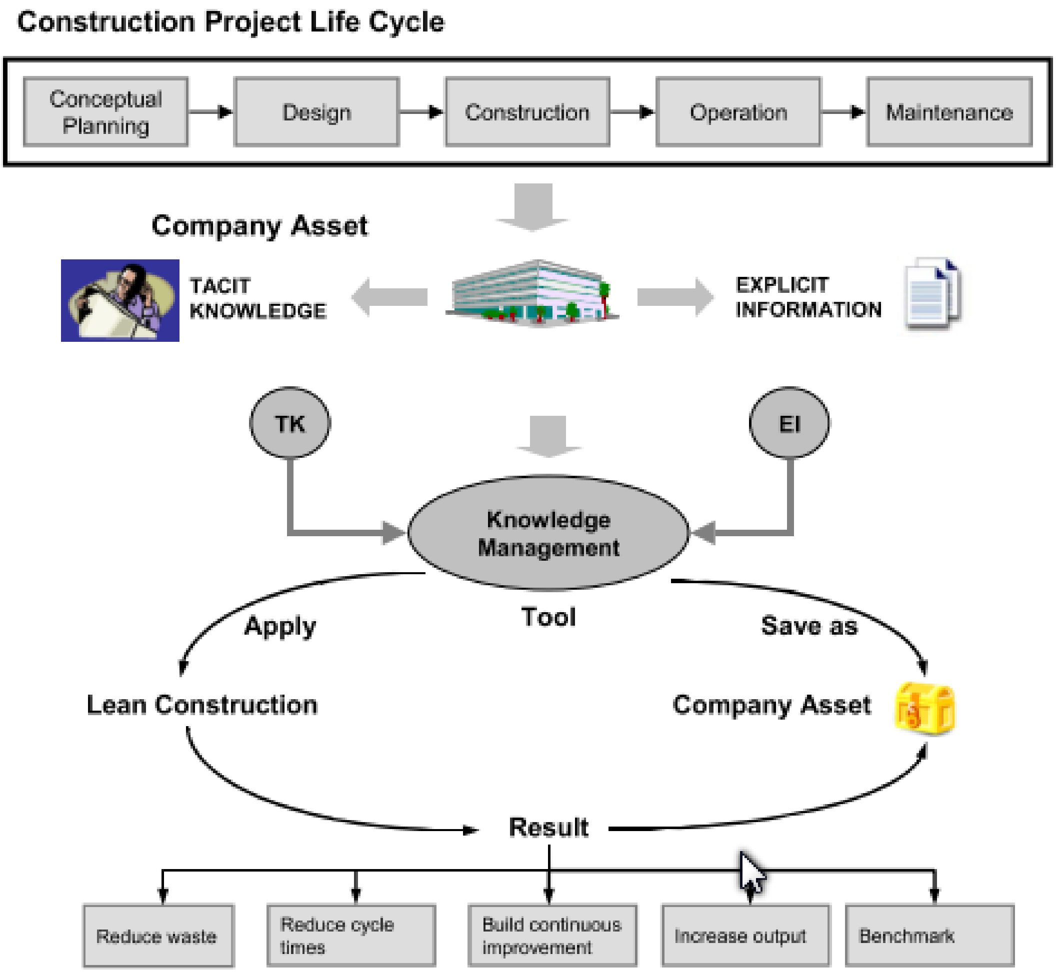


Figure 2-10: The relationship between Knowledge Management and Lean Construction.

Source: Lin & Tserng, (2003)

This process requires identifying the context of whichever knowledge is needed. Afterwards, the current and desired level of motives, goals and conditions need to be identified in order to understand and model the application of KM in CSCs and Lean and Agile Processes. Moreover, the knowledge perspective should be identified, such as the source of the knowledge, to enhance the context-specific knowledge. Nevertheless, KM variables can be considered to develop the structure of application of KM in CSCs and Lean and Agile processes. However, before applying KM in a CSC the supply-chain structure should be identified. In a collaborative CSC, the application of knowledge is critical to acquiring the problem-solving, reasoning and management skills needed by potential employees in the workforce because collective learning is a form of constructive learning in which problem solving and the centricity of learning processes are mainly shifted to practitioners rather than individuals (Shivakumar, 2005). Table 2-9 below shows the perspective of modelling KM in a CSC within the context of Lean and Agile processes. This table gives an overview of how a context-specific knowledge can be gained by identifying the desired levels, the knowledge perspective and its variables. For instance, if a context-specific knowledge is required to increase the flow through a process, in that situation, firstly, managers must measure the current levels of motives, goals and conditions and, afterwards, seek the knowledge perspective and its variables.

Table 2-9: Perspective for modelling in Knowledge Management in CSCs in the context of Lean and Agile Processes

<table>
<tr><th>Context specific knowledge</th><th>Current/Desired Levels</th><th>Knowledge Perspective</th><th>Variables</th></tr>
<tr><td rowspan="4">• Value
• Value Stream
• Flow
• Pull
• Problem Solving
• Developing Partners
• Perfection
• (Continuous improvement)
• Process Domain
• Integration
• Competence
• Team Building
• Technology
• Quality
• Change
• Partnership
• Market
• Education
• Welfare</td><td rowspan="4">Level of Motives
Level of Goals
Level of Conditions</td><td>Process</td><td>• Event, Condition Flow
• Goal, Desired Outcomes, Input/output
• Activity, Action Task</td></tr>
<tr><td>Product</td><td>• Flow of knowledge
• Expert Knowledge
• Type of knowledge
• Structure, taxonomy, Ontology
• Scope</td></tr>
<tr><td>Person</td><td>• Profile
• Skills/interest
• Responsibility
• Organisational Structure
• Network community
• Communication</td></tr>
<tr><td>Productivity Tools</td><td>• Navigation Structure
• Content /Structure
• Architecture Structure
• Function
• Personalisation</td></tr>
</table>

Source: Modified from Jørgensen & Emmitt (2008); Mason-Jones et al. (2000); Xue et al. (2007); Ibbitson & Smith (2010); Egan (1998)

2.3.16 Summary

This section establishes the importance of Tacit Knowledge and its role in the application of Lean, Agile and Supply Chain principles. Firstly, this section highlighted the different schools of thought and the predominant views of knowledge and sources of knowledge. The literature review established that there are only two types of knowledge, tacit and explicit. This study disregards the existence of implicit knowledge. This study also portrays the importance of knowledge sharing while investigating the literature of the functionality of human brain. This section brings forward the importance of knowledge communication in CSCs while having a resource-based view of knowledge. This study identifies a tool to transfer and share Tacit Knowledge.

This section brings forward the following findings:

- The type of knowledge communication depends on the type of construction process and type of knowledge required.
- Knowledge communication creates context specific knowledge.
- The two main aspects of knowledge communication are knowledge transfer and knowledge sharing.
- Tacit knowledge plays an important role in construction supply chains as about ninety percent of construction knowledge is embedded in the head of construction workers.
- Tacit knowledge plays a key role in leveraging the overall quality of knowledge.
- Knowledge transfer end sharing requires the identification of process improvement opportunities.

2.4 Critical Success Factors Associated with Effective Knowledge Management in CSCs in the Context of Lean and Agile Processes

2.4.1 Introduction

The effective management of knowledge and increased effectiveness is influenced by several critical success factors (CSFs). A broad range of factors that influence the success of KM implementation is mentioned throughout the literature. For example, much is stated about culture, information technology (IT) and leadership as important considerations for KM implementation. However, no systematic work exists on characterizing a collective set of CSFs for implementing KM in Lean and Agile processes in CSCs. An appropriate set of CSFs that is relevant for CSCs will help to keep in consideration the important issues that should be dealt with when designing and implementing a KM initiative.

This section explores and investigates the CSCs associated with the effective transferring and sharing of tacit knowledge in both lean and agile construction processes. The literature review highlighted a total number of ten CSFs. Among these ‘Trust among construction organisations” is identified as the foremost. This CSF is followed by others such as motivation, leadership capabilities, business strategies and organisational and individual capabilities.

Some frameworks have been suggested in recent years to manage knowledge transfer and sharing in an organisation and, specifically, in construction projects in addition to the Lean and Agile construction processes. A few of the most relevant frameworks have been introduced by Bou-Llusar & Segarra-Ciprés (2006); Goh (2002); Lin & Tserng (2003b); Martinkenaite (2011) and Narteh (2008). This study critically reviews these frameworks to understand the CSFs of KM in construction projects to improve the efficiency of transferring and sharing tacit knowledge in Lean and Agile processes.

2.4.2 An Integrative Framework: factors influencing effective knowledge transfer

An organisation faces several major challenges when managing its knowledge assets (Goh, 2002). Goh established that an organisational managerial practice require instituting an effective knowledge transfer and sharing process. Figure 2-11 below exhibits the critical success factors which influence the effectiveness of knowledge transfer and sharing.

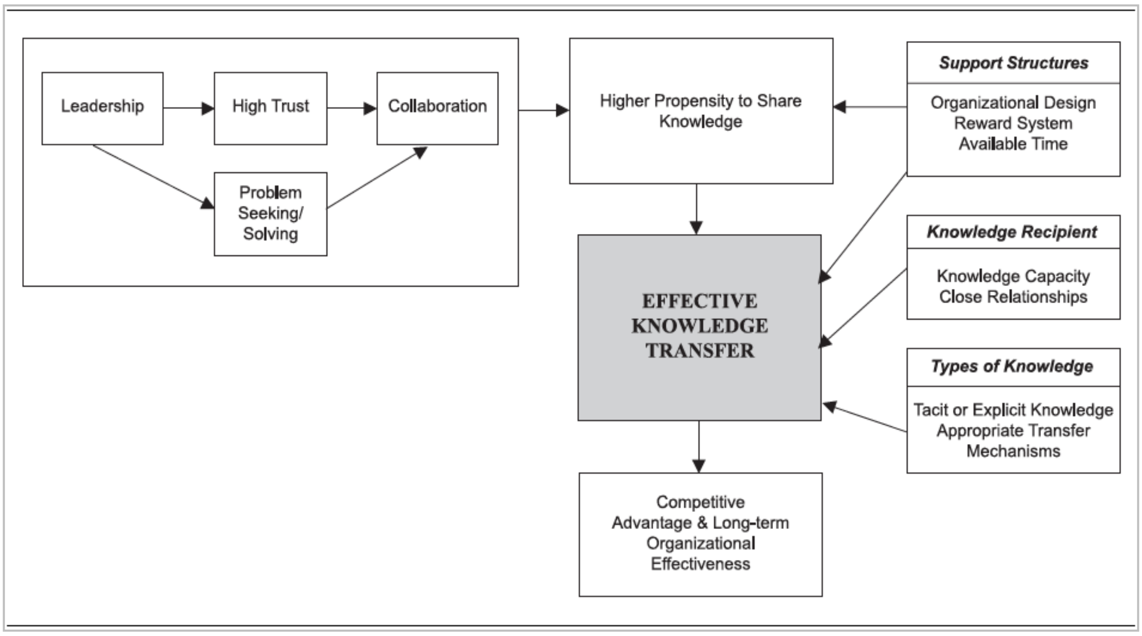


Figure 2-11: An Integrative Framework: factors influencing effective knowledge transfer

Source: Goh (2002)

In his framework, Goh (2002) emphasised that a means of driving the information sharing and KT is to encourage a problem seeking and problem solving culture within an organisation. The three major factors that influence problem seeking and solving are leadership, high trust, and collaboration between employees. However, this framework also emphasises that an organisation must have the supportive structures of organisational design and a reward system. Having these will encourage employees to share knowledge and transfer knowledge for problem seeking and solving approaches. Furthermore, in conclusion, Goh (2002) emphasised that, while encouraging knowledge transfer, an organisation should ensure that both parties should have absorptive and retentive capacity and must consider which type of knowledge needs transferring.

2.4.3 Framework of inter-organisational knowledge transfer

Recently, Martinkenaite (2011) focused on inter-organizational knowledge transfer antecedents and consequences. In Martinkenaite's framework (Figure *2-12*), research is mapped in an integrative framework of knowledge-specific, organisational and network-level antecedents and performance outcomes of transfer. While assuming that the transfer of knowledge does not, by itself, influence organisational performance, this study gives special attention to the mediating role of knowledge acquisition in the relationship between antecedents and the performance outcomes of transfer.

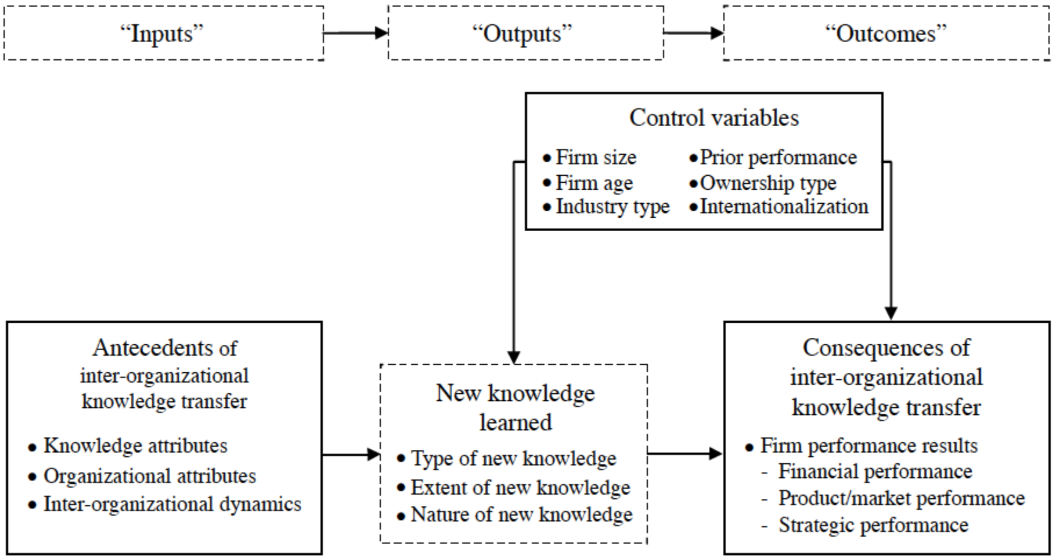


Figure 2-12: Integrative framework of antecedents and the consequences of inter-organizational knowledge transfer

Source: (Martinkenaite 2011)

This framework emphasises the enablers of inter-organisational Knowledge Transfer such as knowledge attributes, organisational attributes and inter-organisational dynamics. These enablers of KT have been seen as the input which outputs the new knowledge learned and further outcomes, the consequences of the inter-organisational knowledge transfer. The output and outcomes are supported by control variables such as firm size, prior performance and ownership type.

2.4.4 Framework of knowledge transfer in inter-firm collaboration

Another KM framework by Narteh (2008), shown in figure 2-13, focuses on knowledge transfer within the developed-developing country based inter-firm collaborations. This framework claims to provide a deeper understanding of the characteristics of transferors and transferees. Additionally, this framework presents how knowledge transfer practice influences knowledge transfer across firm borders. In this, the framework identifies two major sources of knowledge. Firstly, organisationally embedded knowledge and, secondly, cognitively or person embedded knowledge is suggested. Originally, embedded knowledge was considered as the repository of knowledge and it was assumed that the majority of knowledge to be transferred will flow out of the company's existing knowledge stock.

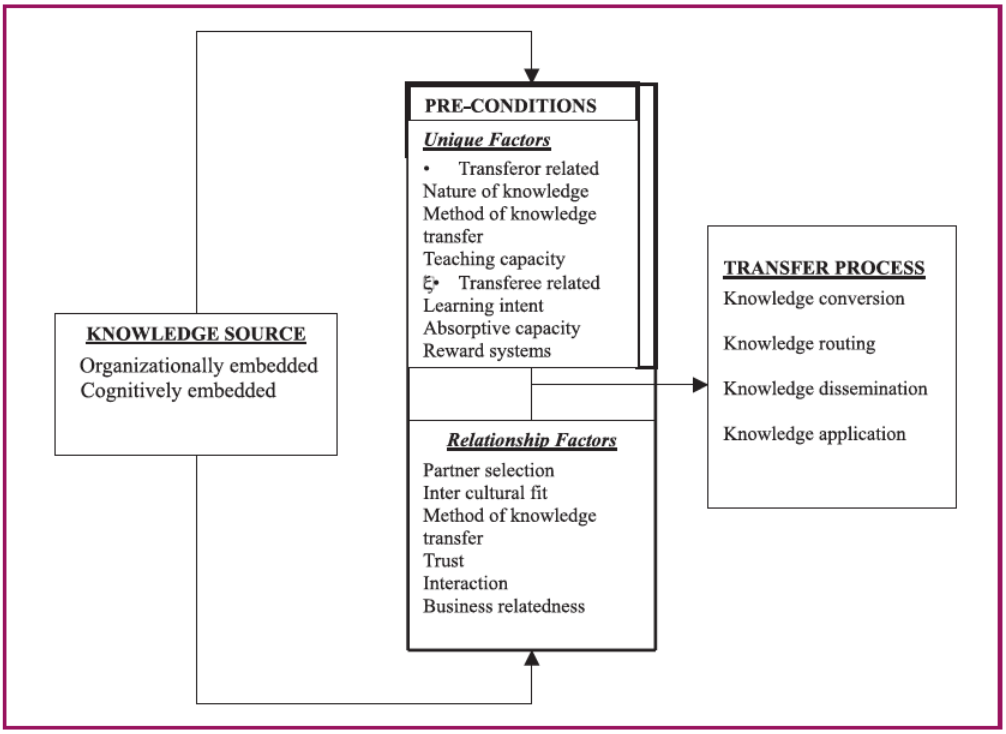


Figure 2-13: Knowledge Transfer Model

Source: Narteh (2008)

This framework assumes that the knowledge stock is found in individual members, roles, organisational structures, standard operating procedures, and practices. The other source of knowledge is cognitive/individually embedded knowledge because it is tacit and embedded in the people. Furthermore, KT requires transferor and transferee related critical success factors such as the nature of knowledge to be transferred, teaching capacity, absorptive capacity, etc. This framework also emphasises the relationship factors when selecting partners, trust, and interaction. Nevertheless, four transfer processes have been put forward, knowledge conversion, routing, dissemination and application to deal with the actual movement of knowledge from the knowledge holder to the knowledge receiver and its subsequent application in the knowledge receiver's firm.

2.4.5 Project oriented KM framework in Lean construction

This framework in figure 2-14 is developed with a view of the implication of KM on Lean construction projects with the IT based view of knowledge. In this framework Lin & Tserng, (2003) assumed that project-oriented knowledge and information is not divided into activity units, while also assuming that some of the information and knowledge belongs to the whole project without clear classification. This means that the framework is developed to manage overall knowledge and information, which flow within the Lean construction project, instead of the context-specific knowledge.

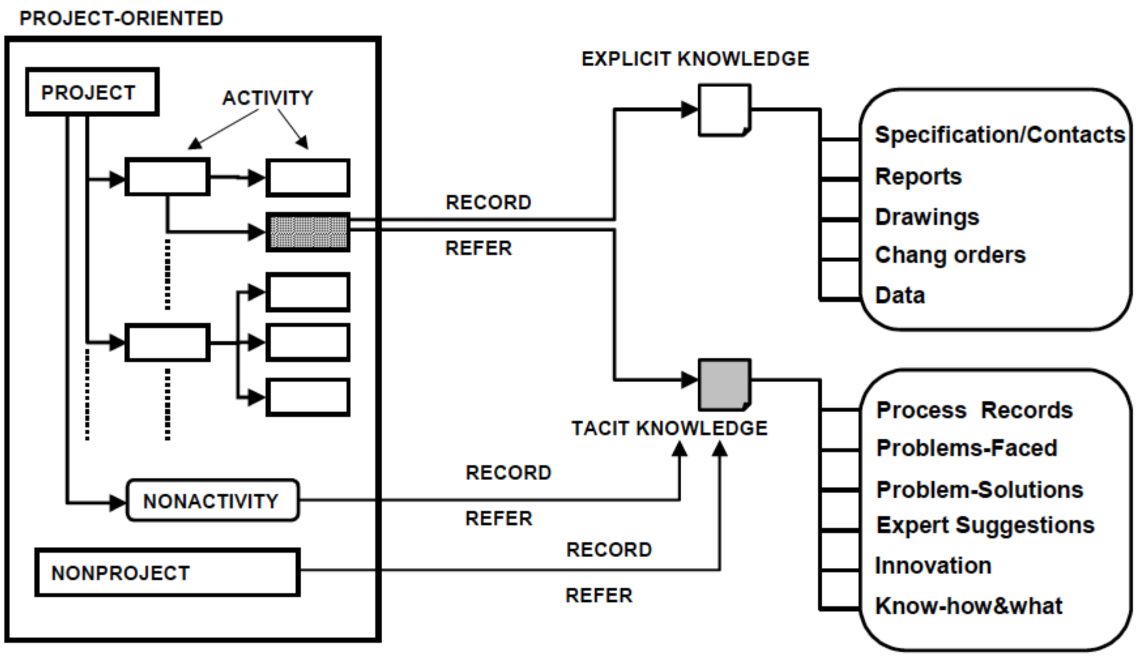


Figure 2-14: Project-Oriented Knowledge Management Concept Framework

Source: Lin & Tserng (2003b)

This framework considers that knowledge and information in Lean construction comes from the project and from outside the project. Moreover, it presents that explicit knowledge comes from the activities and is embedded within the project itself. On the other hand, tacit knowledge is considered as non-activity and non-project knowledge. However, this rejects the theory of the Lean principles, as in Lean thinking tacit knowledge should be developed within the activities within a process.

2.4.6 Critical Success Factors Associated with the Transferring and Sharing of Tacit Knowledge

Having analysed different knowledge management frameworks, this study identifies the main critical factors for transferring and sharing knowledge and knowledge management are Leadership, KM Strategies, Trust, Motivation, Training and Development of Employees. The identified CSFs associated with KM in CSCs is given in table 2-10 below.

Table 2-10: Critical Success Factors of Sharing and Transferring Tacit Knowledge in CSC

Critical Success Factor	Supported Reading
Trust in the construction supply chain	(Lau & Rowlinson, 2010, 2011; Khalfan et. al., 2007; McDermott et. al., 2005; Weber & Carter, 1998, Egan, 1998, Latham, 1994)
Motivation of workers in construction	(Aiyewalehinmi, 2013; Lau & Rowlinson, 2010, 2011; Rose & Manley, 2011; Tabassi & Bakar, 2009; McDermott et al., 2005)
Leadership Capabilities	(BIS, 2014; HM Treasury, 2012; Balasubramanian, 2012; BIS, 2011; Anumba et. al., 2008; Succar, 2009; Maier, 2007; Tiwana, 1999; Egan, 1998)
Business Strategies	(Balasubramanian, 2012; BIS, 2011; Khalfan et al., 2007; Ackerman et al., 2003; Egan, 1998)

Figure 2-15 below exhibits seven (7) potential correlations among those CSFs identified through this literature review. These correlations are further discussed in Chapter (4) (see 4.7.4).

2.4.6.1 Potential Correlation among CSFs

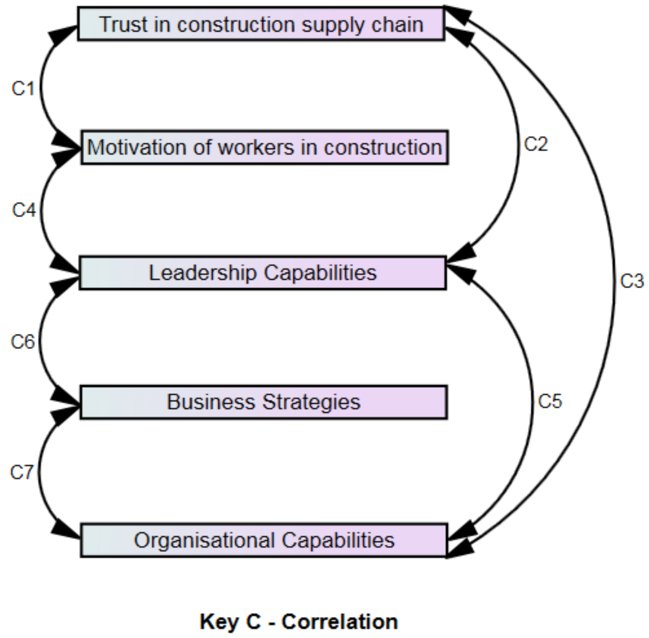


Figure 2-15: Potential correlation among CSFs

2.4.7 Evaluation of Critical Success Factors

Trust, as a critical success factor leading to the success or failure of construction projects, is highlighted in both the Egan (1994) and Latham (1998) reports. There are many definitions of trust based upon the assumptions and the knowledge of the definer. Trust increases order by reducing complexity. Weber and Carter (1998) defined trust as the expectations that people have for others or themselves. Additionally, McDermott et al. (2005) said that trust is the willingness to rely on the actions of others and being dependent and compromising on their actions. Khalfan et al.’s (2007) research entitled ‘Building trust in construction projects’ revealed three main factors of trust, namely, honest communication, reliance, and delivery of outcomes. Their study reveals that trust is concerned with the way in which people communicate with each other. Furthermore, Khalfan et al. (2007) said that people need to be open, willing to share important information, and be honest to reflect the real situation. Trust can only be present if these types of communication exist. A lack of communication within construction projects is the most common project risk (Ceric, 2012).

The studies of Khalfan et al. (2007); Lau & Rowlinson (2011) and Ceric (2012) all mentioned different levels of trust, e.g. 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 for all levels, to drive trust in construction supply chains.

In figure 2-15 above, ‘Potential correlation among CSFs’, seven (7) correlations (C1 to C7) are exhibited, based on an interpretive analysis of the literature of Aiyewalehinmi (2013); Lau & Rowlinson (2010, 2011); Rose & Manley (2011) and Khalfan et al. (2007). The analysis of CSFs below discusses the correlation among CSFs associated with sharing and transfer of knowledge in CSCs.

As discussed earlier, the sharing and transfer of tacit knowledge requires trust among the individuals and organisations within the CSCs. The correlation between trust and motivation (Weber, Malhotra & Murnighan, 2005) could be significant at the individual level but may not be significant at the organisational level as trusted parties necessarily interpret information in the context of their own motivations. The research of Ceric (2012) revealed that incentives do not drive trust in construction at any level. However, Weber et al. (2005) said that, to a large degree, trusting-acts will be driven by the trusted party’s own dependence, motivation and interests. In contrast, Ackerman, Pipek & Wulf, (2003) said that being motivated to share and transfer knowledge requires trust. Based on their study, they revealed that people were less motivated to share knowledge due to organisational actions (such as downsizing) or were afraid that the knowledge would be used against them. Even so, in terms of sharing and transferring tacit knowledge in highly fragmented multi-organisational and short-term CSC activities it can be said that the self-motivation of individuals and, consequently, organisations is an important success factor which drives trust in CSCs. Moreover, motivational barriers to sharing knowledge can be removed through changes in leadership and business strategies (Ackerman et al., 2003).

One of the propositions given by Weber et al. (2005) is that trust is based on the dependence among the trusted parties. In addition, they also emphasised that in-person communication plays an important role in initiating trust, and this leads to partnering in terms of inter-personal relationships instead of inter-organisational relationships. A study by Khalfan et al. (2007) highlighted that an organisation's leadership support is an essential factor in the approach to building trust in construction. Moreover, that said, senior management within construction felt that "any policy to pursue the trusting way of working had to come from the director level." Talking of director level means leadership. The role of senior management and leaders is essential in the sharing and transferring of knowledge. Egan (1998) reported that committed leadership is required to drive forward an agenda for improvement. Anumba et al. (2008) said that KM includes the importance of building trust through leadership. They also said that knowledge leadership is vital for the construction industry. They concluded that, in construction, a KM initiative requires effective vision, leadership, coherent strategies, frameworks, and respect for people, along with trust (Anumba et al., 2008). However, the construction industry has seen a lack of leadership skills for many decades (Balasubramanian, 2012; BIS, 2011; Egan, 1998) and better business strategies are needed to develop leadership in construction.

Moreover, the pre-implementation success factors for trust initiatives in inter-personal relationship Leadership and Business Strategies must be aligned at the inter-organisational level. This requires the capability building of organisations and individuals to deliver and innovate (Al-Hawamdeh, 2002; Yusuf, Sarhadi, & Gunasekaran, 1999; Egan, 1998) and trust in order to share and transfer knowledge among them.

In relation to trust development, the most influential three (3) capabilities required for in-person communication are given in in Table 2-11 below.

Table 2-11: Capability requirements for effective communication

No	Capability	Supported Reading
1	Absorptive Capability	(Tiwana, 1999; Egbu, Anumba & Carrillo, 2005; Bou-Llusar & Segarra-Ciprés, 2006; Anumba, Egbu & Carrillo, 2008; Martinkenaite, 2011)
2	Dissemination Capability	(Egbu et al., 2005; Schwartz, 2005; Anumba et al., 2008; Reimer & Karagiannis, 2008)
3	Knowledge Application Capability	(Tiwana, 1999; Dove, 1999; Alavi & Leidner, 2001; Bou-Llusar & Segarra-Ciprés, 2006; Egbu et al., 2005; Lehtimäki, Reimer & Karagiannis, 2008; Simula & Salo, 2009)

Capability in this context: refers to the capacity of individuals and firms to deploy resources for the purpose of sharing and transferring tacit knowledge.

Capacity in this context: is the capability of individuals and firms to perform sharing and transferring of tacit knowledge to produce efficiency in the processes.

2.4.7.1 Absorptive Capability

Absorptive capability is the capacity or power to absorb or soak up something (Cohen & Levinthal, 1990). Tsai (2001) said that high levels of absorptive capacity are likely to harness new knowledge from other units. He highlighted that organisations must have the capacity to input in order to generate outputs. Moreover, a lack of absorptive capacity is a major barrier to knowledge transfer within and between organisations. However, an organisation's absorptive capacity depends upon individual members (Cohen & Levinthal, 1990). The study of Cohen & Levinthal revealed that the absorptive capability of a firm is based on the structure of the communication system between inter-firm and intra-firm even though, while absorbing knowledge from a process, the knowledge source (individual) also requires observational capability to observe the process and interpret the knowledge.

2.4.7.2 Dissemination Capability

Authors such as Maier (2007) have seen dissemination as a synonym of communication and the diffusion of knowledge. Maier (2007) said "Where knowledge is hard to teach (even to experts) formal training allows by definition of wide-range dissemination." There have been many definitions given on the dissemination of knowledge such as the one by Elashaheb (2005) who said, 'knowledge dissemination is to distribute and pool knowledge from many sources and disseminate knowledge to where it is needed'. However, here in this context, the dissemination of knowledge is the ‘opening of a subject to widespread discussion and debate to share knowledge’ (WordWeb, 2014). This capability is to facilitate lessons learned and successfully disseminate and apply that knowledge to prevent similar problems being encountered (Anumba et al., 2008). There is a requirement to improve knowledge management and continuous insight into the workers’ dissemination capabilities (Tiwana, 1999c).

2.4.7.3 Knowledge Application Capability

Knowledge application capability is the capacity of individuals and firms to use knowledge for a different purpose or context. This requires the sharing, distribution and dissemination of knowledge where it is needed (Elashaheb, 2005). It refers to the actual use of captured or created knowledge, and its placement into the KM cycle (Tiwana, 1999c; Dove, 1999). Lehtimäki et al. (2009) said that before the application of knowledge, the recipient needs training to evaluate the appropriateness of knowledge. The application of knowledge requires interpretation and reflection (Egbu et al., 2005). Moreover, knowledge transfer requires different applications depending on the characteristics of transferred knowledge (Bou-Llusar & Segarra-Ciprés, 2006). Consequently, knowledge application requires the previous knowledge of the recipient about the context for interpretation and the reflection skills to communicate the knowledge further.

2.4.8 Capabilities for Knowledge Communication

In CSCs, an effective communication initiative is for the ‘purpose’ of transferring and sharing Tacit Knowledge. It is to develop communication at the interpersonal, inter-firm, and intra-firm levels.

2.4.8.1 Observational Capability

The act of recording a measurement while taking a patient look at an activity to express careful consideration, and to learn and reflect upon the facts of/from it, is called observational capability. Observation capability plays an essential part in transferring and sharing knowledge. Five different attributes of observational capability, namely, Observation Breadth, Observation Depth, Observation Quality and Observation Data is given by Hu et al., (2014). On the other hand, Chen & Zhang (2014) proposed the Dynamic Observation Capability Index (DOCI) model which also has similar attributes of observational capability. However, their study centres on the observation sensors used on satellites, but the given attributes are the same.

In Observation Breadth, the knowledge recipient must have the capacity to understand a wide range of topics. The recipient should also have the degree of intellectual ability required to penetrate those topics and to explore knowledge with observational depth. Next, the observation frequency is required to define the number of occurrences to be observed to allow them to be categorised statistically. Observation quality defines the apparent individual nature of observation in a sense or grade and collects the observation data/information from which the conclusions may be drawn. Currently, observational capability is widely used in the high-technology world while employing data-based sensors.

Wu (2013) stated that observational capability is manifested in three things, Examining, Analysing and, Judging the things around us. Moreover, Wu said that if an individual can deal with these three aspects, then it means that that person has a strong ability to observe. However, later, Wu said that an individual also requires responsive capability to react to observations.

2.4.8.2 Explanation Capability

Explanation capability is the act of making something plain and graspable by describing the relevant structure, operation or circumstances, etc. Explanation capability means the capability to interpret fuzzy reasoning results to human users in an understandable manner (Ishibuchi et al., 2009). Moreover, Ishibuchi et al. (2009) found that explanation capability is unrelated to interpretability. Their study also considered complexity minimisation to maximise interpretability, but they concluded that complexity minimisation does not always lead to maximise interpretability.

2.4.8.3 Routing Capability

Routing capability is how the message travels from the source to the destination (Pinto, 2007). A dynamic routing capability provides knowledge workers with the flexibility to include new steps and approaches in order to prevent the future problems (Fischer, 2013). In a sophisticated and fast-paced environment, it becomes desirable to be able to prioritize and intelligently route all forms of communication with the goal of expedient and professional service to the client in mind (Shtivelman, 2001). In the case of sharing and transferring Tacit Knowledge, both the source and the recipient of knowledge should have knowledge routing capability to enable them to identify the quickest means of delivering knowledge to the right destination.

2.4.8.4 Conversational Capability

Conversational skills held by the source of knowledge will guarantee the knowledge recipient will better understand that source. On the other hand, the conversational skills of the recipient results in best the better understanding of others. This closely relates to explanation capability. This capability requires conversational skills for knowledge sharing.

2.4.9 Summary

This section presents the critical success factors associated with effective knowledge transfer and sharing. This section also highlights the individual capabilities required to transfer and share Tacit Knowledge. This section highlights the following critical success factors.

- Trust among organisations and individuals in a Construction Supply Chain.
- To transfer and share Tacit Knowledge in a construction process, the construction workers require motivation.
- Leadership capabilities are required to drive knowledge communication.
- Business strategies are required to be aligned with KM strategies in order to initiate the transfer and share of Tacit Knowledge.
- Organisational capabilities and individual capabilities are required to initiate knowledge communication in CSCs. Identification of the types of knowledge to transfer and share requires the identification of the source of knowledge and the identification of the recipient of knowledge.

2.5 Conceptual framework

2.5.1 Introduction

This section focuses on the development of the conceptual framework based on the main findings from the literature review. This centres on the view to initiate the transferring and sharing of context-specific, tacit knowledge from the source (Knowledge Holder) to the recipient (Knowledge Receiver). The aim of developing this framework is to improve awareness and understanding of KM in CSCs in order to increase efficiency in Lean and Agile processes; also to bring collaboration and partnering within CSCs. Based on the literature review, the author contends that, if KM is considered in Lean and Agile processes, it will improve the level of efficiency in CSCs. In addition, this will further develop the collaborative environment within the project-based CSCs.

2.5.2 Main findings from the Literature review

This study identifies that a major problem is faced by the construction sector (see section 2). In addition, the main causes of the problem with the CSCs of project-based organisations are inefficient knowledge communication in the Lean and Agile processes and, furthermore, a lack of integration and collaboration in CSCs.

2.5.2.1 Challenges

This study highlights the main challenges associated with effective knowledge management through the application of Lean and Agile principles in construction supply chains. Firstly, the literature review establishes that the construction sector has a lack of understanding of Lean, Agile and KM concepts. Secondly, as per the BIS report (2013). There is a deficiency of support and funding available for the sector.

The reason for the inefficient implementation of Lean and Agile principles is because hundreds of small & medium organisations are involved in CSCs (BIS, 2011, 2013). These organisations do not have any prior relationship and/or trust between them.

Based on TPS and Womack (1990, 2003), to improve the process, Lean thinking is required to be carried out within all the activities and tasks of a process. Similarly, in an SC, the motive for the application of lean is to reduce waste and generate value in all the activities from suppliers, and within supplier’s originations, to encourage suppliers to reduce the cost.

The arguments put forward in the literature reflect that the true meaning of Lean in construction is misunderstood.

The literature review highlighted that other challenges (see figure 2-2 and table 2-2) are:

2.5.3 Findings

- A lack of understanding and awareness of the importance of KM in Lean and Agile Processes
- Deficiency of trust and motivation among the organisations in CSCs
- Short term SC relationships among suppliers and sub-suppliers
- Traditional ways of working
- The fragmented nature of the construction sector

2.5.3.1 Application of Lean and Agile principles in construction processes

This study finds that Lean and Agile processes work well together in a collaborative environment (Mason-Jones et al., 2000). Both Lean and Agile processes should be embedded in CSCs (based on the studies of Koçoğlu, et. al. (2011) & Orange et al. (1994)). Based on the views of Guo (2012) and Christopher & Towill (2001), it would be wrong to say that Lean by itself can increase the responsiveness of CSCs and can collaborate and integrate project based multi-organisational supply chains. Based on the literature review an effective knowledge sharing approach can enhance the effectiveness of Lean and Agile processes to generate value.

The main findings from this study relating to the contribution of Lean and Agile principles and supply chains are listed below.

I. Contribution of Tacit Knowledge in the application of Lean Principles

a. To reduce waste and generate value in a construction process
b. To enhance flow of materials and information
c. To increase efficiency in the decision making process and continuously improve the construction process.

II. Contribution of Tacit Knowledge in the application of Agile Principles

a. To enhance responsiveness of activities
b. To bring collaboration and partnership and integrate the construction process
c. To empower teams to take efficient decisions

III. Contribution of Tacit Knowledge in the application of SC principles

a. To enhance partnering and collaboration among organisations involved in a construction process
b. To increase the responsiveness and efficiency of a construction process
c. To reduce the negative impact of fragmentation in a CSC

IV. Other findings

a. Lean and Agile processes works well if both work together
b. Lean and Agile processes are both embedded in each other
c. KM plays a significant role in the association of Lean and Agile principles in CSCs
d. KM, Lean and Agile processes should be nested in a SC
e. An effective KM enhances the effectiveness of Lean and Agile processes to generate value and reduce waste.

2.5.3.2 Critical Success Factors

The main CSFs relating to an effective KC within a CSC through the application of Lean and Agile principles are listed below (see 2.4.6 above)

I. Trust and Motivation among organisations and the people in them
II. Leadership and Business strategies
III. Organisational and Individual capabilities for Knowledge Transferring and Sharing

   a. Observational Capability
   b. Absorptive Capability
   c. Application Capability
   d. Dissemination Capability
   e. Explanational and Conversational Capability
   f. Routing Capability

IV. Business strategies aligned to share and transfer Tacit Knowledge in CSCs
V. Identification of process improvement opportunities
VI. Identification of types of knowledge to transfer and share
VII. Identification of knowledge source and recipient

CSCs consist of a large number of SMEs which bring the negative impact of a fragmented SC (BIS, 2013). Most of SMEs are specialists in their fields. These organisations must trust each other to share knowledge (Martinkenaite, 2011). SMEs must also understand that a construction project is not just to make money, but it is also for developing intellectual capital (Narteh, 2008; Bou-Llusar & Segarra-Ciprés, 2006; Goh, 2002). Trust and motivation amongst them will also enhance the possibility that shared knowledge will bring benefit to others and the project itself.

Efficient KM in CSCs requires defining the leadership roles with the alignment of the business strategies with KM, Lean and Agile principles with a view to developing processes and CSCs, and with the wider view of bringing benefit to the construction project and to the client and the SC partners and other stakeholders (Lin & Tserng, 2003). However, to make a KM initiative successful in Lean and Agile processes, people and organisations require Skills and Training on developing capabilities to ensure smooth transferring and sharing of tacit knowledge.

The study also finds that the application of KM in the context of Lean and Agile Processes with Knowledge Communication could improve the efficiency of CSCs.

Knowledge communication brings social integration in the process while transferring and sharing tacit knowledge and offers room for the validation of the knowledge. As knowledge communication demands the collaboration of people and processes, this influences the overall integration and collaboration within the CSC if Knowledge Communication is applied through the Mega processes followed by major processes, sub-process activities and task levels.

This study also finds that the application of Knowledge communication and Lean and Agile principles in CSCs would obtain the maximum benefit of efficiency improvement if Lean, Agile and KM are applied together as a nested model (embedded in each other) and are applied in each organisation involved in the CSC. However, the fragmented nature of the construction sector and the large number of suppliers involved would make the application of KM difficult. To make KM and Lean and Agile process application initiatives successful a construction project will require robust KM, Lean and Agile processes (Know-Le-Agile Process), Procurement, Personnel (Human Resource) and other business strategies.

Based on the preliminary findings and the discussion in Section 2, the construction process is seen as a mega process and Lean and Agile thinking must be implemented at the major process, sub-process, activity and task levels. Furthermore, knowledge communication (KC) must also be implemented within all the levels of a mega process (see section 3).

Based on this, the three-stage framework below has been developed to improve the efficiency of CSCs within the Lean and Agile process and to improve our understanding and awareness of the role of KC in Lean and Agile thinking.

2.5.4 Conceptual Framework

The role of KC is to bridge the process-practice gap. With a KM process in place, best practices quickly become the new, standardised processes (Bergeron, 2003). It is proposed that this view of KC should be used in CSCs in the context of Lean and Agile processes.

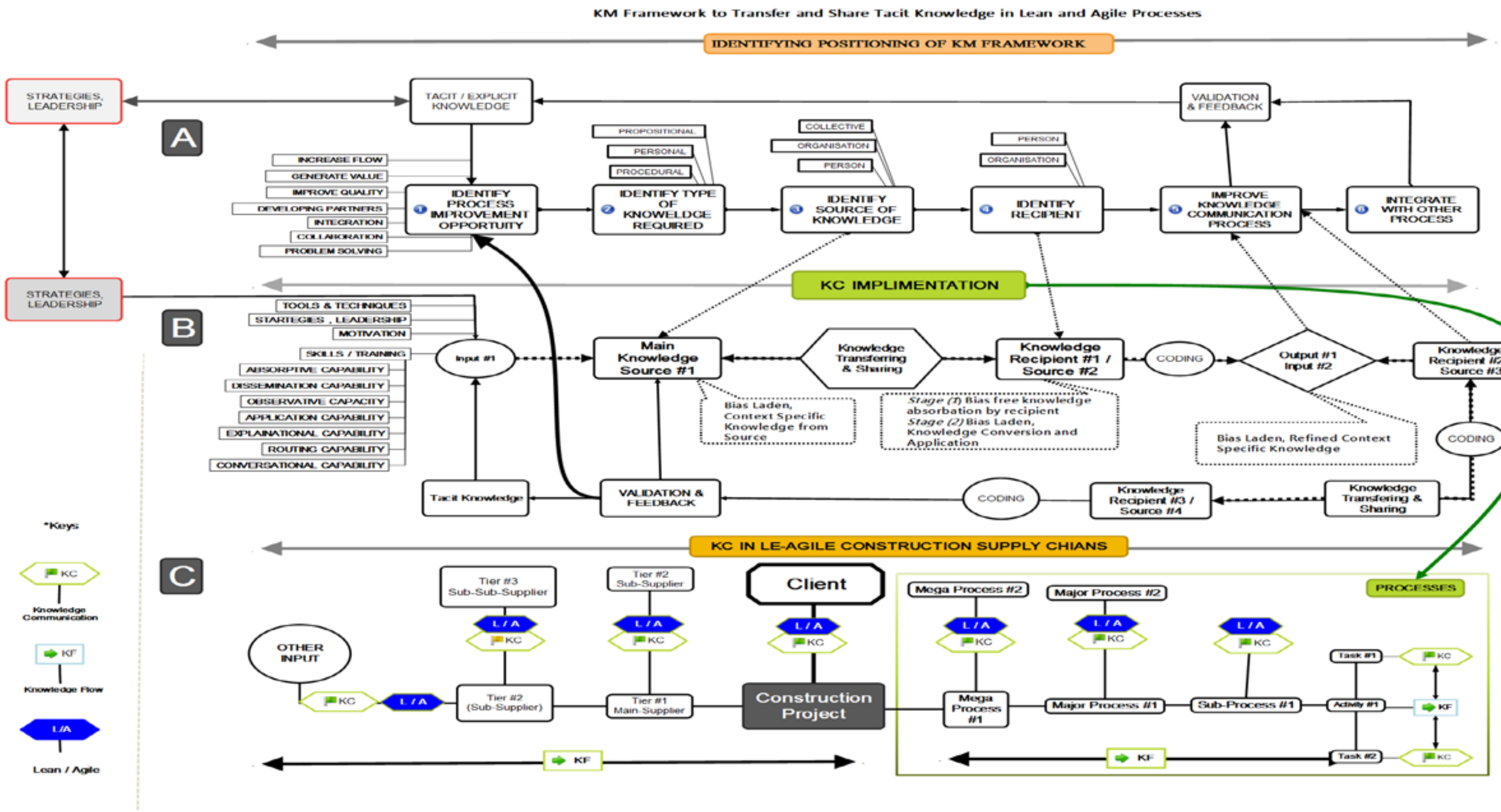


Figure 2-16: Conceptual Framework

The draft of the proposed framework above exhibits a knowledge transfer and sharing approach within the activities of the Lean and Agile process. This research sees transferring and sharing tacit knowledge as a CSF associated with the CSC in the Lean and agile construction processes. This framework views CSC as a set of several project-based multi-organisational supply chains. To bring individuals and organisations together in a collaborative environment, this framework should be implemented at the all levels of a Lean and Agile construction process.

Firstly, to transfer and share tacit knowledge from source to recipient project leaders should have a clear strategy (Trees & Lemons, 2014). This also requires the identification of which type of knowledge is required to be updated. Moreover, it also requires identifying which process to update and the source of the knowledge. In January 2014 (Trees & Lemons, 2014) at a KPMG conference at APQC it was highlighted that, before transferring and sharing tacit knowledge, an organisation must define a strategy and a process to protect critical knowledge. Previous studies indicate that the first requirement of knowledge transfer is to identify the control variables, as suggested by Pheng & Fang (2005) and Sacks et al. (2009) (discussed in section 2.2.8).

Three steps to identify control variables are given by Trees & Lemons (2014). These control variables are the main input in identifying the process improvement opportunities.

1) Create a comprehensive knowledge capture and transfer strategy focused on business continuity
2) Let business leaders drive the strategy and process with KM functioning as an enabler
3) Design the strategy and process with an understanding of the organisational culture and “appetite” in mind

2.5.5 Stage (A) Identifying Positioning for a KM Framework

Table *2-12* below presents the stages of identifying positioning of this KM framework before initiating transfering and sharing Tacit Knowledge in a CSC.

2.5.5.1 Stage (A1)

At this stage of the conceptual framework, enablers of Lean or/and Agile processes need to identify specifically the context-specific critical knowledge to be updated. The main criterion to identify the crucial knowledge (as given by Trees & Lemons (2014)) is to define the alignment of knowledge with business strategy and the applicability of knowledge to other teams and business units. This framework focuses on the alignment of knowledge with CSC strategy and Lean and Agile processes.

Table 2-12: Tasks to Identifying Positioning of KM Framework

Tasks	**Variables**
Step (A1) Selecting Process : Identify Process Improvement Opportunity	• Increase Flow • Generate Value • Improve Quality • Problem Solving • Developing Partners • Integration
Step (A2) Choose Type of Tacit Knowledge Required to Enhance Selected Process	• Propositional • Personal • Procedural
Step (A3) Identify Source of Knowledge	• Organisation • Person • Collective
Step (A4) Identify Knowledge Recipient	• Person • Organisation
Step (A5) Improve Process	• Validation • Feedback
Step (A6) Integrate with other Processes	• Repeat Step 1 To 5

2.5.5.2 Stage (A2)

This stage identifies which type of tacit knowledge is required to enhance the specific process identified at stage (A). At this stage, one among the three types of tacit knowledge (discussed in section 3.14) (namely, personal, procedural and propositional knowledge) should be defined.

2.5.5.3 Stage (A3)

At the third stage, of the source of knowledge within the Lean and Agile process CSC needs identification. If, for example, the type of knowledge required is procedural knowledge, in such a case, the sources of knowledge are more likely to be an individual or an organisation who specialises in that procedure. Sources of knowledge (see 3.15) are personal knowledge, organisational knowledge or collective knowledge. The knowledge source could be the organisation or an individual person who holds the tacit knowledge.

2.5.5.4 Stage (A4)

The fourth stage is to identify the knowledge recipients who have the observation, absorptive, conversational, application, routing, and explanation and dissemination capability to receive the tacit knowledge from the source. At the same time, these capabilities are equally important for the source knowledge. However, this research suggests that the main source of knowledge should at least hold observational, communication and explanation capability. This is in order to observe (task & activities), articulate (new knowledge), communicate, and explain new tacit knowledge to the recipient. The reason why a recipient should have explanation capability is because, on the next stage of KC, the recipient will act as the source and will require explanation capability to transfer and/or share the knowledge further upstream in the SC.

2.5.5.5 Stage (A5)

Once the requirements of stages A1 to A4 are identified, validation is needed to ensure the functionality of this process. This validation will also provide feedback and offer improvement to the process.

2.5.5.6 Stage (A6)

At this stage, the integration opportunity with other processes is to be defined with a view to initiating a collaborative working environment with other processes.

Once the strategies, resources and positioning of the KM framework are defined, section B of the proposed framework needs to be implemented in a lean or agile process. Section B explains how the knowledge communication process should be implemented. Again, in this part, KM strategies need to be defined based on the process.

2.5.6 Stage (B) Knowledge Communication Implementation

Once the above stages (A1 to A6) are finalised, it is important to identify how knowledge communication can be initiated between the source and the recipient of knowledge. At this stage, KC is seen as a continuous process in which the transferred and shared knowledge is flowing through the different processes. This stage within the framework is designed based upon the input – output model, whereby the input is the raw tacit knowledge and the output is the refined knowledge. The reason for using this model is because this is a qualitative technique, which is significantly correlated with KC, and utilises interviewing the source of knowledge to observe and record knowledge.

At this stage, critical success factors are the input (#1) (as discussed earlier in section 2.4) that helps to initiate knowledge communication. This involves defining tools and techniques to transfer and share knowledge, leadership capabilities, motivational tools and techniques and skills required for the knowledge source and the knowledge recipient.

In the KC implementation process, this study suggests that the knowledge from the source must be bias laden because of the nature of Tacit Knowledge being based on experience (as discussed in section 3). Moreover, to ensure the smooth transfer or sharing of Tacit Knowledge, the source of knowledge requires skills and training on observational articulation and explanation capabilities. However, in terms of knowledge sharing, more capabilities such as absorptive, conversational, and application would be required for the knowledge source. On the other hand, the recipient will require both sets of capability because, in the next stage, the recipient will act as a secondary source of knowledge.

After each step of Knowledge transfer and sharing, knowledge input requires routing of knowledge to the experts for feedback and reliability and validation. If, in the case, the captured knowledge does not match with the aim and objectives, the processes A and B both need fine-tuning and revising again.

The source of knowledge often observes processes or an activity. This develops a rationale about the process or activity while validating through his/her experience (see section 2). In this regard, it is natural that the knowledge extracted from its source would be bias-laden context-specific knowledge. The knowledge conversion (within the mind) and application (within process) would also be bias-laden (as discussed further in Chapter 3). However, on the recipient side, the first stage is to ask questions and absorb the knowledge from the source with a bias-free approach. If, in this stage, the recipient's approach is bias laden, then the extracted knowledge may not be as pure as the source was.

Implementation of this framework should be at the task level (see section 1), but the entire KC process must be supported by the SC design, and the project strategy must involve CSFs (see section 3) such as motivation and trust among the multi-organisations, especially among the knowledge sources and the recipients at all stages. Trees & Lemons (2014) suggested that the Top-Down (Management) and the grass root (origin of knowledge, task level) identification approaches should be combined.

2.5.7 Implication of Knowledge Communication in Lean and Agile Supply Chains

This stage looks at the application of lean and agile principles in CSCs. The literature review suggests that, to get the best results, Lean, Agile and KM must be implemented as embedded in each other. This proposed framework does not see Lean, Agile and KM as separate functions. To create value in CSCs, Section (C) of the proposed framework explains how and where the KC framework should be implemented. This stage shows Lean, Agile and KC as embedded within each task within an activity. In addition, stage (A) of this framework requires implementation at the sub-process, major, and mega process levels of an SC. As a construction supply chain is a setup of multi-organisational supply chains, this KC framework is recommended to be implemented within all tiers of a CSC if the origin of knowledge is organisational or collective instead of personal (see section 2). Implementing this framework at all stages of the process will bring collaboration and partnering in CSCs.

2.5.8 Refined Research Scope

The scope of this research has the limitation to the development of knowledge communication framework to initiate transfer and sharing of tacit knowledge in CSCs, within the context of Lean and Agile Construction processes. The findings from literature review leading this study to validate this conceptual framework to transfer and share context specific knowledge within a specific Lean and/or Agile and/or Le-agile construction process. This further requires validating the other findings from literature review defined under headlines 2.1.7; 2.2.5; 2.3.16 and 2.4.9.

The next chapter focuses on defining the research methodological framework to validate conceptual framework and findings from literature review.

3 RESEARCH METHODOLOGY

3.1 Section 1

3.1.1 Introduction

The research context, problem, aim and objectives were set out and established within chapters one to five of this study. This chapter concentrates on establishing and justifying the appropriate methodology for this research. Accordingly, the structure of this chapter is as follows:

- Firstly, this chapter discusses the methodological framework and research philosophies utilised to identify the applicable philosophical stance (Ontological, Epistemological and Axiological).
- Based on the literature review, it projects a fresh Knowledge Driven Research Methodology (KDRM) model that drives the research methodology of this study.
- Secondly, through the KDRM model it defines and justifies the research approaches, the research strategy and methods.
- Finally, this chapter discusses the reliability and validity issues of the suitable research methodology and justifies its choice at the end of this chapter.

3.1.2 Methodological Framework

Research methodology is a vital part of defining research in order to achieve the aims and objectives of the research. Two models are defined which give an overview of Research Methodology, namely, the ‘Research Onion’ in Figure 3-1 below, by Saunders et al. (2009) and the ‘Nested Approach’ in Figure 3-2 below by Kaglioglou et al. (1998).

The Nested Approach explains three elements, Research Philosophy (RP), Research Approach (RA) and Research Techniques (RT). The nested approach defines the structured research techniques. According to Kagioglou et al. (1998), in a research methodology, the first element required is to define the Research Philosophies. The research philosophies and the research approach guides further research techniques. Saunders et al. (2009) presented six (6) layers of research methodology in the Research Onion, as shown in figure 3-1. The research onion also considers the research philosophy as the primary element to define.

Both models are almost similar, but the main difference is the research approach explained in the research onion (Saunders et al., 2007) is also placed in the research strategy, the research choice and the time horizon. On the other hand, in the nested model, Kagioglou et al. (1998) and Sexton

(2000) contended that the research choice and the time horizon should not be driven by research strategy. Lewis et al. (2009) conceptualised the research structure into the form of an ‘onion’. In order to carry out research that will fully answer the research objectives, the research ‘onion’ provides a clear framework. The onion provides a correlation for peeling away layer after layer before an effective research strategy and design is selected. However, there is a criticism in that it fails to establish its influence on the selection of a methodology through the research question and objectives.

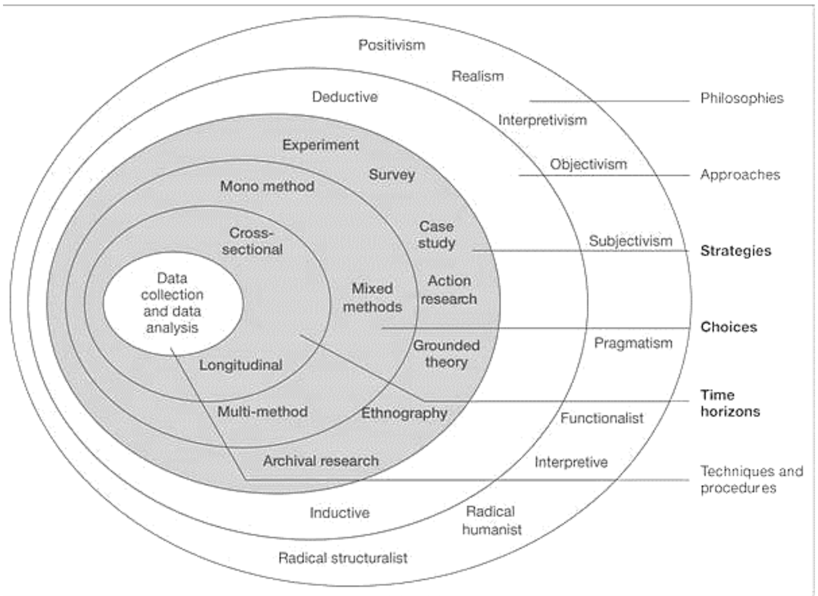


Figure 3-1: Research Onion

Source: Saunders et al. (2009)

In comparison, the nested model only has three layers. In Kagioglou’s view, the research strategies, the research choices and the time horizon should fall into the research approach. However, Saunders expressed research strategy, choices and time horizon as the separate activities/layers of a research methodology. In a comparison of the research onion and the nested approach (Keraminiyage, 2009), despite the commonalities in both research methodological frameworks, the research onion differs from the nested approach. Moreover, the selection of the research approach differs.

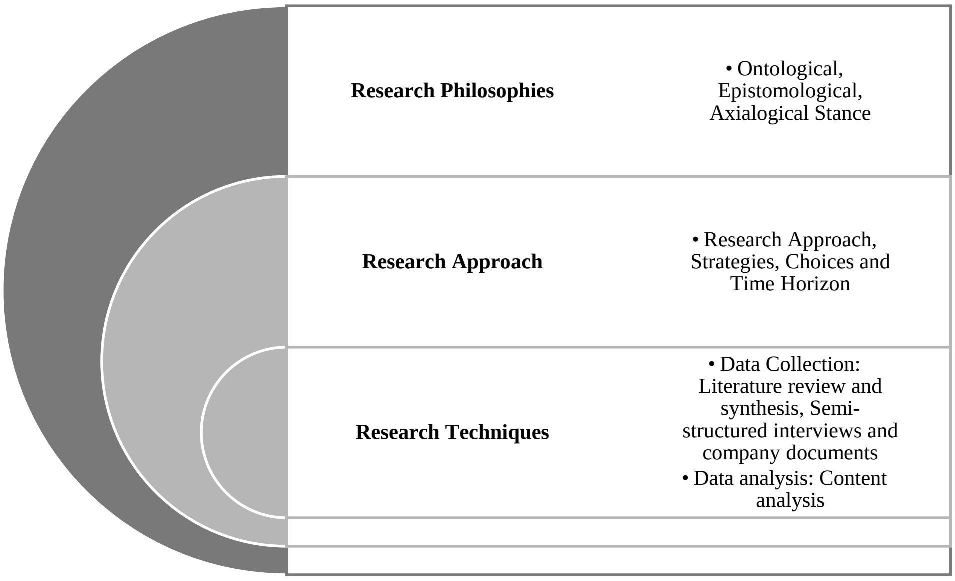


Figure 3-2 Nested Approach Framework

Source: Adopted from Kagioglou et al. (1998)

The ‘nested approach’ and the ‘research onion’ both give a similar understanding of the components of research methodology and gives guidance for research. In the ‘nested approach’, the outer most ring is the research philosophy, which is similar to the presentation in the ‘research onion’, and is based on the epistemological, ontological and axiological assumptions of the researchers. The middle ring consists of the research approach to organising research activities, including the research approach, strategies, choices and time horizon. The innermost circle is the same for the two frameworks and represents the research techniques.

The two methodological approaches are almost same. The ways of presenting the framework differs in the research approach section where Saunders et al. (2007) named it as research strategies and divided this into three different layers for better representation. On the other hand, Kagioglou et al (1998), combine the two layers for an easy representation of the entire methodological framework. This study finds the nested approach framework more suitable for two main reasons:

A) The nested approach to research methodology provides a more structured and defragmented approach for this study.
B) Since this study reveals that the concepts of Lean, Agile and KM are embedded in each other and work well together, this statement directly relates to the nested model and matches with the embedded nature of it.

However, the characteristics of this study require a unique approach to designing the research methodology for this research. As shown below, a Knowledge Driven Research Methodology (KDRM) model is developed which provides a systematic process to choose the relevant research methodology for this study.

3.1.3 Knowledge Driven Research Methodology (KDRM) Model

The research aim and objectives established in chapter (1) drives the philosophical choice for this study. Research must be a systematic process to find the answers with a rational investigation of the facts behind the reasoning (see Table 3-2 and section 3.1.5 below). To establish the philosophical choice of this research, this study reflects on the research title, aim and objectives. A systematic process model, "Knowledge Driven Research Methodology", (KDRM) is developed and adopted throughout this study based upon the literature review conducted in section (3) of chapter (2). Figure 3-3 below provides a clear and deep perception on how to systematically choose the philosophical stance of the study and, furthermore, to inform the choice of the research approach, strategies, choice and tools and techniques.

Step one of the KDRM model establishes the foreground of the research methodology of this study. Step (1) lays down the ground for the RM of this research. The second step portrays the ground for the epistemological and axiological choice in this study. The third step highlights the identification of the research methods and tools and techniques to conduct the research. Afterwards, the fourth step establishes the ground to choose the research strategies (see also 3.1.11 below) based on the type of knowledge needing investigation. Step five lays down the choice of the tools and techniques of data analysis.

3.1.3.1 Research Methodology based on the Research Title and Aim and Objectives

Title of study:

A Framework for Transfering and Sharing <u>Tacit Knowledge</u> in Construction Supply Chains in the Context of Lean and Agile <u>Processes</u>

Aim of Study:

The aim of this study is to develop a framework for the transfer and sharing of tacit knowledge within the context of Lean and Agile processes and to improve the understanding and awareness of Tacit Knowledge in Construction Supply Chains.

Objectives:

- To critically review the concepts of Knowledge Management, Supply Chain Management and Lean and Agile processes in general and, specifically, within Construction Supply Chains.
- To examine the contribution of Tacit Knowledge in the application of Lean and Agile principles within Construction Supply Chains.
- To investigate and document the challenges associated with the effective Transfer and Sharing of Tacit Knowledge through the application of Lean and Agile principles in Construction Supply Chains.
- To identify the critical success factors associated with the effective Transfer and Sharing of Tacit Knowledge in Construction Supply Chains through the application of Lean and Agile principles.
- To develop and validate a knowledge communication framework that improves the level of efficiency in Construction Supply Chains through the application of Lean and agile thinking.

The research title, aim and objectives (see 1.1.5) reflect the fact that the research is investigating Lean, Agile and CSC processes and principles. This suggests the investigation of a particular course of actions and establishes the need for the investigation to explore procedural knowledge. Moreover, the aim and objectives of this research also reflect that the investigation is in the domain of both tacit and explicit knowledge.

The first objective demands to the investigation of the existing literature that falls within the domain of explicit knowledge. The second objective requires investigating explicit knowledge but also demands a validation of the findings through real-life perception through investigating the tacit (personal or procedural) knowledge domain. Likewise, the remaining objectives also demand investigation in both the tacit and explicit knowledge domains. The resultant, investigated explicit knowledge suggests employing the deductive (Qualitative) approach for this study. On the other hand, it demands inductive (Quantitative) study. However, the validation of the findings is also possible with qualitative (interviews) study. The need to employ qualitative or quantitative approaches, or both, to validate the findings depends on the source of knowledge (Unit of Analysis).

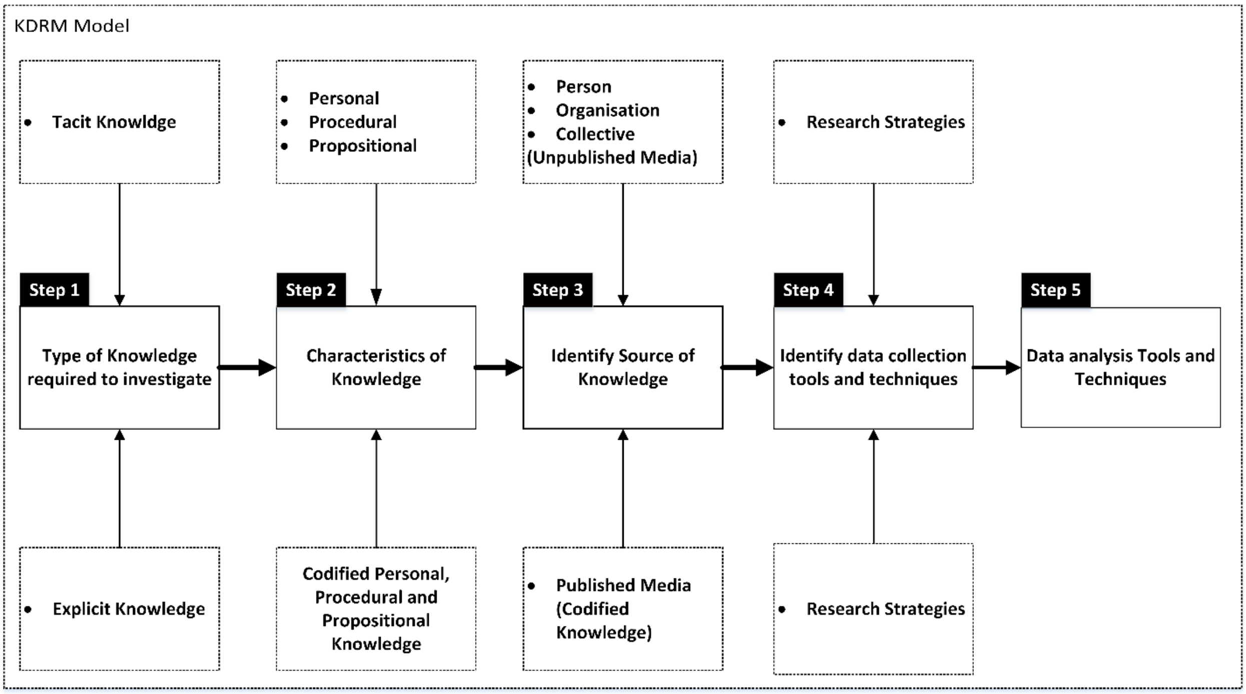


Figure 3-3: Knowledge Driven Research Methodology for Social Science Research

Source: Original

This also establishes the investigation into personal and/or self-knowledge. Investigation into both personal and procedural knowledge establishes the existence of propositional knowledge (a combination of both personal and procedural knowledge; discussed in chapter 2, section 3). Having investigated both the tacit and explicit characteristics of knowledge establishes an early indication that this study demands more than one (1) research method to be adopted in order to fulfil the investigation into explicit and tacit knowledge. This shows that the study demands mixed or multiple methods of research.

Step (3) of the KDRM model establishes the grounds of the unit-of-analysis and the target population for this study. Since, personal and procedural knowledge needs are investigated for this study it requires the exploring of self-knowledge (see 2.3.4.2) and of the Unit of Analysis (UoA). This leads to stage (4) of the KDRM model, the choice of the appropriate research strategy (survey, grounded theory, archival research, etc.) to conduct the investigation.

This also establishes the UoA for this study based on the investigation into Tacit Knowledge and on the employment of a survey (questionnaire and interviews) as the chosen research strategy. To investigate Tacit Knowledge the UoA are the persons involved in construction processes who will respond to the questionnaire and the interviews. However, both types of knowledge requires different forms of research strategy. For example, investigation into an explicit study requires a review of the literature and investigates the theory in the form of published media, books, journals and archive databases and documents. On the other hand, investigation into Tacit Knowledge requires a survey questionnaire (Quantitative), interviews (Qualitative) and observation. This leads this research into the inductive approach. On the other hand, the relevant strategy for explicit knowledge requires an investigation of the literature (Qualitative) and databases from different organisations (Quantitative) covering past years and identifying and analysing challenges, and CSFs, which leads to an deductive approach while testing the theory. See section (3.1.9) below for more discussion on qualitative and quantitative approaches and section (3.1.10) below for inductive and deductive approaches and the additional reasons for employing the varied method approach for this study.

Since stages 1, 2 and 3 of the KDRM model establish that personal perception (views, opinions) can be investigated using a mixed method approach it also establishes this investigation would conclude with multiple realities.

The ontological grounds of this research is based on, the personal knowledge (see chapter 2, section 3) that comes from the mental world (Tacit Knowledge) based on the experience of the knowledge holder. Similarly, an investigation of processes (procedural knowledge) could produce various results since the study demands the investigation of individual knowledge to validate the findings from literature review. This establishes that the ontological assumption for this study is subjective, which will authenticate multiple realities and further support the epistemological assumption as interpretivism (Anti-positivism). Moreover, having an investigation into personal knowledge leads the axiological choice of this research to the value laden approach (see 3.1.7).

3.1.4 Research Tools and Techniques

Table 3-1 below explains the research objectives and the related research questions and what methods of data collection are adopted. This is required to meet the objectives and to answer the research questions. Based on the assumptions made from the KDRM model, this study adopts five types of data collection techniques. These are the literature review, secondary data, archives for investigating explicit knowledge, and a questionnaire and in-person interviews to examine tacit knowledge. However, the data analysis stage also employs observation to study the nature of data and outcomes.

3.1.5 Archive Data and Document Review.

Research into background factors can use different types of data collected by a variety of methods. Primarily, this research uses the data collected by previous researchers (the existing literature, books often stored in archives). As the research progressed, the literature was searched without the reference to any particular industry and the review was narrowed down to the specific subject of transferring and sharing tacit knowledge in CSCs in the context of lean processes. The literature further explored in-depth, and identified, issues relating to the construction industry. Moreover, the research investigated the literature of the current construction industry and its allied problems. Once the problems were defined through the literature (such as the fragmented nature of the construction industry) then further investigation took place to find the causes of the problems. Classical and modern views were explored with the specific view of looking at how KM contributes in CSCs to resolve the previously mentioned problems.

Furthermore, this research developed the proposed framework to transfer and share tacit knowledge in CSCs in the context of Lean and Agile processes. To validate the framework this research was required to self-collect/produce its own data while adopting a robust data collection technique to validate the framework. The self-collect data technique used purposive sampling as discussed below.

3.1.5.1 Data Collection Techniques

This section explains the data collection techniques employed for this research. The research techniques form the framework of the entire research process (Malhotra, 1990). A good data collection technique is critical to ensuring that the information obtained is relevant to the research objectives and obtained by economic procedures (Chisnall, 2001). The data collection technique explains the numerous techniques adopted which includes sampling techniques, data collection instruments/techniques and the data analysis and presentation. (See chapter (4) for an in-depth discussion on data collection techniques and procedures.)

Table 3-1: Research Techniques

Research Objectives	**Research Questions & Hypothesis**	**Methodology & Data Collection Methods**				
		1	***2***	***3***	***4***	***5***
To critically review the concepts of Knowledge Management, Supply Chain Management and Lean and Agile processes in general and, specifically, within the area of Construction Supply Chains	None	***X***	***X***	-	-	***X***
To examine the contribution of Tacit Knowledge in the application of Lean and Agile principles within Construction Supply Chains	What are the main contributions of tacit knowledge in the application of lean and agile principles within construction supply chains?	***X***	***X***	***X***	***X***	***X***
To investigate and document the challenges associated with the effective Transfer and Sharing of Tacit Knowledge through the application of Lean and Agile principles in Construction Supply Chains	What are the challenges associated with the effective transfer and share of tacit knowledge through the application of lean and agile principles in construction supply chains?	***X***	***X***	***X***	***X***	***X***
To identify the critical success factors associated with the effective Transfer and Sharing of Tacit Knowledge in Construction Supply Chains through the application of Lean and Agile principles.	What are critical success factors associated with the effective transfer and share of tacit knowledge in construction supply chains through the application of lean and agile principles?	***X***	***X***	***X***	***X***	***X***
To develop and validate a framework that improves the level of efficiency in Construction Supply Chains.	If the Knowledge Communication framework is considered in Lean and Agile processes it will improve the level of efficiency in Construction Supply Chains	***X***	***X***	***X***	***X***	***X***
***Key: 1 Literature review. 2 Secondary Data. 3 Questionnaire. 4: Face-to -Face Interviews. 5 Archives**		***OBSERVATION***				

3.1.6 Research Philosophies

Pearson’s Web Dictionary (2013) defines research philosophy as an “overarching term relating to the development of knowledge and the nature of that knowledge in relation to research.” The research philosophy refers to the systematic search for existence, knowledge, values, reason, mind, and language. This research requires an open mind in order to establish facts from both new and existing knowledge. However, research and philosophy both have their own definitions.

The WordWeb dictionary provides the following definition “Research is a logical investigation to establish facts” and Philosophy is “The realistic investigation of questions about existence and knowledge and ethics”

Based on other definitions, this study clarifies research philosophy as a systematic, organised and rational investigation of finding answers to questions, to establish facts about the existence of knowledge. See table 3-2 below for the reasoning behind terminologies used in research philosophy.

Table 3-2: Reasoning behind Terminologies used in Research Philosophy

Terminologies	Reasoning of terminologies used
Systematic	Because there is a definite set of procedures and steps which a researcher will follow and there are certain things in the research process that execute the most accurate results.
Organised	This is because there is always a structured approach to undertaking research. It is a planned procedure which focuses on, and limits to, a specific scope.
Finding Answers	Because answers are the end of all research, whether it is an answer to a hypothesis or even a simple question. Research aims to find an answer where it does not matter if answer is positive or negative.
Questions	This is because the research focuses on relevant, useful and important questions. Without a question, research has no focus, drive or purpose.
Rational	This is because the research questions are based on the quality of being consistent with or are based on logic or reasoning and guided by the intellect (as distinguished from experience or emotion)
Investigation	This is because the questions raise an inquiry into unfamiliar or questionable activities in order to study and try to understand the facts behind the reasoning.

It is essential for a researcher to recognise that the choice of the philosophy adopted can provide a means of underpinning the research strategy (Pathirage et. al., 2008).

The choice of philosophy assists in adopting an approach and a strategy. Saunders et al. (2009) encouraged two major ways of thinking about research philosophy, ‘ontology and epistemology’. In epistemology (theory of knowledge), the interest is in discussions on what and how people can know things, and what kind of knowledge is the right knowledge. In ontology, the interests are in discussions on what reality is and what kinds of phenomena are real. Johnson and Clark (2006) argued that the important issue is not so much, whether the research is philosophically informed, but how well it reflects upon philosophical choices.

3.1.7 Philosophical choice

For new theoretical insights into KM in CSCs in the context of lean and agile principles, this research leans towards interpretivism (see Figure *3-4*). The constructive position is adopted as a position as the ontological and axiological position is leaning more towards value (Bias) laden, as established through KDRM model.

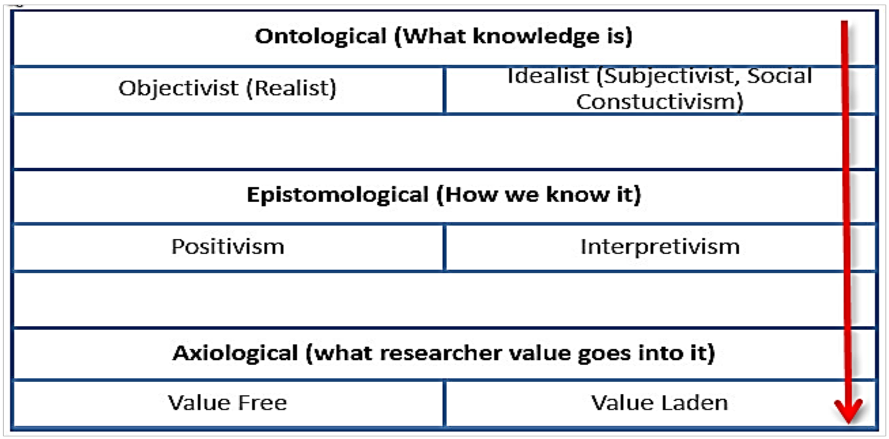


Figure 3-4: The philosophical stance of this research

3.1.8 Ontology, Epistemology, Axiology

The epistemological, ontological and axiological assumptions and undertakings guide an inquiry in a research study, implicitly or explicitly (Denscombe, 2007). In general, epistemology describes ‘how we know’ the reality and assumptions about how knowledge should be acquired and accepted. Ontology explains ‘what knowledge is’ and assumptions about reality. Axiology reveals assumptions about the value system. These epistemological undertakings, ontological assumptions and axiological purposes about the nature of the world complement the formulation of the research philosophy, thereby influencing the selection of the appropriate research approach and methods. In terms of epistemological undertakings, two fundamentally different and competing schools of thoughts are positivism and social-constructionism, these are two extreme ends of a continuum. Gill and Johnson (2002) argued that the deductive approach to research has become synonymous with positivism, whilst the inductive approach has become synonymous with social constructionism. Burrell & Morgan (1979) have presented three main debates in philosophical assumptions.

1. Is reality given or a product of the mind? (Ontological)
2. Must one experience something to understand it? (Epistemological)
3. Do humans have "free will", or does their environment determine them? (Axiological)

Ontological Assumptions

WordWeb Dictionary defines Ontology as representing the metaphysical study of the nature of being and existence. Assumptions are the hypothesis or statement that is assumed as true and from which the conclusion is drawn. In ontological assumption, objectivism and subjectivism describe continuum polar opposites with varying philosophical positions aligned between them (Creswell, 2013). It enables a researcher to claim about what knowledge is and how it is being constructed (Creswell, 2013).

In addition to the earlier assumptions made through implementing the KDRM model, as this research involves the study of complex interactions between people (Main contractor, Sub-contractors, Consultants; see chapter 4) and processes (Lean and Agile and SC), the ontological stance of this research leans towards constructivism because the understanding of the real world (in CSCs and Lean and Agile processes) changes in each organisation and the knowledge is constructed socially (Descartes, Aristotelian, Nonaka & Taguchi, Senge and Devenport; chapter 2.3.10) over time. The other reason for choosing idealism is that there can be multiple realities within organisations/participants which have different schools of thought (see chapter 2.3.7) on each terminology of knowledge, CSC and Lean and Agile processes.

Epistemological assumptions

The Merriam-Webster Dictionary defines epistemology as “the study or a theory of the nature and grounds of knowledge, especially concerning its limits and validity.” The Stanford Encyclopaedia of Philosophy defines epistemology as “the study of knowledge and justified belief”. The Oxford Dictionary defines it as “the theory of knowledge, especially with regard to its methods, validity, and scope, and the distinction between justified belief and opinion.” Since there are many definitions of epistemology, the most predominant definition is “the philosophical theory of knowledge”.

Epistemology attempts to answer the basic question: what distinguishes true (adequate) knowledge from false (inadequate) knowledge (Heylighen, 1993). Burrell & Morgan (1979) gave two different views of epistemology, these are Positivism and Anti-Positivism (Interpretivism). Positivists believe that one can seek to explain and predict what happens in the social world by searching for a pattern and relationship between them. However, anti-positivism rejects the theory of positivism and argues that social science cannot create true objective knowledge of any kind. Interpretivism believes that reality is relative and various (Gettier). Based on this tradition any research could have multiple realities whereas the positivist contends that there is only one reality. Knowledge generated from the interpretivist paradigm is comprehended by socially constructed and subjective interpretations (Greener, 2008; Creswell, 2013).

Based on the assumptions made through the KDRM model (section 3.1.3 above), the interpretivist paradigm of epistemology is the justified approach for this study as it assumes that the existence of multiple realities that are socially constructed focuses on understanding behaviour rather than predicting it (Harrison & Reilly, 2011). In addition, the theory of Edmund Gettier (see 2.3) and his followers suggests that different participant organisations have distinctive views, capabilities and needs concerning knowledge in CSCs and Lean and Agile processes. Based on this, the epistemological stance leans towards ‘Interpretivism’. Some may argue that construction companies could have Techne, Phronesis and Nous (see 2.3) knowledge, even this research assumes that the knowledge is socially constructed. However, the argument here could be that knowledge such as Techne (Skill -Based technical) and Phronesis (Experimental) knowledge also changes over the time and could have multiple realities.

Axiological Assumption

WordWeb Dictionary defines axiology as “The study of values and value judgments." In a research philosophy, axiological assumptions define what value goes into the study (Creswell, 2013).

Based on the KDRM model, the axiological stance leans more towards ‘value laden’ as this research tends to solicit the opinions and experience of researchers to input their value into this research. This research analyses the different views of classical and modern scholars and found the empirical research assumes that knowledge (especially tacit knowledge) does not remain constant (Locke’s, Koieng’s and Devenport’s Perspective, see 2.3) and changes over the time. However, the view of Bacon, Hobbs and Cartesian, and later followers, contends that the creation of new knowledge is highly influenced by the experiences of a person. With that view, this research assumes that this research would have some influence from the opinions and views of others and could not be completely value free.

A researcher presents his bias while designing the research title, aim, objectives, methodology, survey questionnaire, interview questions, theory building and conclusion writing. As per the view of Bacon, Hobbs and Cartesian, it is not wrong that no social science research is bias free. To find more reasoning as to why the stance of this study is Bias Laden it is important to understand the forms and definition of 'Bias', which affects research.

Bias is a partiality that prevents the objective consideration of an issue or situation (WordWeb Dictionary). The table below analyses different definitions of bias to identify the true meaning of bias in distinct situations. Definitions given in the table below (table 3-3) originate from WordWeb, Wikipedia, and Oxford Online Dictionaries.

Table 3-3: Different forms and definitions of bias and the reasoning of the axiological stance of this study

Forms of Bias	Definition	Logical Reasoning
Bias	A concentration on, or interest in, one particular area or subject.	This study focuses on testing the hypothesis and answering the research questions while meeting the aim and objectives of this study.
Selection/Sampling Bias	Where there is an error in choosing the individuals or groups to take part in a scientific study.	Selection Bias can be possible if there is an error in the sampling techniques. It is hard to say that the sampling technique and choice of respondents are perfect for this study. There is always room for error in selecting sampling.
Spectrum Bias	Consists of evaluating the ability of a diagnostic test in a biased group, which leads to an overestimate of the sensitivity and specificity of the test.	This mainly points to medical diagnosis. In general, the diagnosis procedure involves classification techniques. In terms of research based on the experience of respondents, a survey or questionnaire could represent the over/under-estimation of the investigated phenomenon.
Bias of an estimator	The difference between an estimator's expectation and the true value of the parameter being estimated.	In research, while generalising the results of a survey or interviews, there are chances of error by which the true value of a result could be different from the outcome. Another possibility of error is the accumulation of Selection and Spectrum bias.
Statistical Hypothesis Testing	A test is said to be *unbiased* when the probability of rejecting the null hypothesis exceeds the significance level when the alternative is true *and* is less than or equal to the significance level when the null hypothesis is true.	Logically, in a constructivism / subjectivist statistical hypothesis testing, sampling the experience of the respondents is to understand and investigate multiple realities of the facts.
Systematic	External influences that may affect the accuracy of statistical measurements.	If a research seeks to generalise the results, but the survey result differs significantly, then there is always a chance of the influence of systematic bias to generalise the results with other forms of sampling such as interviews or data archives.
Data-snooping bias	Comes from the misuse of data mining techniques.	This is mainly a concern when a large number of hypotheses are tested from a single data set. This study involves several hypotheses. (See chapter 4)

Source: Original; developed from different dictionaries

3.1.9 The Research Approach

The research approach is about organising research activities, including the data collection and the data presentation techniques, in such a way that ensures that they are most likely to achieve the aims (Keraminiyage, 2009). Saunders et al. (2009) divided the research approach into two approaches, deductive and inductive. The difference between the two research approaches is that deductive is intended to test theory and inductive to build theory. The investigated phenomenon of transferring and sharing tacit knowledge within CSCs in relation to lean processes, requires the validation of the proposed framework. It is more appropriate in a qualitative study to choose participants depending on whether they are 'information rich' and relevant to the research questions (Creswell, 2008; Bryman, 2004).

3.1.10 Qualitative and Quantitative

A qualitative approach to research is likely to be associated with an inductive approach to generating theory, often using an interpretive model allowing the existence of multiple subjective perspectives and constructing knowledge rather than seeking to "find' it in 'reality" (Greener, 2008). It is based on the methodological principles of positivism and anti-positivism. This adheres to being standard for strict research design. It uses statistical analysis. A qualitative research with an interpretive model (anti-positivism) contends that there could be multiple realities of the investigated phenomenon.

A quantitative approach to research is likely to be associated with the deductive approach to testing theory, often using a number of facts and, therefore, a positivist or natural science model, and an objectivist view of the objects studied is utilised (Greener, 2008). It is based on the methodological principals of phenomenology, symbolic interactionism and the interpretive or explanatory models. It aims to explore the social world. The main elements are exploration, relationship discovery, establishing a construct, and testing a hypothesis.

3.1.10.1 Qualitative and Quantitative reasoning

This study focuses on the evaluation of the potential application of KM in CSCs in the context of Lean and Agile processes. This study employs both qualitative and quantitative research and a mixed method approach in obtaining data from respondents within numerous construction companies through in-person interviews and questionnaires. As discussed earlier, this study demands explanatory research to test the hypothesis and to explain the social relations and events in order to build a test and revise the theory. This use of an inductive approach is more suitable with quantitative research. Initially, the literature was explored to develop the hypothesis and to develop the facts that support the hypothesis which fall into exploratory research and relate to the deductive approach with the combination of quantitative research.

3.1.11 Deductive and Inductive

The deductive approach is widely used for theory testing and the inductive approach for theory building. Deduction is the dominant research mode in social sciences. In the deduction mode the basic principles present the basis of explanation and the foundation of investigation. Deductive research generally starts from exploring and establishing theories to finding the solutions to problems. Deductive research necessitates the development of theoretical structure prior to engaging in empirical observation.

Robson (2002) gave five stages of deductive theories; this explains the way a deductive research conducts its stages. Firstly, the researcher should deduce the hypothesis of the research from the literature review. The second stage is to express the hypothesis in operational terms. The third stage is testing the operational term while adopting the research techniques which may consist of a variety of research methods, tools and techniques to validate the research operational hypothesis. The fourth stage is to measure the outcome of a specific hypothesis to fulfil the research aim and objectives. The last stage, the theory, is to modify and build the theory as per the outcome of the data analysis.

The inductive process works in the opposite way to the deductive process, moving from specific observations to broader generalisations and theories. In the inductive approach, the researcher begins with specific observations and measures. Afterwards, he/she detects patterns and regularities, formulates some tentative hypotheses to explore and, finally, ends up developing some general conclusions or theories.

Logically, in the beginning, this research leans towards the deductive process as it generates a hypothesis from theories and expresses these in operational terms. Later, it develops a framework to transfer tacit knowledge in CSCs in the context of Lean processes. Furthermore, this research examines the validation of the proposed framework and collects qualitative data to validate the phenomenon.

3.1.11.1 Deductive and Inductive Reasoning

As discussed above, a deductive approach begins by looking at theory, produces hypotheses from that theory (Robson, 2002) which relate to the focus of the research, and then proceeds to test that theory. That is not the only way to use theory in research. An inductive approach starts by looking at the focus of research (the organisation, a business problem, an economic issue etc.) and through that investigation by various research methods, aims to generate theory from the research (Greener 2008). In this study, initially the problems relating to the construction sector and the economic issues of the UK construction sector have been investigated to bring forward the problem statement for this research. Afterwards, different perspectives of KM, Knowledge, Lean and Agile principles and processes have been investigated from the theory with the aim of developing a conceptual framework while deducing a hypothesis, and expressing the hypothesis in operational terms.

3.1.12 Research Strategies

The research strategy brings the focus to the research approach. A research strategy refers to the ways in which to conduct the research. A range of strategies are available. Saunders et al. (2009) argued that no research strategy is superior or inferior to any other. The research question and the objectives drive research strategy and are mutually exclusive. Saunders et al. (2009) and Denscombe (2007) gave strategies for social research namely, Surveys, Case studies, Experiments, Ethnography, Phenomenology, Grounded theory, mixed methods and Action research.

3.1.12.1 Surveys

A survey is a considered an appropriate method for this study. This study requires the collection of data from multiple persons to investigate their understanding to fulfil the objectives. This gives a better insight then the case study method as the case study method does not allow the capturing of the perceptions of individuals.

3.1.12.2 Case studies

Adopting a case study is not suitable for this research as this study requires the investigation of socially constructed knowledge and beliefs to have multiple realities. Moreover, a case study method requires analysis of one to several cases that are unique with respect to the research topic (Patton, 2005). In this study, there are no cases to observe. This makes is an unsuitable strategy to adopt for this study.

3.1.12.3 Experiments

Experimental research is an objective, systematic and controlled investigation for predicting and examining probability and causality among chosen variables (Johansson, 2003). Experimental research is more suitable for investigating cause and error and examining the probability and causality among selected variables. Therefore, this study does not require experiments.

3.1.12.4 Ethnography

Testing a hypothesis for this study does not require the exploration of a culture phenomenon. Instead of social science research, ethnography is pioneered in the biological, social and cultural research (Denscombe, 2007). Therefore, the questions and observations relate to social and cultural processes and shared meanings within a given group of people (Patton, 2005). Thus, ethnography is not a suitable strategy for this study.

3.1.12.5 Phenomenology

As an approach to social research, phenomenology presents as an alternative to positivism (Denscombe, 2007). As a direct contrast to positivism, it is an approach that is reinforced by the fact that it generally deals with people’s attitudes, beliefs, feelings and emotions. It leans towards the description rather than analysis (Patton, 2005). This is a commonly used approach in clinical psychology.

3.1.12.6 Grounded theory

The primary stage of this study adopts grounded theory with the deductive approach to establish the research hypothesis. However, studies generally, grounded theory is a common analytical approach for qualitative studies (Denscombe, 2007; Patton, 2005). It gives an opportunity to understand currency in research concepts. Even so, this approach does not lend itself to precise planning for a whole study (Denscombe, 2007).

3.1.12.7 Mixed Methods

A mixed method approach is one in which the researcher collects, analyses, and integrates both quantitative and qualitative data in a single study or in multiple studies in a sustained programme of inquiry (Creswell, 2013). Researchers can improve their confidence in the accuracy of their findings using different methods to investigate the same subject (Denscombe, 2007). With the principles of triangulation the mixed method approach would be the most appropriate method for this research because testing the research hypothesis demands a mixture of Deductive and Inductive approaches to confirm existing theory and then to analyse the social constructivism and to develop a theory. This also gives the opportunity to check the findings from one method against another to analyse the findings and generalise the different views (Denscombe, 2007). The study employs surveys (Quantitative) and in-person interviews (Qualitative) to answer the research questions. The questions target a limited number of events or conditions and their inter-relationships. The mixed method approach requires a mixed methodology of qualitative and quantitative research. This provides the opportunity for theoretical research and the testing of the conceptual framework. The mixed research technique (surveys and interviews) gives the opportunity to conclude with a better generalisation of results.

The adoption of the mixed methods approach in this research is in order to collect the qualitative data (Survey) to generalise the results, and the quantitative data (Interviews) to validate the quantitative data or vice-versa. It will bring about two main objectives, firstly, to validate the findings in terms of accuracy and, secondly, to check the bias in the research methods (Denscombe, 2007).

3.1.12.8 Action Research

Action research is an application of fact-findings to practical problem solving in a social situation with a view to improving the quality of action within it (Koshy, 2005). This requires the collaboration and cooperation of others (Denscombe, 2007). It can be situational research in which the researcher takes part in the implementation of the findings, and constantly evaluates and adjusts the research and practice.

The testing of a hypothesis for this study does not demand the researcher to solve any practical problems while being involved in the situation and taking part in the implementation of the research in practice. Based on this reason this study is unsuitable for action research.

3.1.13 Research Choices

As established, this research adopts the mixed methods' approach, utilising quantitative and qualitative collection techniques and analysis procedures. Tashakkori and Teddlie (2003) argued that various methods are useful as they provide better opportunities to explore research questions and evaluate the extent to which research findings can be trusted, and inferences made.

A mixed method approach is one in which the researcher collects, analyses, and integrates both quantitative and qualitative data in a single study (Creswell, 2003). Such a combined method would be the most appropriate method for this research because the research aim and objectives demand a mixture of Deductive and Inductive approaches to confirm existing theory and then to analyse the findings through quantitative and qualitative data analysis and to develop a theory.

The mixed method approach requires a blended methodology of qualitative and quantitative research. This gives an opportunity for theoretical research and for testing the conceptual framework. Moreover, the mixed research technique (questionnaire and interviews) gives the opportunity to analyse the findings utilising multi-dimensions. In addition, this provides a stronger argument for generalising the results.

3.1.14 Time Horizons

Time horizons consider the influence and the limitation of time on any research approach. Easterby-Smith et al. (2002) highlighted two types of research approaches based on their focus on the timeline.

- Cross sectional studies
- Longitudinal studies

The focus of a cross-sectional study is not primarily temporal change, but on the qualities, features, conditions and appearances of the phenomenon at a chosen point in time. This research focuses on how the phenomenon infuses various social circumstances for the chosen methods of analysis for this research. Whilst that is the case with cross-sectional studies, a longitudinal study seeks to explore and explain change and development over a lengthy period (i.e. years). The basis for a longitudinal research strategy is that the researcher reviews a phenomenon, observing any changes in it and analyses the factors influencing the change or the consequences of the change over a long period of time (Creswell, 2013).

This research seeks to develop a framework to transfer and share tacit knowledge in CSCs. This requires studying the tools and techniques and supporting factors for transferring and sharing Tacit Knowledge. Furthermore, it requires fulfilling the research objectives while exploring the literature on CSCs, Lean and Agile processes over the period of the study. As the study's emphasis is on concepts and theories, this does not require a long period for their consideration. The investigation into the findings does not demand longitudinal studies but favours cross-sectional studies. However, at some points, the study adopts a longitudinal approach such as during the framework validation through the questionnaire first and then via the interviews.

3.1.15 The Unit of Analysis

The outcome of the phenomenon being investigated is based on the unit-of-analysis (UoA) that is chosen. The main unit of analysis in this study is the organisations in the UK Construction industry, secondly, the higher management within those companies and, thirdly, their middle management such as lean managers, knowledge managers and workers who contribute to the lean and agile construction projects. The reason for choosing a wide range of UoA is the multi-organisational setup of a CSC. Moreover, this also requires understanding and analysing the respondents' perception on the transfer and sharing of tacit knowledge within CSCs. Below is a list of the initially selected UoA within the CSC.

- Higher Management including Designers, Architects, Consultants and Contractors

- Lean, Supply Chain and Knowledge Managers
- Managers, Supervisors, Team Leaders

The choice of the UoA, the recruitment of respondents and the strategy for the data collection are further explored and discussed in chapter 4 in greater depth.

3.1.16 Research Process

This study adopted a systematic research process as exhibited in the figure below (figure 3-5: the research process). This figure shows, at the preliminary stage the aim and objectives of this study, the literature and data from the Department of Business Innovation and Skills (BIS), Her Majesty's Revenue and Customs (HMRC), Her Majesty's Government (HM Govt) and the Office of National Statistics (ONS), and literature from the UK construction industry which are reviewed to identify the problems existing in CSCs. Through this study, five objectives (see 1.1.3) are drawn.

Afterwards, as shown in the sub-process within figure 3-5, an in-depth literature review was conducted to fulfil the objectives and to develop the conceptual framework to initiate the Transfer and Sharing of Tacit Knowledge in CSCs. Based on the outcomes of the literature review undertaken for this study, a novel Knowledge Driven Research Methodology (KDRM) Model was developed. This drove this study to fulfil the aim and objectives. The adoption of KDRM Model also drove the choice of research strategies, approach, methods and data collection and analysis tools and techniques based on the research objectives.

This study demanded a mixed method approach via the choice of a survey questionnaire (quantitative) and expert interviews (qualitative) to collect data to validate the findings from the literature and the conceptual framework. The study further established the target population, the recruitment of respondents based on the external data (BIS, ONS) and the literature analysis. Moreover, quantitative data is analysed in SPSS. Based on the nature of the data (Ordinal Scale, Non-parametric) data analysis tools were employed (see chapter 4). These were Cronbach's Alpha (reliability analysis), Frequency analysis (descriptive) and the Kruskal-Wallis H test (Non-parametric). This helped to test the hypothesis for each variable via boxplot summary and asymptotic significance and Spearman's Correlation (Correlate) analysis to identify the correlation significance among the variables. However, employing these tools was not sufficient for this study because of testing the findings from different disciplines. In that situation, interpretive correlation rank-order analysis was employed to draw the assumptions and generalise the results for further study. The conceptual framework was modified through the findings. Those findings were further analysed and validated through the qualitative data. To validate the findings from the literature review this study employed experts from a construction background for semi-structured interviews. The data collected was analysed through interpretive analysis and the results were generalised to validate the framework. Finally, the framework was modified and the conclusions and recommendations were drawn.

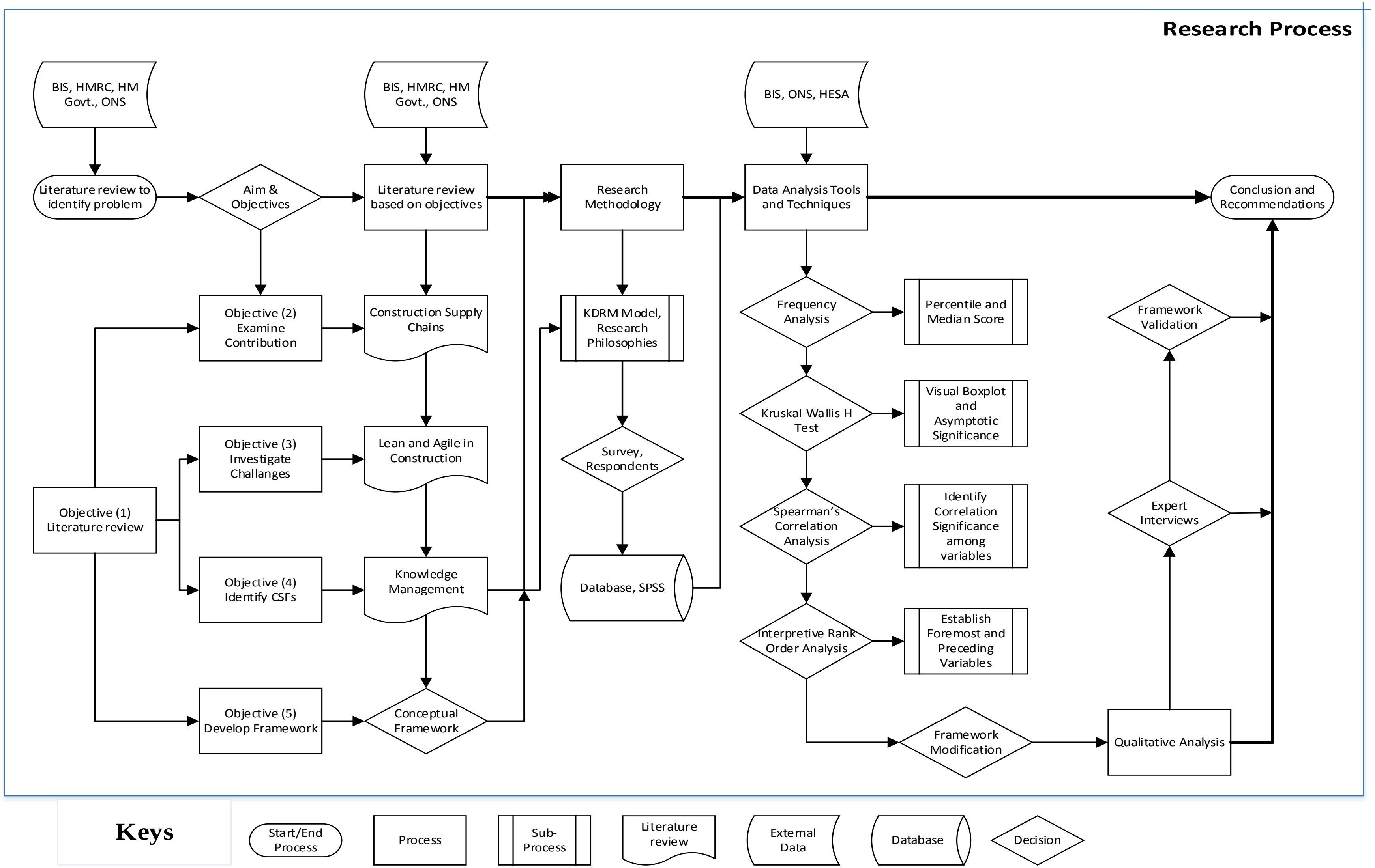


Figure 3-5: The Research Process

3.1.17 Summary

This chapter critically analyses existing research methodological models to develop a robust research methodology for this study. This study develops and employs a KDRM model that helps to establish an appropriate research methodological framework to fulfil the objectives of this research. With the help of the KDRM model, the unit of analysis (see 3.1.15) and the target population (see, chapter 4) were established. Furthermore, the research strategies (see, 3.1.12), survey e-questionnaire and semi-structured interviews, were chosen to collect data from respondents. Afterwards, data analysis tools and techniques were established to analyse the qualitative and quantitative data. In the next chapter (4) data collection tools and techniques are discussed in-depth to identify the UoA, the target population, the questionnaire design and to establish the tools and techniques chosen for the data analysis.

The major findings from this chapter are as follows.

- Both the Nested model and Research Onion methodological frameworks fail to provide the opportunity to drive a research methodology through the research objectives and/or research questions.
- The KDRM model brings the opportunity to establish a research methodological framework driven by the research objectives and/or the research questions.
- This study establishes that no social science research is bias free. This chapter also presents seven different types of researcher’s bias that can influence research.
- A combination of quantitative and qualitative data collection is the most appropriate approach for this study to validate the conceptual framework through different dimensions.
- This study employs the deductive approach to investigate the literature and establish Lean, Agile and SC principles. This also brings forward the challenges and CSFs associated with the effective transfer and sharing of Tacit Knowledge. Furthermore, this study employs an inductive approach to build theory in order to validate the conceptual framework and to generalise the results of the data analysis.

Chapter 4. DATA ANALYSIS: SCOPE AND STRATEGY

4.1 Introduction

This chapter focuses on the design of the survey questionnaire and the interview questions. The purpose of this section is to consider all the aspects of the data collection, questionnaire design and the data analysis.

Firstly, this chapter explores the research strategy chosen for data collection in chapter 3. It considers a measured planning for the data collection and defines the potential difficulties in data collection. Moreover, this chapter reviews the literature and statistics from ONS (2014), HM Government (2014) and BIS (2014) to define the size of the target population. Additionally, this chapter provides the reasoning for the chosen strategy. In addition, this chapter answers the questions below to establish the facts of the data collection strategy.

1. What is the scope of this research?
2. Who can answer the questions?
3. How big is the population of the prospective respondents in this research?
4. What are the potential difficulties in collecting the data from the construction sector?
5. How many responses are required for undertaking the data analysis for this research?

Secondly, this chapter critically discusses the questionnaire design going through each question and its variables. It also establishes and discusses the purpose of asking each question and its variable. Moreover, this chapter defines and critically analyses the data analysis tools and techniques.

4.2 What is the refined scope of research to recruit respondents?

As discussed earlier under the heading 2.2 (The UK Construction Sector) of chapter 2, this research focuses on Construction Supply Chains. A construction supply chain is a complex and multi-organisational supply chain in which there can be more than 100 suppliers as a mixture of Tier (1), Tier (2), and Tier (3) and so on. The member of a construction supply chain as presented by RICS (2011) is shown below in Figure 4-1 and, recently, HM Government (2014) released a “Construction Sector Infographic (see Figure 4-2 below) based on this. The UK construction industry employs 2.9 million people.

In a construction supply chain, project management, main contractors and finance staff play the foremost roles. According to RICS (2011), architects, quantity surveyors, structural engineers and M & E engineers follow project managers; consequently, the project manager is responsible for them. Moreover, sub-contractors follow main contractors. Additionally, component manufacturers follow sub-contractors and, down the line, raw material suppliers follow them. The objectives of this research demand the recruitment of respondents based on the facts below.

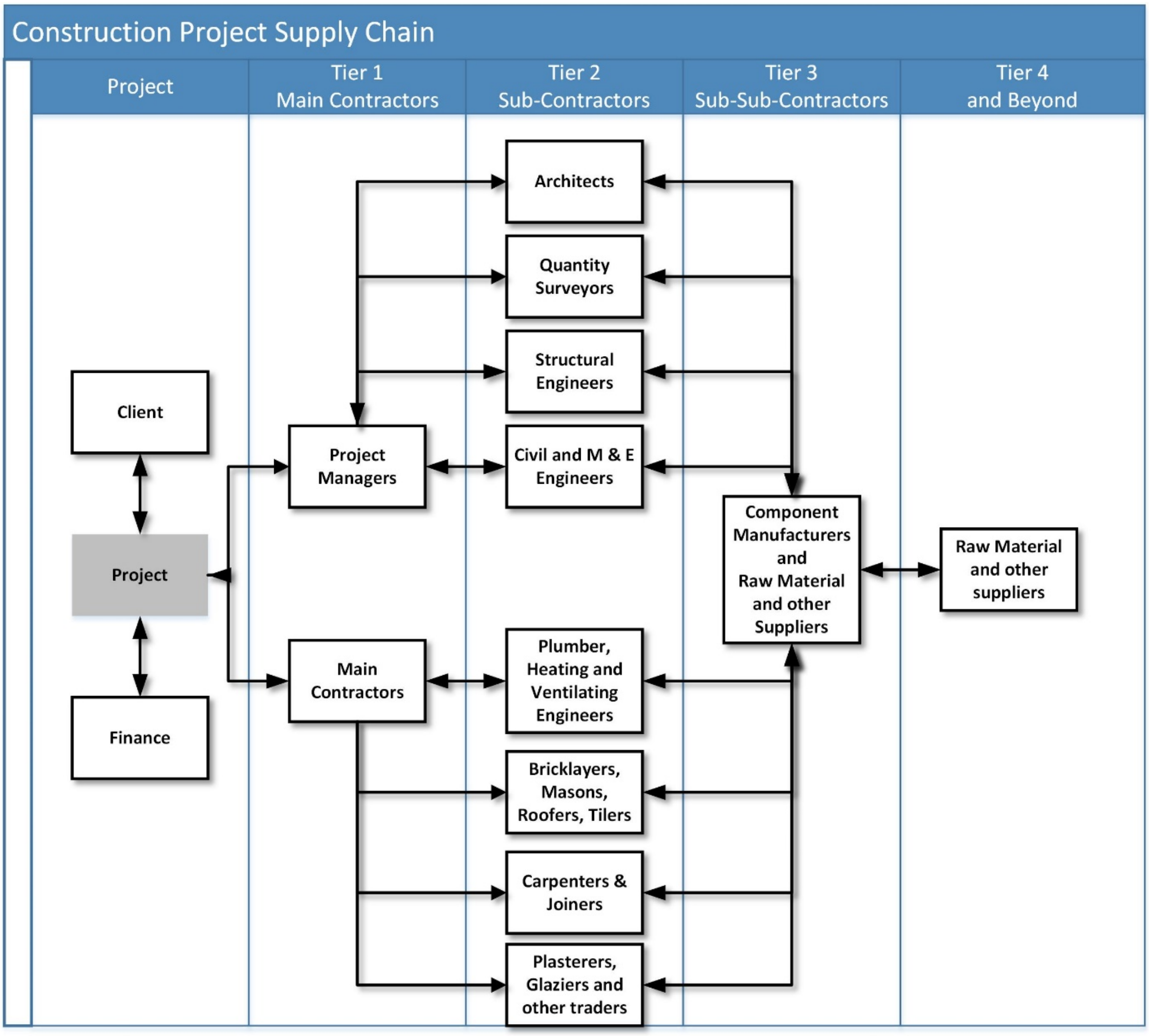


Figure 4-1 Levels within the Construction Project Supply Chain

Source: Developed from BIS (2013), RICS (2011), and H M Government (2014)

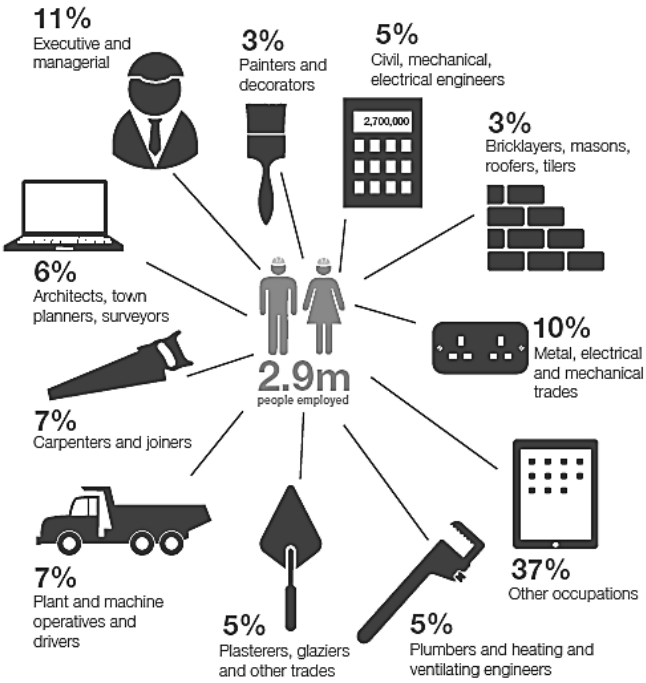


Figure 4-2: Breakdown of the nature of businesses within the construction sector

Source: H M Government (2014)

Table 4-1 below represents the total employment within the construction industry. This is based on above infographic by HM Government (2014) and the RICS Construction supply chain (2011).

Table 4-1 The Construction Industry's Employment Size based on Supply Chain Tiers

Construction Organisations				Employment Size
	Tier 1	Tier 2	Tier 3	
Client/end user				
	Project Managers			
		Executive and Managerial Staff		11%
		Civil, Structural, Mechanical and Electrical Engineer		5%
		Architects, Town Planners and Surveyors		6%
	Main Contractors			
		Carpenters and Joiners		7%
		Plasterers, Glaziers and other trades		5%
		Plumbers and Heating and Ventilating Engineers		5%
		Metal, Electrical and Mechanical Traders		10%
		Bricklayers, Masons, Roofers and Tilers		3%
		Painters and Decorators		3%
		Plant and Machine Operatives and Drivers		7%
		Sub-Contractors		
			Component Manufacturers and Raw Material Suppliers	37%
	Unknown/mixed			1%
Total				100%

Source: HM Government (2014)

Table 4-2 Direct and Indirect Stakeholders of a Construction Project

Stakeholders Classification		Reference
Direct	Indirect	
Client/s	Internal Managers of Organisations involved	DBL (2014), Malkat and Byung (2013) and Barron and Barron (2009)
Project Sponsor/s	Support staff	
Project Managers	National & Local Government	
Project team	Public Utilities	
Material and Equipment Suppliers	Licencing and Inspecting Organisations	
Consultants	Technical Institutions	
Site Personnel	Professional Bodies	
Main Contractors	Personal Interest Groups	
Sub-Contractors		

Source: DBL (2014), Malkat and Byung (2013), Barron and Barron (2009)

Table 4-2 has been developed based on the studies by DBL (2014), Malkat and Byung (2013), Barron and Barron (2009). Based on this analysis, clients, consultants, project managers, project teams and main contractors bring a high level of influence into a construction project, throughout its lifecycle (Malkat and Byung, 2013).

Tables 4-1 and 4-2 exhibit the breakdown of the construction supply chain amongst Tiers (1), (2) and (3). In this study, the main contractors with a first-hand commercial relationship with the client are termed Tier (1). Sub-contractors and suppliers with a direct contract with the Tier (1) main contractor are termed Tier (2). Sub-contractors and suppliers working for the sub-contractors are termed Tier (3). The Tier (3) sub-contractors also employ suppliers and sub-contractors so, in many cases, there will be a fourth or even a fifth tier involved in construction delivery. However, this study does not focus beyond the Tier (2) level because of the facts below which is connected to the research objectives.

1. This study focuses on the application and contribution of tacit knowledge in CSCs and in Lean and Agile construction processes. Therefore, this study requires respondents who have Knowledge and/or understanding of all four disciplines (Knowledge management, Lean, Agile and construction supply chain processes). This restricts the study to utilising respondents who are directly involved in the KM, Lean, Agile and SC Processes, and which fall within and below Tier (2) of CSCs.
2. In construction, supply chain members beyond Tier (2) normally do not become involved in implementing Lean and Agile within the construction process. Beyond Tier (2) the manufacturers and suppliers are the direct supply chain of sub-contractors and may not ever be involved as direct stakeholders in a construction project (see Table 4-2).
3. Based on the literature review and reports from BIS (2013), RICS (2014) and HM Government (2014), only the project managers, main contractors and sub-contractors who are working on the construction site are the organisations and individuals who have direct involvement in the planning and execution of the construction process.
4. Due to the fragmented nature of the construction industry and the lack of skills in Tier (3) contractors, manufacturers and raw material suppliers, this study is restricted to utilising respondents in the supply-chain level Tier (2).

As this study is restricted to Tier (2) of the CSC, the big question that arises here is how many respondents are needed for this study? The three (3) questions are asked to identify the target population for this study.

1. Who can answer the questions asked in the survey?
2. How big is the population of the prospective respondents?
3. How many fully completed responses are required for data analysis?

In answer to these questions, this research focuses on Tier (2) of the construction supply chain and within the CSC, the respondents must have understanding and/or experience of the application of (1) Lean, (2) Agile, (3) Knowledge Management (specifically Transferring and Sharing Tacit Knowledge) and (4) the Construction Supply Chain.

The numbers employed within the UK construction industry is about 2.9m and, among them, 11% are Construction Managers, Directors and Executives (BIS, 2014). Now the question is, out of those 11%, how many individuals would have experience or understanding of working with Lean, Agile, Construction supply-chain Management and KM, all four of those disciplines?

4.3 Who can answer the questions asked in the survey?

This study aims to recruit project managers, executives, consultants, and other managers that are directly involved in the management of a construction project at every stage. Secondly, to fit the purpose of this research, the respondents must have background knowledge of, and experience in, disciplines such as Lean Construction, Agile Construction, the CSC and Knowledge Management in Lean, Agile and CSCs.

4.4 How big is the population of prospective respondents?

Tier (2) of the CSC involves respondents such as Construction Managers, Directors and Executives. These are 11% of the total employment (2.9m) of the construction sector. This gives a target population size of 319,000 (11% of 2.9m = 319k). However, the main question that arise here is, out of 319k individuals, how many of them would have background knowledge or experience or understanding of all four disciplines such as Lean Construction, Agile Construction, CSCs, and KM in Lean, Agile and CSCs?

Based on the facts drawn from above discussion, there is a high possibility that finding respondents from such a background and experience could be difficult. There is no such data available to reveals the numbers concerned.

This necessitates the need for asking the view of industry experts on this question. The question below was asked on social media groups such as those linked to CIOB and Lean Construction Management.

"In your view, how many individuals (managers, consultants and executives) involved in UK construction projects would have collective Knowledge and/or understanding and/or experience of Lean, Agile, Supply Chains and Knowledge Management?"

Just a few responses were received, which revealed the possibility that merely a tiny proportion that is less than < 1% individuals, would have such experience (*see appendix 4.2*). Based on this, less than <1% of 319k (Construction Managers, Directors and Executives) would mean that much less than 3,190 respondents could be a target population for this research.

However, population size is not the only hurdle in the obtaining of rich data from the construction sector. Due to relatively limited resources available to researchers, large sample sizes become difficult to obtain from the construction industry. On the other hand, low sample sizes cast threatening uncertainties and raise questions on the strength of data collected (Root & Blismas, 2003). To define those limitations, the first assumption is that the employees in the construction sector receive a vast number of questionnaire requests.

4.5 What are the potential limitations in collecting data from construction sector?

4.5.1 Number of Researchers vs. Number of Employees in the Construction Sector

A comparison between the number of researchers and the number of employees in the construction sector is made to establish the facts and the reasons for the difficulties faced by researchers in obtaining large amounts of data from the construction industry. The assumption here is that the individuals working within the construction sector receive a large number of questionnaire requests from students. Answering those questionnaires is time consuming. Therefore, the respondents ignore such questionnaires' requests. To establish the assumption this study obtained and investigated the data from the Department of Business Innovation and Skills (BIS), the Office of National Statistics (ONS) and the Higher Education Statistics Agency (HESA).

4.5.2 Number of Employees in the Construction Sector

As revealed by BIS (2014), the employment size of the UK construction sector is about 2.9m in the year 2013. The figure below (figure 4-3) displays the construction sector's employment size since 2010 and its trend. The statistics are based upon the data obtained from ONS and BIS (*see appendix 4.3*).

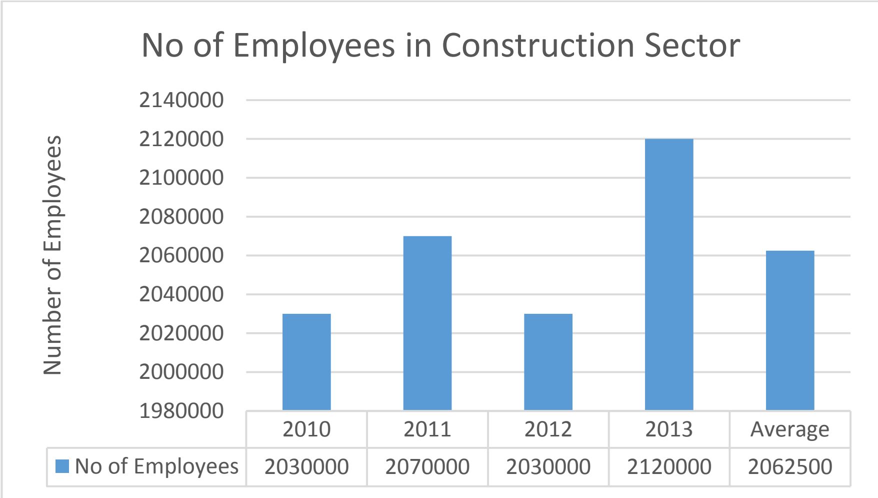


Figure 4-3: Number of employees in construction sector since 2010.

Reference: Based on data obtained from ONS (2014), BIS (2014)

The data analysis reveals that the average number of employees in the construction sector is 206, 2500 units in the last four years. The statistics consist of the number of employees based in the Main Trades (Construction of Buildings, Civil Engineering) and Specialist Trades (Specialised construction activities).

4.5.3 Number of Students in the Construction Sector

The data regarding the number of students was obtained from HESA in 2014 (see appendix 4.4). Based on this data, the analysis below was undertaken and figure 4-4 ws generated to display the number of students (Undergraduate and Post Graduate) studying Architecture, Building and Planning in the last four years.

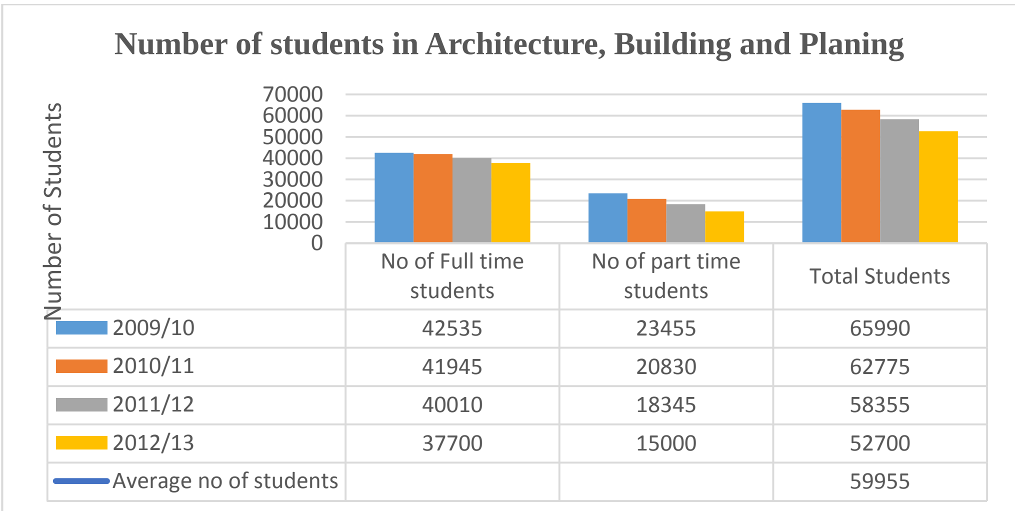


Figure 4-4: Number of students in Architecture, Building and Planning

Source: developed from data obtained from HESA (2014)

The data reveals that an average of the total number of students studying Architecture, Building and Planning is 59,955 over the last four years. However, the question is, on average how many questionnaires does a researcher send to collect data from the construction sector? It is difficult to answer this question as every researcher has different needs based upon the nature of their research, the nature of the questions and the method of application (Root & Blismas, 2003). Defining the actual number of the questionnaires sent is also based on the method of sending questionnaire such as, in-person, postal, email or a web-based survey. This, moreover, depends on the level of study as well, such as undergraduate or postgraduate because, postgraduate study may requires a larger set of responses than those for undergraduates.

However, there is no literature available to investigate this question. Therefore, to answer this question a logical interpretation is used to reveal the minimum size of a population that should be targeted by a researcher.

4.5.4 Interpretation about the target population in the construction sector vs. the number of questionnaires received.

Literature on the survey questionnaire by Hannan & Anderson (2007) reveals that a minimum number of 30 responses is required to undertake statistical analysis. However, the number of responses required also depends upon the type of statistical analysis to be conducted. Some recent researchers, from the years 2010 to 2013, revealed the survey questionnaire response rate from the construction industry is 6.5% to 45%. Therefore, on average, the response rate from the construction industry is about 25.75%. Based on this response rate, if a researcher requires a minimum 30 responses, then at least 120 questionnaires need to be sent based on 95% confidence level and 5% margin of error.

Logically, if a student sends a minimum of 120 units of questionnaires, then an average of the total number of students (59,955 units) sends (59,955 x 120 = 7,194,600) about 7,194,600 units of questionnaires in a year targeting the average population of 2,062,500 units of individuals in the construction industry. In this case, respondents in the construction sector receives an average of (7194600 / 2062500) = 3.488 questionnaires every year. However, these figures are calculated on the lowest requirement of 30 responses for a statistical analysis.

The lowest demand of many statistical analyses is about 100 responses. Again, the ideal numbers of responses are based upon the nature of study.

On the other hand, in the UK construction sector 99% of organisations are small and medium-scale organisations and 80% of them only employ only one or two employees (HM Government, 2014; ONS, 2014). As discussed earlier in chapter 2, the UK construction SMEs are facing a skill shortage (Egan, Latham, Wolstenholme reports and further BIS, H M Government reports) and do not, generally, hold an understanding and knowledge of concepts and their implementation. The result is that this analysis assumes that there is high possibility that the main targets of students' questions are the rest, namely the 20% of employees who can actually answer their questions.

Based on this, if researchers target only 20% of employees in the construction sector, this means they are targeting (2062500 x 20%) = 412,500 units of employees with a set of 7,194,600 questionnaires. Having said that, each employee (among the 20%) would receive (7194600 / 412500) = 17.44 questionnaires in a year. This is based on the lowest requirement of 30 responses for statistical analysis. Other factors which increase the number of approaches requesting participation for research are listed below.

- Mixed method approach used by students (questionnaire and interviews)
- Surveys conducted by government agencies
- Surveys conducted by research groups and institutes
- Surveys conducted by students and institutions from outside the UK

Based on the facts discussed above, the first section of the questionnaire contains five general questions which restricts respondents to only answering the questions if they are suitable respondents for this research. The questions and reasoning behind asking them these questions is given below.

4.6 Questionnaire Design and Purpose

This section discusses the survey questionnaire design. Furthermore, it critically analyses each question and its variables. Moreover, this section reveals and establishes the reasoning behind the design of each question by asking the questions listed below.

- What is the purpose of asking the question and its variables?
- What is the linkage with the research objectives?
- What is the linkage of the question asked with the literature review?
- What is the hypothesis of the question and its variables?
- What type of data is to be collected?
- What type of data analysis technique is to be adopted?

4.6.1 Breakdown of Questionnaire and Reasoning

The questionnaire has been divided into six parts (see appendix 4.1), based on the research questions, to generalise the context-specific results to meet the objectives of this research. In each part of the questionnaire, there are about two (2) to three (3) multiple-choice questions. Out of the six (6) parts, the first part (A) has five (5) general questions focused on identifying the background of the respondents, to ensure the distribution of the questionnaire within the CSC and to understand the correlation between the respondents and the variables of other questions.

The reason for dividing up the questionnaire is to consider each research objective and to get the answers from the most relevant respondents. The general Part (A) of the questionnaire is designed to get the decisive data to generalise the results with other questions and their variables in following Parts B to F. Categorical data helps to correlate and interpret the outcome of the data collected through (Part B to F) questions with the Likert scale (Ordinal data). Further general questions give the opportunity to check if the data is distributed normally. The normality of data guides further to choose parametric or non-parametric data analysis techniques. The structure design is given in table 4-3 below based on the research objectives. All parts of the questionnaire are given in this table and are explained below including the purpose of, and the reasoning behind, the variables. The variables are the preliminary findings from the literature review. Therefore, the table below (table 4-3) clearly justifies the process of choosing variables of this study. For example, in table 4-3 question B has three (3) questions based on (a) Lean (b) Agile and (C) SCs. Through the literature review, this study identified five (5) principles of Lean, four (4) principles of Agile and four

(4) principles of SCs; this jointly makes a total number of thirteen (13) variables having one hypothesis for each variable.

Table 4-3: Structure of the Questionnaire

Part of the Questionnaire	Research Objective/s	Number of Questions	Number of Total Variables
Part A	General Questions	5	29
Part B	To examine the contribution of Tacit Knowledge in the application of both Lean and Agile principles within CSCs.	3	13
Part C	To investigate and document the challenges associated with effective Knowledge Transfer and Sharing through the application of Lean and Agile principles in Construction Supply Chains.	2	12
Part D	To identify the critical success factors associated with effective Knowledge Transfer and Sharing in Construction Supply Chains through the application of Lean and Agile principles.	2	20
Part E	To investigate the contributions of Lean and Agile to Construction Supply Chains in terms of efficiency improvements through the implementation of Knowledge Management	2	8
Part F	To develop and validate a framework that improves the understanding and awareness of Knowledge Management within CSCs.	2	12
Total		16	94

The number of questions has been kept limited for two main reasons.

1. The respondent does not have to spend too much time on answering the questions. If a questionnaire takes more than fifteen (15 to 20) minutes to answer, this would be considered as time-consuming and the chances are increased that it will be left incomplete (Rattray & Jones, 2007).
2. Secondly, having limited questions maintains the focus of the topic and makes it much easier for researchers to handle the data. However, this study has a combination of six

sections (based on the research objectives) having sixteen (16) questions altogether with ninety-four (94) variables.

4.7 Part A: General Questions

4.7.1.1 A1. Please state the size of your organisation.

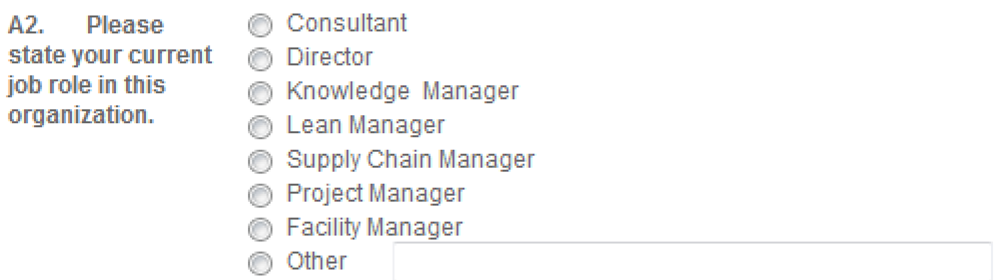
This question asks for the size of the organisation of the respondents. This question aims to ensure that the data is equally distributed (among micro to large organisations). Moreover, that it collects the data from a wide range of organisations involved in a CSC.


A1. Please state the size of your organization.
- Micro (1 to 9 employees)
- Small (10 to 50 employees)
- Medium (50 to 249 employees)
- Large (250 and above)

Screenshot of Question A1.

4.7.1.2 A2. Please state your current job role in this organisation.

This question determines the current job role of the respondents. This study focuses on the respondent's job role instead of job title. This is because, usually in the construction industry, a job title does not reflect the duties and responsibilities of a person. It is often seen (Prospects 2014) that a respondent with the title of Quantity Surveyor or Supply Chain Manager or Consultant is also involved in Lean and/or Agile management and other roles (CIQS, 2014).


A2. Please state your current job role in this organization.
- Consultant
- Director
- Knowledge Manager
- Lean Manager
- Supply Chain Manager
- Project Manager
- Facility Manager
- Other

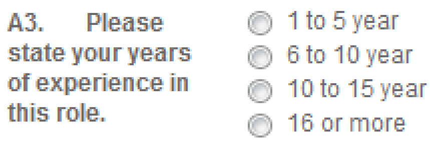
Screenshot of Question A2.

In this question, individuals involved in the Tiers (1) and (2) of the CSC are considered in terms of the role they play in the application of Tacit Knowledge in Lean, Agile and CSCs.

4.7.1.3 A3. Please state your years of experience in this role.

This question links with the above question, A2. This focuses investigating the years of experience of respondents. The reasons for asking this question are:

1. To identify that the distribution of the questionnaire is equal throughout the various years of experience of the respondents.
2. To investigate the level of awareness among the groups with their different years of experience about sharing and transferring Tacit Knowledge in CSCs in the context of lean and agile processes.
3. oTo correlate the current job title (question A2 and A3) of each respondent and the years of experience.



Screenshot of Question A3.

4.7.1.4 A4. Please state the nature of business of your organisation.

This question gives the opportunity to identify the nature of business of the respondent organisations. Based on this, assumptions can be made to identify which types of businesses are directly involved in the application of Lean and Agile in CSCs.

Screenshot of Question A4.

4.7.1.5 A5. Please select in which of the listed areas below you have working experience.

This question focuses on the working experience of the respondents in Knowledge Management, Lean, Agile, Supply Chains and related management fields. Having based on the objectives of study, this question is to investigate the respondent's experience in different fields to define the level of experience the respondents have. This question can also be cross examined with a combination of the above four questions.

A5. Please select in which of below listed areas you have working experience.

- Construction Project Management
- Lean Construction Management
- Agile Construction Management
- Construction Supply Chain Management
- Knowledge Management in one or more of above fields
- Other

Screenshot of Question A5.

The questions asked in this section gives the opportunity to interpret the ‘Confidence Level’ of the researcher and the ‘Margin of Error’ in the responses. However, studies by Ghasemi & Zahediasl (2012a); Chesson (1993); Hannan & Anderson (2007) and Rattray & Jones (2007) reveal that investigating more than one phenomenon with a lower number of population (Zhao, 2009; Root & Blismas, 2003) increases the possibility that the responses received are not distributed normally.

The following sections of the questionnaire focused on addressing the objectives of this research. These questions are designed to get the ordinal scale of data.

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4.7.2 Section (B). Contribution

Section (B) of the questionnaire focuses on examining the level of contribution of Tacit Knowledge in the application of Lean and Agile principles within Construction Supply Chains.

This objective requires identifying the level of contribution of Tacit Knowledge in the application of Lean and Agile processes within the CSC. Along with the findings from the literature review, this requires validation through the respondents who are directly involved in the construction process at strategic levels. This objective can be fulfilled by asking questions to the population in Tier (1) and Tier (2) levels of the CSC. This objective is divided into three sub-questions. The sub-questions are designed to identify and evaluate the level of contribution of Tacit Knowledge in the application of (a) Lean, (b) Agile and (c) SC principles in construction processes. To get the ordinal data from the respondents, a five-point Likert Scale choice of answers is employed to determine the level of contribution from 'Very Low' to 'Very High'. Each sub-question contains the main principles of (a) Lean, (b) Agile and (c) the CSC (see 2.2).

Below are the operational definitions of 'Contribution' and 'Process' in this context.

The "**contribution" in this context,** is the role played by Tacit Knowledge in bringing about efficiency (a) in Lean, (b) in Agile, and (c) in Construction Supply Chain Processes.

The "**process" in this context,** is a series of tasks and activities within (a) Lean, (b) Agile and (c) in the Construction Supply Chain (i.e. brick laying, painting, roof laying

4.7.2.1 Question B1.

What is the level of contribution of Tacit Knowledge in the application of the lean principles listed below within the construction process?

The purpose of this question is to establish and analyse the views of respondents about the application of Tacit Knowledge in the Lean principles within the Construction process. The reason for asking this question is to support the findings from literature review ((Dombrowski et al., 2012; Sacks et al., 2009; Pheng & Fang, 2005) about Lean principles. discussed in chapter (2).

Table 4-4 below establishes the main question and hypothesis relating to this question. Moreover, it also gives the overview of the data type, the purpose of this question and suitable data analysis techniques to test the hypothesis.

Reasoning: The reason for asking this question is to identify the level of contribution Tacit Knowledge plays in the Lean construction process. Based on the views concerning Lean principles in construction processes (see 2.2.3) and on the contribution of Tacit Knowledge in the application of Lean principles (see 2.3.15), the hypothesis below is developed for each variable to test the contribution of Tacit Knowledge in this context.

Table 4-4: Question: Contribution of Tacit Knowledge in the application of Lean Principles in CSC processes.

B1. (a) What is the level of contribution of tacit knowledge in the application of below listed lean principles within the construction process?

	Very Low	Low	Moderate	High	Very High
to reduce waste in construction processes	○	○	○	○	○
to generate value in construction processes	○	○	○	○	○
to enhance material and information flow in construction processes	○	○	○	○	○
to increase efficiency in decision making process	○	○	○	○	○
to continuous improvement in construction processes	○	○	○	○	○

Main Question	What is the level of contribution of Tacit Knowledge in the application of Lean Principles to bring efficiency in construction processes?				
Hypothesis	The contribution of Tacit Knowledge is high in the application of Lean Principles to bring efficiency in construction processes.				
Likert Scale	Very Low	Low	Moderate	High	Very High
Ranking	1	2	3	4	5
Data Type	Ordinal				
Data Analysis Technique/s	Reliability, Normality of distribution, Frequencies, Correlation, Non-parametric analysis				

4.7.2.1.1 Variable 1: To reduce waste in the construction process

Question: What is the level of contribution of Tacit Knowledge in the application of Lean principles to reduce waste in construction processes?

Hypothesis: The level of contribution of Tacit Knowledge in the application of Lean principles to reduce waste in the construction process is high.

4.7.2.1.2 Variable 2: To generate value in the construction process

Question: What is the level of contribution of Tacit Knowledge in the application of Lean processes to generate value in construction processes?

Hypothesis: The level of contribution of Tacit Knowledge in application of Lean principles to generate value in the construction process is high.

4.7.2.1.3 Variable 3: To enhance material and information flow in the construction processes

Question: What is the level of contribution of Tacit Knowledge in the application of Lean processes to enhance material and information flow in the construction process?

Hypothesis: The level of contribution of Tacit Knowledge in application of Lean principles to enhance material and information flow in the construction process is high.

4.7.2.1.4 Variable 4: To increase efficiency in the decision making process in construction processes

Question: What is the level of contribution of Tacit Knowledge in the application of Lean processes to increase efficiency in the construction process?

Hypothesis: The level of contribution of Tacit Knowledge in the application of Lean principles to increase efficiency in the construction process is high.

4.7.2.1.5 Variable 5: To continuously improve the construction process

Question: What is the level of contribution of Tacit Knowledge in the application of Lean processes to continuous improvements in the construction process?

Hypothesis: The level of contribution of Tacit Knowledge in application of Lean principles to continuous improvements in the construction process is high.

4.7.2.2 Question B2

This question focused on identifying the contribution of Tacit Knowledge in the application of Agile principles defined through a critical analysis of the literature (see 2.2.3 and 2.3.14). These principles were taken from various studies (Jørgensen & Emmitt, 2008; Mason-Jones et al., 2000; Xue et al., 2007; Ibbitson & Smith, 2010; Egan, 1998). This question identifies the level of contribution of Tacit Knowledge in the Agile construction process. Table 4-5 below presents the main question, the hypothesis, the type of data and the data analysis tools and techniques. Moreover, a hypothesis for each variable is generated to test the validity of the findings from the literature review.

Table 4-5: Question B2: Contribution

B2. (b) What is the level of contribution of tacit knowledge in the application of below listed Agile Principles in construction processes?

	Very Low	Low	Moderate	High	Very High
to enhance responsiveness of activities in construction processes	○	○	○	○	○
to bring collaboration and partnering in construction processes	○	○	○	○	○
to empower teams to take efficient decision in construction processes	○	○	○	○	○
to integrate construction processes throughout the project	○	○	○	○	○

Main Question	What is the level of contribution of Tacit Knowledge in the application of Agile Principles to bring efficiency in construction processes?				
Hypothesis	The contribution of Tacit Knowledge is high in the application of (a) Lean and (b) Agile, within (c) Construction Supply Chains to bring efficiency in construction processes.				
Likert Scale	Very Low	Low	Moderate	High	Very High
Ranking	1	2	3	4	5
Data Type	Ordinal				
Data Analysis Technique/s	Reliability, Normality of distribution, Frequencies, Non-parametric				

4.7.2.2.1 Variable 1: To enhance the responsiveness of activities in the construction processes

Question: What is the level of contribution of Tacit Knowledge in the application of Agile principles to enhance the responsiveness of activities in the construction processes?

Hypothesis: The level of contribution of Tacit Knowledge in Agile principles to enhance responsiveness in the construction processes is high.

4.7.2.2.2 Variable 2: To bring collaboration and partnering into the construction processes

Question: What is the level of contribution of Tacit Knowledge in the application of Agile principles to bring collaboration and partnering in the construction processes?

Hypothesis: The level of contribution of Tacit Knowledge in the application of Agile principles to bring collaboration and partnering in the construction processes is high.

4.7.2.2.3 Variable 3: To empower teams to take efficient decisions in the construction processes

Question: What is the level of contribution of Tacit Knowledge in the application of Agile principles to empower teams to take efficient decisions in the construction processes?

Hypothesis: The level of contribution of Tacit Knowledge in the application of Agile principles to empower teams to take efficient decisions in the construction processes is high.

4.7.2.2.4 Variable 4: To integrate the construction processes

Question: What is the level of contribution of Tacit Knowledge in the application of Agile principles to integrate the construction processes throughout the project?

Hypothesis: The level of contribution of Tacit Knowledge in Agile principles to integrate the construction processes throughout the project is high.

4.7.2.3 Question B3

Similar to questions B1 and B2, this question is asked in order to identify the contribution of tacit knowledge in the application of SC principles in the construction processes. Table 4-6 below presents the main question and its corresponding hypothesis. Moreover, it represents the type of data collected from this question and the data analysis tools and techniques. It also develops a hypothesis for each variable to test it further to validate the findings from the literature review (see 2.1.4).

Table 4-6: Question B3: Contribution

B3. (c) What is the level of contribution of tacit knowledge in the application of below listed supply chain principles in construction processes?

	Very Low	Low	Moderate	High	Very High
to enhance partnering among organizations within construction processes					
to reduce negative impact of fragmentation in construction supply chains					
to increase efficiency of construction supply chain					
to increase responsiveness of construction supply chain					

Main Question	What is the level of contribution of Tacit Knowledge in the application of the supply chain principles listed below in construction processes?				
Hypothesis	The level of contribution of Tacit Knowledge in the application of Supply Chains' Principles to bring efficiency in construction processes is high.				
Likert Scale	Very Low	Low	Moderate	High	Very High
Ranking	1	2	3	4	5
Data Type	Ordinal				
Data Analysis Technique/s	Reliability, Frequencies, Correlation and Non-parametric Analysis				

4.7.2.3.1 Variable 1: To enhance collaboration among organisations within a CSC

Question: What is the level of contribution of Tacit Knowledge in the application of SC principles to enhance collaboration among organisations within the construction SC?

Hypothesis: The level of contribution of Tacit Knowledge in in the application of SC principles to enhance collaboration among organisations within the construction SC is high.

4.7.2.3.2 Variable 2: To reduce the negative impact of fragmentation in the CSCs

Question: What is the level of contribution of Tacit Knowledge in the application of SC principles to reduce the negative impact of fragmentation in the CSCs?

Hypothesis: The level of contribution of Tacit Knowledge in the application of SC principles to reduce the negative impact of fragmentation in the CSCs is high.

4.7.2.3.3 Variable 3: To increase efficiency of the CSC

Question: What is the level of contribution of Tacit Knowledge in the application of SC principles to increase the efficiency of the CSC?

Hypothesis: The level of contribution of Tacit Knowledge in in the application of SC principles to increase the efficiency of the CSC is high.

4.7.2.3.4 Variable 4: To increase the responsiveness of a CSC

Question: What is the level of contribution of Tacit Knowledge in the application of SC principles to increase the responsiveness of the construction supply chain?

Hypothesis: The level of contribution of Tacit Knowledge in the application of SC principles to increase the responsiveness of the construction supply chain is high.

4.7.3 Section (C) Challenges

This section of the questionnaire focuses on investigating and documenting the challenges associated with the effective transferring and sharing of knowledge through the application of (a) Lean, and (b) Agile principles in Construction Supply Chains.

The **challenge in this context** is a call for the essential factors whose absence hinders the sharing or transference of Tacit Knowledge.

"For explanation purposes both questions C1 and C2 are explained jointly, as both questions have same set of challenges associated with the Transferring and Sharing of Knowledge in Lean and Agile processes. A separate explanation would have led to a repetition of explanation. However, for the purpose of not confusing the respondents, both questions are asked separately in the questionnaire."

4.7.3.1 Question C1 & C2

(a) By drawing from your experience, kindly indicate the level of the challenges listed below associated with the transfer and sharing of Knowledge through the application of Lean & Agile Principles.

This question is about investigating and documenting the challenges associated with effective KM through the application of Lean and Agile Principles. In a construction project, the managers, while implementing and executing the Lean and Agile processes, face these type of challenges.

Table 4-7 below presents the question, the hypothesis, the variables and the type of data and data analysis tools and techniques.

Table 4-7: Question C1 &C2: Challenges

	Not Challenging	Of Little Challenging	Moderately Challenging	Challenging	Highly Challenging
Lack of understanding and importance of transfer and sharing of knowledge	○	○	○	○	○
Lack of trust among the organizations in construction supply chains	○	○	○	○	○
Insufficiency of motivation for organizations in construction supply chains	○	○	○	○	○
Short term supply chain relationship among partners of construction supply chains	○	○	○	○	○
Contractors have traditional ways of doing business	○	○	○	○	○
Fragmented nature of construction sector	○	○	○	○	○

Main Question	What is the level of the challenges listed below associated with the transfer and sharing of Knowledge through the application of Lean Principles?				
Hypothesis	The level of challenge associated with the transfer and sharing of tacit knowledge through the application of Lean Principles is critical.				
Likert Scale	Not Challenging	Of Little Challenging	Moderately Challenging	Challenging	Highly Challenging
Ranking	1	2	3	4	5
Data Type	Ordinal				
Data Analysis Technique/s	Reliability, Normality of distribution, Frequencies, Correlation and Non-parametric Analysis				

4.7.3.1.1 Variable 1

Challenge: The lack of understanding and importance of, transferring and sharing Knowledge

Hypothesis: Lack of understanding and importance of, transferring and sharing Knowledge through the application of Lean Principles is very high.

4.7.3.1.2 Variable 2

Challenge: Lack of trust among the organisations within construction supply chains

Hypothesis: Lack of trust among the organisations in the construction supply chains hindering the transfer and sharing of Tacit Knowledge through the application of Lean and Agile Principles is very high.

4.7.3.1.3 Variable 3

Challenge: Insufficiency of motivation for organisations within the construction supply chains

Hypothesis: Insufficiency of motivation for organisations within the construction supply chains concerning the transfer and sharing of Tacit Knowledge through the application of Lean Principles is very high.

4.7.3.1.4 Variable 4

Challenge: Short-term supply chain relationship among organizations in the construction supply chains

Hypothesis: The short-term supply chain relationship among partners of the construction supply chains is a highly challenging factor that hinders the transfer and sharing of Tacit Knowledge through the application of Lean and Agile Principles.

4.7.3.1.5 Variable 5

Challenge: Contractors have traditional ways of doing business

Hypothesis: Traditional ways of doing business is a highly challenging factor that hinders the transfer and sharing of Tacit Knowledge through the application of Lean and Agile Principles.

4.7.3.1.6 Variable 6

Challenge: Fragmented nature of the construction sector

Hypothesis: The fragmented nature of the construction sector is a highly challenging factor that hinders the transfer and sharing of Tacit Knowledge through the application of Lean and Agile Principles.

4.7.4 Section (D) Critical Success Factors

This section identifies the critical success factors associated with the effectiveness of transferring and sharing Tacit Knowledge (a) in Lean Processes (b) in Agile Processes.

The ***Critical Success Factors in this context*** are the necessary factors whose absence hinder the effectiveness of sharing and transferring Tacit Knowledge.

Corresponding to third objective the questions relating to the critical success factors associated with effective Knowledge Management in the CSC can be asked to the Tier (1) and Tier (2) respondents.

4.7.4.1 Question D1 and D2

Question D1: By drawing from your experience, please kindly indicate the level of criticality of the success factors listed below associated with the transfer and sharing of Tacit Knowledge in Lean Processes.

Question D2: By drawing from your experience, please kindly indicate the level of criticality of the success factors listed below associated with the transfer and sharing of Tacit Knowledge in Agile Processes.

"For explanation purposes both questions D1 and D2 are explained jointly, as both questions have the same set of Success Factors associated with the Transfer and Sharing of Tacit Knowledge in Lean and Agile processes. A separate explanation would have led to the repetition of the explanation. However, for the purpose of not confusing the respondents, both questions are asked separately in the questionnaire."

Table 4-8 below presents a screenshot of the questionnaire along with the main question, the hypothesis, the data type and the data analysis techniques adopted to analyse the data.

Table 4-8: Question D1 & D2: Critical Success Factors

	Not Critical	Of Little Critical	Moderately Critical	Critical	Very critical
Trust among organizations in construction supply chain					
Motivation to share and transfer Tacit Knowledge					
Leadership Capabilities of clients and main contractors to encourage transfer and sharing tacit knowledge					
Business Strategies aligned to transfer and share Tacit Knowledge in organizations within Construction process					
Organizations within Construction Supply Chain must have Capabilities to transfer and share tacit knowledge					
Individual involved in construction process must be capable to transfer and share tacit knowledge					
Identification of process improvement opportunity by managers					
Identification of type of knowledge to to transfer and share tacit knowledge					
Identification of Source of knowledge					
Identification of knowledge recipient					

Main Question	What is the level of criticality of success factors associated with the effectiveness of transferring and sharing Tacit Knowledge (a) in Lean Processes (b) in Agile Processes?				
Hypothesis	The level of criticality of success factors associated with the effectiveness of transferring and sharing Tacit Knowledge (a) in Lean Processes (b) in Agile Processes is high.				
Likert Scale	Not Critical	Of Little Critical	Moderately Critical	Critical	Very Critical
Ranking	1	2	3	4	5
Data Type	Ordinal				
Data Analysis Technique/s	Reliability, Normality of distribution, Frequencies, Correlation and Non-parametric Analysis				

4.7.4.1.1 Variable 1

Critical Success Factor: Trust among organisations in the construction supply chain

Hypothesis: Trust among organisations in the CSC is a highly critical success factor in the Transferring and Sharing of Tacit Knowledge in Lean and Agile processes.

4.7.4.1.2 Variable 2

Critical Success Factor: Motivation to Share and Transfer Tacit Knowledge

Hypothesis: Motivation in the CSC is a highly critical success factor in the Transferring and Sharing of Tacit Knowledge in Lean and Agile Processes.

4.7.4.1.3 Variable 3

Critical Success Factor: Leadership capabilities of clients and main contractors to encourage Sharing and Transferring Tacit Knowledge

Hypothesis: Leadership capabilities of clients and main contractors are a highly critical success factor in the Transferring and Sharing of Tacit Knowledge in Lean and Agile Processes.

4.7.4.1.4 Variable 4

Critical Success Factor: Business Strategies aligned to Sharing and Transferring Tacit Knowledge in organisations within the construction process

Hypothesis: Business strategies are a highly critical success factor aligned to the Transferring and Sharing of Tacit Knowledge in Lean and Agile Processes.

4.7.4.1.5 Variable 5

Critical Success Factor: Organisations must have capabilities to Share and Transfer Tacit Knowledge

Hypothesis: Organisational capabilities are a highly critical success factor in the Transferring and Sharing of Tacit Knowledge in Lean and Agile Processes.

4.7.4.1.6 Variable 6

Critical Success Factor: Individuals involved in a construction process must be capable of Sharing and Transferring Tacit Knowledge

Hypothesis: Individual capability is a highly critical success factor in construction processes concerning the Transferring and Sharing of Tacit Knowledge.

4.7.4.1.7 Variable 7

Critical Success Factor: Identification of process improvement opportunities by managers

Hypothesis: It is highly critical that construction managers identify the process improvement opportunities to Transfer and Share Tacit Knowledge.

4.7.4.1.8 Variable 8

Critical Success Factor: Identification of the type of Knowledge to Share and Transfer

Hypothesis: Identification of the type of Tacit Knowledge to Share and Transfer is a highly critical success factor.

4.7.4.1.9 Variable 9

Critical Success Factor: Identification of Sources of Knowledge

Hypothesis: Identification of Knowledge Sources in order to Share and Transfer Tacit Knowledge is a highly critical success factor.

4.7.4.1.10 Variable 10

Critical Success Factor: Identification of Knowledge recipients

Hypothesis: Identification of Knowledge Recipients with whom to Share and Transfer Tacit Knowledge is a highly critical success factor.

4.7.5 Section (E) Contributions of Lean and Agile Principles in CSCs

This section focuses on examining the contributions of (a) Lean and (b) Agile Principles to Construction Supply Chains in terms of efficiency improvements.

The **Contribution in this context** is the role played by Lean and Agile Principles bringing efficiency into Construction Supply Chains.

The **Efficiency in this context** is to enhance the skilfulness of a supply chain in reducing waste and effort to make it responsive.

4.7.5.1 Question E1

Question: Please indicate the level of contributions of Lean Principles in the construction supply chain.

Table 4-9 below presents a screenshot of the questionnaire along with the main question, the hypothesis, the data type and the data analysis techniques adopted to analyse the data.

Table 4-9: Question E1: Contribution

	Very Low	Low	Moderately Low	High	Very High
to reduce waste i.e (Defects, Over production, Inventory, Over processing, Motion etc..) to generate and add value to construction processes	○	○	○	○	○
to enhance material and information flow within the Construction Supply Chains	○	○	○	○	○
to increase efficiency in decision making process within Construction Supply Chains	○	○	○	○	○
to continuously improve construction supply chains	○	○	○	○	○

Main Question	What is the level of contribution of the Lean and Agile Principles listed below in bringing efficiency into the Construction Supply Chain?				
Hypothesis	The contribution of Lean and Agile Principles to bring efficiency into the Construction Supply Chain is high.				
Likert Scale	Very Low	Low	Moderately Low	High	Very High
Ranking	1	2	3	4	5
Data Type	Ordinal				
Data Analysis Technique/s	Reliability, Normality of distribution, Frequencies, Correlation and Non-parametric Analysis				

4.7.5.1.1 Variable 1

Principle: To reduce waste (i.e. Defects, Over production, Inventory, Over processing, Motion, etc.), to generate and add value to a construction process.

Hypothesis: The contribution of the Lean Principle ‘to reduce waste’ in bringing in efficiency improvements in the CSC is high.

4.7.5.1.2 Variable 2:

Principle: To enhance material and information flow within CSCs

Hypothesis: The contribution of the Lean Principle ‘to enhance material and information flow’ in bringing in efficiency improvements in the CSC is high.

4.7.5.1.3 Variable 3

Principle: To increase efficiency in the decision-making process within Construction Supply Chains

Hypothesis: The contribution of the Lean Principle ‘to increase efficiency in decision-making processes’ in bringing in efficiency improvements in the CSC is high.

4.7.5.1.4 Variable 4

Principle: To continuously improve construction supply chains

Hypothesis: The contribution of the Lean Principle ‘to continuously improve the processes of a CSC’ is high.

4.7.5.2 **Question E2**

Table 4-10: Question E2: Contribution

Please indicate the level of contributions of Agile principles in construction supply chain.

	Very Low	Low	Moderate	High	Very High
to enhance responsiveness of activities within construction supply chains	○	○	○	○	○
to bring collaboration and partnering among organizations within construction supply chains	○	○	○	○	○
to empower teams to take effective decision within the construction supply chains	○	○	○	○	○
to integrate processes throughout the construction project	○	○	○	○	○

Main Question	What is the level of contribution of Agile Principles in bringing efficiency into the Construction Supply Chain?				
Hypothesis	The level of contribution of Agile Principles in bringing in efficiency in the Construction Supply Chain is high.				
Likert Scale	Very Low	Low	Moderate	High	Very High
Data Type	Ordinal				
Data Analysis Technique/s	Reliability, Normality of distribution, Frequencies, Correlation and Non-parametric Analysis				

4.7.5.2.1 Variable 1

Principle: To enhance the responsiveness of activities within construction supply chains

Hypothesis: The level of contribution of Agile principles in enhancing the responsiveness of activities within a CSC is high.

4.7.5.2.2 Variable 2

Principle: To bring collaboration and partnering among organisations within construction supply chains

Hypothesis: The level of contribution of Agile principles in bringing in collaboration and partnering between organisations within a CSC is high.

4.7.5.2.3 Variable 3

Principle: To empower teams to take effective decisions within construction supply chains

Hypothesis: The level of contribution of Agile principles in empowering teams to take efficient decisions within a CSC is high.

4.7.5.2.4 Variable 4

Principle: To integrate processes throughout the construction project

Hypothesis: The level of contribution of Agile principles in integrating processes throughout the construction project is high.

4.7.6 Section (F) Importance and Agreement

This section focuses on identifying the importance of key factors, which enable the sharing, and transferring of Tacit Knowledge in Lean, Agile and CSC processes.

4.7.6.1 Question F1

By drawing from your experience, please kindly indicate the importance of the key factors listed below which enable the sharing and transferring of Tacit Knowledge in lean, agile and construction supply chain processes.

Table 4-11: Question F1: Importance

	Not Important	Low Importance	Moderately Important	Important	Very Important
Leadership capability and intention to share and transfer tacit knowledge	○	○	○	○	○
Corporate strategies to share and transfer tacit knowledge	○	○	○	○	○
Motivation of organizations/people among the construction supply chain to share and tacit transfer knowledge	○	○	○	○	○
Skill enhancement to share and transfer tacit knowledge while providing training to organizations/people	○	○	○	○	○
Identifying, process improvement opportunity i.e (Increase flow of material or problem solving process)	○	○	○	○	○
Identifying, type of knowledge required to enhance the efficiency of construction process i.e (Propositional, Personal or Procedural)	○	○	○	○	○
Identifying, source of knowledge i.e (Person or Organization)	○	○	○	○	○

Main Question	What is the level of importance of the key factors listed below to enable the sharing and transferring of Tacit Knowledge in lean, agile and construction supply chain processes?				
Hypothesis	The level of importance of the key factors listed below to enable the sharing and transferring of Tacit Knowledge in lean, agile and construction supply chain processes is high.				
Likert Scale	Very Low	Low	Moderate	High	Very High
Ranking	1	2	3	4	5
Data Type	Ordinal				
Data Analysis Technique/s	Reliability, Normality of distribution and Frequencies Analysis				

This question is asked to develop and validate the conceptual framework that initiates the transferring and sharing of tacit knowledge within the CSC. The variables presented in table 4-11 above are based on the preliminary findings from this study (see 2.5.2).

4.7.6.1.1 Variable 1

Factor: Leadership capability and intention to Share and Transfer Tacit Knowledge

Hypothesis: The level of importance of Leadership Capability and Intention is a highly important key factor to enable the Sharing and Transferring of Tacit Knowledge in lean, agile and the CSC processes.

4.7.6.1.2 Variable 2

Factor: Corporate strategies to Share and Transfer Tacit Knowledge

Hypothesis: The level of importance of Corporate Strategies is a highly important key factor to enable the Sharing and Transferring of Tacit Knowledge in lean, agile and the CSC processes.

4.7.6.1.3 Variable 3

Factor: Motivation of organisations/individuals among the CSC to Share and Transfer Tacit Knowledge

Hypothesis: Motivation of organisations and individuals is a highly important key factor in the enabling of sharing and transferring Tacit Knowledge in lean, agile and CSC processes.

4.7.6.1.4 Variable 4

Factor: Skill enhancement to Share and Transfer Tacit Knowledge while providing training for organizations/people

Hypothesis: Skill enhancement of organisations and individuals to enable the sharing and transferring of Tacit Knowledge in lean, agile and CSC processes is a highly important key factor.

4.7.6.1.5 Variable 5

Factor: Identifying process improvement opportunities (i.e. Increased flow of material or problem solving process)

Hypothesis: Identifying process improvement opportunities is an important key factor in enabling the sharing and transferring of Tacit Knowledge in lean, agile and CSC processes.

4.7.6.1.6 Variable 6

Factor: Identifying the type of knowledge required to enhance the efficiency of construction processes (i.e. Propositional, Personal or Procedural)

Hypothesis: Identifying the type of knowledge required is an important key factor in enabling the sharing and transferring of Tacit Knowledge in lean, agile and CSC processes.

4.7.6.1.7 Variable 7

Factor: Identifying the source of Knowledge (i.e. Person or Organization)

Hypothesis: Identifying the source of knowledge is an important key factor in enabling the sharing and transferring of Tacit Knowledge in lean, agile and CSC processes.

4.7.6.2 Question F2

By drawing from your experience, please kindly indicate your level of agreement with the statements listed below.

This question is asked to identify the level of agreement of respondents on the key findings from the literature review. The data analysis of the responses to this question establishes a validation of the preliminary findings and the conceptual framework. In Table 4-12 below there is no hypothesis generated for the variables of this question. This is because the level of agreement does not require any hypothesis to be tested. The variables will only be analysed by a frequency analysis.

Table 4-12: Question F2: Agreement

	Strongly Disagree	Disagree	Moderately Agree	Agree	Strongly Agree
Lean and Agile principles works well if both implement together in construction supply chain	○	○	○	○	○
Lean and Agile principles are both embedded in each other	○	○	○	○	○
Knowledge Management plays a significant role in implication of Lean and Agile principles in Construction Supply Chains	○	○	○	○	○
An effective Knowledge Management approach can enhance the effectiveness of Lean to generate value and reduce waste and Agile processes to increase supply chain responsiveness	○	○	○	○	○
An effective Knowledge Management approach can bring collaboration and integration among construction supply chains	○	○	○	○	○

Main Question	What is your level of agreement with the listed preliminary findings (listed below) of this research?				
Hypothesis	None				
Likert Scale	Strongly Disagree	Disagree	Moderately Agree	Agree	Strongly Agree
Ranking	1	2	3	4	5
Data Type	Ordinal				
Data Analysis Technique/s	Reliability, Normality of distribution and Frequencies Analysis				

4.7.6.2.1 Variable 1

Finding: Lean and Agile principles work well if both are implemented together in construction supply chains.

4.7.6.2.2 Variable 2

Finding: Lean and Agile processes work well if both are embedded in each other.

4.7.6.2.3 Variable 3

Finding: Knowledge Management plays a significant role in the implementation of Lean and Agile principles in Construction Supply Chains.

4.7.6.2.4 Variable 4

Finding: An effective Knowledge Management approach can enhance the effectiveness of Lean processes to generate value and reduce waste, and of Agile processes to increase supply chain responsiveness.

4.7.6.2.5 Variable 5

Finding: An effective Knowledge Management approach can bring collaboration and integration within construction supply chains.

4.8 Data Analysis Tools and Techniques

The survey questionnaire is designed to collect interval scale data through general questions (in section A). The rest of the questionnaire collects ordinal scale data. Normally, ordinal data brings non-parametric data analysis techniques into consideration. The data analysis tools and techniques presented below are considered in this study to analyse data and to generalise the results.

4.8.1 Reliability of Data Collected

Reliability requires consistency. As Saunders et. al., (2009) states, for a questionnaire or face-to-face interview to be valid, it must be reliable. Reliability can be assessed by considering these three questions as observed by Easterby-Smith et al. (2008, pp. 109).

1) Will the measures yield the same results on other occasions?
2) Will similar observations be reached by other observations?
3) Is there transparency in the sense made from the raw data?

Taking on board these three questions will bring about high reliability. However, according to Robson (2002), there may be four threats to reliability: participant error, participant bias, and researcher error or researcher bias. These threats may influence the responses from the respondents in a way the researcher does not want. This research recognises participant bias may pose as a threat in this research. Respondents undertaking the questionnaires may exaggerate the answers through their company bias by wanting to portray the company in good light even though the questionnaires are completely anonymous.

4.8.2 Cronbach Alpha Analysis

Cronbach's alpha is a common measure of internal consistency (a measure of reliability) (Cronbach, 1951). It is used to determine how much the items within a scale are measuring the same underlying dimension (Bland & Altman, 1997). Yu (2001) stated that it is most commonly used when researchers have multiple Likert's scale questions in a survey/questionnaire that form a scale or sub-scale, and that it can be determine if the scale is reliable. DeVellis (2003) said that it is often used in conjunction with a data reduction technique such as principal component analysis (PCA) or factor analysis (Pett et al., 2003).

In SPSS Terminology, Kline (2005) said that reliability within Cronbach’s alpha is used to measure the internal consistency where the question has different variables, which in SPSS are called ‘items’ and a group of items is called a ‘scale’. These scales are used most often to determine an average or summated score that represents this underlying construct (Yu, 2001). For example, higher scores might indicate a greater 'amount' of this construct. Sometimes these constructs are referred to as dimensions (Cronbach, 1951). Although Cronbach's alpha tries to determine how well a set of questions is 'grouped together', it cannot determine whether the items it is analysing consist of a single dimension or multiple dimensions. As the questionnaire for this research is drafted to have multiple scales, the result is, therefore, for such a questionnaire (that has multiple dimensions), there is a requirement to run multiple Cronbach's alpha tests. Higher values of Cronbach's alpha are better. What constitutes a good level of internal consistency differs depending on what source is referred to; the minimum value must be above 0.5, although researchers (Field, 2013; Pallant, 2010; Muijs 2010) have recommended that values that have 0.7 or higher to define data will have greater internal consistency. A standardised Cronbach's alpha is the Cronbach's alpha when all the items that make up the scale are standardised to a variance of 1 (Kline, 2005; DeVillis, 2003). Once Cronbach’s alpha shows internal consistency is high, data should be tested to analyse the ‘Distribution of Normality’ (Garson, 2001; Field, 2000). ‘Distribution of Normality’ provides further insight in making assumptions about the data and helps to design the pathway for data analysis such as Parametric or Non-parametric analysis (DeVillis, 2003). However, if the survey questions are based on ordinal data and receive a lower number of responses it is highly possible that the data appears to be not normally distributed.

4.8.3 Distribution for Normality

When analysing differences between groups using parametric tests (e.g., the independent-samples t-test, one-way ANOVA), a common assumption in all these tests is that the dependent variable is approximately normally distributed for each group of the independent variables (Ghasemi & Zahediasl, 2012a). As this study is based on the Construction Supply Chain which consists of multiple sets of roles, organisation size, years of experience and nature of business, the study must cover all the components of the construction supply chain. If not, then the data would not be reliable enough to generalise the assumptions made throughout this study. There are two broad methods of assessing normality: using numeric methods (e.g., statistical tests) or using graphical methods (e.g., visual inspection of graphs) (Walsh, 1962). Numerical methods have the advantage of making an objective judgement of normality but are disadvantaged by sometimes not being sensitive enough at low sample sizes and being overly sensitive to large sample sizes (Conover, 1980 and Rosner, 2000). There are more than nine (9) defined tests (such as the Kolmogorov-Smirnov (K-S) test, the Lilliefors corrected K-S test, the Shapiro-Wilk test, the Anderson-Darling test, the Cramer-von Mises test, the D’Agostino skewness test, the Anscombe-Glynn kurtosis test, the D’Agostino-Pearson omnibus test, and the Jarque-Bera test) but, amongst these, skewness and kurtosis values' tests are most commonly used in the SPSS. However, some researchers also use the

Shapiro-Wilk test. If a sample size is small, a numerical method is normally the best one to rely on.

On the other side, graphical interpretation has the advantage of allowing the researcher to use their own judgement to assess whether there is normality in a given situation. However, as a researcher's own judgement is involved, these methods can be much more effective. Nonetheless, it is a very effective means of assessing normality. The graphical methods include Normal Q-Q Plots and the use of histograms (Ghasemi & Zahediasl, 2012b). Inspecting a histogram is one of most popular ways in which to understand what data "looks like", particularly to see if it is normally distributed. When inspecting a histogram for normality, a classic "bell curve" shape is exhibited by a normal distribution. If data is approximately normally distributed, it should have a shape very similar to this "bell curve" shape. A Normal Q-Q Plot is one of the best methods of assessing normality graphically. If data is normally distributed, the circular dots that represent data points will be positioned approximately along the diagonal line in the Normal Q-Q Plot. However, with 'real world' data, they will not be perfectly aligned on the diagonal line. In reality, there will be some variation from the line even when data are approximately normally distributed.

If the assumption of normality has been violated, then in that case the "**Sig.**" Value will be less than .05 (i.e., the test is significant at the $p < .05$ level). If the assumption of normality has not been violated, then in this case the "**Sig.**" Value will be greater than .05 (i.e., $p > .05$). This is because the Shapiro-Wilk test is testing the null hypothesis that the data's distribution is equal to a normal distribution (Lund Research Ltd, 2013). Rejecting the null hypothesis means that the data's distribution is not equal to a normal distribution.

4.8.4 Parametric or non-parametric assumptions based on the test of normality

Assumption of Normality of data draws further assumptions and analysis as per the nature of analysis such as Parametric (of, or relating to, or in terms of, a parameter) or Non-parametric analysis (not involving an estimation of the parameters of a statistic) (Ghasemi & Zahediasl, 2012a; Cuttance & Ecob, 2009). If the data is normally distributed the graphical visualisation of the data displays a "bell curve" shape in the middle of the display or the Numeric analysis for normality gives a significance level value greater than 0.05 ($p > .05$). If not, then data will appear as not equally distributed.

The distribution of normality reviews the data distributions to analyse the centre, shape and spread of data. Moreover, it describes how the validity of many statistical procedures relies on an assumption of approximate normality.

If the data is normally distributed it falls into Parametric and vice versa (Walsh, 1952). As questionnaires for this research contain Likert Scales which give ordinal data, this falls into Non-parametric data (Ghasemi & Zahediasl, 2012a). Moreover, the questionnaire designed for this research is separated into five (5) sections based on the research objectives. Additionally, each section is divided into two to three questions to specifically analyse the given contexts. Having that means there is a high possibility that the data will be based strongly upon the factors, such as years of experience, area of experience and size of organisation. As a result, the assumption below will be carried forward to define whether which type of test to use and its relevance for Parametric or Non-parametric data. The table below gives the criteria of choice of parametric and non-parametric tests.

Table 4-13: Choosing parametric and non-parametric tests based on Distribution of Normality

	Parametric	**Non-parametric**
Typical data	Ratio or Interval	Ordinal or Nominal
Assumed distribution	Normally Distributed	Not Normally Distributed
Usual central measure	Mean	Median
Choice of Tests	**Parametric test**	**Non-parametric test**
Correlation test	Pearson Correlation	Spearman Correlation
Independent measures, 2 groups	Independent-measures t-test	Mann-Whitney test
Independent measures, >2 groups	One-way, independent-measures ANOVA	Kruskal-Wallis test

Source: Based on the literature of Ghasemi & Zahediasl (2012a); Cuttance & Ecob (2009)

As showed in Table 4-13, since the questionnaire utilises Likert scales, which gives ordinal data; this leads to utilising Non-parametric tests. However, the questionnaire covers a vast range of sampling (as discussed earlier) which comprises data collection from the whole construction supply chain. Each variable needs to be measured to analyse and generalise the results. Even though, there are many variables which are correlated and dependent on others. Therefore, this research assumes that non-parametric tests should be considered in this research. A systematic approach is considered for data analysis assuming the collected data will be non-parametric based on the nature of the questions (Likert Scale) and on which non-parametric tests could be performed. Based on this discussion, a Normality of Distribution test is not relevant for this data analysis.

4.8.4.1 Spearman's Correlation Analysis

The Spearman's rank-order correlation (often abbreviated to Spearman's correlation) calculates a coefficient, r_s or ρ (pronounced "rho") which is a measure of the strength and direction of the association either between two continuous variables, two ordinal variables, or one ordinal and one continuous variable. On the other hand, Pearson's Correlation analysis investigates the relationship between two (2) continuous variables. Moreover, this is conducted if the data is normally distributed. Therefore, this research adopts Spearman's correlation analysis.

4.8.4.2 Choice of the Mann-Whitney Test and/or the Kruskal-Wallis Test

4.8.4.2.1 Mann-Whitney U Test

The Mann-Whitney U test (also called the Wilcoxon-Mann-Whitney test) is a rank-based nonparametric test that can be used to determine if there are differences between two groups on a continuous or ordinal dependent variable (Corder & Foreman, 2009). There can be different assumptions made to choose this test. These assumptions can be made depending on the number of dependent and independent variables to be tested. Mostly, this test can provide the opportunity to test only one independent variable which could have two categorical or independent groups at a time (Denscombe, 2007; Lindner & Wald, 2011). For this study the Mann-Whitney test is not suitable as each independent variable has more than two (2) groups (e.g. question A3 asking about the years of experience of respondents has four (4) groups). If this test is run in SPSS, this test will be required to be told which two (2) specific variables is to be tested, otherwise, this test will not compute the results.

Based on the characterises of this test, it is unsuitable for this research as this study require more than two (2) variables and groups to be tested in each question.

4.8.4.2.2 Kruskal-Wallis H Test

The Kruskal-Wallis H test (Kruskal & Wallis, 1952) (sometimes also called the "one-way ANOVA on ranks") is a rank-based nonparametric test that can be used to determine if there are statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable (Vargha & Delaney, 1998; Corder & Foreman, 2009). Typically, a Kruskal-Wallis H test is used if data have **three (3) or more** categorical, independent groups, but it can be used for just two groups (although a Mann-Whitney U test is more commonly used for two groups) (Hollander et al., 2013). This test offers the computation and testing of more than two (2) groups or variables. Therefore, this fulfils the requirement for tests based on the data to be examined in this research.

The respondent's experience (general question A5) is taken into account for this test. This is because this analysis requires testing the hypothesis of each variable based on the respondent's experience (Tacit Knowledge). This test would not be appropriate for questions A1 (size of organisation), A2 (Current Job Role), A3 (Respondents' years of experience) or A4 (Nature of Business) because of the following facts.

a) The questionnaire is designed to make respondents to think about the questions and answer them by drawing from their own experience based on Tacit Knowledge.
b) The 'Size of Organisation' (Question A1) does not have any influence on a respondent's Tacit Knowledge. The experience of the respondents cannot be calculated based on the size of an organisation.
c) It is possible that the 'current job role of respondent' (Question A2) is not an indication of experience, for example, a respondent could have just started as a Lean Construction Manager, but could also have had past experience as a Project Manager.
d) The 'Respondent's years of experience' (Question A3) could influence the answers. However, it cannot establish that the knowledge of a person with 1 to 5 years of experience would be lower than that of a person with 15 plus years of experience.
e) The 'Nature of Business' of a respondent's organisation (Question A4) also does not have any influence on the experience of respondents for example, a respondent's experience could be in the project management field but the current nature of his business could be a consultants' organization.

Based on these assumptions, a respondent's working experience is the most viable 'Group' to test the hypothesis for this research. Through this test, an assumption can be made using this significance level. This makes it possible to reach a decision with regard as to whether to retain the null hypothesis or accept the alternative hypothesis. The decision can be made, based on this *p*-value and Asymptotic Value (2-sided test) (Rumsey, 2007).

"Asymptotic" means that the *p*-value approaches the real value as the sample size increases. This means that, for smaller sample sizes, the *p*-value calculated from this method is only an approximation to the true *p*-value of the approximation which improves with increasing sample size. The reference to a "(2-sided test)" is commonly known as a 2-tailed test (Corder & Foreman, 2009; Hollander et al., 2013). In other terms if when computed the *p*-value is less than .05 (i.e., $p < .05$) then it rejects the Null Hypothesis and accepts the alternate hypothesis. If the *p*-value is greater than .05 (i.e., $p > .05$), this means it has retained (i.e., failed to reject) the null hypothesis and is not able to accept the alternative hypothesis.

To retain or reject the hypothesis, the following three (3) assumptions could be made based on three different computations.

Retain Hypothesis

1) Retain Null Hypothesis, if the median score is statistically significantly distributed (not different) between groups.
2) Retain Null Hypothesis, if the significance level (*p*-value) is greater than .05 (i.e., $p > .05$)
3) Retain Null Hypothesis, if the computed Asymptotic Value (2-sided test) is the same or higher than current significance (*p*-value)

If any of above three (3) assumptions do not meet, it rejects a null hypothesis and accepts the alternate hypothesis.

4.8.5 Adopted procedure for data analysis

Based on the literature review and the assumptions made on the basis of the nature of data (Ordinal → Non-parametric) The following data analysing and testing procedure on SPSS is defined for this study.

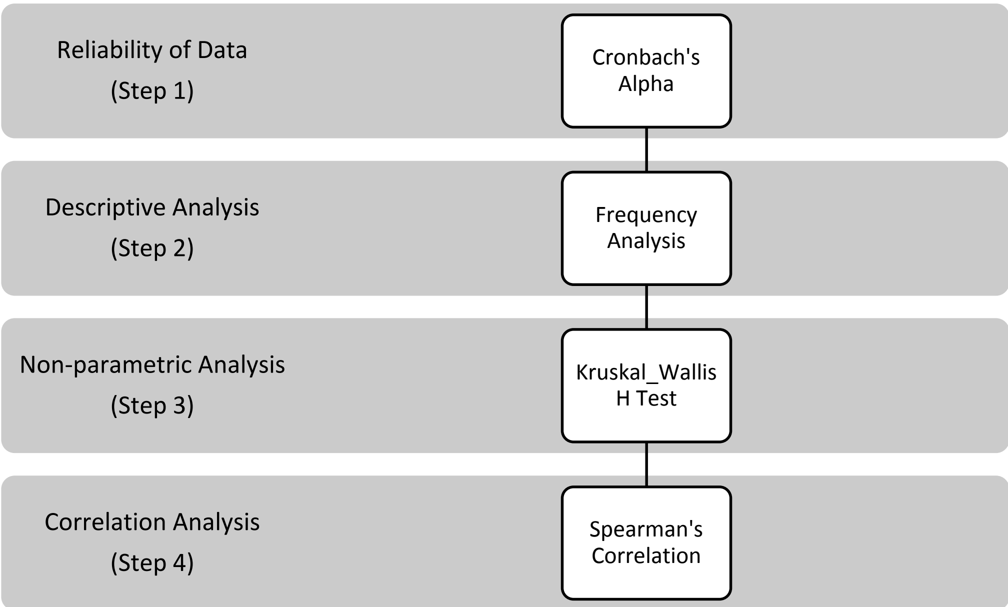


Figure 4-5: Procedure for Data Analysis

Source: Original

As exhibited in figure 4-5 the following four (4) step process is used to analyse the data.

1. The reliability of the data for each question is tested through Cronbach's alpha.

2. Frequency analysis is evaluated for each question and its variables to examine how many respondents accept the hypothesis for each variable. The median score is computed for each variable to analyse the average score and to test the hypothesis in the Kruskal-Wallis H test.
3. The non-parametric Kruskal-Wallis H test is run to test the statistically significant differences between the ‘experience of respondents’ to determine whether the null hypothesis is to be retained or rejected as discussed in the above section (2) of this chapter.
4. The Spearman Correlation test will be run to define the correlation between the variables of each question in order to analyse the interpreted correlation discussed in Chapter (2).

After these four (4) tests have been concluded an interpretive analysis is undertaken based on the correlation coefficient rank order (High to Low). At the end, assumptions are made and the findings are evaluated in terms of modifying the conceptual framework.

4.8.6 Questionnaire administration and difficulties in data collection

The ethical issues of this research required that the data be kept anonymous. The e-survey was designed at Adobe Form Central (a cloud based form service) and the form was distributed through three (3) channels.

1. Websites: Call for Participants (https://www.callforparticipants.com): a research profile was made on this website to ask participants to fill in the forms. The website is designed to promote the research of university students only in order that they can recruit participants from within their own network.
2. Professional Groups (Community of Practice): Professional groups such as the Lean Construction Supply Chain, Agile Construction, Knowledge Management and Chartered Institute of Building (CIOB) members were approached through LinkedIn professional networks. A conversation was opened providing the link to the online questionnaire. Approximately eighteen (18) groups were approached.
3. Email Questionnaire: Firstly, a database of around 150 organisations was developed from researching their websites, from Yellow pages (yell.com) and other classified listing websites such as scoot.co.uk. Approximately 250 emails were sent to those organisations containing the information about the research and its purpose and a link to the e-questionnaire.

As discussed above, these three approaches were utilised to obtain respondents from all four disciplines of this research, Knowledge Management, the Construction Supply Chain, Lean Construction and Agile Construction. The target was approximately 100 fully completed questionnaire responses in order to conduct the set out analysis (see 4.8.5) (although, based on the above discussion on non-parametric analysis, there is no set minimum number of responses required). This study faces the following difficulties in collecting data through e-questionnaires.

- There is no clear understanding of the number of people who have experience of all four of the desired disciplines as discussed above (see 4.4 and 4.5).
- The design of the questionnaire is kept open to collect responses from respondents who have experience of Lean, Agile and SC and KM disciplines.
- Limits were placed on the questionnaire design in order to keep it bias free in terms of reducing any ambiguity by the researcher.
- The questionnaire is kept limited to 16 questions.
- A lack of understanding of respondents on the importance of sharing and transferring tacit knowledge has appeared as another limitation.
- The conclusions made in sections 4.4 and 4.5 about the number of questionnaires received by respondents in a year and on time limitations also appear to be true in this study.

4.9 Summary of this chapter

In this chapter, different types of data collection strategies, data analysis tools and techniques have been analysed. The first section of this chapter looks at the assumptions that led this study to define the potential population for this study. Secondly, the factors that hinder obtaining a large response rate are discussed. In section (2), each question and its variables are discussed to establish a hypothesis for each variable so that it can be tested in SPSS. Finally, data analysis tools and techniques are critically investigated. This chapter establishes the suitable tools and techniques of data analyses.

The discussion in this chapter on the number of respondents, the questionnaire design, the data analysis tools and techniques is extended and further discussed in the next chapter (5). The next chapter focuses on the number of responses received and on the data organisation and data analysis.

Chapter 5. DATA ANALYSIS

5.1 Introduction

After a detailed discussion in chapter 4 about the data analysis scope and strategy, this chapter focuses on the data analysis of the quantitative data gathered through an e-survey questionnaire. As discussed in chapter 4, IBM SPSS qualitative data analysis software is used to analyse the data while running the following tests Reliability (Cronbach's alpha), Descriptive (Frequencies), Non-parametric (the Kruskal-Wallis H Test) and Correlation Analysis.

The questions from the general section (see 4.7) that produces the interval data, was analysed with a descriptive test to define the frequencies of the number of respondents.

Sections (2) to (6) (see 4.7.2 to 4.7.6) of the questionnaire produces ordinal data and for each question and its variable Reliability, Frequency, Correlation Analysis and the Kruskal-Wallis test is run.

Based on the discussion in chapter 4 section (2) each variable is analysed to test its hypothesis. Moreover, based on the discussion in chapter 2 the correlation between the principles of Lean, Agile and CSCs is tested.

5.1.1 Number of responses received

Eighty-three (83) responses were received. Among them, fourteen (14) responses were incomplete and sixty-nine (69) were fully completed responses. The incomplete responses were deleted to maintain the accuracy of data. This gave the opportunity to avoid internal errors.

As the study used multiple channels to distribute the e-survey, defining the total number of responses from each channel is impossible to track. Because the questionnaires were not tracked in order to maintain ethical issues. However, the logical response rate is calculated based on the sampling size required (response received / sampling size) 84/324 x 100 = 25.92%. Now, the questions is, are the responses received adequate for the type of analysis required to validate the findings and framework in this study. The answer is 'yes'. As discussed in chapter 4 (heading 4.5.4) a low number of responses was expected. Since, the questionnaire has sixteen (16) questions with a total number of seventy (70) hypotheses with seventy (70) independent variables and three hundred and fifty (350) dependent variables, this makes it an adequate database to run non-parametric and correlation analysis. Sixty-nine (69) fully completed responses means 24,150 variables to be analysed; this makes it an adequate database to run the desired analyses.

5.1.2 Preparation of Data in SPSS

The data is entered manually into IBM SPSS. This follows the process below in the Variable View window of SPSS.

Variable names are entered for each variable given to the questions. Data 'Type' is selected as Numeric. A 'Label' name is given for each variable. The syntax is created and these are run to input values. (e.g. VALUE LABELS V51, V52, V53, V54, V55, V56, V57, V58, 1 'Very Low' 2 'Low' 3 'Moderate' 4 'High' 5 'Very High').

After setting up the variables in 'Variable View', the data is manually entered in the 'Data View' window.

5.1.3 Cronbach's Alpha

SPSS provides many statistics that help interpret data and report on Cronbach's alpha value. The first table, **Case Processing Summary**, presents how many cases ("**Valid**" row in the "**N**" column) are in the analysis, as shown in table 5-1 below.

Table 5-1: Cronbach's Alpha Analysis

Case Processing Summary

		N	%
Cases	Valid	69	100.0
	Excluded[a]	0	.0
	Total	69	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.920	.921	65

In this analysis, the simple Cronbach's alpha test (Analyse à Scale à Reliability Analysis) is run on all seventy (70) variables from the questionnaire. The case processing summary shows there are sixty-nine (69) cases included for this analysis, and no cases were excluded due to missing values. The Reliability Analysis calculates that Cronbach's alpha (α) is **0.920.** This indicates a high level of internal consistency for this scale. Values higher than 0.7 of Cronbach's alpha are widely considered as best, as discussed in chapter (4).

Section A General Questions

A frequency analysis is run in SPSS (Analyse → Descriptive → Frequency) to analyse and produce a descriptive analysis while exploring the frequencies of the respondents from the questions below.

5.2 Question A1. Please state the size of your organisation.

This question asks for the size of the organisation of the respondents. The frequency analysis in table 5-2 ‘Respondents’ Size of Organisation’ gives how many responses were from which size of organisation.

Table 5-2: Respondents’ Size of Organisation

Respondent's Size of Organisation		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Micro (1 to 9 employees)	26	37.7	37.7	37.7
	Small (10 to 50 employees)	13	18.8	18.8	56.5
	Medium (50 to 249 employees)	18	26.1	26.1	82.6
	Large (250 and above)	12	17.4	17.4	100.0
	Total	69	100.0	100.0	

Based on the frequency analysis on the respondents’ size of organisation, the highest numbers of respondents (26), recorded as 37.7%, are from Micro (1 to 9 employees) firms. The second highest number of respondents (18) recorded (26.1%) are from Medium (50 to 249 employees) firms. The rest (18.8%) are from Small (10 to 50 employees) firms and 17.4% of them are from Large (250 and above employees) firms.

5.2.1 Question A2: Please state your current job role in this organisation.

The frequency analysis of the responses to this question provides observations on the data concerning the current job role of the respondent.

Table 5-3: Question A2- Respondents' Current Job Role

Respondent's Current Job Role		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Consultant	15	21.7	21.7	21.7
	Director	15	21.7	21.7	43.5
	Knowledge Manager	7	10.1	10.1	53.6
	Lean Manager	10	14.5	14.5	68.1
	Supply Chain Manager	5	7.2	7.2	75.4
	Project Manager	7	10.1	10.1	85.5
	Facility Manager	5	7.2	7.2	92.8
	Other	5	7.2	7.2	100.0
	Total	69	100.0	100.0	

It can be seen in the above table (table 5-3) that the highest number of respondents are Consultants (21.7%) and Directors (21.7%) with a cumulative percentage recorded as 43.5%. The second highest number (14.5%) of respondents are Lean Managers. The third highest number (10.1%) are Knowledge Managers and Project Managers with a cumulative percentage recorded as 20.2%. The rest (21.6%) are recorded as Supply Chain, Facility and other managers.

5.2.2 Question A3. Please state your years of experience in this role.

As given in table 5-4 below, the highest number of respondents (29.0%) have 1 to 5 years of experience. The second highest number (27.5%) have 6 to 10 years of experience. The respondents with 10 to 15 years of experience are 20.3% of the respondents and those with 16 or more years of experience are 23.2% of the respondents.

Table 5-4: Question A3- Respondents' Years of Experience

Respondents' Years of Experience		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 to 5 years	20	29.0	29.0	29.0
	6 to 10 years	19	27.5	27.5	56.5
	10 to 15 years	14	20.3	20.3	76.8
	16 or more	16	23.2	23.2	100.0
	Total	69	100.0	100.0	

5.2.3 Question A4. Please state the nature of business of your organisation.

Table 5-5 below gives an overview of the respondents' nature of current business. The highest number (43.5%) are recorded as Consultants. The second highest are Project

Managers, recorded as 24.6%. Main Contractors are 11.6%, Sub-Contractors 4.3%, Manufacturers 2.9% and Suppliers are 5.8%.

Table 5-5: Question A4- Respondents' Nature of Business

Respondents' Nature of business		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Consultants	30	43.5	43.5	43.5
	Project Managers	17	24.6	24.6	68.1
	Main Contractors	8	11.6	11.6	79.7
	Sub-Contractors	3	4.3	4.3	84.1
	Component Manufacturers	2	2.9	2.9	87.0
	Raw Material Suppliers	4	5.8	5.8	92.8
	Other	5	7.2	7.2	100.0
	Total	69	100.0	100.0	

5.2.4 *Question A5. Please select in which of the areas listed below you have working experience.*

Table 5-6 below gives an overview of the respondents' experience within various management fields. The highest number of respondents (34.8%) had experience in the Construction Project Management field. The second highest (23.2%) had experience of Knowledge Management plus one or more other fields. The rest (17.4%) had experience in Lean Construction Management or in Construction Supply-Chain Management (15.9%). Only 4.3% of respondents had experience of Agile Construction Management.

Table 5-6: Question A5- Respondents' Experience in Management Fields

Respondent's Experience		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Construction Project Management	24	34.8	34.8	34.8
	Lean Construction Management	12	17.4	17.4	52.2
	Agile Construction Management	3	4.3	4.3	56.5
	Construction Supply Chain Management	11	15.9	15.9	72.5
	Knowledge Management in one or more of above fields	16	23.2	23.2	95.7
	Other	3	4.3	4.3	100.0
	Total	69	100.0	100.0	

5.2.5 Interpretation of the data analysis of the general questions (A1 to A5).

This study presents the following findings from the analysis of the responses to the general questions asked through the questionnaire.

Based on data from the answers to question (A1), the highest numbers of respondents are from Micro (1 to 9 employees) firms. This result gives the possibility of making an assumption as the UK construction industry is made up of more than 99% of SMEs (BIS, 2014). As a result, the data reveals that 82.6 % of the respondents are from SMEs. In question (A2), ‘the existing job role of respondents’ shows a total percentage of 43.5% among Consultants and Directors. In question (A3), there is not much variation within the respondents’ years of experience. In question (A4), more than 68% of the respondents’ nature of business is as consultants and project managers. In question (A5), more than 58% of respondents have experience within construction project management and Knowledge management in more than one field.

This analysis reveals that the questionnaire fulfils the requirement of collecting data from Tier (1) and Tier (2) of the CSC. However, the data also establishes that the ‘margin of error’ of respondents could be higher. This, consequently, will incur a lower confidence level within the researcher. Even so, for this study, the margin of error is set to 5% and the confidence interval at 95% for all analyses run in SPSS.

Section B Data analysis of Questions B1, B2 and B3

5.3 Question B1

What is the level of contribution of Tacit Knowledge in the application of the Lean Principles listed below within the construction process?

This question has five (5) Lean Principles as variables (named V1 to V5 for presentation purposes), which are as follows:

1 (V1) *B1.0 : Reduce Waste in the Construction Process*
2 (V2) *B1.1 : Generate Value in the Construction Process*
3 (V3) *B1.2 : Enhance Material and Information Flow in the Construction Process*
4 (V4) *B1.3: Increase Efficiency in the Decision Making Process*
5 (V5) *B1.4: Continuous Improvement in the Construction Process*

5.3.1 Cronbach's Alpha Analysis

Cronbach's alpha (α) is **0.859.** This indicates a high level of internal consistency of this data. The further median score in Table 5-7 is calculated as 4.00 (High) for all variations from this question.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.859	.862	5

Table 5-7: Median score for variables of question B1

Statistics

		B1.0 to reduce waste in construction processes	B1.1 to generate value in construction processes	B1.2 to enhance material and information flow in construction processes	B1.3 to increase efficiency in decision making process	B1.4 to continuous improvement in construction processes
N	Valid	69	69	69	69	69
	Missing	0	0	0	0	0
Median		4.00	4.00	4.00	4.00	4.00

The above table (table 5-7) is generated through the Frequency Analysis (Analyse → Descriptive Analysis → Frequencies) of the variables to compute the median score of each variable.

Table 5-8: Frequency Analysis: Contribution of Tacit Knowledge in the application of Lean Principles

B1.0	Lean Principle	Item	Frequency and Percentile				
			1 Very Low	2 Low	3 Moderate	4 High	5 Very High
V1 (B1.0)	To Reduce Waste in the Construction Process	Frequency	2	4	7	26	30
		Percentage	2.9%	5.8%	10.1%	34.7%	43.5%
		Cumulative Percentage	2.9%	8.7%	18.8%	56.5%	100%
V2 (B1.1)	To Generate Value in the Construction Process	Frequency	1	3	15	31	19
		Percentage	1.4%	4.3%	21.7%	44.9%	27.5%
		Cumulative Percentage	1.4%	5.8%	27.5%	72.5%	100%
V3 (B1.3)	To Enhance Material and Information Flow	Frequency	3	6	25	27	8
		Percentage	4.3%	8.7%	36.2%	39.1%	11.6%
		Cumulative Percentage	4.3%	13.0%	49.3%	88.4%	100%
V4 (B1.4)	To Increase Efficiency in the Decision Making Process	Frequency	9	10	11	28	11
		Percentage	13%	14.5%	15.9%	40.6%	15.9%
		Cumulative Percentage	13%	27.5%	43.5%	84.1%	100%
V5 (B1.5)	Continuous Improvement in Construction Process	Frequency	3	15	16	22	13
		Percentage	4.3%	21.7%	23.2%	31.9%	18.8%
		Cumulative Percentage	4.3%	26.1%	49.3%	81.2%	100%

Table 5-9: Kruskal-Wallis H Test of the Contribution of the Application of Tacit Knowledge in Lean Principles

NO	Hypothesis	Median	Ordinal Rank	Statistically Significantly Distributed	(*p*-value)	Accept or Reject (Null Hypothesis)
V1 (B1.0)	Reduce waste in the construction process.	4.00	High	Yes	.699	Accept
V2 (B1.1)	Generate value in the construction process.	4.00	High	Yes	.337	Accept
V3 (B1.2)	Enhance material and information flow in the construction process.	4.00	High	Yes	.521	Accept
V4 (B1.3)	Increase efficiency in decision-making process.	4.00	High	No	.009	Reject
V5 (B1.4)	Continuous improvement in the construction process.	4.00	High	Yes	.203	Accept

The above tables (tables 5-8 and 5-9) have been developed to exhibit frequency analysis and the Kruskal-Wallis H Test for the question B1.0 in order to analyse the contribution of Tacit Knowledge in the application of Lean Principles within construction processes. The following discussion focuses on the results exhibited for each variable from those tables.

5.3.2 Analysis of Lean Principles based on Frequency, the Kruskal-Wallis-H Test and Correlation Analysis

5.3.2.1 V 1: Lean Principle – Reduce Waste in the Construction Process

The frequency analysis of the level of contribution of Tacit Knowledge in the application of Lean principles to reduce waste in the construction process establishes that the highest number of respondents (43.5%) said ‘Very High’ and the second highest (37.7%) respondents said ‘High’. Moreover, only 10.1% of respondents said ‘Moderate’ and 8.7% said Low (5.8%) and Very Low (2.9%). However, the analysis computes the median score of (4.00). This suggests that the data is statistically significantly distributed among the variables. This also suggests that, among the variables (Very Low to Very High), the generalised result is ‘High’. This means the contribution of Tacit Knowledge in the application of Lean Principles in the construction process to reduce waste is high.

The Kruskal-Wallis H test is run to determine if there are any dissimilarities between the score among six (6) groups of participants with various experiences given in the answers to general question A5. Distributions in the ‘Reduce waste in Construction Processes’ scores are statistically significant for all groups, as assessed by visual inspection of a box-plot. The median score (4.00) is statistically significantly distributed between groups (experience of respondents).

5.3.2.2 V2: Lean Principle – Generate Value in the Construction Process

The frequency analysis for this variable established that 44.9% of the respondents said that the contribution of Tacit Knowledge is 'High' in the application of Lean principles to generate value through the construction process. The second highest number of respondents (27.5%) said 'Very High' and 21.7% of the respondents said that the contribution was 'Moderate'. Only 5.8% said Low (4.3%) and Very Low (1.4%).

The distributions of 'Generate Value in the Construction Processes' scores are similar across all groups, as assessed by visual inspection of a box-plot (Figure 5-2). The median score (4.00) is statistically significantly distributed (not different) between groups (experience of respondents). The Asymptotic Significance (2-sided test) *p*-value is recorded at 0.337 (above > 0.05). Based on this analysis, it meets the assumption of the Null hypothesis that the level of contribution of Tacit Knowledge in the application of Lean Principles 'to Generate Value' is 'High' and thus is to be accepted.

Figure 5-1 below shows that the box-plot median score is (4.00) and the Asymptotic Significance (2-sided test) *p*-value is 0.669 (above > 0.05). Based on the analysis, it meets the assumption that the Null hypothesis to be accepted. This has established that the level of contribution of Tacit Knowledge in the application of Lean Principles 'to reduce waste' is 'High'.

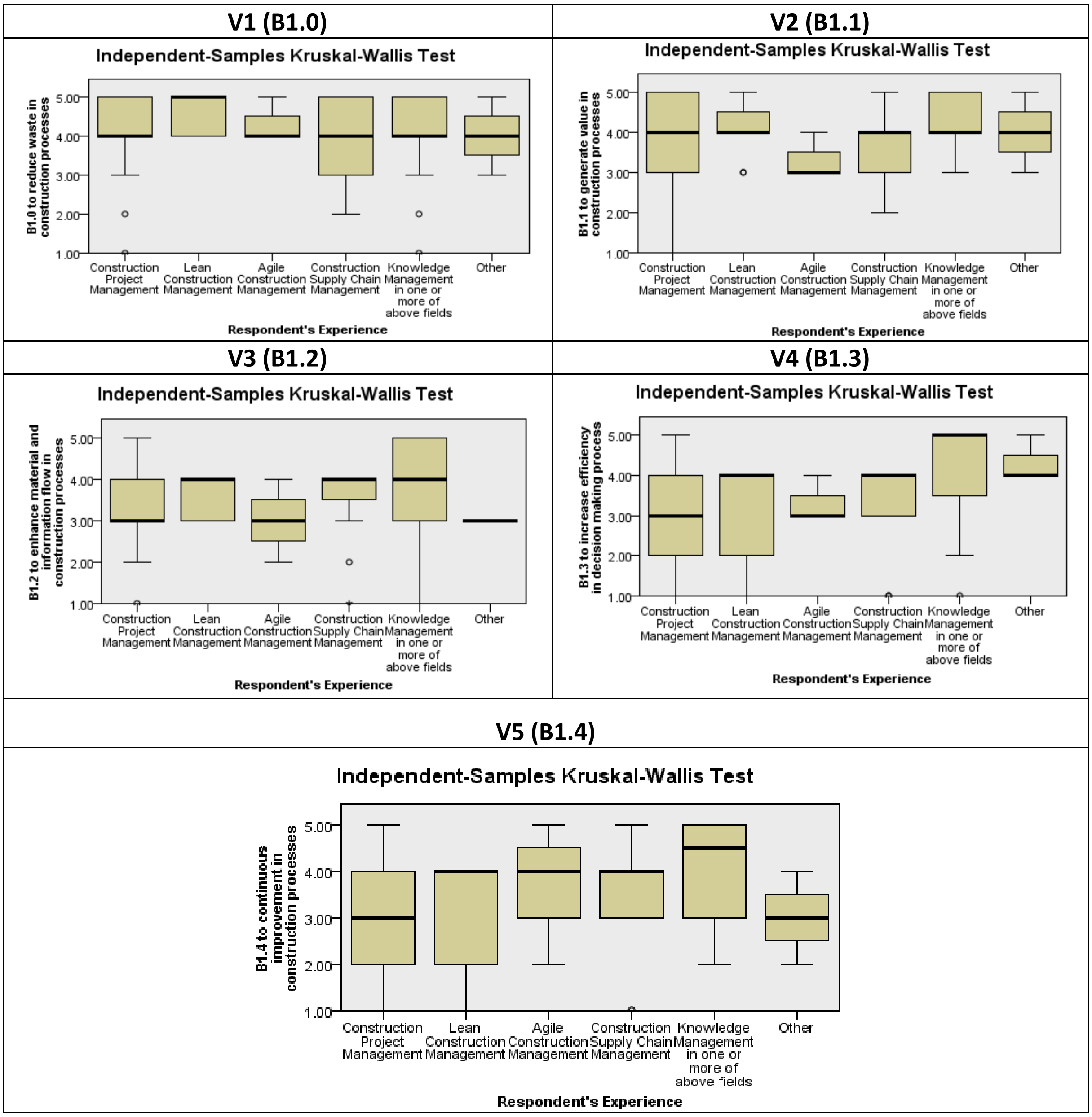


Figure 5-1: Independent Sample showing the Kruskal-Wallis tests Box-plot of Question B1

5.3.2.3 V 3: Lean Principle – Enhance Flow in the Construction Process

The highest number of respondents (39.1%) said that the level of contribution of Tacit Knowledge in Lean principles to enhance the flow of materials and information within the construction process is ‘High’. Moreover, 36.2% of respondents said that the contribution is ‘Moderate’ and 11.6% said ‘Very High’ but just 8.7% said ‘Low’ and 4.3% said ‘Very Low’.

The Kruskal-Wallis H Test for this variable computed the Asymptotic Significance (2-sided test) recorded *p*-value as 0.521 (above > 0.05). The score is statistically significantly distributed among the respondents with the median score of 4.00 in (Figure 5-2). This establishes that the null hypothesis be accepted as the contribution of Tacit Knowledge in

Lean Principles to enhance material and information flow through the construction process is high.

5.3.2.4 V 4: Lean Principle – Increase Efficiency in the Decision-making Process

The highest number of respondents (40.6%) said that the level of contribution of Tacit Knowledge is 'High' to increasing efficiency in the decision-making process. However, other respondents (15.9%) said 'Very High' and 'Moderate' whereas only 14.5% of respondents said 'Low' and 13% said 'Very Low'.

The Kruskal-Wallis H Test for this variable computed the Asymptotic Sig. (2-sided test) recorded *p*-value as 0.009 (below < 0.05). The score is statistically significantly significant among the respondents who responded Low, Moderate, High and Very High with the median score of 4.00 in (Figure 5-1). This rejects the null hypothesis that the contribution of Tacit Knowledge in Lean Principles to enhance material and information flow in the construction process is high.

5.3.2.5 V5: Lean Principle – Continuous Improvement in the Construction Process

The highest number of respondents (31.9%) said that the level of contribution of Tacit Knowledge in application of Lean Principles to improve the construction process is 'High'. The second highest number of respondents (23.2%) said 'Moderate' and 21.7% said 'Low'. 18.8% said 'Low' and only 4.3% said Very Low.

A Kruskal-Wallis H test was run to determine if there were differences between the score among groups of participants with various experiences. The distributions of scores were different for all groups, as assessed by visual inspection of a box-plot. Median scores (4.00) were statistically significantly similar between groups and computed the Asymptotic Significance (2-sided test) recorded *p*-value as 0.203 (above > 0.05). This establishes that the null hypothesis be retained as the contribution of Tacit Knowledge in the application of Lean Principles in the continuous improvement in the construction process is 'High'.

5.3.3 Spearman's Correlation Analysis among Lean Principles

As shown in the table below (table 5-10), Correlations among the Lean Principles is generated (Analyse → Correlate → Bivariate) to identify the correlation significance among the Lean Principles.

Table 5-10: Correlations among the Lean Principles

Correlations among the Lean Principles

			B1.0 to reduce waste in construction processes **(V1)**	B1.1 to generate value in construction processes **(V2)**	B1.2 to enhance material and information flow in construction processes **(V3)**	B1.3 to increase efficiency in decision making processes **(V4)**	B1.4 to continuous improvement in construction processes **(V5)**
Spearman's rho	B1.0 to reduce waste in construction processes **(V1)**	Correlation Coefficient	1.000	.413**	.616**	.398**	.416**
		Sig. (2-tailed)		.000	.000	.001	.000
		N	69	69	69	69	69
	B1.1 to generate value in construction processes **(V2)**	Correlation Coefficient	.413**	1.000	.508**	.458**	.393**
		Sig. (2-tailed)	.000		.000	.000	.001
		N	69	69	69	69	69
	B1.2 to enhance material and information flow in construction processes **(V3)**	Correlation Coefficient	.616**	.508**	1.000	.723**	.691**
		Sig. (2-tailed)	.000	.000		.000	.000
		N	69	69	69	69	69
	B1.3 to increase efficiency in decision making processes **(V4)**	Correlation Coefficient	.398**	.458**	.723**	1.000	.735**
		Sig. (2-tailed)	.001	.000	.000		.000
		N	69	69	69	69	69
	B1.4 to continuous improvement in construction processes **(V5)**	Correlation Coefficient	.416**	.393**	.691**	.735**	1.000
		Sig. (2-tailed)	.000	.001	.000	.000	
		N	69	69	69	69	69

**. Correlations are significant at the 0.01 level (2-tailed).

Correlations among the Lean Principles, as given in Figure 5-2, are discussed below. For presentation purposes, the Lean Principles are coded as Variables (V1 to V5) and Correlations among the Lean Principles are coded as (C1) to (C10).

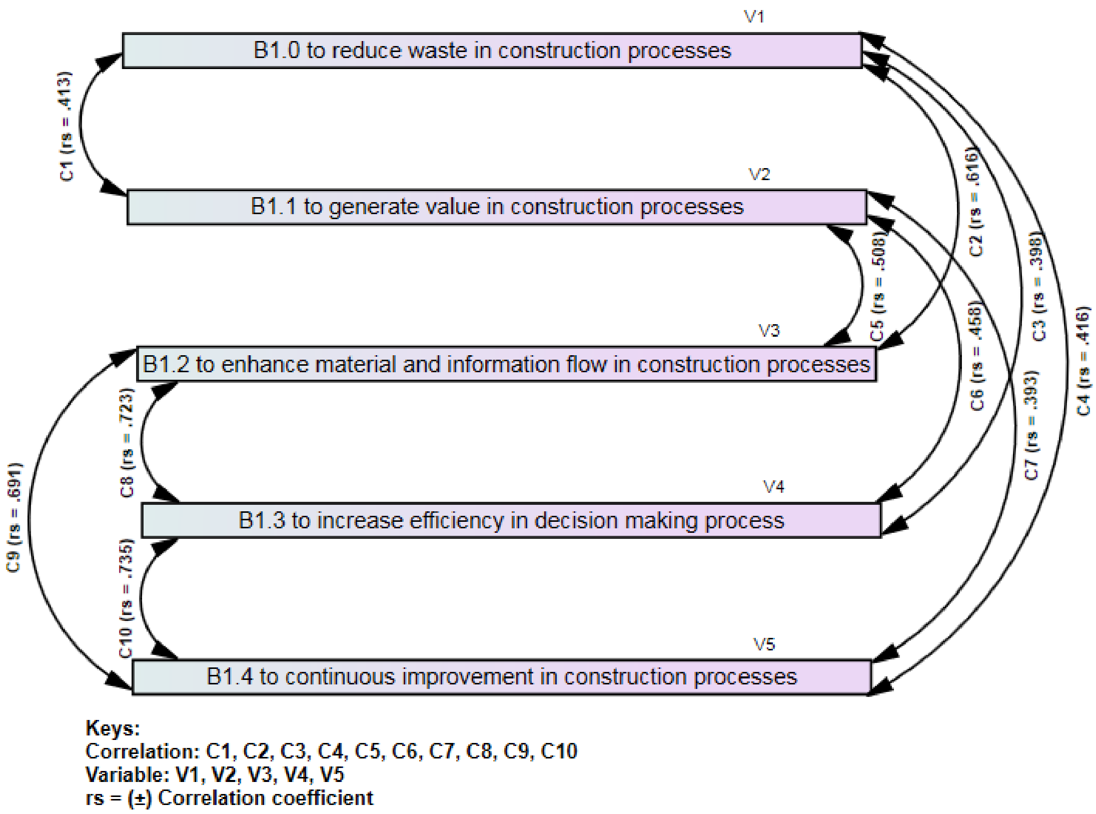


Figure 5-2: Correlations among the Lean Principles

Based on above correlations' (C1 to C10) analysis, the most significant correlation has been found between 'Increasing efficiency in decision-making processes' (V4) and (V5) 'Continuous improvement'. Among these, the positive correlation coefficient is calculated as r_s =.735. The second highest and positive correlation coefficient (r_s =. 723) is calculated between 'Enhance material and information flow' (V3) and (V4) 'Increasing efficiency in the decision-making process'. Moreover, (V3) also has strong positive correlation (r_s =.691) with (V5).

'Reducing Waste in the Construction Process' (V1) is positively associated with (V2), (V3), (V4) and (V5). Among them, the highest positive correlation coefficient (C2) is found (r_s =. 616) between (V1) and (V3) and furthermore (r_s =. 416) between (V1) and (V5), (r_s =. 413) and between (V1) and (V2) and the lowest positive correlation (r_s =. 398) between (V1) and (V4).

However, other variables [(V2), (V3), (V4) and (V5)] have further positive correlations between them. For example, in (C2) the Lean principle, 'To Reduce Waste in Construction Processes' (V1) is positively correlated to 'Enhancing Material and Information Flow' (V3), but (V3) is also positively correlated to (V2), (V4) and (V5).

Table 5-11 below exhibits the rank order of correlation coefficients between the Lean Principles from High (1) to Low (4). In this table, Variable (V1) has the highest correlation coefficient with (V3) and then (V5), (V2) and (V4). Variable (V2) also has the highest correlation coefficient with (V3) and, afterwards, with (V4), (V1) and (V5). Moreover, Variation (V3) has the highest correlation coefficient with (V4) and, further, (V4) and (V5) have highest correlation with each other.

Table 5-11: Interpretive correlation coefficient rank orders of Lean Principles

	Rank			
Principles	**1**	**2**	**3**	**4**
V1	V3	V5	V2	V4
V2	V3	V4	V1	V5
V3	V4	V5	V2	V1
V4	V5	V3	V2	V1
V5	V4	V3	V1	V2
Frequency	V3-2, V4-2	V5-2, V3-2	V2-3, V1-2	V1-2

Based on this interpretive analysis, Table (5-11) showing the correlation coefficient ranking of the Lean Principles has been developed to exhibit the dependency of the correlations among them. In this table, variable (V3) and (V4) fall twice in rank (1). In rank (2) variable (V5) and (V3) fall twice. Variable (V2) falls three times in rank (3) and (V1) falls thrice in rank (3) and rank (4).

As a result, the most predominant variable in rank (1) and rank (2) is (V3) ‘Enhance material and information flow’ with a significant correlation with (V4) ‘Increase efficiency in the decision-making processes'. After that, (V3) and (V4) are followed by (V5), Continuous Improvement, and it is followed by (V1) and (V2).

Based on the interpretive analysis in Table 5-11, the following assumptions can be made based upon the ranking of high to low (1 to 5).

1. To reduce waste in the construction process would require enhancing the material and information flow in the construction process and the continuous improvement of the process which would, consequently, generate value in the construction process and increase efficiency in the decision-making processes.
2. To generate value through the construction process would require enhancing the material and information flow through the construction process. However, this would require

enhancing the decision-making process to reduce waste and then the continuous improvement of the process.

3. To enhance the flow through the construction process would require increasing efficiency in the decision-making process. There is a further requirement for the continuous improvement of the process to enhance the flow in order to generate value and reduce waste in the construction process.
4. To enhance the efficiency of the decision-making process requires continuous improvement in the construction process which, consequently, helps to enhance material and information flow and, furthermore, to generate value while reducing waste in the construction process.
5. To improve the construction process requires enhancing the efficiency of the decision-making process. This would, consequently, increase the flow of material and information and further reduce waste in the construction process, resulting in generating value.

In summary, it can argued that enhancing the material and information flow is the foremost principle followed by an efficient decision-making process, even though the null hypothesis was rejected by the Kruskal-Wallis H test because the data was not statistically significantly distributed. This reveals that the importance of decision making in Lean through Tacit Knowledge is not widely understood in general terms, and different CoPs have differing views about it. Moreover, continuous improvement in the process helps reduce waste and generate value through the construction process. However, in contrast, this establishes that Tacit Knowledge plays a crucial role in the application of Lean Principles in the construction process.

5.4 Evaluation of the level of contribution of Tacit Knowledge in the application of Lean Principles within the construction process.

As discussed earlier in chapter 4, in section (B) the question is designed to identify and evaluate the level of contribution of Tacit Knowledge in the application of (a) Lean (b) Agile and (c) CSCs principles. The question is based on the research question (1) and the research objective (2) set in the introductory Chapter 1. Based on the data analysis, the findings are listed below.

The level of contribution of Tacit Knowledge in the application of Lean Principles within the Construction Process to reduce waste, generate value, enhance material and information flow, increase efficiency in decision-making process and provide continuous improvement within the construction process is high.

1) To reduce waste and generate value in the construction process requires enhancing the material and information flow. To enhance the flow through the construction process will require increasing efficiency in the decision-making process. Furthermore, to enhance efficiency in the decision-making process requires continuous improvement. Additionally, to improve the construction process requires enhancing the efficiency of the decision-making process.

In summary, based on data analysis, enhancing the material and information flow is the foremost principle followed by an efficient decision-making process. It is clear from the findings that the level of contribution of Tacit Knowledge in the application of Lean Principles is high. This clearly pinpoints that Tacit Knowledge plays an important role in the application and efficiency of Lean Principles.

5.5 Data Analysis of Question B2

What is the level of contribution of Tacit Knowledge in the application of the Agile Principles listed below in the construction processes?

This question has four (4) Agile Principles as variables named (V6 to V9) for presentation purposes. These variables are as follows:

1) (V6) B2.0: Enhance responsiveness of activities in the construction process
2) (V7) B2.1: Bring collaboration and partnering in the construction process
3) (V8) B2.2: Empowering teams to take efficient decisions in the construction process
4) (V9) B2.3: Integrate the construction process throughout the project

5.5.1 Cronbach's Alpha

Cronbach's alpha (α) is **0.791** (as shown in table 5-12 which indicates a high level of internal consistency for this data. Furthermore, the median score in table 5-13 is calculated as 4.00 (High) for (V6) and (V7) and 3.00 Moderate for the (V8) and (V9) variables in this question.

Table 5-12: Reliability Analysis Question B2

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.791	.792	4

Table 5-13: Median score for the variables of question B2

Statistics

		B2.0 to enhance responsiveness of activities in construction processes	B2.1 to bring collaboration and partnering in construction processes	B2.2 to empower teams to take efficient decision in construction processes	B2.3 to integrate construction processes throughout the project
N	Valid	69	69	69	69
	Missing	0	0	0	0
Median		4.00	4.00	3.00	3.00

Table 5-14: Frequency Analysis: Contribution of Tacit Knowledge in the application of Lean Principles

B2.0	Agile Principle	Item	Frequency and Percentile				
			1 Very Low	2 Low	3 Moderate	4 High	5 Very High
V6 (B2.0)	To enhance responsiveness of activities in construction processes	Frequency	3	2	16	27	21
		Percentage	4.3%	2.9%	23.2%	39.1%	30.4%
		Cumulative Percentage	4.3%	7.2%	30.4%	69.6%	100%
V7 (B2.1)	To bring collaboration and partnering in construction processes	Frequency	2	7	18	33	9
		Percentage	2.9%	10.1%	26.1%	47.8%	13.0%
		Cumulative Percentage	2.9%	13.0%	39.1%	87.0%	100%
V8 (B2.2)	To empower teams to take efficient decisions in construction processes	Frequency	6	11	22	18	12
		Percentage	8.7%	15.9%	31.9%	26.1%	17.4%
		Cumulative Percentage	8.7%	24.6%	56.5%	82.6%	100%
V9 (B2.3)	To integrate construction processes throughout the project	Frequency	4	8	31	13	13
		Percentage	5.8%	11.6%	44.9%	18.8%	18.8%
		Cumulative Percentage	5.8%	17.4%	62.3%	81.2%	100%

5.5.2 Analysis of Agile Principles based on Frequency, Kruskal-Wallis and Correlation Analysis

5.5.2.1 (V6) (B2.0) Enhance responsiveness of activities in the construction process

The frequency analysis (as shown in table 5-14) of the level of contribution of Tacit Knowledge in the application of Agile principles to enhance the responsiveness of activities throughout the construction process (V6) establishes that the highest number of respondents (39.1%) said 'High' and the second highest number of respondents (30.4%) said 'Very High'. Moreover, the median value in table 5-13 for this variable is calculated as High (4.00).

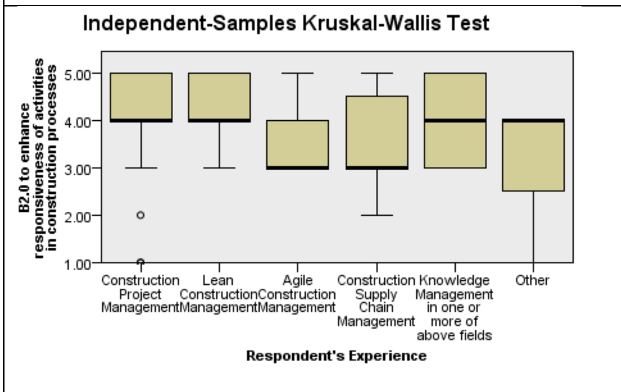
Moreover, in table 5-15 the Kruskal-Wallis H Test and figure 5-4 exhibit the box-plot median score is (4.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.562 (above > 0.05). Based on this analysis, it meets the assumption that the

Null hypothesis be accepted. This has stablished that the level of contribution of Tacit Knowledge in application of Agile Principles ‘to enhance the responsiveness of activities throughout the construction processes is significantly ‘High’.

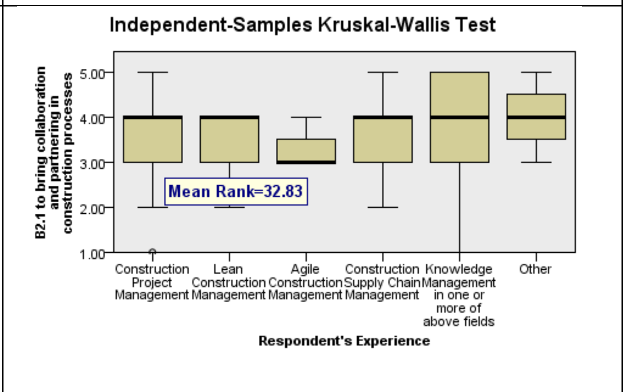
Table 5-15: Kruskal-Wallis H Test of the Contribution of Tacit Knowledge application of in Agile Principles

NO	Hypothesis	Median	Ordinal Rank	Statistically Significantly Distributed	(*p*-value)	Accept or Reject (Null Hypothesis)
1	To enhance responsiveness of activities in construction processes	4.00	High	Yes	.562	Accept
2	To bring collaboration and partnering in construction processes	4.00	High	Yes	.645	Accept
3	To empower teams to take efficient decisions in construction processes	3.00	Moderate	Yes	.338	Accept
4	To integrate construction processes throughout the project	3.00	Moderate	Yes	.064	Accept

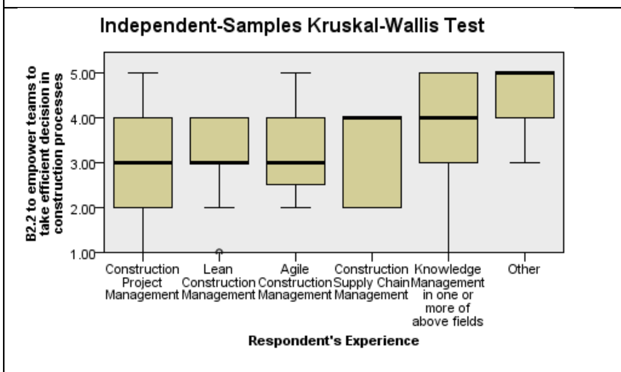
(V6) B2.0



(V7) B2.1



(V8) B2.2



(V9) B2.3

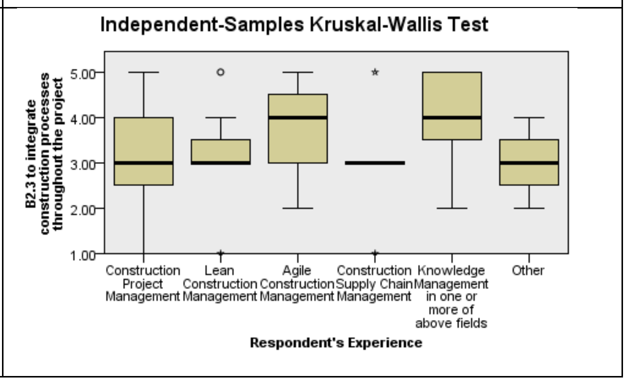


Figure 5-3: Kruskal-Wallis H Test Boxplot for question B2

5.5.2.2 (V7) B2.1: Bring collaboration and partnering in the construction process

The frequency analysis in table 5-14 on the level of contribution of Tacit Knowledge in the application of Agile principles to bring collaboration and partnering within the construction process (V7) establishes that the highest number of respondents (47.8%) said ‘High’ and the second highest number of respondents (26.1%) said ‘Moderate’. Moreover, the median value (in Table 5-13) for this variable is calculated as High (4.00).

Moreover, as shown in table 5-15 the Kruskal-Wallis H Test and figure 5-4 exhibit the box-plot median score is (4.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.645 (above > 0.05). Based on the analysis, it meets the assumption that the Null hypothesis is to be accepted. This establishes that the level of contribution of Tacit Knowledge in the application of Agile Principles ‘to bring collaboration and partnering in the construction processes’ is significantly ‘High’.

5.5.2.3 (V8) B2.2: Empowering teams to take efficient decisions in the construction process

The frequency analysis in table 5-14 for this variable establishes that the highest number of respondents (31.9%) said that the contribution of Tacit Knowledge in the application of Agile Principles to empower teams to take an efficient decisions in the construction process is ‘Moderate’. The second highest number of respondents (26.1%) said the contribution is ‘High’. Moreover, only 17.4% of the respondents said the contribution is ‘Very High’ and a total of 24.6% respondents said ‘Low (15.9%) and Very Low (8.7%)’. In table 5-13 the median score is calculated as 3.00 (Moderate). Moreover, the Kruskal-Wallis H Test in table 5-15 and figure 5-4 establishes that the box-plot median score is (3.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.338 (above > 0.05); by which meaning that in this the data is statistically significantly distributed. Based on the analysis, it meets the assumption that the Null hypothesis is to be accepted. This establishes that the level of contribution of Tacit Knowledge in the application of Agile Principles ‘to empower teams to take an efficient decisions in the construction process’ is significantly ‘Moderate’. However, it rejects the null hypothesis established earlier in chapter 4 as a ‘High contribution’. Therefore, it accepts the alternate hypothesis as a ‘moderate contribution’.

5.5.2.4 (V9) B2.3: Integrate construction process throughout the project

The frequency analysis in table 5-14 on this variable establishes that the highest number of respondents (44.9%) said that the contribution of Tacit Knowledge in the application of Agile Principles to integrate construction processes throughout the project is ‘Moderate’. The second highest number of respondents (37.6%) said the contribution is ‘High’ (18.8%) and ‘Very High’ (18.8%). Moreover, only 11.6% of the respondents said the contribution is ‘Very High’. The median score is calculated as (3.00) ‘Moderate’.

Moreover, the Kruskal-Wallis H Test as shown in table 5-15 and figure 5-4 establishes that the box-plot median score is (3.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.064 (above > 0.05); in this, the data is statistically significantly distributed. As the result, it meets the assumption that the Null hypothesis is to be accepted.

However, this rejects the Null Hypothesis. This establishes that the level of contribution of Tacit Knowledge in the application of Agile Principles 'to integrate the construction process throughout the project is significantly 'Moderate'.

5.5.3 Spearman's Correlation Analysis among Agile Principles

Table 5-10 below shows that the Correlation among Lean Principles is generated (Analyse → Correlate → Bivariate) to identify and investigate the correlation significance among the Agile Principles. The correlations among the Agile Principles as given below in Figure 5-4 and Table 5-17 are discussed below. For presentation purposes, the correlations among the Agile Principles are coded as (C1) to (C6).

Table 5-16: Spearman's Correlations among Agile Principles

Spearman's Correlations among Agile Principles

			B2.0 to enhance responsiveness of activities in construction processes	B2.1 to bring collaboration and partnering in construction processes	B2.2 to empower teams to take efficient decisions in construction processes	B2.3 to integrate construction processes throughout the project
Spearman's rho	B2.0 to enhance responsiveness of activities in construction processes **(V6)**	Correlation Coefficient	1.000	.414**	.416**	.116
		Sig. (2-tailed)		.000	.000	.341
		N	69	69	69	69
	B2.1 to bring collaboration and partnering in construction processes **(V7)**	Correlation Coefficient	.414**	1.000	.688**	.498**
		Sig. (2-tailed)	.000		.000	.000
		N	69	69	69	69
	B2.2 to empower teams to take efficient decisions in construction processes **(V8)**	Correlation Coefficient	.416**	.688**	1.000	.504**
		Sig. (2-tailed)	.000	.000		.000
		N	69	69	69	69
	B2.3 to integrate construction processes throughout the project **(V9)**	Correlation Coefficient	.116	.498**	.504**	1.000
		Sig. (2-tailed)	.341	.000	.000	
		N	69	69	69	69

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

Based on the above correlations' (C1 to C6) analysis in table 5-16, the most significant correlation has been found between (V7) and (V8). Between those, the positive correlation coefficient is calculated as r_s =.668. The second highest and positive correlation coefficient (r_s =. 504) is calculated between (V8) and (V9). Moreover, (V7) also has a strong positive correlation (r_s =. 498) with (V9).

'Enhancing responsiveness of activities' (V6) in the construction process is positively associated with (V7), (V8) and (V9). Among them, as shown in Figure 5-5 below, the highest positive correlation coefficient (C2) is found (r_s =. 416) between (V6) and (V8) and furthermore (C1) with (r_s =. 414) between (V6) and (V7) and the lowest positive correlation (C3) with (r_s =. 116) is between (V6) and (V9).

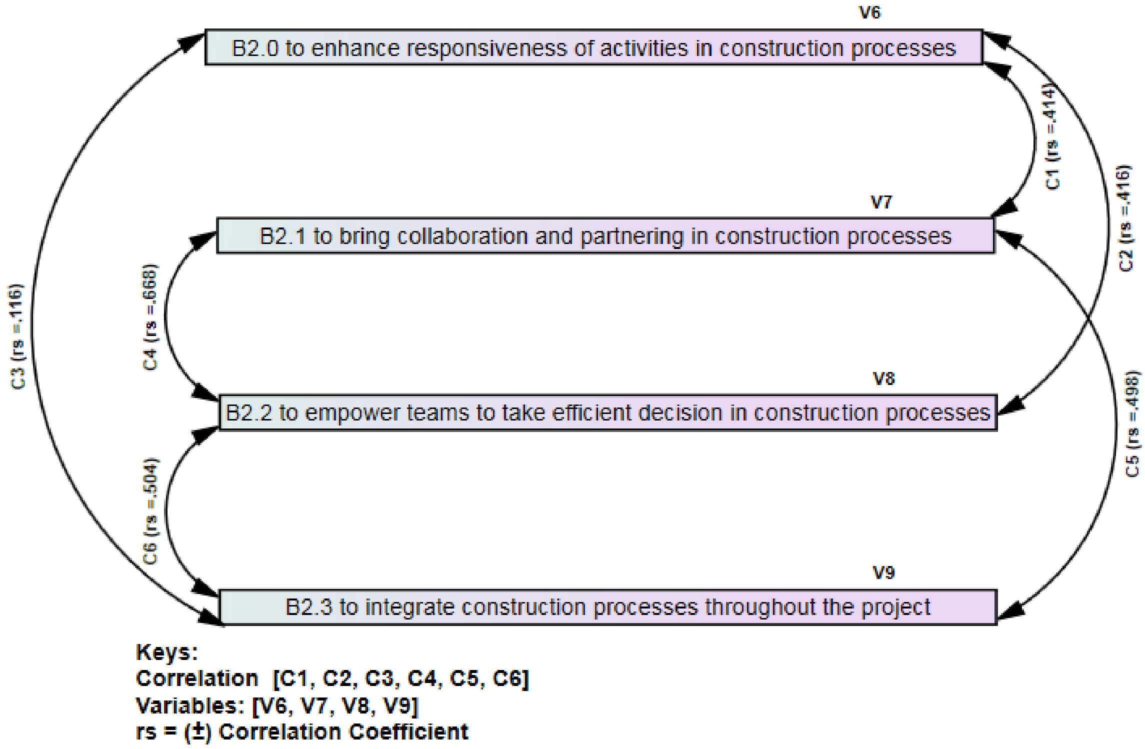


Figure 5-4: Correlation among Agile Principles

Table 5-17 below exhibits the ranking order of the correlation coefficients between the Agile Principles from High (1) to Low (3). In this table, Variable (V6) has the highest correlation coefficient with (V8) and then with (V7) and (V9). Variable (V7) also has the highest correlation coefficient with (V8) and then, afterwards, with (V9) and (V6). Moreover, Variation (V9) also has the highest correlation coefficient with (V8) and furthermore with (V7) and (V6) have highest correlation with each other.

Table 5-17: Interpretive correlation coefficient ranking orders of Agile Principles

Principles	Rank		
	1	2	3
V6	V8	V7	V9
V7	V8	V9	V6
V8	V6	V9	V7
V9	V8	V7	V6
Frequency	V8-3	V7-2, V9-2	V6-2

The interpretive analysis in table 5-17 for the correlation coefficients between Agile principles shows a ranking 'High (1) to Low (3)'. In rank (1) variable (V8) is most predominant correlated with (V6), (V7) and (V9) at the highest correlation coefficient. It is followed by (V7) and (V9) and these are followed by (V6).

Moreover, based on the above interpretive analysis in table 5-23, the following assumptions can be made in respect to the 'highest to the lowest' correlation coefficient of Agile Principles.

1. To enhance the responsiveness of activities within the construction process would require the empowerment of teams to take efficient decisions. This would, consequently, bring collaboration and partnering into the construction process and further integrate construction processes throughout the construction project.
2. To bring collaboration and partnering into the construction process would require empowering teams to take efficient decisions. This would, as a result, help to bring the integration of construction processes throughout the construction project and further enhance the responsiveness of activities in construction processes.
3. To empower teams to take efficient decisions in the construction process would require the enhancement of the responsiveness of activities. This would help to integrate activities throughout the construction project. This, consequently, would bring collaboration and partnering.
4. To integrate activities in the construction process would require empowering teams to make efficient decisions. This would bring collaboration and partnering and, consequently, increase the responsiveness of activities.

In summary, the data analysis of the responses to this question establishes that empowering teams to take efficient decisions has the most common and significant correlations with (V7) to bring collaboration and (V9) to integrate construction process. Moreover, it has significant correlation with (V6) to bring the responsiveness of activities in the construction process. This would be the foremost agile principle to apply in the construction process which would, consequently, help bring integration and collaboration and partnering into the construction process which would further enhance the responsiveness of activities among construction processes.

Equally important, the frequency and the Kruskal-Wallis H tests establish that there is a significant contribution by Tacit Knowledge in the application of Agile Principles.

5.5.4 Evaluation of the level of contribution of Tacit Knowledge in the application of Agile Principles within the Construction Process

As highlighted, the data analysis of the responses to this question establishes that empowering teams to take efficient decisions is the most common and the foremost agile principle to apply to the construction process which would, consequently, help to bring integration and collaboration. In addition, it would enhance the responsiveness of activities among construction processes. The following conclusions are made from the data analysis of the responses to this question.

1. The level of contribution of Tacit Knowledge in the application of Agile Principles within the Construction Process to bring collaboration and partnering and enhance the responsiveness of activities within the construction processes is high. However, in terms of empowering teams to make effective decisions and integrate activities within construction processes the contribution is moderate.
2. To enhance the responsiveness of activities, to bring collaboration and partnering and to integrate activities in the construction process would require the empowering of teams to take efficient decisions.

In summary, the data analysis of the responses this question establishes that, even though the contribution of Tacit Knowledge to empowering teams to take efficient decisions is moderate, this is still the most common agile principle which has significant correlation with another three (3) principles. This would be the foremost agile principle to apply in the construction process.

5.6 Data analysis of Question B3

What is the level of contribution of Tacit Knowledge in the application of the supply chain principles listed below in construction processes?

This question has four (4) Supply Chain Principles. The variables, named as (V10) to (V13) for presentation purposes, are as follows:

1) (V10) *B3.0 to enhance collaboration among organisations in construction processes*
2) (V11) *B3.1 to reduce the negative impact of fragmentation in Construction Supply Chain processes*
3) (V12) *B3.2 to increase the efficiency of the Construction Supply Chain*
4) (V13) *B3.3 to increase the responsiveness of the Construction Supply Chain*

5.6.1 Cronbach's Alpha Reliability Test

Cronbach's alpha (α) is **observed as 0.827** in table 5-18. This indicates a high level of internal consistency for this data. Moreover, the median score in table 5-19 is calculated as 4.00 (High) for variable (V10). In addition, Moderate (3.00) is calculated for variables (V11), (V12) and (V12).

Table 5-18: Reliability Test of Question B3

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.827	.831	4

Table 5-19: Median score for variables of question B3

Statistics

		B3.0 to enhance collaboration among organizations in construction processes	B3.1 to reduce negative impact of fragmentation in construction supply chainsprocesses	B3.2 to increase efficiency of construction supply chain	B3.3 to increase responsiveness of construction supply chain
N	Valid	69	69	69	69
	Missing	0	0	0	0
Median		4.00	3.00	3.00	3.00

Table 5-20: Frequency Analysis: Contribution of Tacit Knowledge in the application of Supply Chain Principles

B3.0	Supply Chain Principle	Item	Frequency and Percentile				
			1 Very Low	2 Low	3 Moderate	4 High	5 Very High
V10 (B3.0)	To enhance collaboration among organisations in construction processes	Frequency	3	3	12	40	11
		Percentage	4.3%	4.3%	17.4%	58.0%	15.9%
		Cumulative Percentage	4.3%	8.7%	26.1%	84.1%	100%
V11 (B3.1)	To reduce negative impact of fragmentation in Construction Supply Chain processes	Frequency	4	7	27	23	8
		Percentage	5.8	10.1%	39.1%	33.3%	11.6%
		Cumulative Percentage	5.8%	15.9%	55.1%	88.4%	100%
V12 (B3.2)	To increase the efficiency of the Construction Supply Chain	Frequency	3	9	26	25	6
		Percentage	4.3%	13.0%	37.7%	36.2%	8.7%
		Cumulative Percentage	4.3%	17.4%	55.1%	91.3%	100%
V13 (B3.3)	To increase the responsiveness of the Construction Supply Chain	Frequency	4	18	24	14	9
		Percentage	5.8%	26.1%	34.8%	20.3%	13.0%
		Cumulative Percentage	5.8%	31.9%	66.7%	87.0%	100%

5.6.2 Analysis of supply chain principles based on Frequency, Kruskal-Wallis and Correlation Analysis

5.6.2.1 (V10) (B3.0) to enhance collaboration among organisations in construction processes

The frequency analysis shown in table 5-20 of the level of contribution of Tacit Knowledge in the application of SC principle (V10) to enhance collaboration among organisations in the construction process establishes that the highest number of respondents (58.0%) said ‘High’ and the second highest number of respondents (30.4%) said ‘Very High’. Moreover, the median value (as shown in Table 5-19) for this variable is calculated as High (4.00).

Moreover, as shown in table 5-21 the Kruskal-Wallis H Test and Figure 5-6 exhibit the box-plot median score is (4.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.590 (above > 0.05). This analysis meets the assumption that the Null hypothesis be accepted. This establishes that the level of contribution of Tacit Knowledge in the application of the Supply Chain Principle 'to enhance collaboration among organisations in construction processes' is significantly 'High' .

Table 5-21: Kruskal-Wallis H Test of Contribution of Tacit Knowledge in the application of in SC Principles

NO	Hypothesis	Median	Ordinal Rank	Statistically Significantly Distributed	(*p*-value)	Accept or Reject (Null Hypothesis)
V10 (B3.0)	To enhance collaboration among organisations in construction processes	4.00	High	Yes	.590	Accept
V11 (B3.1)	To reduce negative impact of fragmentation in Construction Supply Chain processes	3.00	Moderate	Yes	.527	Accept
V12 (B3.2)	To increase the efficiency of the Construction Supply Chain	3.00	Moderate	Yes	.339	Accept
V13 (B3.3)	To increase the responsiveness of the Construction Supply Chain	3.00	Moderate	No	.022	Reject

5.6.2.2

5.6.2.3 (V11) (B3.1) to reduce negative impact of fragmentation in Construction Supply Chain processes

As seen in table 5-20, the frequency analysis of the level of contribution of Tacit Knowledge in the application of SC principle (V11) to reduce the negative impact of fragmentation in the Construction Supply Chain processes establishes that the highest number of respondents (39.1%) said 'Moderate' and the second highest number of respondents (33.3%) said 'High'. Moreover, the median value (as shown in Table 5-19) for this variable is calculated as 'Moderate' (3.00).

Moreover, as seen in table 5-21 the Kruskal-Wallis H Test and Figure 5-6 exhibit the box-plot median score is (3.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.527 (above > 0.05). This analysis meets the assumption that the alternate hypothesis is to be accepted. This establishes that the level of contribution of Tacit Knowledge in the application of the Supply Chain Principle ‘to reduce the negative impact of fragmentation in the Construction Supply Chain processes’ is significantly ‘Moderate’.

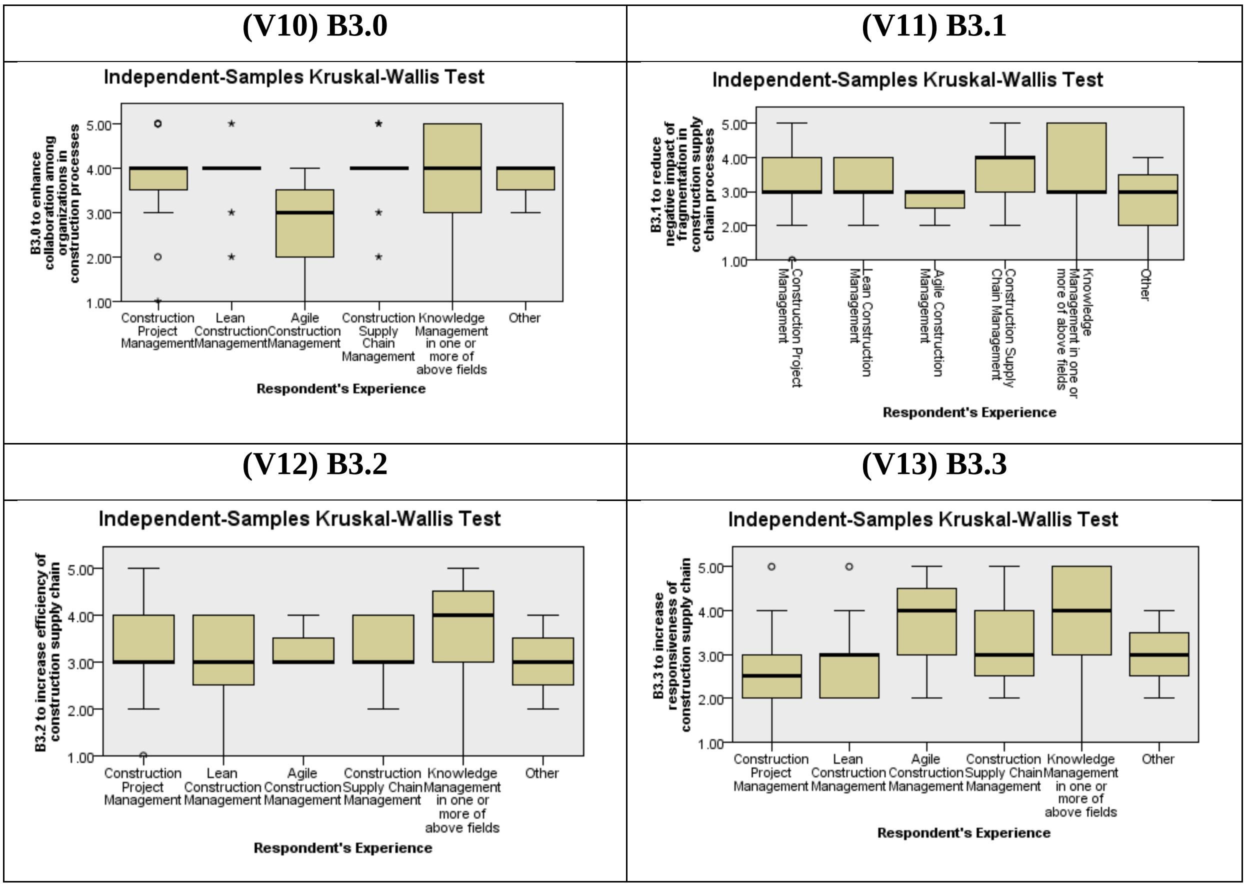


Figure 5-5: Kruskal-Wallis H Test Boxplot for question B3

5.6.2.4 (V12) (B3.2) to increase the efficiency of Construction Supply Chains

The frequency analysis (as shown in table 5-20) establishes that the highest number of respondents (37.7%) said ‘Moderate’ and the second highest number of respondents (36.2%) said ‘High’ with the median value (as shown in table 5-19) calculated as ‘Moderate’ (3.00) concerning the level of contribution of Tacit Knowledge.

Moreover, as shown in table 5-21, the Kruskal-Wallis H Test and figure 5-6 also exhibit the box-plot median score is (3.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.339 (above > 0.05). This analysis accepts the alternate hypothesis. This establishes that the level of contribution of Tacit Knowledge in the application of the Supply-Chain Principle ‘to increase the efficiency of the CSC’ is significantly ‘Moderate’.

5.6.2.5 (V13) (B3.3) to increase the responsiveness of the Construction Supply Chain

The frequency analysis in table 5-20 establishes the level of contribution of Tacit Knowledge in the application of the SC principle ‘to increase the responsiveness of the Construction Supply Chain’. The highest number of respondents (34.8%) said ‘Moderate’ and the second highest number of respondents (26.1%) said ‘Low’. Moreover, the median value calculates as ‘Moderate’ (3.00) (as shown in table 5-19).

As seen in table 5-21. The Kruskal-Wallis H Test and figure 5-6 also exhibit that the box-plot median score is (3.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) p-value is 0.022 (below < 0.05). Based on this analysis, it meets the assumption that the alternate hypothesis to be accepted. This establishes that the level of contribution of Tacit Knowledge in application of the Supply Chain Principle ‘to increase the responsiveness of the Construction Supply Chain’ is significantly ‘Moderate’.

5.6.3 Spearman’s Correlation Analysis among Supply Chain Principles

Table 5-22 below has been generated to identify the correlation significance among the SC principles. Correlations among SC principles (as given in figure 5-7 and table 5-23) are discussed below. For presentation purposes, the correlations among the SC principles are coded as (C1) to (C6).

Based on correlations’ (C1 to C6) analysis below (see Table 5-22), the most significant correlation has been found between (V12) and (V13). Among these, the positive correlation coefficient is calculated as r_s =.662. The second highest and positive correlation coefficient (r_s =. 558) is calculated between (V10) and (V11). Figure 5-7 below presents all six (6) correlations among these four (4) variables.

Table 5-22: Spearman's Correlations among Supply Chain Principles

			B3.0 to enhance collaboration among organisations in construction processes	B3.1 to reduce negative impact of fragmentation in Construction Supply Chain processes	B3.2 to increase the efficiency of the Construction Supply Chain	B3.3 to increase the responsiveness of the Construction Supply Chain
Spearman's rho	B3.0 to enhance collaboration among organisations in construction processes **(V10)**	Correlation Coefficient	1.000	.558**	.501**	.297*
		Sig. (2-tailed)		.000	.000	.013
		N	69	69	69	69
	B3.1 to reduce negative impact of fragmentation in Construction Supply Chain processes **(V11)**	Correlation Coefficient	.558**	1.000	.544**	.354**
		Sig. (2-tailed)	.000		.000	.000
		N	69	69	69	69
	B3.2 to increase the efficiency of the Construction Supply Chain **(V12)**	Correlation Coefficient	.501**	.544**	1.000	.662**
		Sig. (2-tailed)	.000	.000		.000
		N	69	69	69	69
	B3.3 to increase the responsiveness of the Construction Supply Chain **(V13)**	Correlation Coefficient	.297*	.354**	.662**	1.000
		Sig. (2-tailed)	.341	.000	.000	
		N	69	69	69	69

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

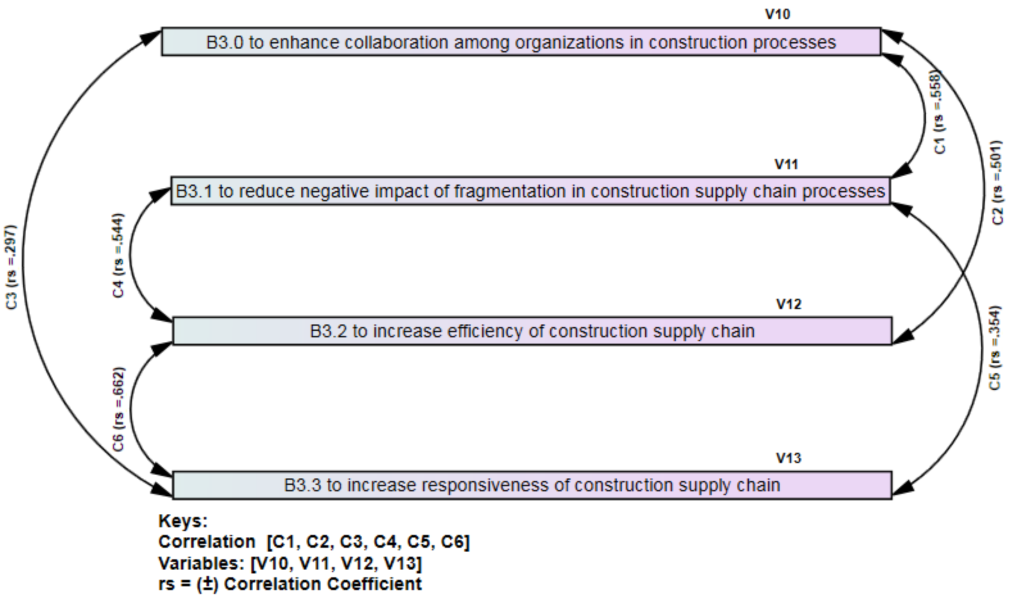


Figure 5-6: Correlation among Supply Chain Principles

Table 5-23 below exhibits the ranking order of the correlation coefficients between the SC principles from the ‘Highest Correlated Coefficient’ (1) to the ‘Lowest Correlated Coefficient’ (3). In this table, in Rank 1 all the variables are highly correlated with each other. But in Rank 2 (V11) and (V12) and in Rank 3 (V13) and (V14) appear twice. As a result, Variable (V10) ‘to enhance collaboration among organisations in construction processes’ is highly correlated with (V11) and then with (V12) and (V13).

Table 5-23: Interpretive correlation coefficient rank orders of Lean Principles

	Rank		
Principles	**1**	**2**	**3**
V10	V11	V12	V13
V11	V10	V12	V13
V12	V13	V11	V10
V13	V12	V11	V10
Frequency	-	V12-2, V11-2	V13-2, V10-2

Through the interpretive analysis shown in table 5-23, the following assumptions can be made in respect to the ‘highest to the lowest' correlation coefficient of SC principles.

5.6.3.1 Assumptions

1. Enhancing collaboration in CSCs would reduce the negative impact of fragmentation which, in turn, would increase the efficiency and responsiveness of CSCs.
2. Enhancing efficiency in CSCs would increase the responsiveness of the CSCs. It would, in addition, reduce the negative effect of fragmentation and hence enhance collaboration in CSCs.
3. Increasing the responsiveness of CSCs would enhance efficiency in CSCs. Furthermore, it would reduce the negative effect of fragmentation and, consequently, enhance collaboration in CSCs.

In line with the evidence provided above it is tough to establish which SC principle is the foremost amongst the others. This analysis presents an equal contribution of these principles to the success of a CSC. However, the frequency analysis and the Kruskal-Wallis H tests establish that there is significant contribution by Tacit Knowledge in the application of SC Principles.

5.6.4 Evaluation of the level of contribution of Tacit Knowledge in the application of SC Principles within the Construction Process

The contribution of Tacit Knowledge in the application of the SC principle, to enhance collaboration among organisations in construction processes, is found to be ‘high’. For other principles, the contribution of Tacit Knowledge is observed as ‘moderate’. The data analysis establishes an equal contribution of Tacit Knowledge in application of these principles to the success of a CSC.

Section C Data analysis of Questions C1 and C2

This section examines the challenges associated with the effective transferring and sharing of Tacit Knowledge through the application of (a) Lean and (b) Agile Principles in Construction Supply Chains.

The ‘challenge’ in this context is a call for the essential factors whose absence hinders the sharing or transference of Tacit Knowledge.

5.7 Question C1

By drawing from your experience, kindly indicate the level of the challenges listed below associated with the transfer and sharing of Tacit Knowledge through the application of Lean Principles.

This question has six (6) challenges (named as variables V1 to V6) for presentation purposes, and they are as follows:

1) (V1) C1.0 Lack of understanding and of importance of the transfer and sharing of Tacit Knowledge
2) (V2) C1.1 Lack of trust among organisations in Construction Supply Chains
3) (V3) C1.2 Insufficiency of motivation for organisations in Construction Supply Chains
4) (V4) C1.3 Short term supply chain relationship among partners of Construction Supply Chains
5) (V5) C1.4 Contractors have their traditional way of doing business
6) (V6) C1.5 Fragmented nature of the construction sector

Table 5-24: Reliability Test for question C1

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.702	.696	6

5.7.1 Cronbach's Alpha Reliability Test

Cronbach's alpha (α) **0.702** is calculated as shown in table (5-24**)**. This establishes that the data has an adequate level of internal consistency. The further median score (as shown in table 5-25) is calculated as 4.00 (Challenging) for variables (V1), (V2) and (V3). Moreover, it shows Moderately Challenging (3.00) for variables (V4), (V5) and (V6) within this question.

Table 5-25: Median score for variables of question C1

Statistics

		C1.0 Lack of understanding of importance of transfer and sharing of knowledge	C1.1 Lack of trust among the organizations in construction supply chains	C1.2 Insufficiency of motivation for organizations in construction supply chains	C1.3 Short term supply chain relationship among partners of construction supply chains	C1.4 Contractors have traditional ways of doing business	C1.5 Fragmented nature of construction sector
N	Valid	69	69	69	69	69	69
	Missing	0	0	0	0	0	0
Median		4.00	4.00	4.00	3.00	3.00	3.00

5.7.2 Analysis of challenges associated with the transfer and sharing of Tacit Knowledge in the application of Lean Principles based on Frequency Analysis and the Kruskal-Wallis H Test

5.7.2.1 (V1) C1.0 Lack of understanding of importance of transfer and sharing of Tacit Knowledge

As shown by the frequency analysis depicted in table 5-26 the highest number of respondents (44.9%) said that the lack of understanding of importance of transfer and sharing of Tacit Knowledge (V1) is 'Challenging'. The second highest number of respondents (34.8%) said 'Moderately Challenging'. Moreover, the median value as shown in table 5-25 for this variable is calculated as 'Challenging' (4.00).

Moreover, as seen in table 5-27, the Kruskal-Wallis H Test and figure 5-8 exhibit that the box-plot median score is (4.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.890 (above > 0.05). This meets the assumption that the Null hypothesis is to be accepted. This establishes that the lack of understanding of importance of transfer and sharing of Tacit Knowledge in the application of Lean Principles in construction processes is significantly 'Challenging'.

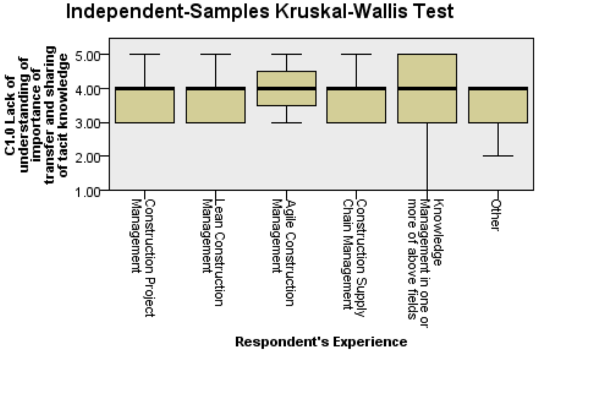
Table 5-26: Frequency analysis of Question C1

C1	Challenges	Item	Frequency and Percentile				
			1 Not Challenging	2 Little Challenging	3 Moderately Challenging	4 Challenging	5 Highly Challenging
V1 (C1.0)	Lack of understanding of importance of transferring and sharing Tacit Knowledge	Frequency	2	2	24	31	10
		Percentage	2.9%	2.9%	34.8%	44.9%	14.5%
		Cumulative Percentage	2.9%	5.8%	40.6%	85.1%	100%
V2 (C1.1)	Lack of trust among the organisations in Construction Supply Chains	Frequency	0	5	10	34	20
		Percentage	0.0%	7.2%	14.5%	49.3%	29.0%
		Cumulative Percentage	0.0%	7.2%	21.7%	71.0%	100%
V3 (C1.2)	Insufficiency of motivation for organisations in Construction Supply Chains	Frequency	3	2	16	33	15
		Percentage	4.3%	2.9%	23.2%	47.8%	21.7%
		Cumulative Percentage	4.3%	7.2%	30.4%	78.3%	100%
V4 (C1.3)	Short term supply chain relationship among partners in Construction Supply Chains	Frequency	1	11	28	26	3
		Percentage	1.4%	15.9%	40.6%	37.7%	4.3%
		Cumulative Percentage	1.4%	17.4%	58.0%	95.7%	100%
V5 (C1.4)	Contractors have traditional ways of doing business	Frequency	2	12	22	19	14
		Percentage	2.9%	17.4%	31.9%	27.5%	20.3%
		Cumulative Percentage	2.9%	20.3%	52.2%	79.7%	100%
V5 (C1.5)	Fragmented nature of construction sector	Frequency	4	8	26	22	9
		Percentage	5.8%	11.6%	37.7%	31.9%	13.0%
		Cumulative Percentage	5.8%	17.4%	55.1%	87.0%	100%

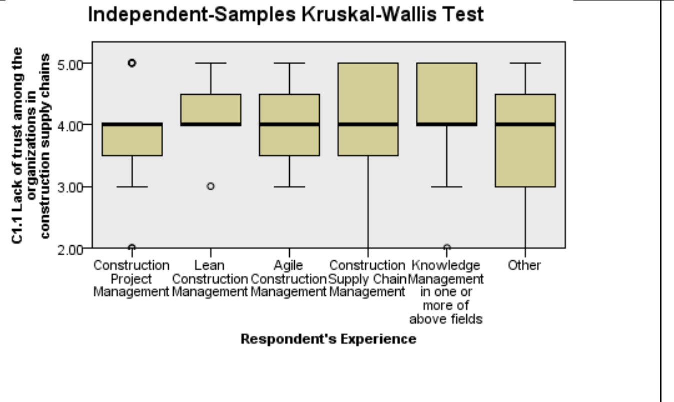
Table 5-27: Kruskal-Wallis H Test of Challenges of transferring and sharing Tacit Knowledge in the application of Lean Principles

NO	Hypothesis	Median	Ordinal Rank	Statistically Significantly Distributed	(*p*-value)	Accept or Reject (Null Hypothesis)
V1 (C1.0)	Lack of understanding of importance of transferring and sharing Tacit Knowledge	4.00	Challenging	Yes	.890	Accept
V2 (C1.1)	Lack of trust among the organisations in Construction Supply Chains	4.00	Challenging	Yes	.927	Accept
V3 (C1.2)	Insufficiency of motivation for organisations in Construction Supply Chains	4.00	Challenging	Yes	.992	Accept
V4 (C1.3)	Short term supply chain relationship among partners of Construction Supply Chains	3.00	Moderate	No	.046	Reject
V5 (C1.4)	Contractors have traditional ways of doing business	3.00	Moderate	Yes	.219	Accept
V6 (C1.5)	Fragmented nature of construction sector	3.00	Moderate	Yes	.134	Accept

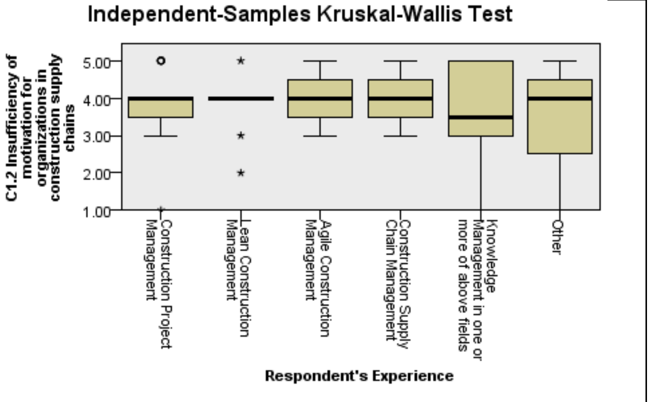
(V1) C1.0



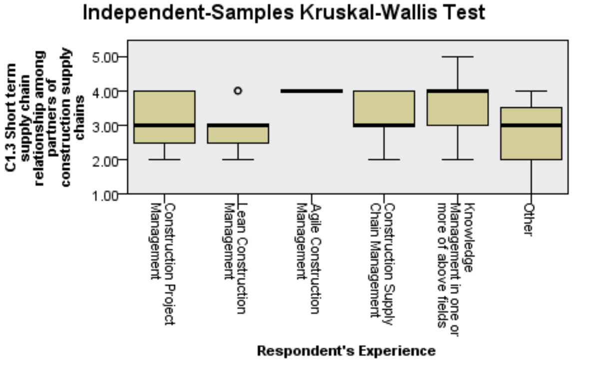
(V2) B3.1



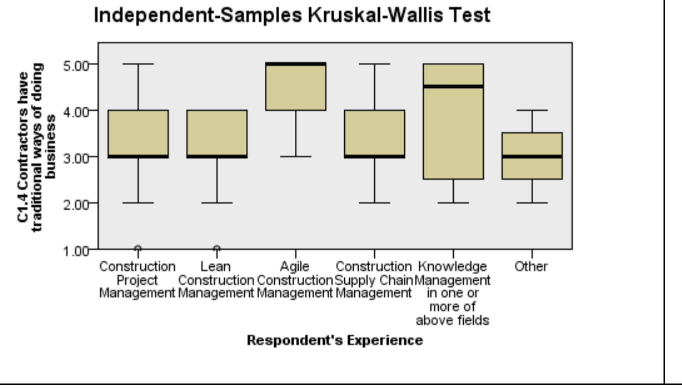
(V3) C1.2



(V4) C1.3



(V5) C1.4



(V6) C1.5

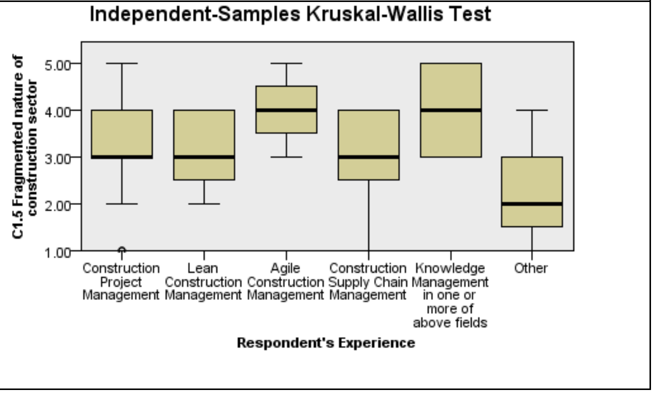


Figure 5-7: Kruskal-Wallis Test Boxplot Summary Question C1

5.7.2.2 (V2) C1.1: Lack of trust among the organisations in Construction Supply Chains

The frequency analysis depicted in table 5-26 on the lack of trust among organisations in Construction Supply Chains in the application of Lean Principles (V2) establishes that the highest number of respondents (49.3%) said ‘Challenging’ and the second highest number of respondents (29.0%) said ‘Highly Challenging’. Moreover, the median value (as seen in Table 5-25) for this variable is calculated as ‘Moderate’ (4.00).

Moreover, as shown in table 5-27 the Kruskal-Wallis H Test and figure 5-8 exhibit that the box-plot median score is (4.00) as assessed by visual inspection. The 2-sided Asymptotic Sig. (2-sided test) *p*-value is observed as 0.927 (above > 0.05). Based on this analysis, it meets the assumption that the null hypothesis to be accepted. This establishes that the trust among the organisations to Transfer and Share Tacit Knowledge in the application of Lean Principle within construction processes is significantly ‘Challenging’.

5.7.2.3 (V3) C1.2: Insufficiency of motivation for organisations in Construction Supply Chains

The data analysis for this variable is to identify the level of challenge in the application of Lean Principles due to the insufficiency of motivation for organisations in Construction Supply Chains. The median value, as shown in table 5-25, for variable (V3) is recorded as ‘Challenging’ (4.00). In table 5-26 showing the frequency analysis, the highest number of respondents (47.8%) said ‘Challenging’ and the second highest number of respondents (23.2%) said ‘Moderate’ and furthermore 21.7% respondents said ‘Highly Challenging’. Moreover, the Kruskal-Wallis H test as shown in table 5-27 and the box-plot summary in figure 5-8 establishes that the null hypothesis is to be accepted with calculated median score of (4.00) and an Asymptotic Sig. (2-sided test) *p*-value of 0.992 (above > 0.05).

5.7.2.4 (V4) C1.3: Short term supply chain relationship among partners in Construction Supply Chains

The data analysis of this variable (V4) rejects the null hypothesis. The short-term, supply chain relationship is found ‘Moderately Challenging’ with the Median value calculated (as shown in table 5-25) as (3.00). The frequency analysis shown in in table 5-26 establishes that the highest number of respondents (40.6%) said ‘Moderately Challenging’ and the second highest number of respondents (37.7%) said ‘Challenging’. Moreover, the Kruskal_Wallis H Test shown in table 5-27 and the box-plot summary in figure 5-8 also establish that the data is not statistically significantly distributed with the Asymptotic Sig. (2-sided test) *p*-value being

0.046 (below > 0.05) and the median value is (3.00). However, based on median value and frequency analysis this accepts the alternate hypothesis that a short term supply chain in the application of Lean principles within construction processes is 'Moderately' challenging.

5.7.2.5 (V5) C1.4: Contractors have traditional way of doing business

The median score in table 5-25 for this variable is calculated as 'Moderate' (3.00). In the frequency analysis shown in table 5-26 the highest number of respondents (31.9%) said that the traditional way of doing business is 'Moderately Challenging' and the second highest number of respondents (21.5%) said 'Challenging'.

Moreover, as shown in table 5-27, the Kruskal-Wallis H Test and figure 5-8 exhibit that the box-plot median score is (3.00) as assessed by visual inspection of a box-plot. In addition, the Asymptotic Sig. (2-sided test) *p*-value is observed as 0.219 (above > 0.05). This analysis accepts the null hypothesis. This establishes that the traditional way of doing business in the Transferring and Sharing of Tacit Knowledge in the application of Lean Principles within construction processes is 'Moderately Challenging'.

5.7.2.6 (V6) C1.5: Fragmented nature of the construction sector

The data analysis for variable (V6) establishes it as 'Moderately Challenging'. The frequency analysis shown in table 5-26 and in table 5-25 shows median scores calculated as (3.00). The highest number of respondents (37.7%) said 'Moderately Challenging' and the second highest number of respondents (31.9%) said 'Challenging'.

The Kruskal-Wallis H test establishes the Asymptotic Sig. (2-sided test) *p*-value as 0.134 (above > 0.05) and figure 5-8 shows that the box-plot median score is (3.00) as assessed by visual inspection. This accept the hypothesis that the fragmented nature of the construction sector in the transferring and sharing of Tacit Knowledge in the application of Lean Principles is 'Moderately Challenging'.

5.7.3 Spearman's Correlation Analysis among Challenges

Table 5-28 below has been generated to identify the correlation significance among the challenges in the Transferring and Sharing of Tacit Knowledge in the application of Lean Principles. Correlations among the challenges is given in figure 5-9 and table 5-29 below and are also discussed below. For presentation purposes, the correlations among the challenges are coded as (C1) to (C15) and the variables (challenges) are coded as (V1) to (V6).

Based on correlations (C1) to (C15) in figure 5-9, and the correlation analysis of the challenges (see Table 5-28), the most significant correlation has been found between (V2) and

(V3). Among these the positive correlation coefficient is calculated as *(r_s* =. 601). The second highest and positive correlation coefficient (r_s =. 581) is calculated between (V4) and (V5). The third highest correlation coefficient is found between (V1) and (V5). Fifteen (15) positive correlations are found and table 5-29 below is developed based on the ranking order from high to the low correlation coefficients. This exhibits the ranking order of the correlation coefficients between the SC principles from the ‘Highest Correlated Coefficient’ (1) to the ‘Lowest Correlated Coefficient’ (5).

Based on the interpretive analysis in table 5-29 below, the following assumptions can be made in respect to the ‘highest to the lowest' correlation coefficients of named challenges.

Table 5-28: Spearman's Correlation Analysis among Challenges

Correlations among Challenges			C1.0 Lack of understanding of importance of transfer and sharing of Tacit Knowledge	C1.1 Lack of trust among the organisations in Construction Supply Chains	C1.2 Insufficiency of motivation for organisations in Construction Supply Chains	C1.3 Short term supply chain relationship among partners of Construction Supply Chains	C1.4 Contractors have traditional ways of doing business	C1.5 Fragmented nature of construction sector
Spearman's rho	C1.0 Lack of understanding of importance of transfer and sharing of Tacit Knowledge **(V1)**	Correlation Coefficient	1.000	.385**	.170	.066	.431**	.250*
		Sig. (2-tailed)		.001	.161	.588	.000	.039
		N	69	69	69	69	69	69
	C1.1 Lack of trust among the organisations in Construction Supply Chains **(V2)**	Correlation Coefficient	.385**	1.000	.601**	.247*	.310**	.080
		Sig. (2-tailed)	.001		.000	.040	.010	.511
		N	69	69	69	69	69	69
	C1.2 Insufficiency of motivation for organisations in Construction Supply Chains **(V3)**	Correlation Coefficient	.170	.601**	1.000	.396**	.284*	.188
		Sig. (2-tailed)	.161	.000		.001	.018	.122
		N	69	69	69	69	69	69
	C1.3 Short term supply chain relationship among partners of Construction Supply Chains **(V4)**	Correlation Coefficient	.066	.247*	.396**	1.000	.581**	.245*
		Sig. (2-tailed)	.588	.040	.001		.000	.042
		N	69	69	69	69	69	69
	C1.4 Contractors have traditional ways of doing business **(V5)**	Correlation Coefficient	.431**	.310**	.284*	.581**	1.000	.494**
		Sig. (2-tailed)	.000	.010	.018	.000		.000
		N	69	69	69	69	69	69
	C1.5 Fragmented nature of construction sector **(V6)**	Correlation Coefficient	.250*	.080	.188	.245*	.494**	1.000
		Sig. (2-tailed)	.039	.511	.122	.042	.000	
		N	69	69	69	69	69	69

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Keys: Variables: V1 to V6

Correlations: C1 to C15

Figure 5-8: Correlations among the Challenges to Transfer and Share Tacit Knowledge in Lean Processes

In table 5-29, below in (Rank 1) variable (V5) is highly correlated with (V1), (V4) and (V6). However, in (Rank 2) Variable (V1) appears twice and in (Rank 3) Variable (V5) again can be observed twice. In (Rank 4) (V6) and (V3) appear twice. The result is variable (V10) 'to enhance collaboration among organisations in construction processes' is highly correlated with (V11) and then with (V12) and (V13).

5.7.3.1 Assumptions

Based on the interpretive rank order analysis below of the correlations among the challenges of Transferring and Sharing Tacit Knowledge in the application of Lean Principles the assumptions below based on (Rank 1) can be made.

1) The most predominant challenge is (V5) the traditional way of doing business, which encourages (V1) lack of understanding of importance of transferring and sharing Tacit Knowledge and vice versa.
2) Contractors have a traditional way of doing business is also highly correlated with (V3) insufficiency of motivation and (V6) fragmented nature of the construction sector.

3) Due to the fragmented nature of the construction sector and insufficiency of motivation for organisations, there is a lack of understanding of importance of transferring and sharing Tacit Knowledge.

Table 5-29: Interpretive correlation coefficient ranking orders of Challenges for Question C1

	Rank				
Challenges	**1**	**2**	**3**	**4**	**5**
V1	V5	V2	V6	V3	V4
V2	V3	V1	V5	V4	V6
V3	V2	V4	V5	V6	V1
V4	V5	V3	V2	V6	V1
V5	V4	V6	V1	V2	V3
V6	V5	V1	V4	V3	V2
Frequency	V5-3	V1-2	V5-2	V6-2, V3-2	V1-2

5.8 Data analysis of Question C2

By drawing from your experience, kindly indicate the level of the challenges listed below associated with the transfer and sharing of Knowledge through the application of Agile Principles.

This question has six (6) challenges named as variables (V1 to V6) for presentation purposes and they are listed below.

1) (V1) C2.0 Lack of understanding of importance of transferring and sharing of Tacit Knowledge
2) (V2) C2.1 Lack of trust among the organisations in Construction Supply Chains
3) (V3) C2.2 Insufficiency of motivation for organisations in Construction Supply Chains
4) (V4) C2.3 Short term supply chain relationship among partners in Construction Supply Chains
5) (V5) C2.4 Contractors have a traditional way of doing business
6) (V6) C2.5 Fragmented nature of the construction sector

5.8.1 Cronbach's Alpha Reliability Analysis for Question C2

Cronbach's alpha (α) is **0.702** as shown in table 5-30. This establishes that the data have a high level of internal consistency. Furthermore, the median score in table 5-31 is calculated as 4.00 (Challenging) for variables (V1), (V2) and (V3). In addition, it shows the median score 3.00 (Moderately Challenging) for variables (V4), (V5) and (V6).

Table 5-30: Cronbach's Alpha Analysis for question C2

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.702	.705	6

Table 5-31: Median score for question C2

Statistics

		C2.0 Lack of understanding and importance of transfer and sharing of knowledge	C2.1 Lack of trust among the organizations in construction supply chains	C2.2 Insufficiency of motivation for organizations in construction supply chains	C2.3 Short term supply chain relationship among partners of construction supply chains	C2.4 Contractors have traditional ways of doing business	C2.5 Fragmented nature of construction sector
N	Valid	69	69	69	69	69	69
	Missing	0	0	0	0	0	0
Median		4.00	4.00	4.00	3.00	3.00	3.00

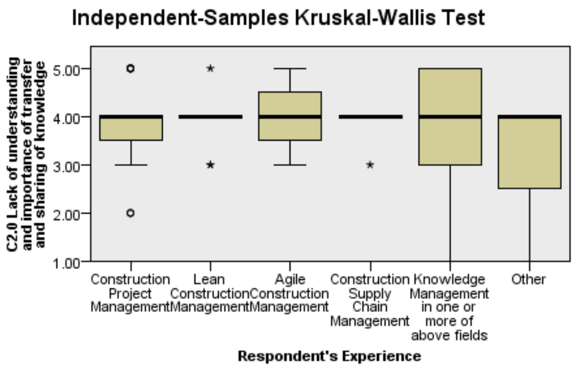
Table 5-32: Frequency Analysis of Question C2

C2	Challenges	Item	Frequency and Percentile				
			1 Not Challenging	**2 Little Challenging**	**3 Moderately Challenging**	**4 Challenging**	**5 Highly Challenging**
V1 (C2.0)	Lack of understanding of importance of transferring and sharing Tacit Knowledge	Frequency	4	2	11	41	11
		Percentage	5.8%	2.9%	15.9%	59.4%	15.9%
		Cumulative Percentage	5.8%	8.7%	24.6%	84.1%	100%
V2 (C2.1)	Lack of trust among the organisations in Construction Supply Chains	Frequency	3	1	12	33	20
		Percentage	4.3%	1.4%	17.4%	47.8%	29.0%
		Cumulative Percentage	4.3%	5.8%	23.2%	71.0%	100%
V3 (C2.2)	Insufficiency of motivation for organisations in Construction Supply Chains	Frequency	0	4	15	28	22
		Percentage	0.0%	5.8%	21.7%	40.6%	31.9%
		Cumulative Percentage	0.0%	5.8%	27.5%	68.1%	100%
V4 (C2.3)	Short term supply chain relationship among partners in Construction Supply Chains	Frequency	1	7	38	20	3
		Percentage	1.4%	10.1%	55.1%	29.0%	4.3%
		Cumulative Percentage	1.4%	11.6%	66.7%	95.7%	100%
V5 (C2.4)	Contractors have traditional ways of doing business	Frequency	3	10	27	21	8
		Percentage	4.3%	14.5%	39.1%	30.4%	11.6%
		Cumulative Percentage	4.3%	18.8%	58.0%	88.4%	100%
V5 (C2.5)	Fragmented nature of construction sector	Frequency	2	11	28	20	8
		Percentage	2.9%	15.9%	40.6%	29.0%	11.6%
		Cumulative Percentage	2.9%	18.8%	59.4%	88.4%	100%

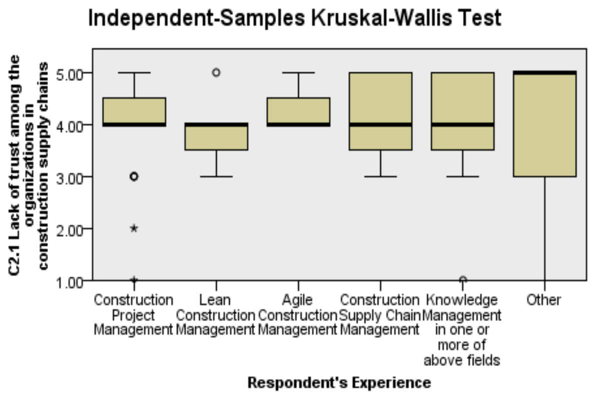
Table 5-33: Kruskal-Wallis H Test of Question C2

NO	Hypothesis	Median	Ordinal Rank	Statistically Significantly Distributed	(*p*-value)	Accept or Reject (Null Hypothesis)
V1 (C2.0)	Lack of understanding of importance of transferring and sharing Tacit Knowledge	4.00	Challenging	Yes	.971	Accept
V2 (C2.1)	Lack of trust among the organisations in Construction Supply Chains	4.00	Challenging	Yes	.861	Accept
V3 (C2.2)	Insufficiency of motivation for organisations in Construction Supply Chains	4.00	Challenging	Yes	.252	Accept
V4 (C2.3)	Short term supply chain relationship among partners in Construction Supply Chains	3.00	Moderate	No	.280	Accept
V5 (C2.4)	Contractors have traditional ways of doing business	3.00	Moderate	Yes	.656	Accept
V6 (C2.5)	Fragmented nature of construction sector	3.00	Moderate	Yes	.212	Accept

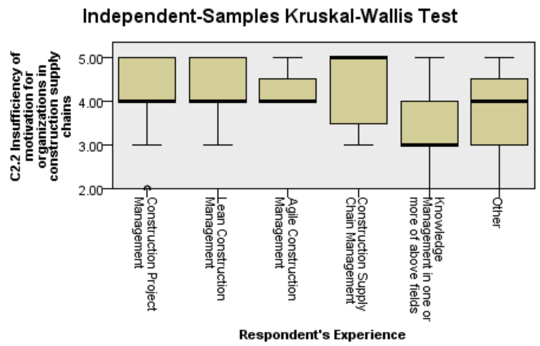
(V1) C2.0



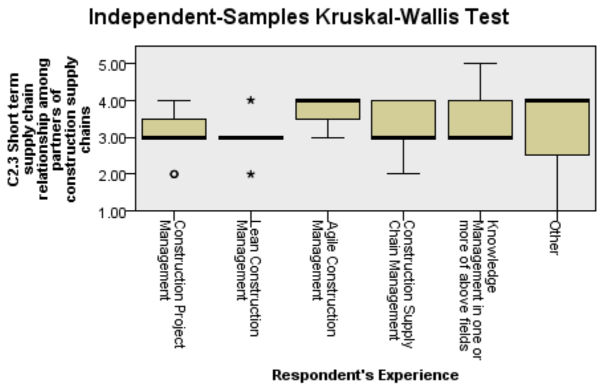
(V2) C2.1



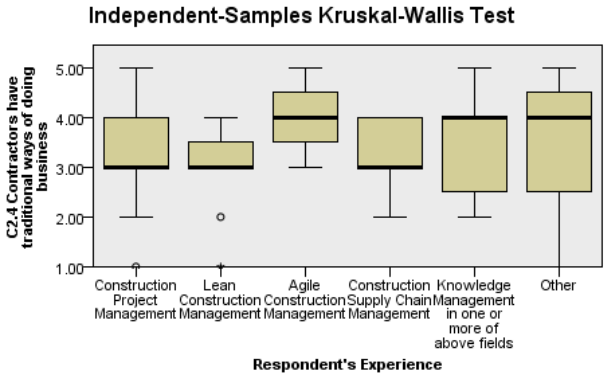
(V3) C2.2



(V4) C2.3



(V5) C2.4



(V6) C2.5

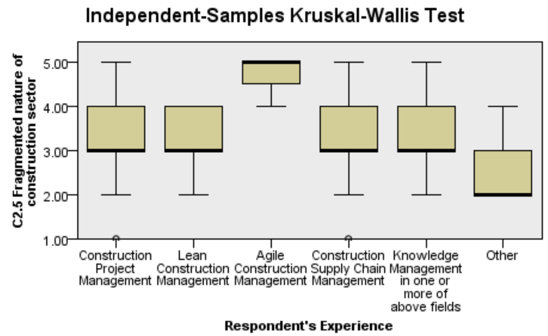


Figure 5-9: Kruskal-Wallis Test Boxplot Summary for Question C2

5.8.2 Analysis of the challenges associated with the transfer and sharing of Tacit Knowledge in the application of Agile Principles based on Frequency Analysis and the Kruskal-Wallis H Test

5.8.2.1 (V1) C2.0 Lack of understanding of importance of the transfer and sharing of Tacit Knowledge

The frequency analysis presented in table 5-32 shows that the highest number of respondents (59.4%) said that the lack of understanding of importance of the transfer and sharing of Tacit Knowledge (V1) is ‘Challenging’. The second highest number of respondents (15.9%) said ‘Moderately Challenging’ and ‘Highly Challenging’. Moreover, the median value (as shown in table 5-31) for this variable is calculated as ‘Challenging’ (4.00).

Moreover, in table 5-33, the Kruskal-Wallis H Test and figure 5-10 show the box-plot median score is (4.00) as assessed by visual inspection. This calculates the Asymptotic Sig. (2-sided test) *p*-value as 0.971 (above > 0.05). This accepts the Null hypothesis. This establishes that the lack of understanding of importance of the transfer and sharing of Tacit Knowledge in application of Agile Principles in construction processes is significantly ‘Challenging’.

5.8.2.2 (V2) C2.1 Lack of trust among the organisations in Construction Supply Chains

The frequency analysis in table 5-32 shows the lack of trust among the organisations in Construction Supply Chains in the application of Lean Principles (V2) and establishes that the highest number of respondents (47.8%) said ‘Challenging’ and the second highest number of respondents (29.0%) said ‘Highly Challenging’. Moreover, the median value, as shown in table 5-31, for this variable is calculated as ‘Challenging’ (4.00).

Moreover, in table 5-33, the Kruskal-Wallis H Test and figure 5-10 show the box-plot median score is (4.00) as assessed by visual inspection. This calculates the Asymptotic Sig. (2-sided test) *p*-value as 0.861 (above > 0.05). This accepts the null hypothesis. This establishes that trust among organisations to Transfer and Share Tacit Knowledge in the application of Agile Principles within construction processes is significantly ‘Challenging’.

5.8.2.3 (V3) C2.2 Insufficiency of motivation for organisations in Construction Supply Chains

The data analysis for this variable is to attempt to identify the level of the challenge in the application of Agile Principles due to the insufficiency of motivation for organisations in Construction Supply Chains. The median value as shown in table 5-31 for (V3) is recorded as ‘Challenging’ (4.00). In table 5-32 showing the frequency analysis, the highest number of respondents (40.9%) said ‘Challenging’ and the second highest number of respondents (31.9%) said ‘Highly Challenging’. Moreover, the Kruskal-Wallis H test shown in table 5-33 and box-plot summary in figure 5-10 establishes the null hypothesis is to be accepted with the calculated median score of (4.00) and the Asymptotic Sig. (2-sided test) *p*-value of 0.252 (above > 0.05).

5.8.2.4 (V4) C2.3 Short term supply chain relationship among partners in Construction Supply Chains

The data analysis of this variable (V4) establishes that the null hypothesis be rejected and thus there is a need to draw on the alternate hypothesis. The short-term, supply chain relationship is found to be ‘Moderately Challenging’ with the Median value calculated in table 5-31 as (3.00). The frequency analysis shown in table 5-32 establishes that the highest number of respondents (55.1%) said ‘Moderately Challenging’ and second highest number of respondents (29.0%) said ‘Challenging’. Moreover, the Kruskal_Wallis H Test in table 5-27 and the box-plot summary in figure 5-10 also establishes that data are statistically significantly distributed with the Asymptotic Sig. (2-sided test) *p*-value as 0.280 (below > 0.05) and the median value being (3.00). Based on the median value and the frequency analysis this accepts the null hypothesis that the short-term supply chain in the application of Agile Principles within construction processes is ‘Moderately Challenging’.

5.8.2.5 (V5) C2.4 Contractors have a traditional way of doing business

The median score as shown in table 5-31 for this variable is calculated as (3.00), thus as ‘Moderate’. In the frequency analysis shown in table 5-32 the highest number of respondents (39.1%) said that the traditional way of doing business is ‘Moderately Challenging’ and the second highest number of respondents (30.4%) said ‘Challenging’ regarding the Transfer and Sharing of Tacit Knowledge in the application of Lean Principles.

Moreover, in table 5-33, the Kruskal-Wallis H Test and figure 5-10 show the box-plot median score is (3.00) as assessed by visual inspection. This calculates the Asymptotic Sig. (2-sided test) *p*-value as 0.656 (above > 0.05). Based on this, the null hypothesis is accepted. Therefore, it establishes that the traditional way of doing business in the Transfer and Sharing of Tacit Knowledge in the application of Agile Principles within construction processes is ‘Moderately Challenging’.

5.8.2.6 (V6) C2.5 Fragmented nature of the construction sector

The data analysis for variable (V6) establishes that the fragmented nature of the construction sector is ‘Moderately Challenging’ via the frequency analysis presented in table 5-32.

Moreover, in the table 5-31 the median score is calculated as (3.00). The highest number of respondents (40.6%) said ‘Moderately Challenging’ and the second highest number of respondents (29.0%) said ‘Challenging’.

The Kruskal-Wallis H test establishes the Asymptotic Sig. (2-sided test) *p*-value as 0.212 (above > 0.05), and figure 5-10 shows the box-plot median score is (3.00) as assessed by visual inspection. This establishes that the null hypothesis be accepted as the fragmented nature of the construction sector in the transfer and sharing of Tacit Knowledge in the application of Agile Principles is ‘Moderately Challenging’.

5.8.3 Spearman’s correlation analysis of the challenges to Transfer and Share Tacit Knowledge in the application of Agile Principles.

To identify the correlation significance among the challenges in the Transfering and Sharing of Tacit Knowledge in the application of Agile Principles, table 5-34 below has been generated. Correlations among the challenges are discussed below. For presentation purposes, the correlations among the challenges are coded as (C1) to (C15) and the variables (challenges) are coded as (V1) to (V6).

Based on correlations (C1) to (C15) in Figure 5-11 below and the correlations’ analysis of the challenges (see Table 5-28), the most significant correlation has been found between (V5) and (V6). Among these, the positive correlation coefficient is calculated as r_s =.640. The second highest and positive correlation coefficient (r_s =. 487) is calculated between (V2) and (V3). The third highest correlation coefficient is found between (V4) and (V5). Among the fifteen (15) correlations, a negative correlation is found between (V1) and (V4), calculated as (r_s = -080). Table 5-29 below is developed based upon the ranking order from the high to the low correlation coefficients. This exhibits the ranking order of the correlation coefficients between the challenges from the ‘Highest Correlated Coefficient’ (1) to the ‘Lowest Correlated Coefficient’ (5).

5.9 Evaluation of the challenges associated with the Transfer and Sharing of Tacit Knowledge through the application of both (a) Lean and (b) Agile Principles.

The main determinations of the challenges associated with the Transfer and Sharing of Tacit Knowledge are given below.

Lack of understanding of importance, lack of trust among organisations and lack of motivation for organisations within Construction Supply Chains to Transfer and Share Tacit Knowledge in the application of both the Lean and Agile Principles are challenging. Other challenges, namely, the short term supply chain relationship, traditional ways of doing business and the fragmented nature of the construction sector have appeared 'moderately challenging' in the Transfer and Sharing of Tacit Knowledge in the application of both Lean and Agile Principles.

In the application of both Lean and Agile Principles, the most predominant challenge that hinders the Transfer and Sharing of Tacit Knowledge is observed to be the traditional ways of doing business. This analysis establishes, two (2) other challenges, namely, the fragmented nature of the construction sector and the lack of motivation for organisations to Transfer and Share Tacit Knowledge.

This analysis also pinpoints that the short-term supply chain relationship supports the lack of trust between organisations that leads to the fragmented nature of the construction sector.

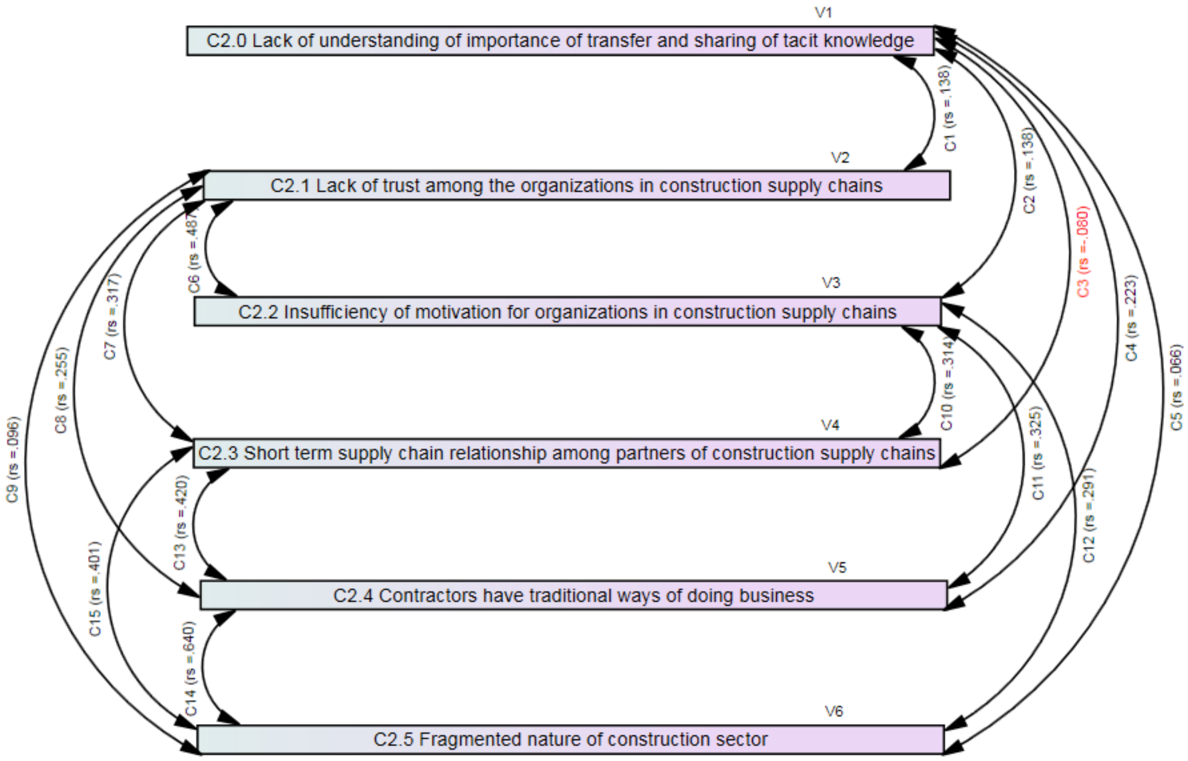
The causes of fragmentation and their supported factors found through the data analysis are similar to those found in the literature review in Chapter (2). The literature review suggested that the main challenges are the lack of the knowledge management system, and that within KM systems there is a lack of transfer and sharing Tacit Knowledge. This, therefore, requires developing an awareness of transferring and sharing Tacit Knowledge.

Table 5-34: Spearman's Correlation Analysis for Question C2

Correlations

			C2.0 Lack of understanding of importance of transferring and sharing of Knowledge **(V1)**	C2.1 Lack of trust among the organisations in Construction Supply Chains **(V2)**	C2.2 Insufficiency of motivation for organisations in Construction Supply Chains **(V3)**	C2.3 Short term supply chain relationship among partners in Construction Supply Chains **(V4)**	C2.4 Contractors have traditional ways of doing business **(V5)**	C2.5 Fragmented nature of construction sector **(V6)**
Spearman's rho	C2.0 Lack of understanding of importance of transferring and sharing of Knowledge **(V1)**	Correlation Coefficient	1.000	.138	.138	-.080	.223	.066
		Sig. (2-tailed)		.258	.260	.513	.065	.587
		N	69	69	69	69	69	69
	C2.1 Lack of trust among the organisations in Construction Supply Chains **(V2)**	Correlation Coefficient	.138	1.000	.487**	.317**	.255*	.096
		Sig. (2-tailed)	.258		.000	.008	.034	.433
		N	69	69	69	69	69	69
	C2.2 Insufficiency of motivation for organisations in Construction Supply Chains **(V3)**	Correlation Coefficient	.138	.487**	1.000	.314**	.325**	.291*
		Sig. (2-tailed)	.260	.000		.009	.006	.015
		N	69	69	69	69	69	69
	C2.3 Short term supply chain relationship among partners in Construction Supply Chains **(V4)**	Correlation Coefficient	-.080	.317**	.314**	1.000	.420**	.401**
		Sig. (2-tailed)	.513	.008	.009		.000	.001
		N	69	69	69	69	69	69
	C2.4 Contractors have traditional ways of doing business **(V5)**	Correlation Coefficient	.223	.255*	.325**	.420**	1.000	.640**
		Sig. (2-tailed)	.065	.034	.006	.000		.000
		N	69	69	69	69	69	69
	C2.5 Fragmented nature of construction sector **(V6)**	Correlation Coefficient	.066	.096	.291*	.401**	.640**	1.000
		Sig. (2-tailed)	.587	.433	.015	.001	.000	
		N	69	69	69	69	69	69

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).



Keys: Variables: V1 to V6

Correlations: C1 to C15

Figure 5-10: Correlation analysis of the Challenges in the Application of Agile Principles

Based on the above interpretive analysis in table 5-29, the following assumptions can be made in respect to the 'highest to the lowest' correlation coefficients of the named challenges (V1 to V6). In rank (1), challenge (V5) has a positive correlation coefficient with (V1), (V4) and (V6). In rank (2), challenge (V4) has a positive correlation coefficient with (V2), (V5) and (V6). In rank (3), challenge (V3) is correlated to (V5) and (V6). Moreover, challenge (V2) is also correlated to (V5) and (V6) at rank (4).

Table 5-35: Interpretive correlation coefficient ranking orders of the Challenges for Question C2

	Rank				
Challenges	**1**	**2**	**3**	**4**	**5**
V1	V5	V2, V3	V6	-	V4
V2	V3	V4	V5	V1	V6
V3	V2	V5	V4	V6	V1
V4	V5	V6	V2	V3	V1
V5	V6	V4	V3	V2	V1
V6	V5	V4	V3	V2	V1
Frequency	V5-(3)	V4-(3)	V3-(2)	V2-(2)	V1-(4)

5.9.1.1 Assumptions

Based on the above interpretive ranking order analysis of the correlations among the challenges of Transferring and Sharing Tacit Knowledge in the application of Agile Principles the following assumptions based on (Rank 1) can be established.

The most predominant challenge that hinders the transfer and sharing of Tacit Knowledge is observed as (V5), traditional ways of doing business. In rank one (V5) is highly correlated with (V1), (V4) and (V6).

1) It can be said that the lack of understanding of importance of Transferring and Sharing Tacit Knowledge is because of the traditional ways of doing business. This is highly correlated with (V4) short-term supply chain relationship, and (V6) the fragmented nature of the construction sector.
2) In (Rank 2), short-term supply chain relationship (V4) boosts the lack of trust between organisations (V2) leaded by the fragmented nature of the construction sector (V6), and contractors having traditional ways of doing business (V5).
3) In (Rank 3), insufficiency of motivation for organisations in CSCs (V3) is because of contractors having traditional ways of doing business (V5) and the fragmented nature of the construction sector (V6).

Based on above interpreted assumptions, the fragmented nature of the construction sector (V6) is observed in all three assumptions. Secondly, the traditional way of doing business (V5) is observed in connection with assumptions (2) and (3). It follows the fragmented nature of the construction sector (V6) and causes short-term supply chain relationships (V4). Furthermore, in assumption (2), (V4) boosts the lack of trust between organisations, and additionally, this results in the lack of understanding of importance of sharing Tacit Knowledge in the application of Agile Principles..

Section D Data Analysis of Questions D1 and D2

This section looks at identifying the critical success factors associated with the effectiveness of the Transfer and Sharing of Tacit Knowledge (a) in Lean Processes (b) in Agile Processes.

The Critical Success Factors in this context are the necessary factors whose absence hinders the effectiveness of sharing and transferring Tacit Knowledge.

5.10 Question D1

By drawing from your experience, please kindly indicate what is the level of criticality of the success factors listed below associated with the transfer and sharing of Tacit Knowledge in Lean Processes?

This question has ten (10) critical success factors as variables (named V1 to V10) for presentation purposes and are as follows:

1) (V1) D1.0 Trust among the organisations in Construction Supply Chains
2) (V2) D1.1 Motivation to Transfer and Share Tacit Knowledge
3) (V3) D1.2 Leadership capabilities of clients and main contractors to encourage Transfer and Sharing of Tacit Knowledge
4) (V4) D1.3 Business Strategies aligned to the Transfer and Sharing of Tacit Knowledge in organisations within the construction process
5) (V5) D1.4 Organisational capabilities to Transfer and Share Tacit Knowledge
6) (V6) D1.5 Individuals involved in the construction process must be capable of Transferring and Sharing Tacit Knowledge
7) (V7) D1.6 Identification of process improvement opportunities by managers
8) (V8) D1.7 Identification of the type of Knowledge to Transfer and Share
9) (V9) D1.8 Identification of the Source of Knowledge
10) (V10) D1.9 Identification of Knowledge recipient

5.10.1 Cronbach's Alpha Analysis for Question D1

Cronbach's alpha (α) is recorded as **0.766** in table (5-36**)**. This reveals a high level of internal consistency for this data. A further median score in table 5-37 is calculated. It shows that only one variable (V5) is recorded with the median score of 3.00 (Moderately Critical). The rest are recorded as 4.00 (Critical).

Table 5-36: Reliability Test for question D1

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.766	.774	10

Table 5-37: Median score for question D1

Statistics

		V1 (D1.0)	V2 (D1.1)	V3 (D1.2)	V4 (D1.3)	V5 (D1.4)	V6 (D1.5)	V7 (D1.6)	V8 (D1.7)	V9 (D1.8)	V10 (D1.9)
N	Valid	69	69	69	69	69	69	69	69	69	69
	Missing	0	0	0	0	0	0	0	0	0	0
Median		4.00	4.00	4.00	4.00	3.00	4.00	4.00	4.00	4.00	4.00

5.10.2 Analysis of CSFs associated with the transfer and sharing of Tacit Knowledge in Lean processes based on Frequency Analysis and the Kruskal-Wallis H Test

5.10.2.1 D1.0 Trust among the organisations in Construction Supply Chains

In the frequency analysis in table 5-38 the highest number of respondents (43.5%) said that the level of trust among construction organisations as a critical success factor in the transfer and sharing of Tacit Knowledge (V1) is ‘Critical’. The second highest number of respondents (40.6%) said ‘Highly Critical’ and just less than 16% of the respondents said ‘Moderately Critical’. Moreover, the median value shown in table 5-37 for this variable is calculated as ‘Critical’ (4.00).

Moreover, in table 5-39 the Kruskal-Wallis H Test and figure 5-12 show the box-plot median score is also (4.00) as assessed by visual inspection. Moreover, it gives the Asymptotic Sig. (2-sided test) *p*-value as 0.996 (above > 0.05). Therefore, it meets the assumptions and accepts the Null hypothesis. This establishes that trust among construction organisations (V1) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Lean Processes.

Table 5-38: Frequency Analysis of question D1

Question D1	Critical Success Factors	Item	Frequency and Percentile				
			1 Not Critical	2 Little Critical	3 Moderately Critical	4 Critical	5 Highly Critical
V1 (D1.0)	Trust among the organisations in Construction Supply Chains	Frequency	1	1	9	30	28
		Percentage	1.4%	1.4%	13.0%	43.5%	40.6%
		Cumulative Percentage	1.4%	2.9%	15.9%	59.4%	100.0%
V2 (D1.1)	Motivation to share Tacit Knowledge	Frequency	1	3	11	33	21
		Percentage	1.4%	4.3%	15.9%	47.8%	30.4%
		Cumulative Percentage	1.4%	5.8%	21.7%	69.6%	100.0%
V3 (D1.2)	Leadership Capabilities of clients and main contractors to encourage sharing Tacit Knowledge	Frequency	2	0	6	35	26
		Percentage	2.9%	0.0%	8.7%	50.7%	37.7%
		Cumulative Percentage	2.9%	2.9%	11.6%	62.3%	100.0%
V4 (D1.3)	Business Strategies aligned to Share Tacit Knowledge in organisations within the Construction process	Frequency	1	2	9	45	12
		Percentage	1.4%	2.9%	13.0%	65.2%	17.4%
		Cumulative Percentage	1.4%	4.3%	17.4%	82.6%	100.0%
V5 (D1.4)	Organisations within the Construction Supply Chain must have Capabilities to Share Tacit Knowledge	Frequency	1	4	34	23	7
		Percentage	1.4%	5.8%	49.3%	33.3%	10.1%
		Cumulative Percentage	1.4%	7.2%	56.5%	89.9%	100.0%
V6 (D1.5)	Individuals involved in the construction process must be capable of sharing Tacit Knowledge	Frequency	2	5	27	27	8
		Percentage	2.9%	7.2%	39.1%	39.1%	11.6%
		Cumulative Percentage	2.9%	10.1%	49.3%	88.4%	100.0%
V7 (D1.6)	Identification of process improvement opportunities by managers	Frequency	3	5	14	43	4
		Percentage	4.3%	7.2%	20.3%	62.3%	5.8%
		Cumulative Percentage	4.3%	11.6%	31.9%	94.2%	100.0%
V8 (D1.7)	Identification of the type of Knowledge to Share	Frequency	0	2	26	33	5
		Percentage	0.0%	7.2%	37.7%	47.8%	7.2%
		Cumulative Percentage	0.0%	7.2%	44.9%	92.8%	100.0%
V9 (D1.8)	Identification of the Source of Knowledge	Frequency	0	10	18	36	5
		Percentage	0.0%	14.5%	26.1%	52.2%	7.2%
		Cumulative Percentage	0.0%	14.5%	40.6%	92.8%	100.0%
V10 (D1.9)	Identification of Knowledge recipient	Frequency	3	8	17	36	5
		Percentage	4.3%	11.6%	24.6%	52.2%	7.2%
		Cumulative Percentage	4.3%	15.9%	40.6%	92.8%	100.0%

Table 5-39: Kruskal-Wallis H Test of D1

NO	Hypothesis	Median	Ordinal Rank	Statistically Significantly Distributed	(*p*-value)	Accept or Reject (Null Hypothesis)
V1 (D1.0)	Trust among the organisations in Construction Supply Chains	4.00	Critical	Yes	.996	Accept
V2 (D1.1)	Motivation to share Tacit Knowledge	4.00	Critical	NO	.012	Reject
V3 (D1.2)	Leadership Capabilities of clients and main contractors to encourage sharing Tacit Knowledge	4.00	Critical	Yes	.254	Accept
V4 (D1.3)	Business Strategies aligned to Share Tacit Knowledge in organisations within the Construction process	4.00	Critical	Yes	.539	Accept
V5 (D1.4)	Organisations within the Construction Supply Chain must have Capabilities to Share Tacit Knowledge	3.00	Moderately Critical	Yes	.539	Accept
V6 (D1.5)	Individuals involved in the construction process must be capable of sharing Tacit Knowledge	4.00	Critical	Yes	.717	Accept
V7 (D1.6)	Identification of process improvement opportunities by managers	4.00	Critical	Yes	.286	Accept
V8 (D1.7)	Identification of the type of Knowledge to Share	4.00	Critical	Yes	.870	Accept
V9 (D1.8)	Identification of the Source of Knowledge	4.00	Critical	Yes	.054	Accept
V10 (D1.9)	Identification of Knowledge recipient	4.00	Critical	Yes	.522	Accept

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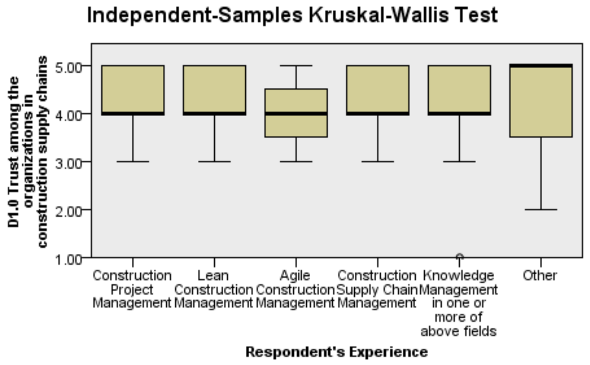
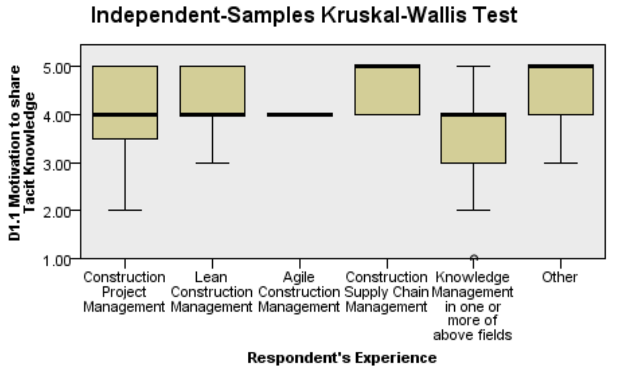
<tr><td>
</td><td>
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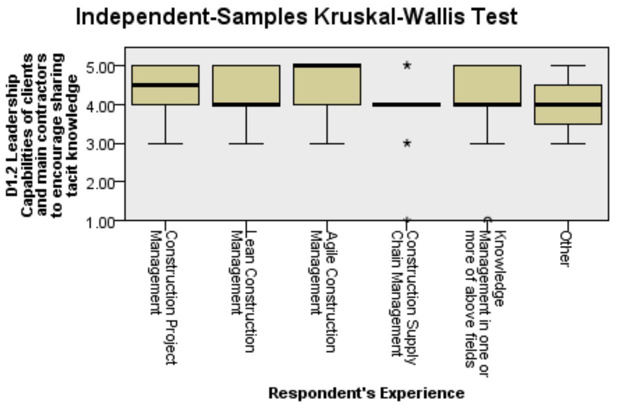
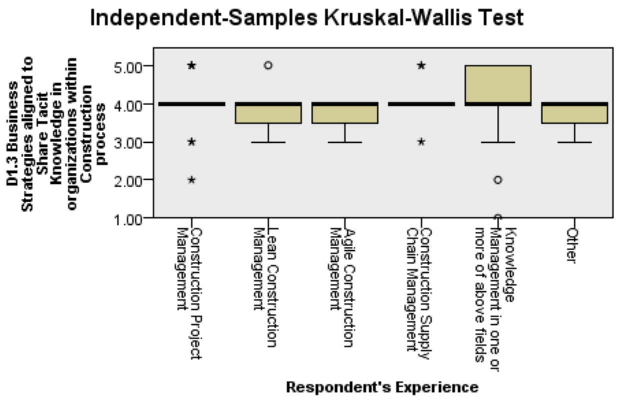
<tr><td>
</td><td>
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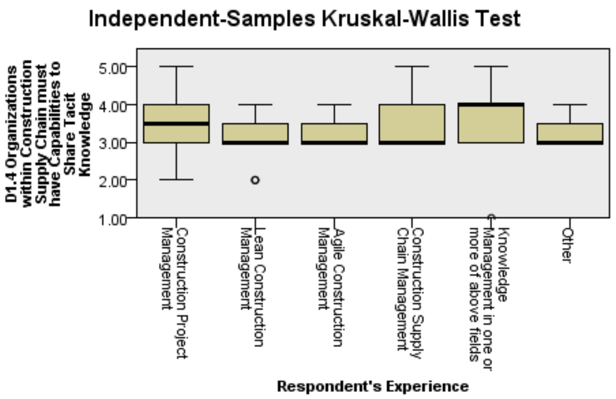
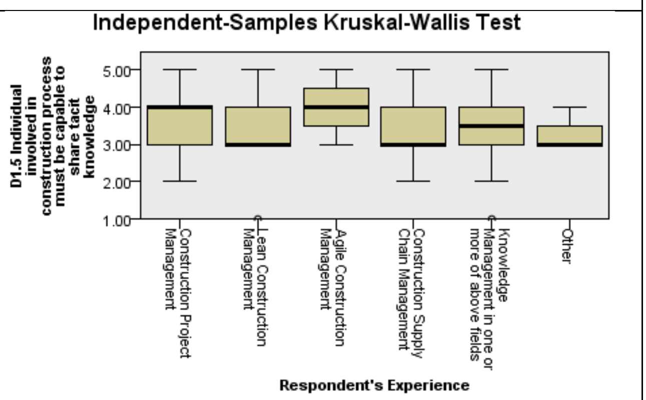
<tr><td>
</td><td>
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<tr><th>V7 (D1.6)</th><th>V8 (D1.7)</th></tr>
<tr><td colspan="2">Figure continued on next page</td></tr>
</table>

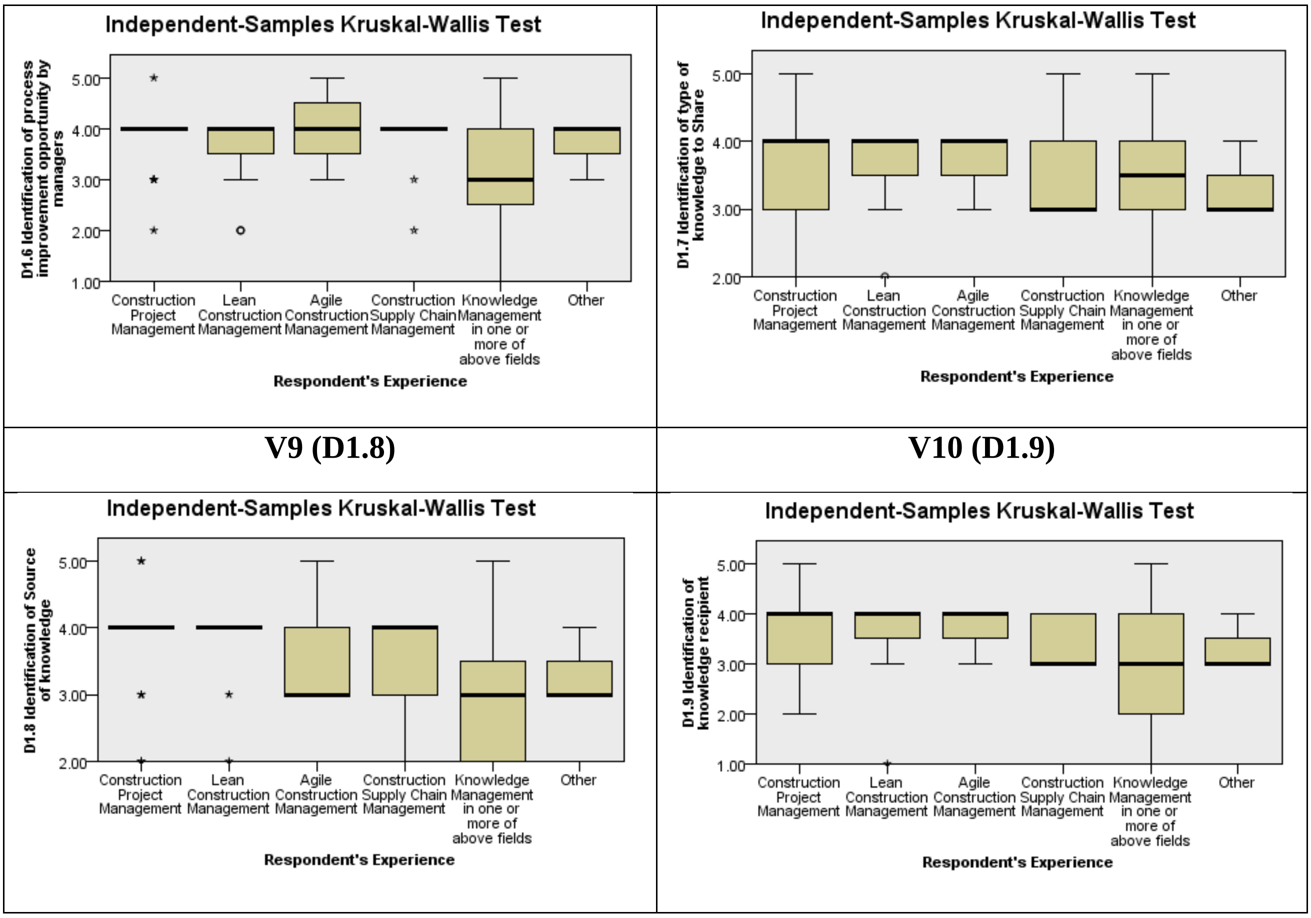

Figure 5-11: Kruskal-Wallis H Test Boxplot Summary of Question D1

5.10.2.2 (V2) D1.1 Motivation to share Tacit Knowledge

The frequency analysis shown in table 5-38 shows that, the highest number of respondents (47.8%) said that level of motivation to transfer and share Tacit Knowledge (V2) is ‘Critical’. The second highest number of respondents (30.4%) said ‘Highly Critical’ and just less than 22% of the respondents said ‘Moderately Critical’ and below. Moreover, the median value, as shown in table 5-37, for this variable is calculated as ‘Critical’ (4.00).

In table 5-39 the Kruskal-Wallis H Test and figure 5-12 show the box-plot median score is (4.00) as assessed by visual inspection. In addition, this calculates the Asymptotic Sig. (2-sided test) p-value as 0.012 (below < 0.05). The null hypothesis is rejected as the data are not statistically significantly distributed. However, this establishes that the motivation to Transfer and Share Tacit Knowledge in a construction organisation (V2) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Lean Processes.

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5.10.2.3 (V3) D1.2 Leadership capabilities of clients and main contractors to encourage the sharing of Tacit Knowledge

The frequency analysis shown in table 5-38 shows the highest number of of respondents (50.7%) said that level of leadership capabilities of clients and main contractors, as a critical success factor in the transferring and sharing of Tacit Knowledge (V3) is ‘Critical’. The second highest number of respondents (37.7%) said ‘Highly Critical’ and just less than 9% of respondents said ‘Moderately Critical’. Moreover, the median value shown in table 5-37 for this variable is calculated as ‘Critical’ (4.00).

Moreover, in table 5-39 the Kruskal-Wallis H Test and figure 5-12 show the box-plot median score is also (4.00) as assessed by visual inspection. The Asymptotic Sig. (2-sided test) *p*-value is 0.254 (above > 0.05). This accepts the Null hypothesis. This analysis establishes that the leadership capability of clients and main contractors (V3) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Lean Processes.

5.10.2.4 (V4) D1.3 Business Strategies aligned to Transfer and Share Tacit Knowledge in organisations within Construction process

From the frequency analysis shown in table 5-38 the highest number of of respondents (65.2%) said that level of business strategies as a critical success factor in the transferring and sharing of Tacit Knowledge (V4) is ‘Critical’. The second highest number of respondents (17.4%) said ‘Highly Critical’ and just 13% of respondents said ‘Moderately Critical’. Moreover, the median value as shown in table 5-37 for this variable is calculated as ‘Critical’ (4.00).

Moreover, in table 5-39 the Kruskal-Wallis H Test and figure 5-12 show the box-plot median score is also (4.00) as assessed by visual inspection. Furthermore, this test calculates the Asymptotic Sig. (2-sided test) *p*-value as 0.539 (above > 0.05). This accepts the Null hypothesis. This establishes that business strategies aligned to the Transfer and Sharing of Tacit Knowledge in organisations within construction processes (V4) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Lean Processes.

5.10.2.5 (V5) D1.4 Organisational Capabilities to Share Tacit Knowledge

As seen from the frequency analysis shown in table 5-38 the highest number of respondents (49.3%) said that level of organisational capabilities as a critical success factor in the transfer and sharing of Tacit Knowledge (V5) is ‘Moderately Critical’. The second highest number of respondents (33.3%) said ‘Critical’ and just 10.1% of respondents said ‘Highly Critical’.

Moreover, the median value, as shown in table 5-37, for this variable is calculated as ‘Moderate’ (3.00).

In addition, in table 5-39 the Kruskal-Wallis H Test and figure 5-12 show the box-plot median score is also (3.00) as assessed by visual inspection. Furthermore, this test records the Asymptotic Sig. (2-sided test) *p*-value as 0.539 (above > 0.05). This establishes that organisational capability (V5) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Lean Processes. Based on this analysis, it meets the assumptions that the Null hypothesis be accepted.

5.10.2.6 (V6) D1.5 Individuals involved in the construction process must be capable of sharing Tacit Knowledge

The frequency analysis shown in table 5-38 shows that the highest number ofof respondents (78.2%) said that the level of capability of individuals involved throughout the construction process as a critical success factor in the transfer and sharing of Tacit Knowledge (V6) is ‘Moderately Critical’ and ‘Critical’. Just 11.6% of the respondents said ‘Highly Critical’. Table 5-37 presents the median score for this variable as ‘Critical’ (4.00).

Moreover, in table 5-39, the Kruskal-Wallis H Test and figure 5-12 show the box-plot median score is also (4.00) as assessed by visual inspection. This gives the Asymptotic Sig. (2-sided test) *p*-value as 0.717 (above > 0.05). This establishes that individual capability in a construction process (V6) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Lean Processes. This analysis meets the assumption that the Null hypothesis be accepted.

5.10.2.7 (V7) D1.6 Identification of process improvement opportunities by managers

From the frequency analysis in table 5-38, it can be seen that the highest number of respondents (62.3%) said that level of identification of process improvement opportunities by managers, as a critical success factor in the transfer and sharing of Tacit Knowledge, (V7) is ‘Critical’. The second highest number of respondents (20.3%) said ‘Moderately Critical’. Moreover, the median value (as shown in table 5-37) for this variable is calculated as ‘Critical’ (4.00).

Moreover, in table 5-39, the Kruskal-Wallis H Test and figure 5-12 show the box-plot median score is also (4.00) as assessed by visual inspection. In addition, this calculates the Asymptotic Sig. (2-sided test) *p*-value as 0.286 (above > 0.05). This establishes that the identification of process improvement opportunities (V7) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Lean Processes. The analysis accepts the null hypothesis.

5.10.2.8 (V8) D1.7 Identification of the type of Knowledge to Share

The frequency analysis shown in table 5-38 shows the highest number of respondents (47.8%) said that level of identification of the type of Knowledge to share as a critical success factor in the transfer and sharing of Tacit Knowledge (V8) is ‘Critical’. The second highest number of respondents (37.7%) said ‘Moderately Critical’. The median value (as shown in table 5-37) for this variable is calculated as ‘Critical’ (4.00). Moreover, in table 5-39 the Kruskal-Wallis H Test and figure 5-12 show the box-plot median score is also (4.00) as assessed by visual inspection. This presents the Asymptotic Sig. (2-sided test) *p*-value as 0.870 (above > 0.05). This accepts the Null hypothesis. This establishes that the identification of the type of Knowledge to share in the Transfer and Sharing of Tacit Knowledge within construction processes (V8) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Lean Processes.

5.10.2.9 (V9) D1.8 Identification of the Source of Knowledge

The frequency analysis in table 5-38 shows that the highest number of respondents (52.2%) said that the level of identification of the source of Knowledge as a critical success factor in the transfer and sharing of Tacit Knowledge (V9) is ‘Critical’. The second highest number of respondents (26.1%) said ‘Moderately Critical’. The median value (as shown in table (5-37) for this variable is calculated as ‘Critical’ (4.00). Moreover, in table 5-39 the Kruskal-Wallis H Test and figure 5-12 show the box-plot median score is also (4.00) as assessed by visual inspection. This calculates the Asymptotic Sig. (2-sided test) *p*-value as 0.054 (above > 0.05). Therefore, this accepts the null hypothesis. This establishes that the identification of the source of Knowledge to Transfer and Share Tacit Knowledge within construction processes (V8) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Lean Processes.

5.10.2.10 (V10) D1.9 Identification of Knowledge recipient

The frequency analysis presented in table 5-38 shows the highest number of respondents (52.2%) said that the level of identification of the recipient of Knowledge with whom to share information as a critical success factor in the transfer and sharing of Tacit Knowledge (V9) is ‘Critical’. The second highest number of respondents (24.6%) said ‘Moderately Critical’. The median value (shown in table 5-37) for this variable is calculated as ‘Critical’ (4.00). Moreover, in table 5-39 the Kruskal-Wallis H Test and figure 5-12 show the box-plot median score is also (4.00) as assessed by visual inspection. In addition, this presents the Asymptotic

Sig. (2-sided test) *p*-value as 0.522 (above > 0.05). Therefore, this accepts the null hypothesis. This establishes that the identification of the recipient of Knowledge to whom to, Transfer and Share Tacit Knowledge within construction processes (V9) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Lean Processes.

Table 5-40 has been generated to identify the correlation significance among the critical success factors, which enables the Transfer and Sharing of Tacit Knowledge in the application of Lean Processes. For presentation purposes, the variables (Critical Success Factors) are coded as (V1) to (V10).

Based on the correlation analysis of CSFs in Table 5-40, the most significant correlation has been found between (V9) and (V10). Among these, the positive correlation coefficient is calculated as r_s =.775. This reflects that the identification of both the source and the recipient of Knowledge are essential CSFs in the Transfer and Sharing of Knowledge in Lean Processes.

The second highest and positive correlation coefficient (r_s =. 595) is calculated between (V8) and (V9). The third highest correlation coefficient is found between (V8) and (V10). Among the forty-five (45) correlations, a negative correlation is found between (V1) and (V9), calculated as (r_s = -042). Table 5-41 below has been developed based upon the ranking order from high to the low correlation coefficients. This shows the ranking order of correlation coefficients between the CSFs from the ‘Highest Correlated Coefficient’ (1) to the ‘Lowest Correlated Coefficient’ (9).

5.10.3 Interpretive correlation coefficient ranking orders of CSFs for Question D1

Based on the interpretive analysis table below (table 5-41), the following assumptions can be made in respect of the ‘highest to the lowest' correlation coefficients of the named CSFs (V1 to V10). The following three (3) assumptions are made based on (Rank 1-3) to avoid duplication of assumptions and developing confusion while interpreting the presumptions.

Table 5-40: Correlations among CSFs associated with the Transfer and Sharing of Tacit Knowledge in Lean Processes

Correlations

			V1 (D1.0)	V2 (D1.1)	V3 (D1.2)	V4 (D1.3)	V5 (D1.4)	V6 (D1.5)	V7 (D1.6)	V8 (D1.7)	V9 (D1.8)	V10 (D1.9)
Spearman's rho	V1 (D1.0)	Correlation Coefficient	1.000	.457**	.417**	.182	.370**	.119	.132	.001	-.042	.062
		Sig. (2-tailed)		.000	.000	.135	.002	.330	.281	.996	.735	.615
		N	69	69	69	69	69	69	69	69	69	69
	V2 (D1.1)	Correlation Coefficient	.457**	1.000	.214	.013	.162	.083	.392**	.130	.228	.088
		Sig. (2-tailed)	.000		.078	.913	.183	.496	.001	.286	.059	.473
		N	69	69	69	69	69	69	69	69	69	69
	V3 (D1.2)	Correlation Coefficient	.417**	.214	1.000	.396**	.260*	.379**	.303*	.092	.237*	.145
		Sig. (2-tailed)	.000	.078		.001	.031	.001	.011	.453	.049	.235
		N	69	69	69	69	69	69	69	69	69	69
	V4 (D1.3)	Correlation Coefficient	.182	.013	.396**	1.000	.212	.163	.288*	.428**	.256*	.263*
		Sig. (2-tailed)	.135	.913	.001		.080	.182	.016	.000	.034	.029
		N	69	69	69	69	69	69	69	69	69	69
	V5 (D1.4)	Correlation Coefficient	.370**	.162	.260*	.212	1.000	.424**	.178	.081	.153	.074
		Sig. (2-tailed)	.002	.183	.031	.080		.000	.143	.510	.210	.547
		N	69	69	69	69	69	69	69	69	69	69
	V6 (D1.5)	Correlation Coefficient	.119	.083	.379**	.163	.424**	1.000	.240*	.150	.288*	.194
		Sig. (2-tailed)	.330	.496	.001	.182	.000		.047	.217	.016	.110
		N	69	69	69	69	69	69	69	69	69	69
	V7 (D1.6)	Correlation Coefficient	.132	.392**	.303*	.288*	.178	.240*	1.000	.446**	.591**	.451**
		Sig. (2-tailed)	.281	.001	.011	.016	.143	.047		.000	.000	.000
		N	69	69	69	69	69	69	69	69	69	69
	V8 (D1.7)	Correlation Coefficient	.001	.130	.092	.428**	.081	.150	.446**	1.000	.595**	.585**
		Sig. (2-tailed)	.996	.286	.453	.000	.510	.217	.000		.000	.000
		N	69	69	69	69	69	69	69	69	69	69
	V9 (D1.8)	Correlation Coefficient	-.042	.228	.237*	.256*	.153	.288*	.591**	.595**	1.000	.775**
		Sig. (2-tailed)	.735	.059	.049	.034	.210	.016	.000	.000		.000
		N	69	69	69	69	69	69	69	69	69	69
	V10 (D1.9)	Correlation Coefficient	.062	.088	.145	.263*	.074	.194	.451**	.585**	.775**	1.000
		Sig. (2-tailed)	.615	.473	.235	.029	.547	.110	.000	.000	.000	
		N	69	69	69	69	69	69	69	69	69	69

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

5.10.3.1 Assumptions

1. In rank (1), CSF (V9) has a positive correlation coefficient with (V7), (V8) and (V10). Moreover, (V1) has a positive correlation coefficient with (V2) and (V3). This establishes that identifying the source of Knowledge (V9) is the foremost CSF that strongly requires the identification of the type of Knowledge to Transfer and Share (V8) and further also requires the identification of the Knowledge recipient (V10). Similarly, trust between organisations (V1) demands motivation to Transfer and Share Tacit Knowledge (V2). Additionally, this demands leadership capabilities to encourage the Transferring and Sharing of Tacit Knowledge.
2. Following (Rank 1), in (Rank 2), CSF (V3) has positive correlation coefficients with (V1), (V4) and (V6). This establishes the assumption that Leadership Capabilities to encourage the Transfer and Sharing of Knowledge (V3) requires aligned business strategies to Transfer and Share Tacit Knowledge in organisations (V4) and further requires the capabilities of individuals to Transfer and Share Tacit Knowledge within the construction processes (V6).
3. In (Rank 3), CSF (V7) is correlated with (V4), (V8), (V9) and (V10). This highlights that the identification of process improvement opportunities (V7) is also an essential CSF to relate with (Rank 1) and assumption (1) with CSFs (V8), (V9) and (V10). This establishes that, before identifying CSF's (V8), (V9) and (V10), it is vital to identify the process improvement opportunities by managers (V7).

Table 5-41: Interpretive correlation coefficient ranking orders of CSFs for Question D1

CSFs	Rank								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
V1	V2	V3	V5	V4	V7	V6	V10	V8	V9
V2	V1	V7	V9	V3	V5	V8	V10	V6	V4
V3	V1	V4	V6	V7	V5	V9	V2	V10	V8
V4	V8	V3	V7	V10	V9	V5	V1	V6	V2
V5	V6	V1	V3	V4	V7	V2	V9	V8	V10
V6	V5	V3	V9	V7	V10	V4	V8	V1	V2
V7	V9	V10	V8	V2	V3	V4	V6	V5	V1
V8	V9	V10	V7	V4	V6	V2	V3	V5	V1
V9	V10	V8	V7	V6	V4	V3	V2	V5	V1
V10	V9	V8	V7	V4	V6	V3	V2	V5	V1
Frequency	**V9 -3 V1 -2**	**V3 -3 V8 - 2 V10 - 2**	**V7 - 4 V9 - 2**	**V4- 4 V7- 2**	**V5 – 2 V6 – 2 V7 - 2**	**V2 – 2 V3 – 2 V4 - 2**	**V2 – 2 V10 - 2**	**V5 – 4 V6 – 2 V8 - 2**	**V1 – 4 V2 - 2**

5.11 Question D2

By drawing from your experience, please kindly indicate what is the level of criticality of the success factors listed below, in the transfer and sharing of Tacit Knowledge in Agile Processes?

This question has ten (10) critical success factors as variables (named V1 to V10) for presentation purposes, and are as follows:.

1) (V1) D2.0 Trust among the organisations in Construction Supply Chains
2) (V2) D2.1 Motivation to share Tacit Knowledge
3) (V3) D2.2 Leadership capabilities of clients and main contractors to encourage the sharing of Tacit Knowledge
4) (V4) D2.3 Business Strategies aligned to Transfering and Sharing Tacit Knowledge in organisations within the construction process
5) (V5) D2.4 Capabilities to Share Tacit Knowledge
6) (V6) D2.5 Individuals involved in the construction process must be capable of sharing Tacit Knowledge
7) (V7) D2.6 Identification of process improvement opportunities by managers
8) (V8) D2.7 Identification of the type of Knowledge to Share
9) (V9) D2.8 Identification of the Source of Knowledge
10) (V10) D2.9 Identification of Knowledge recipient

5.11.1 Cronbach's Alpha Analysis

Cronbach's alpha (α) is calculated as **0.839** in Table 5-42. This indicates a high level of internal consistency for this data.

Table 5-42: Reliability Analysis for Question D2

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.839	.840	10

Furthermore, the calculated median scores are shown in table (5-43), only one variable (V5) is recorded with the median score 3.00 (Moderately Critical). All the others are recorded as median score 4.00 (Critical).

Table 5-43: Median Scores for question D2

Statistics

		V1 (D2.0)	V2 (D2.1)	V3 (D2.2)	V4 (D2.3)	V5 (D2.4)	V6 (D2.5)	V7 (D2.6)	V8 (D2.7)	V9 (D2.8)	V10 (D2.9)
N	Valid	69	69	69	69	69	69	69	69	69	69
	Missing	0	0	0	0	0	0	0	0	0	0
Median		4.00	4.00	4.00	4.00	3.00	4.00	4.00	4.00	4.00	4.00

5.11.2 Analysis of CSFs associated with the transfer and sharing of Tacit Knowledge in Agile processes based on Frequency Analysis and the Kruskal-Wallis H Test

5.11.2.1 (V1) D2.0 Trust among the organisations in Construction Supply Chains

From the frequency analysis in table 5-44, it can be seen that the highest number of respondents (47.8%) said that the level of trust among construction organisations as a critical success factor in the transfer and sharing of Tacit Knowledge (V1) is ‘Highly Critical’. The second highest number of respondents (39.1%) said ‘Critical’ and just less than 9% of respondents said ‘Moderately Critical’. Moreover, the median value in table 5-43 for this variable is calculated as ‘Critical’ (4.00).

In table 5-45, the Kruskal-Wallis H Test and figure 5-13 show the box-plot median score is also (4.00) as assessed by visual inspection. This calculates the Asymptotic Sig. (2-sided test) *p*-value as 0.674 (above > 0.05). This accepts the Null hypothesis as ‘Critical’ This established that the trust among construction organisations is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Agile Processes. (V2) D2.2 Motivation to Transfer and Share Tacit Knowledge in Agile Processes

The frequency analysis in table 5-44 shows that the highest number of of respondents (42.0%) said that level of motivation as a critical success factor in the transfer and sharing of Tacit Knowledge (V3) is ‘Critical’. The second highest number of respondents (34.8%) said ‘Highly Critical’ and just 23.2% of the respondents said ‘Moderately Critical’. Moreover, the median value as shown in table 5-43 for this variable is calculated as ‘Critical’ (4.00). In table 5-45 the Kruskal-Wallis H Test and figure 5-13 also show the box-plot median score is also (4.00) as assessed by visual inspection. Moreover, it gives the Asymptotic Sig. (2-sided test) *p*-value as 0.064 (above > 0.05). This accepts the Null hypothesis. This establishes that motivation (V2) is a 'Critical' success factor in the transfer and sharing of Tacit Knowledge in Agile Processes.

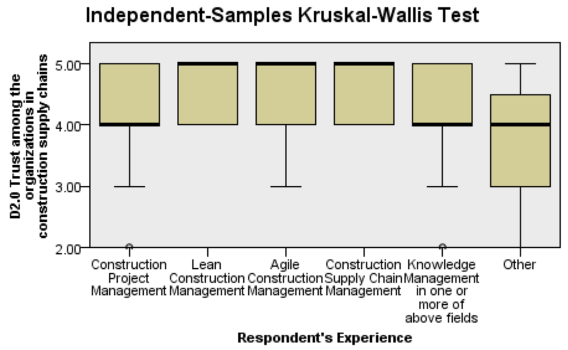
Table 5-44: Frequency Analysis of Question D2

Question D2	Critical Success Factors	Item	Frequency and Percentile				
			1 Not Critical	2 Little Critical	3 Moderately Critical	4 Critical	5 Highly Critical
V1 (D2.0)	Trust among the organisations in Construction Supply Chains	Frequency	0	3	6	27	33
		Percentage	0.0%	4.3%	8.7%	39.1%	47.8%
		Cumulative Percentage	0.0%	4.3%	13.0%	52.2%	100.0%
V2 (D2.1)	Motivation to share Tacit Knowledge	Frequency	0	4	12	29	24
		Percentage	0.0%	5.8%	17.4%	42.0%	34.8%
		Cumulative Percentage	0.0%	5.8%	23.2%	65.2%	100.0%
V3 (D2.2)	Leadership Capabilities of clients and main contractors to encourage the sharing of Tacit Knowledge	Frequency	0	2	11	28	18
		Percentage	0.0%	2.9%	15.9%	55.1%	26.1%
		Cumulative Percentage	0.0%	2.9%	18.8%	73.9%	100.0%
V4 (D2.3)	Business Strategies aligned to Sharing Tacit Knowledge in organisations within the Construction process	Frequency	1	5	10	37	16
		Percentage	1.4%	7.2%	14.5%	53.6%	23.2%
		Cumulative Percentage	1.4%	8.7%	23.2%	76.8%	100.0%
V5 (D2.4)	Organisations within the Construction Supply Chain must have Capabilities to Share Tacit Knowledge	Frequency	0	4	33	26	6
		Percentage	0.0%	5.8%	47.8%	37.7%	8.7%
		Cumulative Percentage	0.0%	5.8%	53.6%	91.3%	100.0%
V6 (D2.5)	Individuals involved in the construction process must be capable of sharing Tacit Knowledge	Frequency	0	6	27	28	8
		Percentage	0.00%	8.70%	39.10%	40.60%	11.60%
		Cumulative Percentage	0.00%	8.70%	47.80%	88.40%	100.00%
V7 (D2.6)	Identification of process improvement opportunities by managers	Frequency	4	4	14	28	9
		Percentage	5.8%	5.8%	20.3%	55.1%	13.0%
		Cumulative Percentage	5.8%	11.6%	31.9%	87.0%	100.0%
V8 (D2.7)	Identification of the type of Knowledge to Share	Frequency	1	9	13	41	5
		Percentage	1.4%	13.0%	18.8%	59.4%	7.2%
		Cumulative Percentage	1.4%	14.5%	33.3%	92.8%	100.0%
V9 (D2.8)	Identification of the Source of Knowledge	Frequency	2	9	12	36	10
		Percentage	2.9%	13.0%	17.4%	52.2%	14.5%
		Cumulative Percentage	2.9%	15.9%	33.3%	85.5%	100.0%
V10 (D2.9)	Identification of Knowledge recipient	Frequency	3	10	14	37	5
		Percentage	4.3%	14.5%	20.3%	53.6%	7.2%
		Cumulative Percentage	4.3%	18.8%	39.1%	92.8%	100.0%

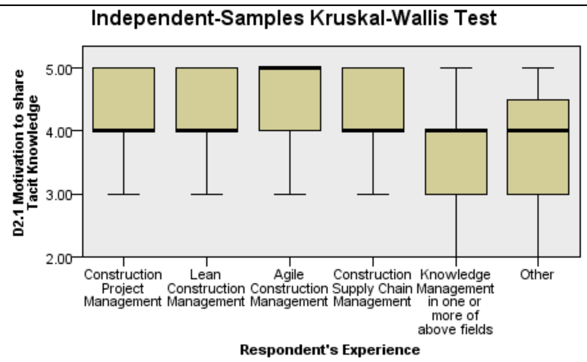
Table 5-45: Kruskal-Wallis H Test of Critical Success Factors in the Transfer and Sharing of Tacit Knowledge in Agile Processes

NO	Hypothesis	Median	Ordinal Rank	Statistically Significantly Distributed	(*p*-value)	Accept or Reject (Null Hypothesis)
V1 (D1.0)	Trust among the organisations in Construction Supply Chains	4.00	Critical	Yes	.674	Accept
V2 (D1.1)	Motivation to share Tacit Knowledge	4.00	Critical	Yes	.064	Accept
V3 (D1.2)	Leadership Capabilities of clients and main contractors to encourage sharing of Tacit Knowledge	4.00	Critical	Yes	.177	Accept
V4 (D1.3)	Business Strategies aligned to Sharing Tacit Knowledge in the organisations within Construction process	4.00	Critical	Yes	.562	Accept
V5 (D1.4)	Organisations within the Construction Supply Chain must have Capabilities to Share Tacit Knowledge	3.00	Moderately Critical	No	.022	Reject
V6 (D1.5)	Individuals involved in the construction process must be capable of sharing Tacit Knowledge	4.00	Critical	Yes	.063	Accept
V7 (D1.6)	Identification of process improvement opportunities by managers	4.00	Critical	No	.005	Reject
V8 (D1.7)	Identification of the type of Knowledge to Share	4.00	Critical	Yes	.735	Accept
V9 (D1.8)	Identification of the Source of Knowledge	4.00	Critical	Yes	.251	Accept
V10 (D1.9)	Identification of Knowledge recipient	4.00	Critical	Yes	.603	Accept

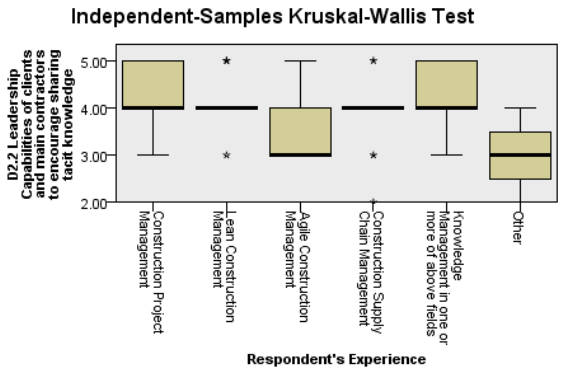
V1 (D2.0)



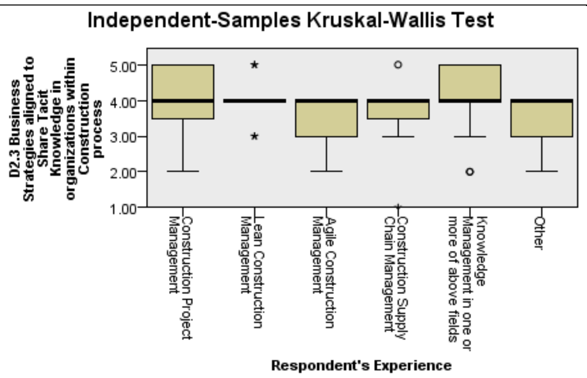
V2 (D2.1)



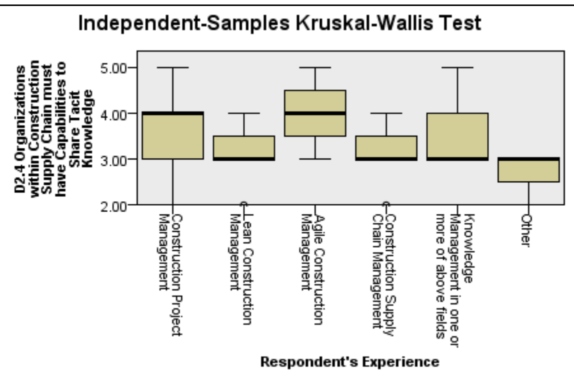
V3 (D2.2)



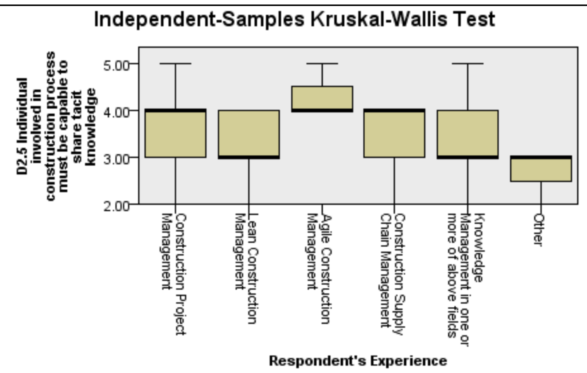
V4 (D2.3)



V5 (D2.4)



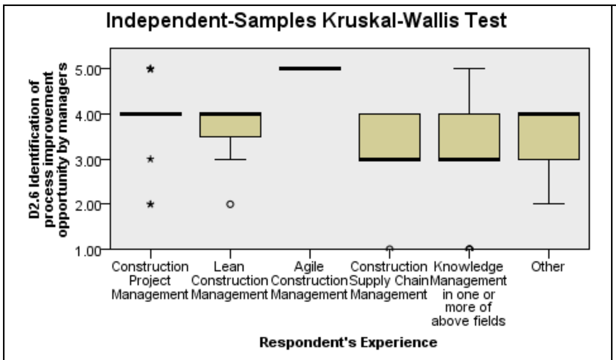
V6 (D2.5)

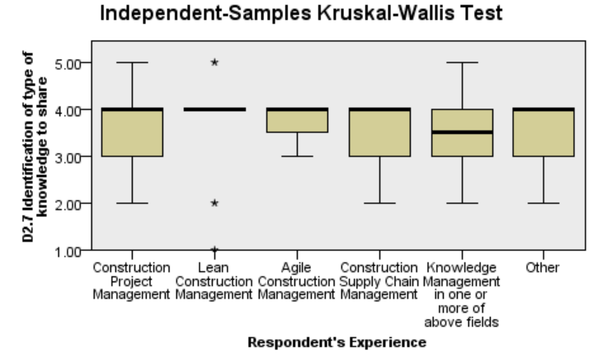


V7 (D2.6)

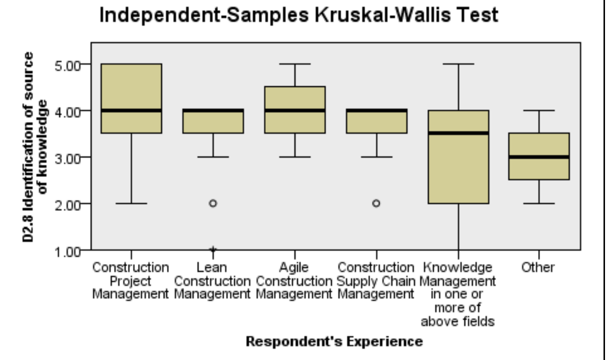
V8 (D2.7)

Image continued on next page





V9 (D2.8)	V10 (D2.9)



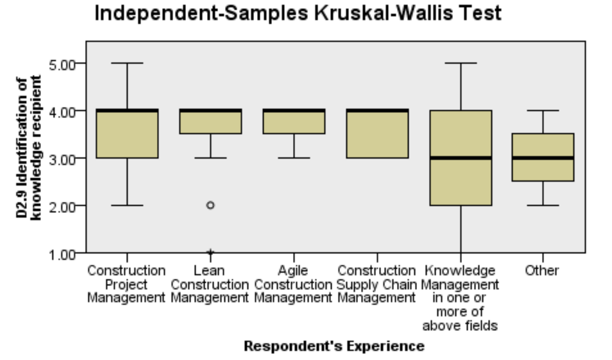


Figure 5-12: Kruskal-Wallis H Test Boxplot Summary of Question D2

5.11.2.2 (V3) D2.2 Leadership capabilities of clients and main contractors to encourage sharing of Tacit Knowledge

The frequency analysis shown in table 5-44 shows the highest number of of respondents (55.1%) said that the level of leadership capabilities of clients and main contractors as a critical success factor in the transfer and sharing of Tacit Knowledge (V3) is ‘Critical’ in Agile processes. The second highest number of (26.1%) respondents (55.1%) said ‘Highly Critical’ and 15.9% of respondents said ‘Moderately Critical’. Moreover, the median value (shown in table 5-37) for this variable is calculated as ‘Critical’ (4.00). In table 5-45 the Kruskal-Wallis H Test and figure 5-13 also show the box-plot median score is (4.00) as assessed by visual inspection. This gives the Asymptotic Sig. (2-sided test) *p*-value as 0.177 (above > 0.05). This accepts the Null hypothesis. In addition, it establishes that the leadership capability of clients and main contractors (V3) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Agile Processes.

5.11.2.3 (V4) D2.3 Business Strategies aligned to the Transfer and Sharing of Tacit Knowledge in organisations within Construction process

The median value shown in table 5-43 for this variable is calculated as 'Critical' (4.00). The frequency analysis (shown in table 5-44) shows that the highest number of respondents (53.6%) said that the level of business strategies as a critical success factor in the transfer and sharing of Tacit Knowledge (V4) is 'Critical'. The second highest number of respondents (23.2%) said 'Highly Critical' and just 14.5% of respondents said 'Moderately Critical'.

Moreover, in table 5-45, the Kruskal-Wallis H Test and figure 5-13 show the box-plot median score is also (4.00) as assessed by visual inspection. This calculates the Asymptotic Sig. (2-sided test) *p*-value as 0.562 (above > 0.05). Thus, this accepts the Null hypothesis. In addition, it establishes that business strategies aligned to Transferring and Sharing Tacit Knowledge in organisations within construction processes (V4) is a 'Critical' success factor in the transfer and sharing of Tacit Knowledge in Agile Processes.

5.11.2.4 (V5) D2.4 Organisational Capabilities to Share Tacit Knowledge

The median value shown in table 5-43 for this variable is calculated as 'Critical' (3.00). Moreover, the frequency analysis in table 5-44 shows that the highest number of respondents (47.8%) said that the level of organisational capabilities as a critical success factor in the transfer and sharing of Tacit Knowledge (V5) is 'Moderately Critical'. The second highest number of respondents (37.7%) said 'Critical' and just 8.7% of respondents said 'Highly Critical'. Furthermore, in table 5-45 the Kruskal-Wallis H Test and figure 5-13 also show the box-plot median score is (3.00) as assessed by visual inspection. This gives the Asymptotic Sig. (2-sided test) *p*-value as 0.022 (below < 0.05). In addition, it establishes that the data on this variable are not significantly statically distributed. Therefore, based on the frequency analysis of this variable, the alternative hypothesis is accepted. This portrays that this success factor is 'Moderately Critical' to the transferring and sharing of Tacit Knowledge in Agile Processes.

5.11.2.5 (V6) D2.5 Individuals involved in the construction process must be capable of Transferring and Sharing Tacit Knowledge

The median value (as shown in table 5-43) for this variable is calculated as 'Critical' (4.00). The frequency analysis (shown in table 5-44) shows that the highest number of respondents (40.60%) said that the level of capability of individuals involved in the construction process as a critical success factor in the transfering and sharing of Tacit Knowledge (V6) is 'Critical'. The second highest number of respondents (39.10%) said 'Moderately Critical' Just

11.6% respondents said ‘Highly Critical’. Moreover, in table 5-45 the Kruskal-Wallis H Test and figure 5-13 show the box-plot median score is also (4.00) as assessed by visual inspection. This gives the Asymptotic Sig. (2-sided test) *p*-value as 0.063 (above > 0.05). Thus, it establishes that individual capability in a construction process (V6) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Agile Processes. This accepts the null hypothesis.

5.11.2.6 (V7) D2.6 Identification of process improvement opportunities by managers

The frequency analysis presented in table 5-44 shows the highest number of of respondents (55.1%) said that the level of identification of process improvement opportunities by managers as a critical success factor in the transfer and sharing of Tacit Knowledge (V7) is ‘Critical’. The second highest number of respondents (20.3%) said ‘Moderately Critical’. Moreover, the median value (as shown in table 5-43) for this variable is calculated as ‘Critical’ (4.00). In table 5-45 the Kruskal-Wallis H Test and figure 5-13 also show the box-plot median score is (4.00) as assessed by visual inspection. This gives the Asymptotic Sig. (2-sided test) *p*-value as 0.005 (below < 0.05). This establishes that the data for this variable are not significantly statically distributed. Therefore, this accepts the alternative hypothesis. This portrays that this success factor is ‘Critical’ in the transfer and sharing of Tacit Knowledge in Agile Processes.

5.11.2.7 (V8) D2.7 Identification of the type of Knowledge to Share

The frequency analysis presented in table 5-44 shows that the highest number of respondents (59.4%) said that the level of identification of the type of Knowledge to share as a critical success factor in the transfer and sharing of Tacit Knowledge (V8) is ‘Critical’. The second highest number of respondents (18.8%) said ‘Moderately Critical’. The median value, as shown in table 5-43, for this variable is calculated as ‘Critical’ (4.00). Moreover, in table 5-45, Kruskal-Wallis H Test and figure 5-13 show the box-plot median score is also (4.00) as assessed by visual inspection. This calculates the Asymptotic Sig. (2-sided test) *p*-value as 0.735 (above > 0.05). Based on this analysis, it meets the assumption that the Null hypothesis be accepted. This establishes that the identification of the type of Knowledge to Transfer and Share Tacit Knowledge within construction processes (V8) is a ‘Critical’ success factor in the transferring and sharing of Tacit Knowledge in Agile Processes.

5.11.2.8 (V9) D2.8 Identification of the Source of Knowledge

The frequency analysis shown in table 5-44 shows that the highest number of of respondents (52.2%) said that the level of identification of the source of Knowledge as a critical success factor in the transfer and sharing of Tacit Knowledge (V9) is ‘Critical’. The second highest number of respondents (17.4%) said ‘Moderately Critical’. The median value (as shown in table 5-43) for this variable is calculated as ‘Critical’ (4.00). Moreover, in table 5-45. The Kruskal-Wallis H Test and figure 5-13 show the box-plot median score is also (4.00) as assessed by visual inspection. This gives the Asymptotic Sig. (2-sided test) *p*-value as 0.251 (above > 0.05). This meets the assumption that the Null hypothesis be accepted. This establishes that the identification of the source of Knowledge to Transfer and Share Tacit Knowledge within construction processes (V8) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Agile Processes.

5.11.2.9 (V10) D2.9 Identification of Knowledge recipient

The frequency analysis (shown in table 5-44) shows that the highest number of respondents (53.6%) said that the level of identification of the recipient of Knowledge (with whom to share that knowledge) as a critical success factor in the transfer and sharing of Tacit Knowledge (V9) is ‘Critical’. The second highest number of respondents (20.3%) said ‘Moderately Critical’. The median value (as shown in Table 5-43) for this variable is calculated as ‘Critical’ (4.00). Moreover, (shown in Table 5-45) the Kruskal-Wallis H Test and Figure 5-13) show the box-plot median score is also (4.00), as assessed by visual inspection. This gives the Asymptotic Sig. (2-sided test) *p*-value as 0.522 (above > 0.05). This accepts the null hypothesis. This establishes that the identification of the recipient of Knowledge to Transfer and Share Tacit Knowledge within construction processes (V9) is a ‘Critical’ success factor in the transfer and sharing of Tacit Knowledge in Agile Processes. .

5.11.3 Spearman’s Correlation Analysis for Question D2

The Spearman’s Correlation analysis has been run and table 5-46 has been generated to identify the correlation significance among the critical success factors that enable the Transfer and Sharing of Tacit Knowledge in the application of Agile Processes. For presentation purposes, the variables (Critical Success Factors) are coded as (V1) to (V10).

Based on the correlation analysis of CSFs (shown in Table 5-46), the most significant correlation has been found between (V8) and (V10). Among these, the positive correlation coefficient is calculated as (r_s =. 719). This reflects that the identification of both the type of Knowledge and the recipient of Knowledge are essential CSFs in the Transfer and Sharing of Knowledge in Agile Processes and are highly correlated with each other.

The second highest and positive correlation coefficient (r_s =. 657) is calculated between (V9) and (V10). This portrays that identification of both the source and the recipient of Knowledge are also highly correlated CSFs.

The third highest significant correlation coefficient (r_s =. 651) is found between (V8) and (V9). This correlation reflects that the identification of both the type of Knowledge and the source of Knowledge are essential CSFs in the Transfer and Sharing of Knowledge in Agile Processes and are highly correlated with each other.

The fourth highest correlation coefficient (r_s =. 594) is found between (V3) and (V4). This establishes that the leadership capabilities of clients and main contractors to encourage the sharing of Tacit Knowledge in Agile Processes is highly correlated with business strategies. Moreover, the fifth highest positive correlation coefficient (r_s =. 499) is recorded between (V3) and (V5). This establishes that, along with business strategies (V4), leadership capabilities are also highly correlated with organisational capabilities (V5).

Table 5-46: Correlations among CSFs associated with the Transfer and Sharing of Tacit Knowledge in Agile Processes

Correlations

			V1 (D2.0)	V2 (D2.2)	V3 (D2.2)	V4 (D2.3)	V5 (D2.4)	V6 (D2.5)	V7 (D2.6)	V8 (D2.7)	V9 (D2.8)	V10 (D2.9)
Spearman's rho	V1 (D2.0)	Correlation Coefficient	1.000	.561**	.347**	.370**	.435**	.280*	.031	.205	.215	.109
		Sig. (2-tailed)		.000	.003	.002	.000	.020	.803	.092	.076	.372
		N	69	69	69	69	69	69	69	69	69	69
	V2 (D2.2)	Correlation Coefficient	.561**	1.000	.295*	.171	.338**	.282*	.271*	.437**	.498**	.238*
		Sig. (2-tailed)	.000		.014	.160	.004	.019	.024	.000	.000	.048
		N	69	69	69	69	69	69	69	69	69	69
	V3 (D2.2)	Correlation Coefficient	.347**	.295*	1.000	.594**	.499**	.181	.119	.216	.297*	.008
		Sig. (2-tailed)	.003	.014		.000	.000	.137	.330	.074	.013	.945
		N	69	69	69	69	69	69	69	69	69	69
	V4 (D2.3)	Correlation Coefficient	.370**	.171	.594**	1.000	.378**	.174	.157	.369**	.306*	.261*
		Sig. (2-tailed)	.002	.160	.000		.001	.152	.198	.002	.011	.030
		N	69	69	69	69	69	69	69	69	69	69
	V5 (D2.4)	Correlation Coefficient	.435**	.338**	.499**	.378**	1.000	.461**	.247*	.243*	.368**	.103
		Sig. (2-tailed)	.000	.004	.000	.001		.000	.041	.044	.002	.401
		N	69	69	69	69	69	69	69	69	69	69
	V6 (D2.5)	Correlation Coefficient	.280*	.282*	.181	.174	.461**	1.000	.425**	.237*	.472**	.410**
		Sig. (2-tailed)	.020	.019	.137	.152	.000		.000	.050	.000	.000
		N	69	69	69	69	69	69	69	69	69	69
	V7 (D2.6)	Correlation Coefficient	.031	.271*	.119	.157	.247*	.425**	1.000	.390**	.419**	.459**
		Sig. (2-tailed)	.803	.024	.330	.198	.041	.000		.001	.000	.000
		N	69	69	69	69	69	69	69	69	69	69
	V8 (D2.7)	Correlation Coefficient	.205	.437**	.216	.369**	.243*	.237*	.390**	1.000	.651**	.719**
		Sig. (2-tailed)	.092	.000	.074	.002	.044	.050	.001		.000	.000
		N	69	69	69	69	69	69	69	69	69	69
	V9 (D2.8)	Correlation Coefficient	.215	.498**	.297*	.306*	.368**	.472**	.419**	.651**	1.000	.657**
		Sig. (2-tailed)	.076	.000	.013	.011	.002	.000	.000	.000		.000
		N	69	69	69	69	69	69	69	69	69	69
	V10 (D2.9)	Correlation Coefficient	.109	.238*	.008	.261*	.103	.410**	.459**	.719**	.657**	1.000
		Sig. (2-tailed)	.372	.048	.945	.030	.401	.000	.000	.000	.000	
		N	69	69	69	69	69	69	69	69	69	69

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Additionally, Motivation to Transfer and Share Tacit Knowledge (V2) is found to be significantly correlated with trust among the organisations in CSCs (V1) with (r_s =. 561) and furthermore with (V9) identification of the source of Knowledge with (r_s =. 498) and (V9) is further significantly correlated with (V6) with (r_s =. 472).

Table 5-47 below has been developed based on the ranking order from high to low correlation coefficient. This exhibits the ranking order of the correlation coefficients between the CSFs from the 'Highest Correlated Coefficient' (1) to the 'Lowest Correlated Coefficient' (9).

Based on the interpretive analysis below (see Table 5-47), the following assumptions can be made in respect to the 'highest to the lowest' correlation coefficients of named the CSFs (V1 to V10). The following three (3) assumptions are made based on (Rank 1 to 3) to avoid duplication of the assumptions and any arising confusion while interpreting the presumptions.

5.11.3.1 Interpretive correlation coefficient ranking orders of CSFs for Question D2

Table 5-47: Interpretive correlation coefficient ranking orders of CSFs for Question D2

CSFs	Rank								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
V1	V2	V5	V4	V3	V6	V9	V8	V10	V7
V2	V1	V9	V8	V5	V3	V6	V7	V10	V4
V3	V4	V5	V1	V9	V2	V8	V6	V7	V10
V4	V3	V5	V1	V8	V9	V10	V6	V2	V7
V5	V3	V6	V1	V4	V9	V2	V7	V8	V10
V6	V9	V5	V7	V10	V2	V1	V7	V3	V4
V7	V10	V6	V9	V8	V2	V5	V4	V3	V1
V8	V10	V9	V3	V7	V4	V5	V6	V3	V1
V9	V10	V8	V2	V6	V7	V5	V4	V3	V1
V10	V8	V9	V7	V6	V4	V2	V1	V5	V3
Frequency	V10 – 3 V3 – 2	V5 – 4 V6 - 2 V9 - 2	V1 - 3 V7 - 2	V6 - 2 V8 – 2	V2 – 3 V4 – 2 V9 - 2	V5 - 3 V2 - 2	V6 - 3 V7 - 3	V3 – 4 V10 - 2	V1- 3 V4 – 2 V7 – 2 V10 - 2

5.11.3.2 Assumptions

1) In rank (1):
   a) CSF (V10) has positive correlation coefficients 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. This is highly correlated with the identification of process improvement opportunities (V7), the type of Knowledge to Transfer and Share (V8) and furthermore, the identification of the Knowledge source (V10).

b) The leadership capabilities of clients and main contractors (V3) require business strategies aligned to Transferring and Sharing Tacit Knowledge (V4) and (V5) organisational capabilities to Transfer and Share Tacit Knowledge.

2) Following (Rank 1), in (Rank 2):

a) CSF (V5) has positive correlation coefficients with (V1), (V3), and (V4) and (V6). This establishes the assumption that Organisational Capabilities to Transfer and Share Knowledge (V5) requires trust between organisations (V1), the leadership capabilities of clients and main contractors (V3), aligned with business strategies to Transfer and Share Tacit Knowledge (V4) and the capabilities of individuals involved in construction processes (V6).
b) Furthermore, the capabilities of individuals (V6) require identification of process improvement opportunities (V7) and, additionally, this requires identification of the type of Knowledge to Transfer and Share (V8) and identification of the source of Knowledge (V10).

3) In (Rank 3):

a) CSF (V1) is correlated with (V3), (V4) and (V5). This highlights that trust among organisations within CSCs (V1) is significantly correlated with leadership capabilities (V3), Business Strategies (V4) and organisational capabilities (V5).
b) Moreover, the identification of process improvement opportunities (V7) has significant coefficients with individuals involved in the construction process (V6) and identification of the Knowledge recipient (V10); this correlates with above assumption (2b).

5.12 Evaluation of Critical Success Factors in the Transfer and Sharing of Tacit Knowledge through the application of both (a) Lean and (b) Agile Processes.

This section is to identify the CSFs associated with the effectiveness of the Transfer and Sharing of Tacit Knowledge (a) in Lean Processes (b) in Agile Processes. Through the literature review, a total number of ten (10) necessary factors whose absence hinders the effectiveness of sharing and transference of Tacit Knowledge were revealed. The data analysis in Chapter 5 establishes that nine (9) out of those ten (10) CSFs observed have a level of criticality that is ‘High’. Only the organisational capability to Transfer and Share Tacit Knowledge is observed as having the level of criticality of ‘Moderately Critical’ in both

Lean and Agile Processes. Based on the assumptions made in Chapter 5 and section (D) the following has been established.

Identifying the source of knowledge is the foremost CSF that is essentially required for identifying the type of knowledge to Transfer and Share alongside the identification of the knowledge recipient, in Lean Processes. However, in Agile Processes, the foremost CSF is identifying the knowledge recipient. This further requires identifying the process improvement opportunities followed by the type of knowledge to share and, lastly, identification of the source of knowledge.

Furthermore, in Lean Processes, trust between organisations is observed as the second CSF that requires 'motivation' and, furthermore, motivation is required to identify the type of knowledge to transfer and share. However, motivation should be supported by leadership and organisational capabilities. In Agile Processes, leadership capabilities are the second most necessary CSF that requires business strategies aligned with requiring organisational capabilities and trust between organisations. However, in rank three of CSFs in Agile Processes, engaged motivation is an important factor which requires back up by leadership and organisational capabilities. Additionally, both Lean and Agile Processes also require individual capabilities.

Section E Data Analysis of Questions E1 and E2

5.13 Questions E1 and E2

This section examines the contributions of (a) Lean and (b) Agile Principles in Construction Supply Chains in terms of efficiency improvements.

The 'Contribution' in this context is the role played by Lean and Agile processes in bringing in efficiency in Construction Supply Chains.

'Efficiency' in this context is enhancing the skilfulness of the supply chain to reduce waste and effort in order to make the SC responsive.

5.13.1 Question E1

This question has four (4) different contributions as variables (named V1 to V4) for presentation purposes, and these are:

1) (V1) E1.0 To reduce waste in Construction Supply Chains
2) (V2) E1.1 To enhance material and information flow within Construction Supply Chains
3) (V3) E1.2 To increase efficiency in the decision making process within Construction Supply Chains
4) (V4) E1.3 To continuously improve Construction Supply Chains

5.13.1.1 Cronbach Alpha Analysis of Question E1

Cronbach's alpha (α) is **0.675** (see Table 5-48**)** for question E1 which indicates an adequate level of internal consistency for this data.

Table 5-48: Reliability Analysis of question E1

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.675	.666	4

The calculated median scores are shown in table 5-49 and only one variable (V1) is recorded with the median score of 4.00 (High) concerning a contribution to CSCs. (V2) and (V4) are recorded as median score 3.00 (Moderate) and (V3) as 2.00 (Low) for their contributions to CSCs.

Table 5-49: Median Statistics of question E1

Median Statistics for question E1

		E1.0 To reduce waste in Construction Supply Chain	E1.1 To enhance material and information flow within the Construction Supply Chains	E1.2 To increase efficiency in decision making process within Construction Supply Chains	E1.3 To continuously improve construction supply chains
N	Valid	69	69	69	69
	Missing	0	0	0	0
Median		4.00	3.00	2.00	3.00

5.13.2 Analysis of the contribution of Lean Principles to Construction Supply Chains in terms of efficiency improvement, based on Frequency Analysis and the Kruskal-Wallis H Test

5.13.2.1 (V1) E1.0 to reduce waste in Construction Supply Chains

The frequency analysis shown in table 5-50 shows that the highest number of respondents (42.0%) said that the level of contribution of the Lean principle ‘reduce waste’ in the construction process is ‘High’. The second highest number of respondents (34.8%) said ‘Very High’ and 20.3% of the respondents said ‘Moderate’. Moreover, the median value in table 5-49 for this variable is calculated as ‘High’ (4.00). In addition, in table 5-51, Kruskal-Wallis H Test and figure 5-14 show the box-plot median score is also (4.00) as assessed by visual inspection. This gives the Asymptotic Sig. (2-sided test) *p*-value as 0.021 (Below < 0.05). However, based on the Kruskal-Wallis H test, this rejects the null hypothesis. This is because the data are not statistically significantly distributed. As a result, this accepts the alternate hypothesis based on the frequency analysis. This establishes that the Lean Principle ‘reduce waste’ has a ‘High’ contribution in CSCs in terms of efficiency improvement.

5.13.2.2 (V2) E1.1 to enhance material and information flow within Construction Supply Chains

The frequency analysis shown in table 5-50 shows that the highest number of of respondents (34.8%) said that the level of contribution of the Lean principle ‘to enhance material and information flow' in the construction process is 'High'. The second highest number of respondents (29.0%) said 'Moderate' and 26.1% of respondents said 'Low'. Moreover, the median value (shown in Table 5-49) for this variable is calculated as 'Moderate' (3.00). In addition, in table 5-51, the Kruskal-Wallis H Test and Figure 5-14 shows the box-plot median score is (3.00) as assessed by visual inspection. This gives the Asymptotic Sig. (2-sided test) *p*-value as 0.645 (above > 0.05). This accepts the null hypothesis as the contribution of the Lean Principle is 'Moderate' in terms of efficiency improvement in CSCs, even though the Asymptotic Sig. *p*-value is high.

5.13.2.3 (V3) E1.2 to increase efficiency in the decision making process within Construction Supply Chains

The frequency analysis shown in table 5-50 shows that the highest number of respondents (50.7%) said that the level of contribution of the Lean principle 'to increase efficiency in the decision-making process' within the construction process is 'Low'. The second highest number of respondents (24.6%) said 'High' and 13.0% of respondents said 'Moderate'. Moreover, the median value in table 5-49 for this variable is calculated as 'Low' (2.00). Furthermore, in table 5-51, the Kruskal-Wallis H Test and Figure 5-14 show the box-plot median score is also (2.00) as assessed by visual inspection. This gives the Asymptotic Sig. (2-sided test) *p*-value as 0.338 (above > 0.05). In addition, it establishes that the Null Hypothesis is to be accepted as the contribution of the Lean Principle 'to increase efficiency in the decision-making processes is 'Low' in terms of efficiency improvements in CSCs, even though the Asymptotic Sig. *p*-value is adequate.

5.13.2.4 (V4) E1.3 to continuously improve Construction Supply Chains

The frequency analysis shown in table 5-50 shows that the highest number of respondents (30.4%) said that the level of contribution of the Lean principle 'to continuously improve CSCs in the construction process is 'High'. The second highest number of respondents (29.0%) said 'Moderate' and 15.9% of the respondents said 'Very High'. Moreover, the median value in table 5-49 for this variable is calculated as 'Moderate' (3.00). The Kruskal-Wallis H Test in table 5-51 and figure 5-14 show the box-plot median score is also (2.00) as assessed by visual inspection. This calculates the Asymptotic Sig. (2-sided test) *p*-value as 0.064 (above > 0.05). In addition, it establishes that the Null Hypothesis is to be accepted as the contribution of the Lean Principle 'to continuously improve CSCs is 'High' in terms of efficiency improvements in CSCs.

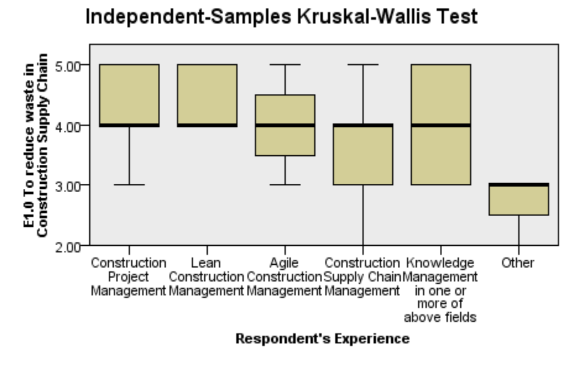
Table 5-50: Frequency Analysis: Contribution of Lean Principles in increasing efficiency in CSCs.

No E1.0	**Contribution**	**Item**	**Frequency and Percentile**				
			1 Very Low	**2 Low**	**3 Moderate**	**4 High**	**5 Very High**
V1 (E1.0)	To reduce waste in Construction Supply Chains	Frequency	0	2	14	29	24
		Percentage	0.0%	2.9%	20.3%	42.0%	34.8%
		Cumulative Percentage	0.0%	2.9%	23.2%	65.2%	100%
V2 (E1.1)	To enhance material and information flow within Construction Supply Chains	Frequency	1	18	20	24	6
		Percentage	1.4%	26.1%	29.0%	34.8%	8.7%
		Cumulative Percentage	1.4%	27.5%	56.5%	91.3%	100%
V3 (E1.2)	To increase efficiency in the decision making process within Construction Supply Chains	Frequency	2	35	9	17	6
		Percentage	2.9%	50.7%	13.0%	24.6%	8.7%
		Cumulative Percentage	2.9%	53.6%	66.7%	91.3%	100%
V4 (E1.3)	To continuously improve Construction Supply Chains	Frequency	2	15	20	21	11
		Percentage	2.9%	21.7%	29.0%	30.4%	15.9%
		Cumulative Percentage	2.9%	24.6%	53.6%	84.1%	100%

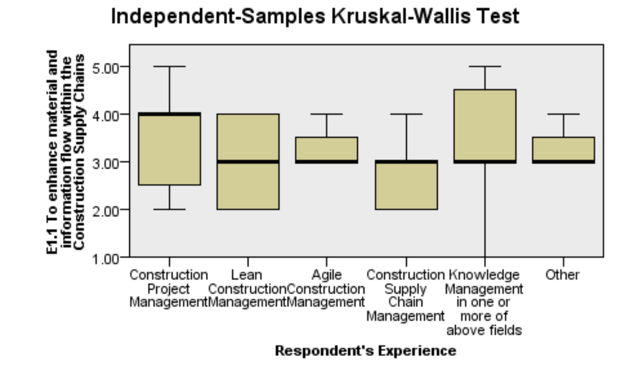
Table 5-51: Kruskal-Wallis H Test for Question E1

NO	Hypothesis	Median	Ordinal Rank	Statistically Significantly Distributed	(*p*-value)	Accept or Reject (Null Hypothesis)
V1 (E1.0)	To reduce waste in Construction Supply Chains	4.00	High	No	.021	Reject
V2 (E1.1)	To enhance material and information flow within Construction Supply Chains	3.00	Moderate	Yes	.645	Accept
V3 (E1.2)	To increase efficiency in the decision making process within Construction Supply Chains	2.00	Low	Yes	.338	Accept
V4 (E1.3)	To continuously improve Construction Supply Chains	3.00	Moderate	Yes	.064	Accept

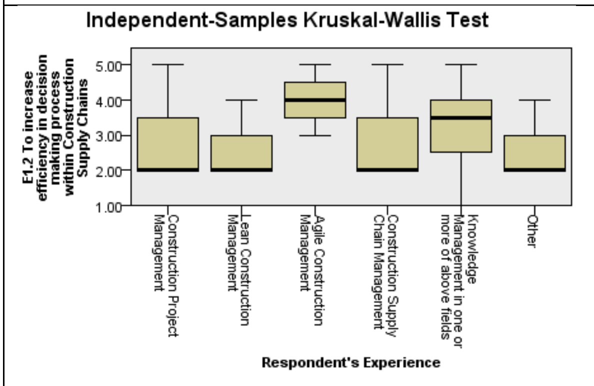
V1 (E1.0)



V2 (E1.1)



V3 (E1.2)



V4 (E1.3)

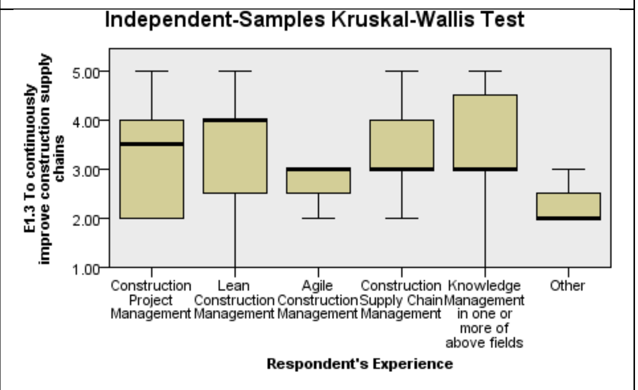


Figure 5-13: Boxplot Summary of Question E1

5.14 Question E2

This question has four (4) different contributions as variables (named V5 to V8) for presentation purposes, as follows:

1) (V5) E2.0 To enhance the responsiveness of activities within Construction Supply Chains
2) (V6) E2.1 To bring collaboration and partnering among organisations within Construction Supply Chains
3) (V7) E2.2 To empower teams to take effective decisions within Construction Supply Chains
4) (V8) E2.3 To integrate processes throughout the construction project

5.14.1.1 Cronbach's Alpha Analysis for question E2

Cronbach's alpha (α) is **0.854** (as shown in Table 5-52**)** for question E2 which indicates a high level of internal consistency for this data.

Table 5-52: Reliability Analysis for Question E2

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.854	.854	4

Table 5-53 shows the calculated median scores, and variables (V5) and (V6) are recorded with the median score 4.00 (High) concerning their contribution to CSCs, and (V7) and (V8) are recorded as median score 3.00 (a Moderate contribution to CSCs).

Table 5-53: Median Statistics of question E2

Statistics

		E2.0 To enhance responsiveness of activities within construction supply chains	E2.1 To bring collaboration and partnering among organizations within construction supply chains	E2.2 To empower teams to take effective decision within the construction supply chains	E2.3 To integrate processes throughout the construction project
N	Valid	69	69	69	69
	Missing	0	0	0	0
Median		4.00	4.00	3.00	3.00

5.14.2 Analysis of the contribution of Lean Principles to Construction Supply Chains in terms of efficiency improvements, based on Frequency Analysis and the Kruskal-Wallis H Test

5.14.2.1 (V5) E2.0 to enhance the responsiveness of activities within Construction Supply Chains

The frequency analysis shown in table 5-54 shows that the highest numberof respondents (42.0%) said that the level of contribution of the Agile principle ‘to enhance the responsiveness of activities in CSCs’ is ‘High’. The second highest number of respondents (34.8%) said ‘Very High’ and 17.4% of respondents said ‘Moderate’. The median value shown in table 5-53 for this variable is calculated as ‘High’ (4.00). Moreover, in table 5-55, the Kruskal-Wallis H Test and figure 5-15 show the box-plot median score is also (4.00) as assessed by visual inspection. This gives the Asymptotic Sig. (2-sided test) *p*-value as 0.245 (above > 0.05). This establishes that the Null Hypothesis is to be accepted as the contribution of this Agile Principle is ‘High’ in terms of efficiency improvements in CSCs.

5.14.2.2 (V6) E2.1 to bring collaboration and partnering among organisations within Construction Supply Chains

The median score for this variable is calculated as (4.00) ‘High’, as shown in table 5-53. The highest number of respondents (43.5%) said that the level of contribution of the Agile principle ‘to bring collaboration and partnering among organisations in CSCs’ is ‘High’. The second highest number of respondents (23.2%) said ‘Low’ and the third highest number of respondents (20.3%) said ‘Moderate’. Moreover, in table(5-55 the Kruskal-Wallis H Test and figure 5-15 show the box-plot median score is also (4.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.939 (above > 0.05). This establishes that the Null Hypothesis is to be accepted as the contribution of this Agile Principle is ‘High’ in bringing collaboration and partnering among organisations, in terms of efficiency improvements in CSCs.

Table 5-54: Frequency Analysis: Contribution of Agile Principles in increasing efficiency in CSCs

E2.0	Contribution	Item	Frequency and Percentile				
			1 Very Low	2 Low	3 Moderate	4 High	5 Very High
V5 (E2.0)	To enhance the responsiveness of activities within Construction Supply Chains	Frequency	0	4	12	29	24
		Percentage	0.0%	5.8%	17.4%	42.0%	34.8%
		Cumulative Percentage	0.0%	5.8%	23.2%	65.2%	100%
V6 (E2.1)	To bring collaboration and partnering among organisations within Construction Supply Chains	Frequency	0	16	14	30	9
		Percentage	0.0%	23.2%	20.3%	43.5%	13.0%
		Cumulative Percentage	0.0%	23.2%	43.5%	87.0%	100%
V7 (E2.2)	To empower teams to take effective decisions within Construction Supply Chains	Frequency	2	18	15	31	3
		Percentage	2.9%	26.1%	21.7%	44.9%	4.3%
		Cumulative Percentage	2.9%	29.0%	50.7%	95.7%	100%
V8 (E2.3)	To integrate processes throughout the construction project	Frequency	3	29	20	11	6
		Percentage	4.3%	42.0%	29.0%	15.9%	8.7%
		Cumulative Percentage	4.3%	46.4%	75.4%	91.3%	100%

5.14.2.3 Table 5-55: Kruskal-Wallis H Test for Question E2

NO	Hypothesis	Median	Ordinal Rank	Statistically Significantly Distributed	(*p*-value)	Accept or Reject (Null Hypothesis)
V5 (E2.0)	To enhance the responsiveness of activities within Construction Supply Chains	4.00	High	Yes	.245	Accept
V6 (E2.1)	To bring collaboration and partnering among organisations within Construction Supply Chains	4.00	High	Yes	.939	Accept
V7 (E2.2)	To empower teams to take effective decisions within Construction Supply Chains	3.00	Moderate	Yes	.878	Accept
V8 (E2.3)	To integrate processes throughout the construction project	3.00	Moderate	Yes	.357	Accept

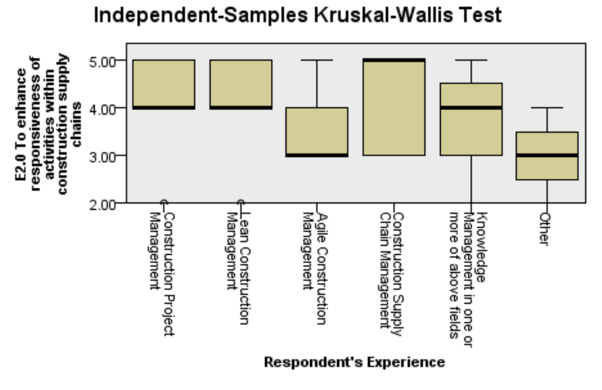
5.14.2.4 V7) E2.2 to empower teams to take effective decisions within Construction Supply Chains.

In this variable, the median score is calculated as (3.00) ‘Moderate’ as shown in table (5-53). The highest number of respondents (44.9%) said that the level of contribution of the Agile principle ‘to empower teams to take an effective decision within the CSCs’ is ‘High’. The second highest number of respondents (26.1%) said ‘Low’ and the third highest number of respondents (21.7%) said ‘Moderate’. Moreover, in table 5-55, the Kruskal-Wallis H Test and figure 5-15 show the box-plot median score is also (3.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.878 (above > 0.05). This establishes that the Null Hypothesis is to be accepted as the contribution of this Agile Principle is ‘Moderate’ in empowering teams to take effective decisions within the CSCs, in terms of efficiency improvements in CSCs.

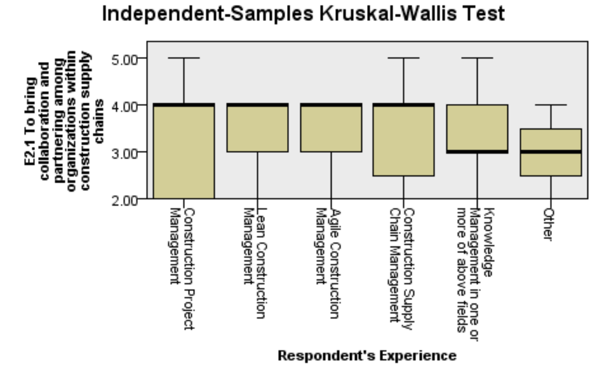
5.14.2.5 (V8) E2.3 to integrate processes throughout the construction project

In this variable, the median score is calculated as (2.00) ‘Moderate’ (as shown in table 5-53). The highest number of respondents (42.0%) said that the level of contribution of the Agile principle ‘to integrate processes throughout the construction process’ is ‘Low’. The second highest number of respondents (29.0%) said ‘Moderate’ and third highest number of respondents (15.9%) said ‘High’. Moreover, in table(5-55, the Kruskal-Wallis H Test and figure 5-15 show the box-plot median score is also (2.00) as assessed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.357 (above > 0.05). This establishes that the Null Hypothesis is to be accepted as the contribution of this Agile Principle is 'Low' in integrating processes throughout the construction process, in terms of efficiency improvements in CSCs.

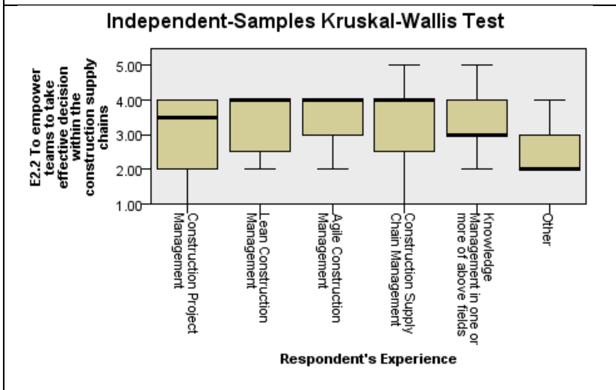
V5 (E2.0)



V6 (E2.1)



V7 (E2.2)



V8 (E2.3)

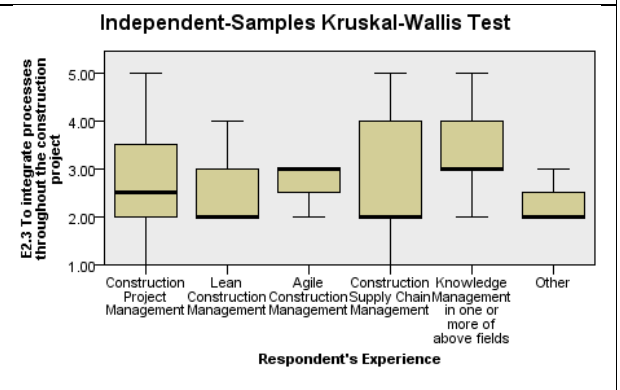


Figure 5-14: Boxplot Summary of Question E2

Section F Data Analysis of Questions F1 and F2

5.15 Question F1

This question is to investigate the level of importance of key factors listed below to enable the sharing and transferring of Tacit Knowledge in Lean, Agile and Construction Supply Chain processes.

This question has seven (7) different factors as variables (named V1 to V7) for presentation purposes, and are as follows:

1) (V1) F1.0 Leadership capability to Transfer and Share Tacit Knowledge
2) (V2) F1.1 Corporate strategies to Transfer and Share Tacit Knowledge
3) (V3) F1.2 Motivation of organisations/people within Construction Supply Chains to share and transfer Tacit Knowledge
4) (V4) F1.3 Skill enhancement of Transferring and Sharing Tacit Knowledge by providing training for organisations/people
5) (V5) F1.4 Identifying process improvement opportunities
6) (V6) F1.5 Identifying the type of Knowledge required to enhance the efficiency of construction processes
7) (V7) F1.6 Identifying the source of Knowledge

5.15.1 Cronbach's Alpha Analysis

Cronbach's alpha (α) is **0.830** (as shown in Table 5-56**)** for this questio, which indicates a high level of internal consistency for this data.

Table 5-56: Reliability Analysis of Question F1

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.830	.828	7

Table 5-57 shows the calculated median scores for all the variables (Factors) and all of them are shown as 4.00 (Important) to enable the Sharing and Transferring of Tacit Knowledge in Lean, Agile and Construction Supply Chain processes.

Table 5-57: Median Statistics of Question F1

Statistics

		F1.0 Leadership capability and intention to share and transfer tacit knowledge	F1.1 Corporate strategies to share and transfer tacit knowledge	F1.2 Motivation of organizations/ people among the construction supply chain to share and tacit transfer knowledge	F1.3 Skill enhancement to share and transfer tacit knowledge while providing training to organizations/ people	F1.4 Identifying, process improvement opportunity	F1.5 Identifying, type of knowledge required to enhance the efficiency of construction process	F1.6 Identifying, source of knowledge
N	Valid	69	69	69	69	69	69	69
	Missing	0	0	0	0	0	0	0
Median		4.00	4.00	4.00	4.00	4.00	4.00	4.00

5.15.2 Analysis of the level of importance of the factors listed below in the Transferring and Sharing of Tacit Knowledge in Construction Supply Chains, based on Frequency Analysis and the Kruskal-Wallis H Test

5.15.2.1 (V1) F1.0 Leadership capability to Transfer and Share Tacit Knowledge

The frequency analysis shown in in table 5-58 shows that the highest number of of respondents (55.1%) said that ‘leadership capability’ is an ‘Important’ factor in Transferring and Sharing of Tacit Knowledge. The second highest number of respondents (30.4%) said ‘Very Important’ and only 13.0% respondents said ‘Moderately Important’. The median value (as shown in table 5-57) is observed as ‘Important’ (4.00). Moreover, in table 5-59, the Kruskal-Wallis H Test and figure 5-16 the box-plot median score is also (4.00) as observed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.279 (Below < 0.05). As a result, this accepts the null hypothesis that leadership capabilities to Transfer and Share Tacit Knowledge is an important factor.

5.15.2.2 (V2) F1.1 Corporate strategies to Transfer and Share Tacit Knowledge

Corporate strategy is also observed as an ‘Important’ factor in the Transfer and Sharing of Tacit Knowledge. The frequency analysis shown in table 5-58 shows that the highest number of respondents (50.7%) said that ‘Corporate Strategies’ is an ‘important’ factor in the Transferring and Sharing of Tacit Knowledge. The second highest number of respondents (31.9%) said ‘Very Important’ and only 14.5% respondents said ‘Moderately Important’. The median value (as shown in table 5-57) is observed as ‘Important’ (4.00). Moreover, in table 5-59, the Kruskal-Wallis H Test and figure 5-16 show the box-plot median score is also (4.00) as observed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.055 (Below < 0.05). This portrays that ‘corporate strategies’ is an important factor in the Transfer and Sharing of Tacit Knowledge. This accepts the null hypothesis.

Table 5-58: Frequency Analysis of Question F1

Question F1	Critical Success Factors	Item	Frequency and Percentile				
			1 Not Important	2 Little Important	3 Moderately Important	4 Important	5 Highly Important
V1 (F1.0)	Leadership capability to Transfer and Share Tacit Knowledge	Frequency	0	1	9	38	21
		Percentage	0.0%	1.4%	13.0%	55.1%	30.4%
		Cumulative Percentage	0.0%	1.4%	14.5%	69.6%	100.0%
V2 (F1.1)	Corporate strategies to Transfer and Share Tacit Knowledge	Frequency	0	2	10	35	22
		Percentage	0.0%	2.9%	14.5%	50.7%	31.9%
		Cumulative Percentage	0.0%	2.9%	17.4%	68.1%	100.0%
V3 (F1.2)	Motivation of organisations/people within the Construction Supply Chain to share and transfer tacit Knowledge	Frequency	3	1	18	27	20
		Percentage	4.3%	1.4%	26.1%	39.1%	29.0%
		Cumulative Percentage	4.3%	5.8%	31.9%	71.0%	100.0%
V4 (F1.3)	Skill enhancement of Transferring and Sharing Tacit Knowledge by providing training for organisations/people	Frequency	2	4	11	39	13
		Percentage	2.9%	5.8%	15.9%	56.5%	18.8%
		Cumulative Percentage	2.9%	8.7%	24.6%	81.2%	100.0%
V5 (F1.4)	Identifying process improvement opportunities	Frequency	0	4	25	29	11
		Percentage	0.0%	5.8%	36.2%	42.0%	15.9%
		Cumulative Percentage	0.0%	5.8%	42.0%	84.1%	100.0%
V6 (F1.5)	Identifying the type of Knowledge required to enhance the efficiency of construction processes	Frequency	3	5	19	33	9
		Percentage	4.3%	7.2%	27.5%	47.8%	13.0%
		Cumulative Percentage	4.3%	11.6%	39.1%	87.0%	100.00%
V7 (F1.6)	Identifying the source of Knowledge	Frequency	1	4	28	31	5
		Percentage	1.4%	5.8%	40.6%	44.9%	7.2%
		Cumulative Percentage	1.4%%	7.2%	47.8%	92.8%	100.0%

5.15.2.3 (V3) F1.2 Motivation of organisations/people within the Construction Supply Chain to share and transfer tacit Knowledge

The frequency analysis shown in table 5-58 shows that the highest number of of respondents (39.1%) said that ‘motivation’ is an ‘Important’ factor in the Transfer and Sharing of Tacit Knowledge. The second highest number of respondents (29.0%) said ‘Very Important’ and 26.1% respondents said ‘Moderately Important’. The median value (shown in table 5-57) is observed as ‘Important’ (4.00). Moreover, in table 5-59, the Kruskal-Wallis H Test and figure 5-16 show the box-plot median score is also (4.00) as observed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.206 (Below < 0.05). In this case null hypothesis is to be accepted, that, motivation is an important factor in the Transferring and Sharing of Tacit Knowledge.

5.15.2.4 (V4) F1.3 Skill enhancement of Transferring and Sharing Tacit Knowledge by providing training for organisations/people

Skill enhancement of Transferring and Sharing Tacit Knowledge by providing training for organisations and people is also observed as an important factor in the Transferring and Sharing of Tacit Knowledge. For this variable, it can be seen from the frequency analysis shown in table 5-58 that the highest number of respondents (56.5%) said that 'skill enhancement' is an 'Important' factor in the Transfer and Sharing of Tacit Knowledge. The second highest number of respondents (18.8%) said 'Very Important' and 15.9% of the respondents said 'Moderately Important'. The median value shown in table 5-57 is observed as 'Important' (4.00). Moreover, in table 5-59, the Kruskal-Wallis H Test and figure 5-16 show the box-plot median score is also (4.00) as observed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.605 (Below < 0.05). This establishes that the null hypothesis is to be accepted, that skill enhancement is an important factor in the Transfer and Sharing of Tacit Knowledge.

5.15.2.5 (V5) F1.4 Identifying process improvement opportunities

The data analysis of this factor portrays, from the frequency analysis in table 5-58, that the highest number of respondents (42.0%) said that 'identifying process improvement opportunities' is an 'Important' factor in the Transfer and Sharing of Tacit Knowledge. The second highest number of respondents (36.2%) said 'Moderately Important' and 15.9% of respondents said 'Highly Important'. The median value (as shown in table 5-57) is observed as 'Important' (4.00). Moreover, in table 5-59, the Kruskal-Wallis H Test and figure 5-16 show the box-plot median score is also (4.00) as observed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.481 (Below < 0.05). This highlights that the null hypothesis is to be accepted, that identifying process improvement opportunities is an important factor in the Transfer and Sharing of Tacit Knowledge.

5.15.2.6 (V6) F1.5 Identifying the type of Knowledge required to enhance the efficiency of construction processes

The highest number of respondents (47.8%) (as shown in table 5-58) said that 'identifying the type of Knowledge required' is an 'Important' factor in the Transfer and Sharing of Tacit Knowledge. The second highest number of (27.5%) respondents (47.8%) said 'Moderately Important' and 13.0% of respondents said 'Highly Important'. The median value (shown in Table 5-57) is observed as 'Important' (4.00). Moreover, in table 5-59, the Kruskal-Wallis H Test and figure 5-16 show the box-plot median score is also (4.00) as observed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.739 (Below <

0.05). This establishes that the null hypothesis is to be accepted, that identifying the type of Knowledge required to enhance the efficiency of construction processes is an important factor in the Transfer and Sharing of Tacit Knowledge.

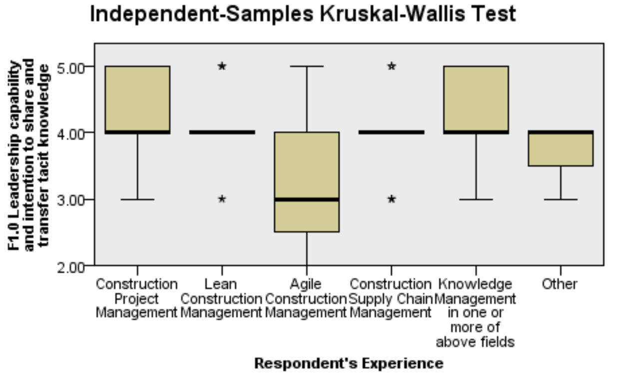
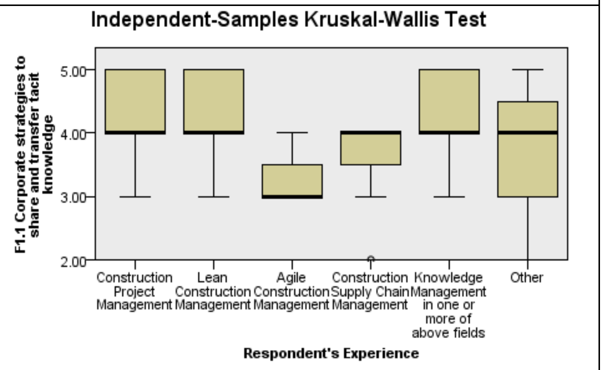
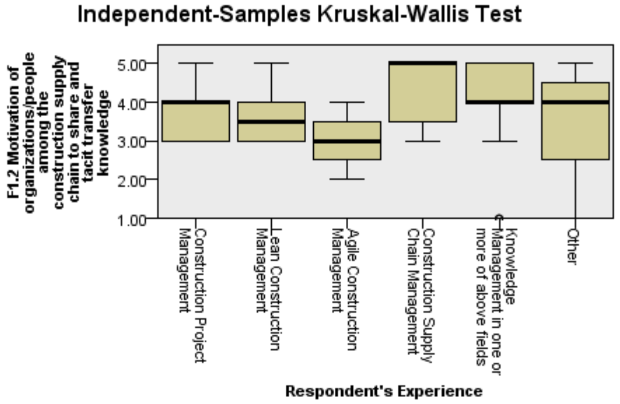
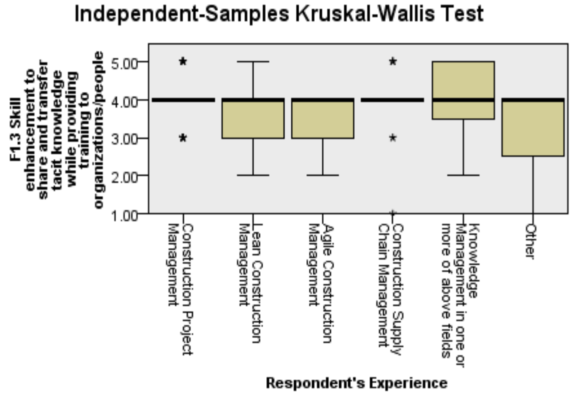
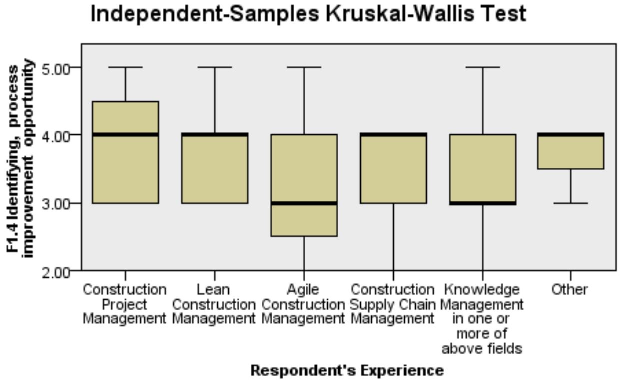
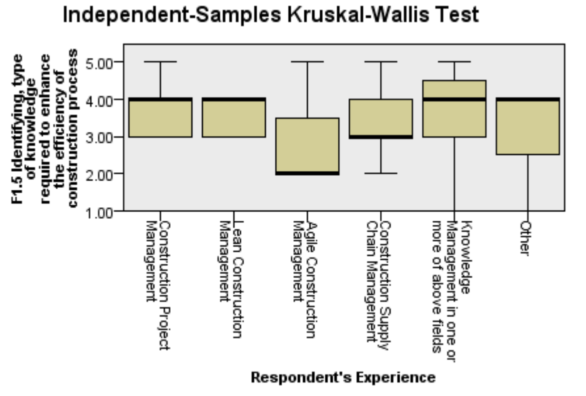
5.15.2.7 (V7) F1.6 Identifying the source of Knowledge

According to the frequency analysis shown in table 5-58, the highest number of respondents (44.9%) said that 'identifying the source of Knowledge' is an 'Important' factor in the Transfer and Sharing of Tacit Knowledge. The second highest number of respondents (40.6%) said 'Moderately Important' and only 7.2% of the respondents said 'Highly Important'. The median value (as shown in table 5-57) is observed as 'Important' (4.00). Moreover, in table 5-59, the Kruskal-Wallis H Test and figure 5-16 show the box-plot median score is also (4.00) as observed by visual inspection of a box-plot and the Asymptotic Sig. (2-sided test) *p*-value is 0.837 (Below < 0.05). This establishes that the null hypothesis is to be accepted, that identifying the source of Knowledge is an important factor in the Transfer and Sharing of Tacit Knowledge.

5.15.3 Kruskal-Wallis H Test of Question F1

Table 5-59: Kruskal-Wallis H Test of Question F1

No	Hypothesis	Median	Ordinal Rank	Statistically Significantly Distributed	(*p*-value)	Accept or Reject (Null Hypothesis)
V1 (F1.0)	Leadership capability to Transfer and Share Tacit Knowledge	4.00	Important	Yes	.279	Accept
V2 (F1.1)	Corporate strategies to Transfer and Share Tacit Knowledge	4.00	Important	Yes	.055	Accept
V3 (F1.2)	Motivation of organizations/people within the Construction Supply Chain to share and transfer Tacit Knowledge	4.00	Important	Yes	.206	Accept
V4 (F1.3)	Skill enhancement of Transferring and Sharing Tacit Knowledge by providing training for organizations/people	4.00	Important	Yes	.605	Accept
V5 (F1.4)	Identifying, process improvement opportunities	4.00	Important	Yes	.481	Accept
V6 (F1.5)	Identifying the type of Knowledge required to enhance the efficiency of construction processes	4.00	Important	Yes	.739	Accept
V7 (F1.6)	Identifying the source of Knowledge	4.00	Important	Yes	.837	Accept

V1 (F1.0)	**V2** (F1.1)
	
V3 (F1.2)	**V4** (F1.3)
	
V5 (F1.4)	**V6** (F1.5)
	

V7 (F1.6)

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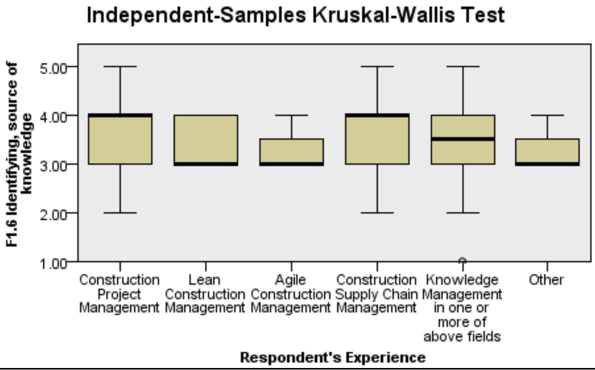


Figure 5-15: Boxplot Summary of Question F1

5.16 Question F2

This question is to examine the level of agreement with the preliminary findings listed below of this research.

The ‘Agreement’ in this context is the agreement of respondents (based on their experience) with the statements below.

In this question, respondents are asked to indicate their level of agreement with the statements listed below.

1. (V1) F2.0 Lean and Agile Principles work well if both are implemented together in Construction Supply Chains
2. (V2) F2.1 Lean and Agile Principles should both be embedded in each other
3. (V3) F2.2 Knowledge Management plays a significant role in the implementation of Lean and Agile Principles in Construction Supply Chains
4. (V4) F2.3 An effective Knowledge Management approach can enhance the effectiveness of Lean principles in generating value and reducing waste and the effectiveness of Agile processes to increasing supply chain responsiveness
5. (V5) F2.4 An effective Knowledge Management approach can bring collaboration and integration among Construction Supply Chains

5.16.1 Cronbach’s Alpha Analysis of Question F2

Cronbach's alpha (α) is **0.735** (as shown in Table 5-60**)** for question F2 which indicates a high level of internal consistency for this data.

Table 5-60: Reliability Analysis of Question F2

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.735	.739	5

As shown in table 5-57, the calculated median score for all variables is given as 4.00 (Agreed) to enable the Sharing and Transferring of Tacit Knowledge in Lean, Agile and Construction Supply Chain processes.

Table 5-61: Median Statistics of Question F2

Statistics

		F2.0 Lean and Agile principles works well if both implement together in construction supply chain	F2.1 Lean and Agile principles should both be embedded in each other	F2.2 Knowledge Management plays a significant role in implication of Lean and Agile principles in Construction Supply Chains	F2.3 An effective Knowledge Management approach can enhance the effectiveness of Lean to generate value and reduce waste and Agile processes to increase supply chain responsiveness	F2.4 An effective Knowledge Management approach can bring collaboration and integration among construction supply chains
N	Valid	69	69	69	69	69
	Missing	0	0	0	0	0
Median		4.00	4.00	4.00	4.00	4.00

5.16.2 Analysis of level of agreement on the preliminary findings, based on the experience of respondents

5.16.2.1 (V1) F2.0 Lean and Agile Principles work well if both are implemented together in Construction Supply Chains

The frequency analysis shown in table 5-62 shows that the highest number of respondents (40.6%) agreed that ‘Lean and Agile Principles work well if both are implemented together in Construction Supply Chains’. The second highest number of respondents (24.6%) said ‘Highly Agreed’ and 17.4% of respondents said ‘Moderately Agreed’. The median value (shown in table 5-61) is observed as ‘Agreed’ (4.00). In this case, the null hypothesis accepts that Lean and Agile Principles work well if both are implemented together in Construction Supply Chains.

5.16.2.2 (V2) F2.1 Lean and Agile Principles should both be embedded in each other

The frequency analysis shown in table 5-62 shows that the highest number of respondents (50.7%) agreed that ‘Lean and Agile Principles should both be embedded in each other’. The second highest number of respondents (29.0%) said ‘Moderately Agreed’ and 11.6% of respondents said ‘Highly Agreed’. The median value shown in table 5-61 is observed as ‘Agreed’ (4.00). In this case the null hypothesis is to be accepted that Lean and Agile Principles should both be embedded in each other.

5.16.2.3 (V3) F2.2 Knowledge Management plays a significant role in the implication of Lean and Agile Principles in Construction Supply Chains

The median value (as shown in table 5-61) is observed as ‘Agreed’ (4.00). The frequency analysis (shown in table 5-62) shows that the highest number of respondents (58.0%) agreed that ‘Knowledge Management plays a significant role in the implication of Lean and Agile Principles in Construction Supply Chains’. The second highest number of respondents (20.3%) said ‘Highly Agreed’ and 17.4% of respondents said ‘Moderately Agreed’. In this case the null hypothesis is to be accepted, that Knowledge Management plays a significant role in the implication of Lean and Agile Principles in Construction Supply Chains.

5.16.2.4 (V4) F2.3 An effective Knowledge Management approach can enhance the effectiveness of Lean processes to generate value and reduce waste and the effectiveness of Agile processes to increase supply chain responsiveness

The frequency analysis shown in table 5-62 shows that the highest number of respondents (20.3%) agreed that ‘An effective Knowledge Management approach can enhance the effectiveness of Lean processes to generate value and reduce waste and the effectiveness of Agile processes to increase supply chain responsiveness’. The second highest number of respondents (30.4%) stated ‘Moderately Agreed’ and 20.3% of respondents said ‘Highly Agreed’. The median value in table 5-61 is observed as ‘Agreed’ (4.00). In this case the null hypothesis is to be accepted, that an effective Knowledge Management approach can enhance the effectiveness of Lean processes to generate value and reduce waste and the effectiveness of Agile processes to increase supply chain responsiveness.

5.16.2.5 (V5) F2.4 An effective Knowledge Management approach can bring collaboration and integration among Construction Supply Chains

The frequency analysis shown in table 5-62 shows that the highest number of respondents (55.1%) agreed that ‘An effective Knowledge Management approach can bring collaboration and integration among Construction Supply Chains’. The second highest number of respondents (21.7%) stated ‘Moderately Agreed’ and 17.4% of respondents said ‘Highly Agreed’. In total, 72.5% of the respondents agreed with this statement. The median value, as shown in table 5-61, is observed as ‘Agreed’ (4.00). In this case the null hypothesis is to be accepted, that an effective Knowledge Management approach can bring collaboration and integration among Construction Supply Chains.

5.16.3 Frequency Analysis of Question F2

Table 5-62: Frequency Analysis of Question F2

Question F1	Critical Success Factors	Item	Frequency and Percentile				
			1 Strongly Disagree	2 Disagree	3 Moderately Agree	4 Agree	5 Strongly Agree
V1 (F2.0)	Lean and Agile Principles work well if both are implemented together in Construction Supply Chains	Frequency	1	3	12	36	7
		Percentage	1.4%	4.3%	17.4%	52.2%	24.6%
		Cumulative Percentage	1.4%	5.8%	23.2%	75.4%	100.0%
V2 (F2.1)	Lean and Agile Principles should both be embedded in each other	Frequency	3	3	20	35	8
		Percentage	4.3%	4.3%	29.0%	50.7%	11.6%
		Cumulative Percentage	4.3%	8.7%	37.7%	88.4%	100.0%
V3 (F2.2)	Knowledge Management plays a significant role in the implication of Lean and Agile Principles in Construction Supply Chains	Frequency	0	3	12	40	14
		Percentage	0.0%	4.3%	17.4%	58.0%	20.3%
		Cumulative Percentage	0.0%	4.3%	21.7%	79.7%	100.0%
V4 (F2.3)	An effective Knowledge Management approach can enhance the effectiveness of Lean processes to generate value and reduce waste and the effectiveness of Agile processes to increase supply chain responsiveness	Frequency	1	1	21	32	14
		Percentage	1.4%	1.4%	30.4%	46.4%	20.3%
		Cumulative Percentage	1.4%	2.9%	33.3%	79.7%	100.0%
V5 (F2.4)	An effective Knowledge Management approach can bring collaboration and integration among Construction Supply Chains	Frequency	3	1	15	38	12
		Percentage	4.3%	1.4%	21.7%	55.1%	17.4%
		Cumulative Percentage	4.3%	5.8%	27.5%	82.6%	100.0%

Chapter 6. FRAMEWORK FOR THE TRANSFER AND SHARING OF TACIT KNOWLEDGE

6.1 Introduction

This chapter focuses on modifying the conceptual framework based on the findings from THE data analysis in chapter (5). Firstly, based on the findings from question (B) (see chapter 5, section B) lays on the ground for the application of Lean, Agile and Supply Chains principles and their contributions in construction processes. Secondly, question (C) (see chapter 5, section C) establishes the most predominant challenges associated with the transfer and sharing of Tacit Knowledge through the application of Lean and Agile processes. Moreover, findings from question (D) (see chapter 5, section D) to present the dominant critical success factors associated with the successful transfer and sharing of Tacit Knowledge. Based on the predominance and the importance of these factors, the conceptual framework is modified.

6.2 Level of contribution to tacit knowledge by Lean, Agile and supply chain principles.

The data analysis that measures the contribution of Tacit Knowledge in Lean principles presents that, enhancing materials and information flow is the foremost principle followed by an efficient decision-making process. The analysis highlights that tacit knowledge plays a substantial role in improving the efficiency of Lean principles in CSCs. In Agile principles, however, the contribution of Tacit Knowledge in empowering teams to take efficient decisions is moderate. Still, this is established as the most common Agile principle which has significant correlation with three other (3) principles. In SCs, the principle, to enhance collaboration among organisations in construction processes is found to be ‘high’. For other principles, the contribution of Tacit Knowledge is observed as ‘moderate’. The data analysis establishes equal contribution by Tacit Knowledge in the application of these principles to the success of a Construction Supply Chain.

This analysis establishes that the contribution of tacit knowledge is high in the application of Lean, Agile and SC principles in construction processes. However, the results from Question (E1) highlight that the contribution of the Lean principle to improve efficiency of the decision-making processes in CSCs is low, and is moderate concerning the principles ‘to enhance material and information flow’ and ‘continuously improve CSCs’. Furthermore, agile principles (see question E2) highlight there is high contribution to enhancing the responsiveness of activities and bringing collaboration and partnering, but are moderate in terms of empowering teams to make effective decisions and integrate construction processes. This establishes that applying only Lean and Agile principles within construction supply chains is not sufficient to get the desired results.

Moreover, the data analysis of question (F2) also establishes that, if efficiency improvements in CSCs is desired, Lean and Agile principles should be implemented together to support Construction Supply Chain principles. It also establishes that an effective knowledge management approach along with Lean and Agile principles can bring collaboration and partnering among construction supply chains. In this respect, this framework is named as the Know-Le-Agile CSC framework.

The result of having equal contributions of tacit knowledge among the application of these principles' highlights that, the primary findings (see chapter 2, sections 2 and 5) from the literature review appear true and no modification is required in Stage (C) of the conceptual framework.

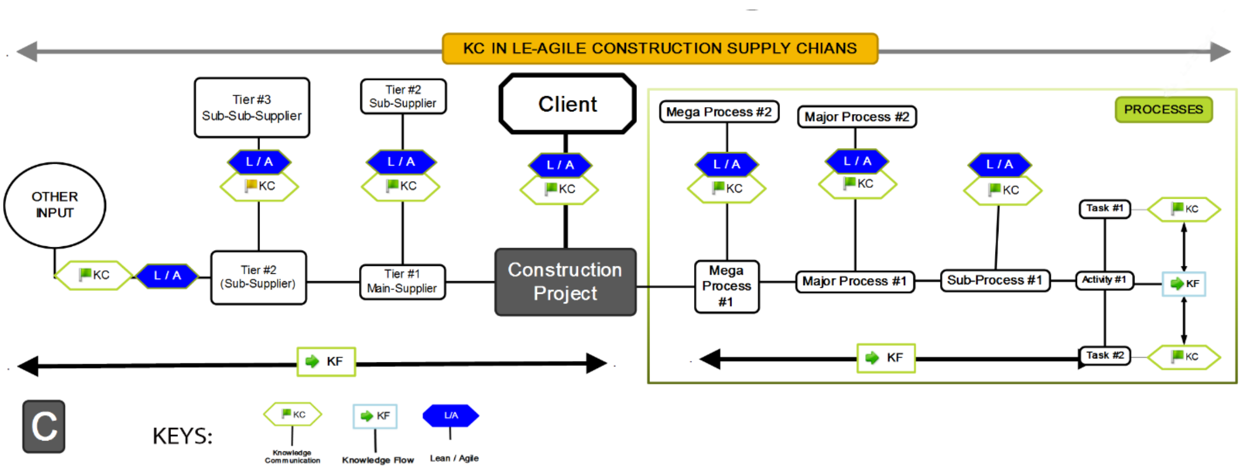


Figure 6-1: Stage C of Know-Le-Agile CSC Framework

6.3 Critical success factors associated with the effective transfer and sharing of Tacit Knowledge

Through the literature review, the preliminary findings of this study highlighted a total number of ten critical success factors associated with the effective transfer and sharing of tacit knowledge in the both lean and agile construction processes. Among these, ‘Trust among construction organisations’ is identified as the foremost CSF. Moreover, this CSF is followed by others such as motivation, leadership capabilities, business strategies and organisational and individual capabilities. However, the data analysis (see chapter 5, section D) highlights that ‘identifying the source of knowledge’ is the leading CSF which is essentially required to identify the type of knowledge required to Transfer and Share Tacit Knowledge and is also required to identify the knowledge recipient in the Lean processes. In Agile Processes, the prime CSF is identification of the knowledge recipient. This further requires identifying the process improvement opportunities followed by the type of knowledge to be shared and, lastly, the identification of the source of knowledge.

Furthermore, in lean construction processes, trust between organisations is observed as the second CSF that requires ‘motivation’ and further that motivation is required to identify the type of knowledge to transfer and share. Moreover, motivation should be supported by leadership and organisational capabilities. However, in Agile Processes, leadership capabilities are the second most CSF that requires alignment with business strategies and, furthermore, requires organisational capabilities and trust between organisations. Even so, in rank three of the CSFs in Agile Processes, engaged motivation is an important factor that additionally requires back up by leadership and organisational capabilities. However, both Lean and Agile Processes, additionally, require individual capabilities.

Moreover, in both the Lean and Agile processes, only organisational capability appears to have the level of criticality as moderate. Based on these findings and the assumptions made through the correlation analysis (in chapter 5, section D) stages A and B of the conceptual framework is modified.

6.3.1 Modifications in stage A of the framework

The assumptions made through the correlation coefficient ranking order highlighted that, in Lean processes, identifying the source of Knowledge is the foremost CSF that greatly requires the identification of the type of knowledge and, furthermore, identification of the knowledge recipient. But, before identifying the type, source and recipient of knowledge, it is vital for managers to identify the process improvement opportunities. Furthermore, in Agile processes, identifying the recipient of knowledge is the foremost CSF and is highly correlated with the identification of process improvement opportunities, which, in turn, need the identification of the type of knowledge and, further, demands the identification of the knowledge source to transfer and share tacit knowledge. Moreover, in both the Lean and Agile processes, the levels of criticality of these factors are recorded as critical. This portrays that, at stage A of the framework, there are no major modifications needed. The only modification undertaken is based on the assumption made that leadership capability should be backed by aligned business strategies and, furthermore, by organisational capability.

6.3.2 Modifications in stage B of the framework

At this stage, leadership capabilities, followed by aligned business strategy and individual capabilities and organisational capabilities, are kept within the framework, based on the assumptions made in the interpretive correlation analysis. There are no major changes established through the data analysis. The modified framework is shown in figure 6.2 below.

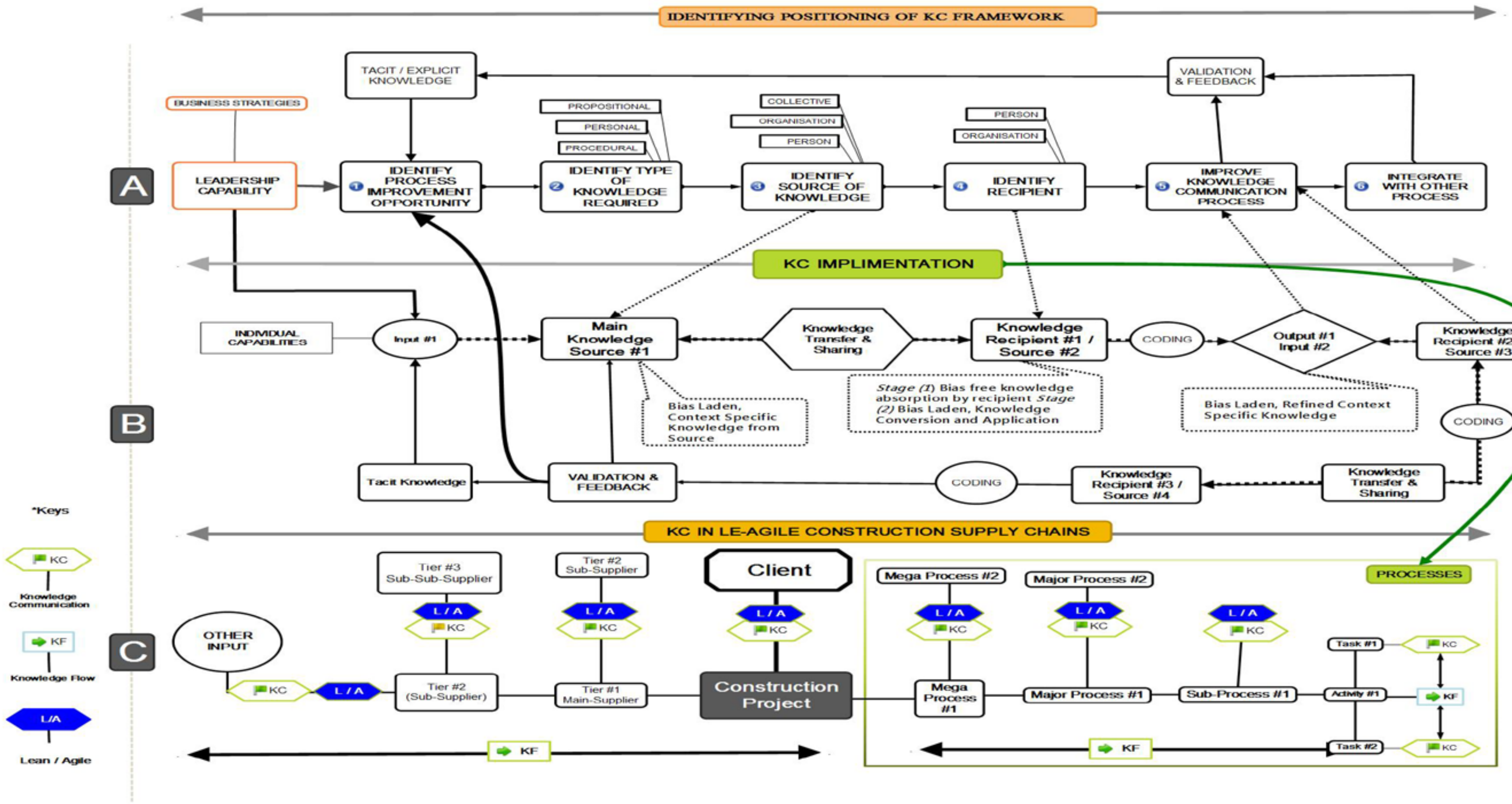


Figure 6-2: Know-Le-Agile Framework to Transfer and Share Tacit Knowledge in Construction Processes

Chapter 7. FRAMEWORK VALIDATION

7.1 Introduction

This chapter focuses on the validation of the framework. It also identifies the applicability of the framework to construction processes and its potential applicability to other industries.

Experts from the construction industry were interviewed to validate the framework. A semi-structured interview process (see appendix 7.4) was developed to interview experts from the construction industry. A total number of four (4) interviews were conducted. Moreover, the interviews were recorded by an audio device. Notes were made with notepad and pen. Furthermore, the recordings were interpretively analysed to validate the framework.

Finally, this chapter discusses the emerging themes from the qualitative analysis.

7.1.1 Selection of Interviewees

Interviewees were selected based on their experience of the construction industry. As discussed in chapter 4.4, there are limitations in finding respondents with the background of, and knowledge of, Lean, Agile, Construction Supply Chain and Knowledge Management processes. Having acknowledge that, the respondents were carefully chosen from the construction industry and had an understanding and knowledge of all four concepts. The table below gives an overview of the profile of the respondents.

Table 7-1: Interviewees' Profile

Respondents	Profile
(1)	Construction and Project Management, with experience of Industry and Academia within Construction Management, Building Information Modelling, Knowledge Management and Integrated Design and Delivery Systems.
(2)	Architect with experience and understanding of BIM implementation and Construction Management with experience of Lean and knowledge management and working experience within several construction projects in the UK and internationally.
(3)	Knowledge transfer partnerships, Architecture, Construction Economics and Project Management coupled with in-depth investigation experience of Lean construction techniques and Building Information Modelling (BIM).
(4)	Operations, Supply Chain and Logistics, Knowledge Management, Project management, Lean and Agile processes

Section G Qualitative Analysis of the Interviews

7.2 Question (1)

The first section of the questionnaire is to examine the contribution of Tacit Knowledge in the application of Lean and Agile Principles within the Construction Supply Chain. All respondents agreed that contribution of tacit knowledge is high in terms of the application of Lean and Agile principles in construction supply chains. The respondents also expressed their views that Lean and Agile processes should be implemented together to gain the most out of them.

7.2.1 Question (1) to what extent does tacit knowledge contribute in the application of Lean and Agile principles in the Construction Supply Chain.

Respondent (1) expressed that Lean and Agile principles both play an important role in construction supply chains in terms of efficiency improvements. However, Tacit Knowledge also plays an important role alongside Lean and Agile principles. Especially in the application of them. In his view, Lean and Agile principles should be implemented in the Construction Supply Chain with the combination of knowledge management.

Respondent (2) also expressed a similar view regarding the role of Tacit Knowledge in application of Lean and Agile principles in construction. However, he also expressed that having agility in construction processes is the way forward. Similarly, respondent (3) verbalized that having Lean and Agile principles is important in construction supply chains but having lean principles should not only be assumed as reducing waste in the construction process, it also has importance in standardizing the process. Respondent (4) expressed that, as 99% of our construction knowledge stays within the mind, it is quite clear the role of tacit knowledge is vital in the application of Lean and Agile principles. In addition, the purpose of implementing Lean and Agile principles may change from project to project and differ between Supply Chains. Therefore, the requirements of tacit knowledge may also change.

7.2.2 Based on your experience, between Lean and Agile principles, which one of them is most important?

The respondents expressed that having both Lean and Agile principles are important. Respondent (1) expressed that, during the design phase of construction, architects and designers face the biggest challenge of last minute design changes. In this case, agility is essential to respond to change as per the demand. The respondent provided many real-life examples to support his view. He also expressed that Just-in-Time (JIT) knowledge plays an important role in responding to these types of changes. Respondent (2) also stressed the role of agility in construction processes to avoid risks. Respondent (3) gave equal weight to the importance level of both Lean and Agile principles in construction. Respondent (4) expressed that, as Lean and Agile principles have different characteristics in terms of their application and level of importance there could be many phases where the importance of these may change. This may depend upon their application in different supply chains for different purposes.

7.2.3 Could you please tell me why transferring and sharing tacit knowledge is becoming important in construction supply chains in the context of Lean and Agile principles?

In the answer to this question, the respondents stated that transferring and sharing tacit knowledge is very important in construction supply chains. Respondent (1) started with an example of a design change during a construction process. He said that, on a project in UAE, the client visited a new railway station site and asked that the construction of railway station be stopped after the foundations had been laid down and asked the designer to redesign the housing blocks within a week. Thus, it was then down to the knowledge sharing of the main contractors and architects to transform the site to a housing block. He also expressed that, nowadays, construction is much easier since we have technology like BIM in place; however, the role of transferring and sharing Tacit Knowledge is still important. Respondent (2) stated that knowledge sharing is vital and the way forward if the construction industry is to respond to changes. Respondent (3) also expressed that knowledge transferring and sharing is important but that there is a need of awareness among construction organisations. Respondent (4) stated that Tacit Knowledge has always been important in all disciplines; if we look back hundreds of years, there have been several studies attempting to understand the capture of Tacit Knowledge. The numbers of such studies have increased in the last two decades. This shows how the importance of tacit knowledge has grown. This may be because the use of technology has grown and because we now are live in a global market which demands replicating tacit knowledge to fulfil the global demand.

7.3 Question (2)

This section is to identify the challenges associated with the effectiveness of transferring and sharing tacit knowledge in Construction Supply Chains through the application of Lean and Agile principles.

7.3.1 In your opinion what are the challenges that hinder the transfer and sharing of Tacit Knowledge?

This question intends to explore further challenges identified through the literature review and validated through the quantitative study. Respondent (1) said a lack of trust and a lack of understanding of the importance of sharing tacit knowledge are the most challenging factors that hinder the sharing of Tacit Knowledge. Respondent (2) also expressed a similar view. Respondent (3) added that a lack of skills and expertise in SMEs is also challenging and, because of that, they continue with the traditional ways of doing business. However, SMEs have a lack of finance and support to employ or develop skills. Respondent (4) also expressed that there is a lack of skills and expertise in SMEs. However, skills can be enhanced by sharing knowledge but the question arises that, if the knowledge source is an organisation or person, why should they share knowledge with other SMEs if they are not getting anything in return? Respondents (1) and (2) also added "Who will be responsible for risks if there are any? In such a situation, it is down to the client to involve some sort of knowledge-sharing framework in the contract and to motivate organisations to share knowledge. In general, all the respondents expressed that a lack of trust is the most challenging factor in terms of transferring and sharing knowledge.

7.4 Question (3)

This section is to identify the critical success factors associated with the effectiveness of transferring and sharing tacit knowledge in Construction Supply Chains through the application of Lean and Agile principles.

7.4.1 Questions (A)

7.4.1.1 What are critical success factors that help to increase the effectiveness of sharing Tacit Knowledge?

In answer to this question, all the respondents expressed that, along with individual capabilities, trust among organisations is the most critical success factor. Respondents (1), (3) and (4) expressed a similar view that, to initiate the transfer and sharing of Tacit Knowledge, incentives or some kind of financial reward must be introduced to motivate organisations and individuals to share knowledge. Respondent (1) also expressed that a reason to introduce incentives is the lack of understanding of the importance of knowledge transfer and sharing. Respondent (1) added that, if we ask organisations to share knowledge, the first question they would ask is why should we share our Tacit Knowledge and what will the firm gain from it? Respondent (3) concluded that, as small and medium-size organisations are already struggling to make profits, they are always keen to look out for financial benefits. Respondents (3) and (4) expressed that initiating knowledge transfer and sharing is down to the client, and there must be some kind of framework agreement or contract to drive it as an essential property of a construction process.

7.4.1.2 What is the most critical success factor among all the critical success factors?

All the respondents expressed that trust among individuals and organisations is the most influential critical success factor. Respondent (1) added that trust is second to none. Respondent (2) stated that financial benefits to drive knowledge transfer and sharing is the second influential CSF. However, respondents (3) and (4) said that business strategies and individual capabilities driven by leadership are equally important.

7.5 Question (4)

7.5.1.1 Question (A): In your opinion, will Lean and Agile processes work well if both are implemented together in CSCs.

In answer to this question all the respondents agreed that Lean and Agile processes should be implemented together in CSCs. However, respondent (2) added that managers must look at the purpose of employing Lean and Agile processes in a supply chain.

7.5.1.2 In your opinion, will an effective knowledge management approach enhance the effectiveness of Lean and Agile processes?

All the respondents agreed that a knowledge management approach can enhance the effectiveness of Lean and Agile processes. Respondent (4) added that it depends on what kind of approach of KM should be taken; also that the approach must be driven by the specific problem which needs to be resolved. Respondent (1) expressed that, sometimes, knowledge is readily available to solve a problem but, again as each construction project is unique, the problems may be different and the KM approach must be customised as per the problem.

7.5.1.3 In your opinion, can effective knowledge communication bring collaboration and partnering among construction supply chains?

Again, all the respondents agreed that knowledge communication can bring collaboration and partnering among CSCs. Respondent (2) added that the vision must be clear and respondent (4) said that all organisations must work towards one goal to fulfil the objectives of knowledge communication.

7.5.1.4 In your opinion, is this framework applicable to transfer and share tacit knowledge in the CSC and other industries?

All respondents stated that this framework is generic and can be applied to the CSC and other industries. Respondent (1) said “I do not have experience of other industries, but I cannot see any reason why it cannot be applied to other supply chains”. Respondent (2) said “Yes, it can be applied to other industries but would need some modification as per the nature of the industry". Respondent (3) said "This framework is generic and can be applied in different contexts". Respondent (4) also expressed a similar view.

7.5.2 Main Findings from the Qualitative Investigation

The findings obtained through this question establish that having both Lean and Agile principles are important for a construction process. Both Lean and Agile principles should be implemented together in conjunction with a knowledge transfer and sharing approach. However, due to changing trends in the construction sector, responses to change are considerably significant and, because of this, having agility in decision-making is also significant. Furthermore, since new approaches such BIM exist in the design phase, Lean should be more focused on the standardisation of processes and materials. In the response to sudden changes, JIT knowledge plays an important role.

At the same time, to initiate knowledge transferring and sharing, trust plays the foremost role. Additionally, with trust, there is a need to motivate individuals and organisations with the attraction of financial incentives. These incentives need to be driven by clients, contracts, frameworks and policies.

7.5.3 Emerging Themes

This analysis establishes two main emerging themes, namely, trust among individuals and organisations, and incentives to drive the transfer and sharing of tacit knowledge in construction processes. Earlier, (in chapter 2; 2.4.1), the literature review established that trust is one of the most important critical success factors. However, the quantitative data analysis in chapter 5.10 43.5% of respondents expressed trust as a 'Critical' success factor and 40.6% of respondents showed it to be a 'Very Critical' success factor in Lean processes, and 47.5% of respondents stated it to be 'Very Critical' in Agile processes. Additionally, based on the interpretive correlation coefficient analysis ranking order in chapter 5.12, trust between organisations is observed as the second most important CSF. However, the interviewed experts established that trust is the most critical success factor that brings people together for communication.

The second emerging theme is, 'Financial Incentives' which drive the motivation to transfer and share Tacit Knowledge. These incentives need to be introduced by clients or policies or framework agreements. The quantitative data analysis (see 5.10 and 5.12) establishes that motivation is a critical success factor in driving transfer and sharing Tacit Knowledge. Moreover, the industry experts suggested that financial incentives would motivate individuals and organisations to transfer and share Tacit Knowledge.

7.5.4 Summary

Validating this framework through the experts' views has established that there must be some kind of financial incentive to drive knowledge transfer and sharing in construction processes. Secondly, trust is the most critical success factor that plays an important role in the transferring and sharing of tacit knowledge. Based on these findings the framework is modified, as shown below.

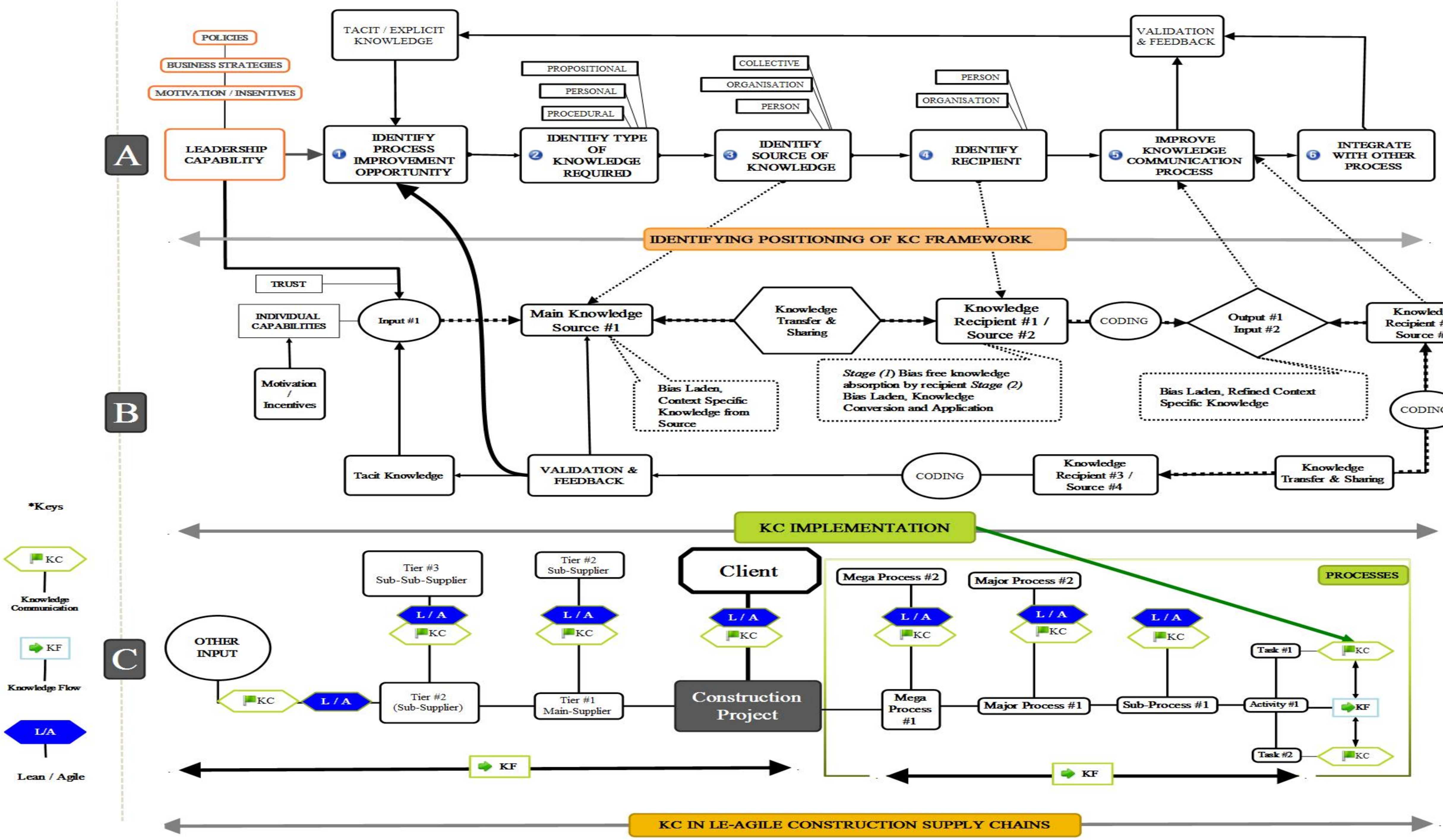


Figure 7-1: Validated Framework to Transfer and Share Tacit Knowledge in Construction Supply Chains.

Chapter 8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This thesis started with the aim of developing a Knowledge Transfer and Sharing framework within the context of Lean and Agile processes in order to improve awareness and understanding of Tacit Knowledge in Construction Supply Chains and to initiate collaboration and partnering among SCs in order to increase their efficiency through the transfer and sharing of Tacit Knowledge. In order to satisfy this aim, the following objectives were instituted.

- To critically review the concepts of Knowledge Management, Supply Chain Management and Lean and Agile processes in general and, specifically, within Construction Supply Chains.
- To examine the contribution of Tacit Knowledge in the application of Lean and Agile principles within Construction Supply Chains.
- To investigate and document the challenges associated with the effective Transfer and Sharing of Tacit Knowledge through the application of Lean and Agile principles in Construction Supply Chains.
- To identify the critical success factors associated with the effective Transfer and Sharing of Tacit Knowledge in Construction Supply Chains through the application of Lean and Agile principles.
- To develop and validate a knowledge communication framework that improves the level of efficiency in Construction Supply Chains through the application of Lean and agile thinking.

The first objective was initiated to explore the named concepts using an investigation of the literature. Having undertaken a primary literature review, further objectives were set out to investigate the contribution of tacit knowledge in the application of Lean and Agile principles, and the challenges and critical success factors associated with the effective transfer and sharing of tacit knowledge in construction supply chains through the application of Lean and Agile principles in construction processes. Finally, further objectives were set to develop a knowledge communication that would initiate the transfer and sharing of Tacit Knowledge and improve the level of efficiency in construction supply chains through the application of Lean and Agile thinking.

8.2 Conclusions

Through this work, all the initial objectives conceived for this work have been satisfied, and the following conclusions are drawn from this study.

1) The preliminary study found that the foremost challenge that hinders the transfer and sharing of tacit knowledge is the fragmented nature of the construction sector. The negative impact of fragmentation appears to be affected by supporting causes and supporting factors (see 2.1.1) such as the lack of partnering and collaboration; the lack of construction processes' integration, the lack of effective knowledge management systems, the lack of trust and motivation among individuals and organisations. Surprisingly, the literature review reveals a few interesting themes which supported the main challenges such as the lack of skills in the construction sector (BQF, 2013 and Guo, 2012), the lack of adequate support to develop (BIS, 2011, 2013b; Schulz, 2012) and the lack of learning capacity and capabilities (Baets, 2005; Tsai, 2001). However, previous studies suggest that there is a gap in knowledge communication, specially, in transferring and sharing tacit knowledge within Construction Supply Chains. Moreover, the investigation of the literature also led this study to conclude that the root cause of the lack of collaboration and partnering is the insufficiency in the transfer and sharing of knowledge (knowledge communication). Furthermore, it can be concluded that the insufficiency of knowledge communication is because of the lack of individual and organisational capabilities and the lack of awareness of the importance of knowledge communication between organisations. In addition, the quantitative analysis (see 5.3) also established that the contribution of the transfer and sharing of Tacit Knowledge to bring collaboration and partnering and to further increase the efficiency of CSCs is high. Additionally, qualitative analyses (see 7.2) also validate the standardised view concluded from the literature review and the quantitative analysis. From this evidence, this study establishes that an effective knowledge communication approach would help to bring collaboration and partnering between organisations and, consequently, increase the efficiency of CSCs.
2) The findings from the literature review also concluded that adopting just Lean or Agile principle concepts alone in CSCs does not solve existing problems such as integration, collaboration, and partnering in supply chains. The Lean principle is widely considered to reduce waste and lead-time in a supply chain and agility is merely considered as being responsive to unpredictable demand and markets. However, Lean and Agile principles require the collaboration and partnering of the stakeholders in any

organisation. In reality, Lean and Agile processes both work well together. The literature concluded that, as regards CSCs, it will be unfair to say that CSCs are entirely based on Lean or Agile principles. Conversely, the Lean principle is only successful when the SC is responsive and works together with Agile thinking. Furthermore, this investigation concludes through quantitative analysis (see 5.16) and qualitative analysis (see 7.4.2), and generalises, that without effective KM and, especially, without knowledge communication neither Lean nor Agile principles would perform effectively to bring collaboration and partnering and develop an efficient CSC.

3) The literature review established that Lean and Agile principles should both be embedded in each other. The quantitative analysis (see 5.16) establishes that more than fifty percent (50%) of the respondents agreed with this view. However, it can also be concluded that knowledge management plays a significant role in the implementation of Lean and Agile principles in construction supply chains. Fifty-eight percent (58%) of the respondents agreed with this conclusion and further qualitative study through the expert interviews validated this agreement.
4) The generalised result from this study also concludes that an effective knowledge management approach can enhance the effectiveness of Lean processes to generate value and reduce waste and the effectiveness of Agile processes to increase supply chain responsiveness. The results were validated by experts and quantitative analysis, (in which forty-six percent (46%) of the respondent indicated their agreement).
5) The investigation of the critical success factors associated with the effective transfer and sharing of Tacit Knowledge concludes with some interesting facts. The conclusion drawn from the literature review portrays that trust among organisations and individuals was found to be the predominant CSF to initiate knowledge transfer and sharing. However, the quantitative analysis (see 5.12) demonstrates that identifying the source of knowledge is the leading CSF that is essentially required to identify the type of knowledge to Transfer and Share, in addition to the identification of the knowledge recipient, in Lean Processes. However, in Agile Processes, the foremost CSF is determined to be the identifying of the knowledge recipient. This further requires identifying the process improvement opportunities followed by the type of knowledge to share and, lastly, identification of the source of knowledge as exhibited in Stage (A) of the framework.
6) The literature review of the critical success factors also concludes that leadership capabilities are the second most predominant CSF aligned with business strategies to

initiate KC and additionally requiring trust between organisations. Moreover, the qualitative analysis (see 7.4) establishes that business strategies and individual capabilities driven by leadership are equally important. The standardised results from the literature review, and the qualitative and quantitative analyses conclude that identifying process improvements is the most predominant CSF but there must be an equal input by trust, leadership capability, corporate strategies, and motivation.

7) To initiate knowledge communication in construction processes, there are a certain set of individual capabilities that are required for the source and the recipient of knowledge. The study concludes that individuals will require observational, absorptive, knowledge application, dissemination, explanation, and conversational and routing capabilities. However, to make a KM initiative successful within Lean and Agile processes, people and organisations require skills and training in developing their capabilities in order to ensure the smooth transferring and sharing of tacit knowledge. Additionally, the investigation of literature also establishes that SMEs have a lack of adequate support and finances available to invest in skills and training (see 2.1.2).
8) The main aim of this study is fulfilled by the conclusion (which was drawn from primary and secondary study sources) which proves that an effective knowledge management approach can bring collaboration and partnering among construction supply chains. Over 72% of the respondents providing the cumulative generalised result by stating ‘agreed’ and ‘highly agreed’ with such a conclusion. Further, this finding was validated and generalised through the experts’ views.

Based on the above conclusions drawn, this study establishes a generalised conclusion that collaboration and partnering among organisations and individuals can bring efficiency in construction supply chains. However, this requires the involvement of the client to establish business strategies to drive trust through introducing incentives and motivation. In addition, it also requires skills’ and capability enhancement of organisations and individuals. Supported by these capabilities, if this knowledge transfer and sharing framework is used in construction processes in conjunction with Lean and Agile processes it would bring collaboration and partnering and, consequently, efficiency in CSCs.

8.3 Original Contributions of this Research

There are several major contributions made by this research, some of them are for policy and framework makers in the construction sector and some are for Lean, Agile, Knowledge Management and Supply Chain Practitioners in the construction sector. Additionally, the findings would also contribute to academia in modifying, and being reflected in, the curriculum for higher education. The original contributions of this research is divided into three (3) sections, namely, the Contribution to Literature (8.3.1), the Contribution to Academia (8.3.2) and the Contribution for Policy Makers (8.3.3).

8.3.1 Contribution in Literature

1) This study brings originality in the literature of the construction sector and establishes the challenges in, and the reasons for, the non-performance of construction supply chains while implementing Lean and Agile thinking.
2) In addition, there is a significant contribution by this study to the literature in defining problems existing within the construction sector. Moreover, it provides a novel understanding of the challenges and of the sub-causes and root causes of those challenges. Furthermore, this research establishes the CSFs associated with the effectiveness of knowledge transfer and sharing in construction processes.
3) The study fills a gap in literature on construction processes by developing new literature on knowledge management and establishing that Tacit Knowledge can be transferred and shared.
4) There is a lack of KM frameworks in terms of the transfer and sharing of Tacit Knowledge. The development of the framework in this study fills this gap in the existing literature.
5) The data analysis of the results from the questionnaire survey also reveal new findings; previously there has been a paucity of research in these areas.

8.3.2 Contribution to Academia

1) This study contributes to raising substantive awareness in terms of the articulation of knowledge and the individual capabilities required to articulate and share Tacit Knowledge, by exploring cross-disciplinary concepts in human biology and the functionality of the human brain in terms of transferring and sharing tacit knowledge.
2) This research contributes to the KM process in the context of its contribution to the application of Lean and Agile principles in CSCs.
3) In the research methodology area, this research contributes with the KDRM model used to define the research methodology driven by the type of knowledge required to fulfil the objectives of research. This study also reveals some interesting facts from the literature on research methods.

8.3.3 Contribution for Policy Makers

1) In terms of CSCs, this study could contribute to remodelling existing policies concerning managing knowledge to facilitate project efficiency and collaboration and partnering among stakeholders of a construction project.
2) Additionally, this study may simulate Lean, Agile, KM and SC communities (not just in the construction sector) to rethink the role and importance of Knowledge Communication. This study and framework could also influence other closely related industries in terms of a knowledge transfer and sharing approach.

8.4 Limitations of this research

This study has the following limitations:

1) The study is restricted to the UK construction sector and thus it cannot be generalised universally until more research has been conducted in other countries and regions throughout the world.
2) The use of a survey questionnaire with questions in the areas of Supply Chain, Lean, Agile and Knowledge Management limits the scope of employing a wider population to be tested for their perceptions.
3) Utilising experts who have a knowledge and understanding of the Construction Supply Chain, and Implementing Lean and Agile and KM principles in the construction process also limited the validation of the framework.
4) , This framework for the transfer and sharing of tacit knowledge is still unique and generic. However, it would need some customisation to be implemented in each construction project or beyond the construction sector.

8.5 Emerging Fields for Future Research

There are several areas of future research that a researcher can pursue taking this thesis as a starting point. There are many prospective research fields that have emerged from this study.

1) Firstly, the challenges, and suggested ways, of resolving the negative effects of construction can be explored further. For example, trust appears as one of the challenging factors in terms of the transfer and sharing of knowledge. This can be further investigated to identify the factors that drive trust among individuals and organisations. Secondly, the role of motivation and incentives can be investigated to identify the role of these in building trust. Moreover, the existing government policies and support for SMEs can be investigated to identify any gaps and reasons why they have traditional ways of doing business.

2) A similar study in other sectors might highlight a different set of CSFs for the transfer and sharing of Tacit Knowledge. Therefore, it is important to undertake a sector-specific study and test the findings of this study by taking it as a starting point.
3) In terms of individual capabilities to transfer and share knowledge, this study can be taken as a starting point to construct a basis for further research on the type of skills and training which should be provided to employees.
4) Further research on the KDRM model should be attempted in terms of customising it as a generic framework for other types of studies.

8.6 Scope for Further Research

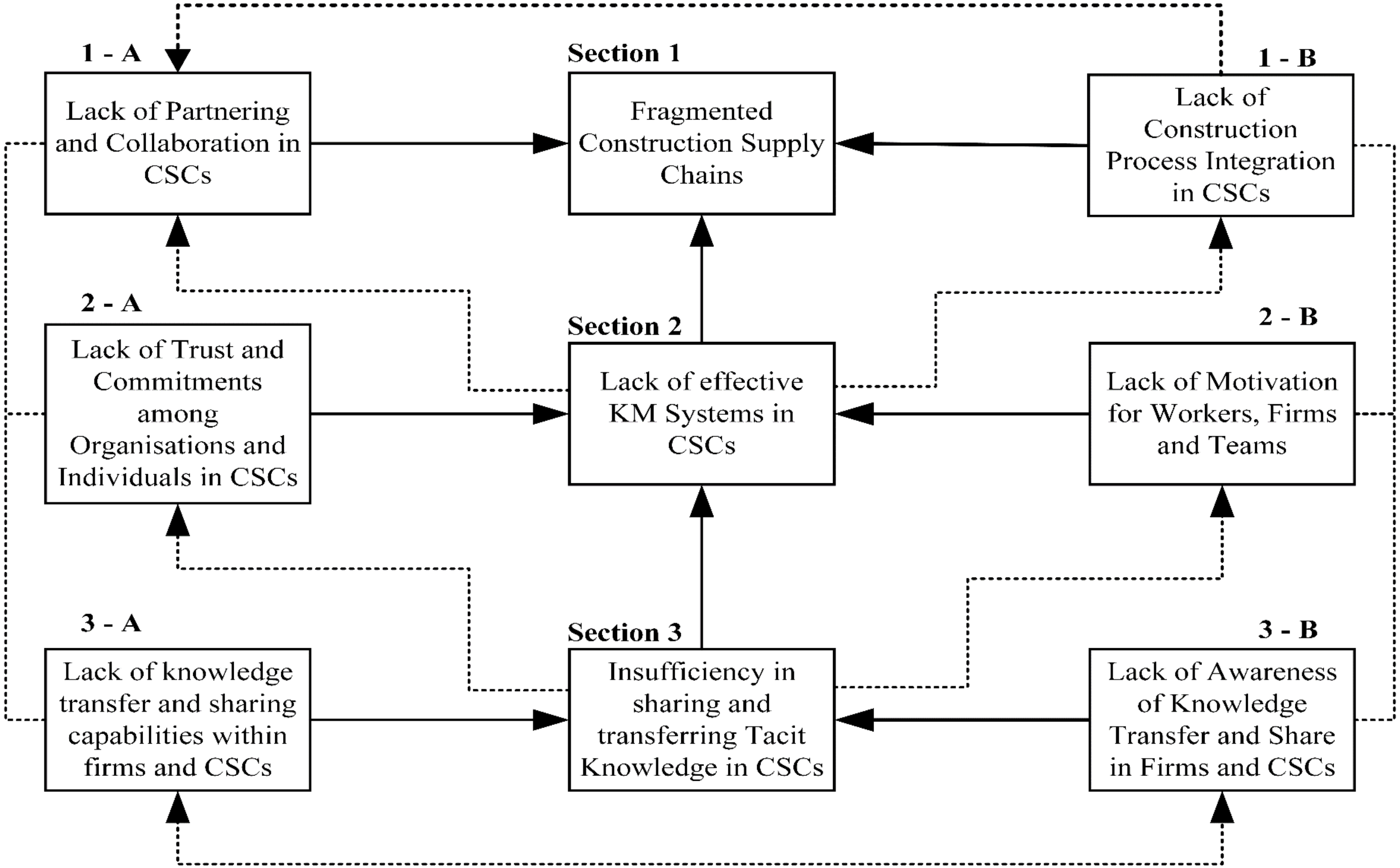
This study brings scope for further research in many ways. The study could lead to the following prospective further research.

1. A total number of seventy hypotheses were defined in chapter (4) based on the findings from the literature review. Each of these can be further investigated and tested in different contexts, while having this study as a guide.
2. Findings from the data analysis can lead to further research based on each question asked in the questionnaire survey.
3. The framework to transfer and share tacit knowledge can be further tested in practice and can also be updated in different contexts.
4. The KDRM model can be further tested in different types of research in order to develop generic methodological models.
5. The existing challenges in the construction sector as defined in this study can lead to further research.
6. The challenges and CSFs identified in the context of transferring and sharing tacit knowledge can be further tested.
7. The assumptions made during the quantitative data analysis through the ranking order analysis can be further tested.
8. The named individual capabilities required to transfer and share tacit knowledge could be further researched to identify their potential and to develop the practice of capability building in individuals.

APPENDICES

This section contains supporting material, documents, tables, questionnaire and documents support data collection. All appendices are named as per the corresponding chapters in the main content.

Appendix 2


1 - A
Section 1
1 - B
Lack of Partnering and Collaboration in CSCs
Fragmented Construction Supply Chains
Lack of Construction Process Integration in CSCs
2 - A
Section 2
2 - B
Lack of Trust and Commitments among Organisations and Individuals in CSCs
Lack of effective KM Systems in CSCs
Lack of Motivation for Workers, Firms and Teams
3 - A
Section 3
3 - B
Lack of knowledge transfer and sharing capabilities within firms and CSCs
Insufficiency in sharing and transferring Tacit Knowledge in CSCs
Lack of Awareness of Knowledge Transfer and Share in Firms and CSCs

Appendix 4

4.1 Survey Questionnaire

A separately printed file is of questionnaire survey is attached after this page.

4.2 Responses for Headline 4.4

To keep response analymous names and personal data of respondents is removed from below image

Help needed: for a quick analysis on construction sector | LinkedIn https://www.linkedin.com/grp/post/2622826-5941215019088 7813...

Search for people, jobs, companies, and more... Advanced

Home Profile Connections Education Jobs Interests Business Services Premium Resource

Lean Construction Network 5,446 members Member

Discussions Promotions Jobs About Search

Mandeep Saini (MBA, MSc, Dip. M) [redacted]

Help needed: for a quick analysis on construction sector

In your view, how many individuals (Managers, consultants and executives) involved in the UK construction projects, would have collective knowledge/understanding/experience of Lean, Agile, Supply Chain and Knowledge Management?

Give your view in (%) present such as 5% or 10% or 25% or other
Please share if you have any article, journal or report on this topic

Comment (7) • Like (0) • Unfollow 4 months ago

[redacted]

Mandeep - I don't understand how individuals can have "collective" knowledge/understanding /experience - can you explain please.

do you want separate percentages for knowledge, understanding and experience?

do you want separate percentages for lean, agile, supply chain, KM?

when you say "supply chain" do you mean
* supply chain management

* supply chain development

* supply chain integration

* supply chain something else?

are you interested in building, infrastructure or engineering construction - or all three?

why are you asking? how will you use the data? Alan

Like (0) • Reply privately • Report spam 4 months ago

Mandeep Saini (MBA, MSc, Dip. M)

Hi [redacted]
Thanks for your reply.
I will try to explain in better words. The employment size of construction industry is about 2.9m and among them 11% are Construction Managers, Directors and Executives (BIS, 2014) Out of them, how many (in percentage) of the individuals would have experience of working with Lean, Agile, Construction supply chain Management and KM all four disciplines.
I am looking for individuals who are experienced in all four disciplines.

I am asking about construction industry as general. I need that data to generate a case for to back up my chosen research strategy. As currently I can't find such data. If I can get at least 10 views from Linkedin I can still support my decision of selecting population for interviews to be conducted for my research.

I hope it's clear now

Like (0) • Delete 4 months ago

[redacted]

Thanks Mandeep - My guess would be way less than 1% - [redacted]

Like (2) • Reply privately • Report spam 4 months ago

Mandeep Saini (MBA, MSc, Dip. M)

Thanks [redacted]

Like (0) • Delete 4 months ago

[redacted]

Hi Mandeep

I know you are researching the UK market and I have no knowledge or opinion on that

However, here in Canada I agree with Alan, Design and Construciton Industry knowlodge is less than 1%

However, the Government of Saskatchawen is promoting and training Lean Culture and thinking to all Saskatchewan Government departments, starting with Health, then Education and now all Ministries and soon Crowns. So lean knowledge in the Saskatchewan public sector would range higher than 50%. This Owner knowledge of Lean is prompting the design and construction industry in Saskatchewan to take notice and should have the effect of creating a thirst for Lean knowledge in the sector just to keep up with the Owner Group from the Saskatchewan 4 months ago

Your group contribution level

Start by commenting in a discussion. Group participants get 4x the number of profile views.

Getting Started

Subgroups

Lean Construction Africa
13 members

Teaching Lean Construction
325 members

Last Planner Users
2,026 members

About | Feedback | Privacy & Terms
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4.3 Number of employees in construction sector

There were 2.12 million jobs in the construction industry in Q4 2013, 6.5% of the total. The number of jobs in the construction industry over the last thirty years is shown in the table below. Over the last ten years, the number of workforce jobs in the construction industry peaked in 2007 at 2.29 million.

Workforce jobs in the construction industry, UK

	Millions	% of all jobs
1983	1.85	7.1%
1993	1.85	6.7%
2003	2.08	6.8%
2004	2.17	7.0%
2005	2.23	7.1%
2006	2.32	7.3%
2007	2.31	7.2%
2008	2.32	7.3%
2009	2.13	6.8%
2010	2.03	6.5%
2011	2.07	6.5%
2012	2.03	6.4%
2013	2.12	6.5%

Source: ONS Nomis Database, Workforce Jobs
Notes: Q4 each year

Rhodes, 2014

Source: House of Commons: The Construction Industry Statistics and Policy

4.4 Number of Students in Construction Sector

Note: Excess Data from below tables is removed

Data for Year 2009/2010

Students by subject of study, first year indicator, mode of study and level of study 2009/10

	First years								All years							
	Full-time				Part-time				Full-time				Part-time			
	Postgraduate	First degree	Other undergraduate	**Total**	Postgraduate	First degree	Other undergraduate	**Total**	Postgraduate	First degree	Other undergraduate	**Total**	Postgraduate	First degree	Other undergraduate	**Total**
Broadly-based programmes within architecture, building & planning	20	80	0	**105**	0	0	0	**0**	30	265	0	**295**	5	10	0	**15**
Architecture	2080	5270	815	**8160**	945	215	195	**1355**	3195	14055	1575	**18825**	1960	1595	365	**3920**
Building	1285	3770	1005	**6055**	875	1525	2110	**4510**	1860	10830	1605	**14295**	2745	6405	4435	**13585**
Landscape design	240	315	145	**695**	95	20	165	**275**	410	765	185	**1360**	205	120	240	**565**
Planning (urban, rural & regional)	1605	1410	140	**3155**	1000	145	620	**1760**	2120	4635	260	**7015**	2935	550	1210	**4690**
Others in architecture, building & planning	155	180	5	**340**	175	5	170	**345**	280	465	5	**750**	405	50	225	**680**
Architecture, building & planning total	**5380**	**11020**	**2110**	**18510**	**3085**	**1910**	**3255**	**8250**	**7890**	**31010**	**3635**	**42535**	**8255**	**8735**	**6465**	**23455**

In this table 0, 1, 2 are rounded to 0. All other numbers are rounded up or down to the nearest multiple of 5.
see relevant footnote in Notes to tables.

Data for Year 2010/2011

Students by subject of study, first year indicator, mode of study and level of study 2010/11

	First years								All years							
	Full-time				Part-time				Full-time				Part-time			
	Postgraduate	First degree	Other undergraduate	**Total**	Postgraduate	First degree	Other undergraduate	**Total**	Postgraduate	First degree	Other undergraduate	**Total**	Postgraduate	First degree	Other undergraduate	**Total**
Broadly-based programmes within architecture, building & planning	20	105	0	**120**	0	0	0	**0**	30	290	0	**320**	5	10	0	**15**
Architecture	2060	5095	585	**7745**	1045	160	215	**1420**	3500	14405	1355	**19265**	1960	1320	370	**3650**
Building	1190	3310	755	**5260**	810	1445	1750	**4005**	1830	10220	1415	**13465**	2450	5915	3440	**11805**
Landscape design	275	285	90	**650**	90	15	75	**180**	440	745	145	**1330**	225	100	140	**465**
Planning (urban, rural & regional)	1780	1240	115	**3130**	785	110	570	**1465**	2385	4300	170	**6855**	2475	515	1125	**4120**
Others in architecture, building & planning	145	120	0	**265**	100	5	290	**395**	310	405	0	**715**	400	50	335	**780**
Architecture, building & planning total	**5470**	**10155**	**1545**	**17170**	**2830**	**1735**	**2895**	**7465**	**8495**	**30365**	**3085**	**41945**	**7515**	**7905**	**5410**	**20830**

In this table 0, 1, 2 are rounded to 0. All other numbers are rounded up or down to the nearest multiple of 5.

Data for Year 2012/13

Students by subject of study, first year indicator, mode of study and level of study 2012/13

Click on [+] to display detailed data. Alternatively use [1] [2] in top left of worksheet to expand or collapse the data.

	First years								All years							
	Full-time				Part-time				Full-time				Part-time			
	Postgraduate	First degree	Other undergraduate	**Total**	Postgraduate	First degree	Other undergraduate	**Total**	Postgraduate	First degree	Other undergraduate	**Total**	Postgraduate	First degree	Other undergraduate	**Total**
Architecture	2555	4800	365	**7720**	1025	100	120	**1245**	4205	14410	800	**19415**	1940	1085	215	**3245**
Building	1085	2425	255	**3765**	710	1110	915	**2740**	1665	8315	685	**10665**	2100	4455	2070	**8625**
Landscape & garden design	250	225	80	**550**	60	10	20	**90**	415	660	100	**1175**	185	75	50	**310**
Planning (urban, rural & regional)	1485	995	50	**2535**	470	55	145	**670**	1980	3775	65	**5820**	1455	310	680	**2440**
Others in architecture, building & planning	100	180	0	**280**	140	0	60	**205**	180	320	0	**505**	265	30	70	**365**
Broadly-based programmes within architecture, building & planning	10	25	0	**30**	5	0	0	**5**	20	95	0	**115**	5	5	0	**10**
Architecture, building & planning total	**5485**	**8645**	**755**	**14885**	**2415**	**1280**	**1265**	**4960**	**8465**	**27580**	**1650**	**37700**	**5955**	**5960**	**3085**	**1500 0**

In this table 0, 1, 2 are rounded to 0. All other numbers are rounded up or down to the nearest multiple of 5.

Appendix 7

7.1 Interview Information Sheet

7.1.1 Operational definitions used in this study have been given in alphabetical order

i. **Agile as a principle** is to increase responsiveness of each of current, following and related activities within a task and further in processes to integrate with others.

ii. **Agreement in this context** is your agreement based on your experience on below statements in terms of right or wrong.

iii. **Capability in this context** refers to the capacity of individuals and firms to deploy resources in terms of sharing and transferring tacit knowledge.

iv. **Capacity in this context** is the capability of individuals and firms to perform sharing and transferring of tacit knowledge to produce efficiency to the processes.

v. **Challenges in this context** is a call for the essential factors whose absence hinders the sharing or transference of tacit knowledge.

vi. **Construction Supply Chain** is to integrate and add value to key business processes from original suppliers to end user and further to add value to a product or service which is being delivered to the end user.

vii. **Construction Supply Chains** is a combination of multi-organisational supply chains, where several supply chains jointly establish a mega supply chain.

viii. **Contribution in this context** is the role played by tacit knowledge to bring about the efficiency (a) in Lean, (b) in Agile and (c) in Construction Supply Chain Processes.

ix. **Critical Success Factors in this context** are the absolutely necessary factors whose absence hinders the effectiveness of transference and sharing of tacit knowledge.

x. **Efficiency in this context** is to enhance the skilfulness of supply chain to reduce waste and effort to make it responsive.

xi. **Knowledge Management** is the process of identifying, transfer and effectively sharing tacit knowledge to support other processes, wherever and whenever required.

xii. **Lean as a principle** is to increase value of a business process while relentlessly eliminating waste from each of the task within the current, following and related activities.

xiii. **Principle in this context** is a basic generalisation rule or rule of law concerning a natural phenomenon or the function of a complex system that is accepted as true and that can be used as a basis for reasoning or conduct.

xiv. **Process in this context** is a series of tasks and activities within (a) Lean, (b) Agile and (c) in Construction Supply Chain. (Such as) Brick Laying, Painting, Roof Laying

xv. **Tacit Knowledge** is the point of view in the human mind, which is gained over the time by experience, learning, sensing, analysing, witnessing and observing a process or series of processes in physical world.

7.1.2 Introduction

This framework is developed in a view to initiate transfer and sharing of tacit knowledge with a goal to bring collaboration and partnering, consequently increase efficiency of construction supply chain. In this study Construction Supply Chains is considered as a combination of multi-organisational supply chains.

Fragmentation in construction sector has always been seen as a critical barrier to change, and considered that fragmentation can inhibit knowledge production that lead to the low level of productivity of construction sector. Since 1994, Egan, Latham and other reports by BIS and recent studies has appointed 'collaboration and partnering' among supply chain is an entire factor that would reduce the negative impact (low level of productivity, less efficient supply chain, lack of value generation) of fragmentation.

7.1.3 Background

The Egan, Letham & BIS reports suggested that the SMEs holds an important position in the construction industry. However, the individuals SMEs may hold specialised skills and knowledge in one of the aspect of CSC, but not necessarily they hold the skills of transferring and sharing knowledge with the other stakeholders within a CSC. Resultant, the knowledge of an individual SME does not contribute in a manner it should be within a CSC. Herewith, the problem consists with the communicating knowledge within the CSC and more importantly transferring and sharing tacit knowledge with others. This result, in developing a highly fragmented and un-collaborated supply chain.

Different knowledge based and process based solutions has been proposed in the past to overcome the problem of negative impact of fragmentation. Lean construction is a production management-based approach to project delivery. The application of Lean production management to manufacturing caused a revolution. The objectives of the Lean production system are to maximise value and minimise waste to specific techniques, and applies those techniques to form a project-based production system. Lean Construction is particularly useful on complex, uncertain, and quick projects. The Lean principles are based to increase quality of work and products, increase value by eliminating waste and increase flow of the process. On the contrary, Agile Thinkers contended that Agile paradigm has values that can enhance the business capability of SMEs. But, very few construction SMEs are aware of the Agile paradigm. It is observed that Agile concept has considerable potential in pre-design and design phases in CSC but that there are significant hurdles to its adoption in the construction phase. There could be more to offer in the construction sector than the application of “Agile” such as pull demand and customisation of products. Agility stresses different values to Lean, typically learning, rapid configuration, and change. In this study different perspectives of Lean Thinkers and Agile Thinkers has been taken in consideration to investigate the application of Lean and Agile principles to the CSCs and analyse potential of those to increase efficiency while reducing the negative effect of fragmentation.

It is against this back drop that this study examine the reasons for the fragmentation of CSC, as a results of a series of inter-linked causes. The literature review revealed that the main reason for the fragmented nature of the construction industry is the absence of knowledge (tacit knowledge) transferring and sharing practice within the construction processes and within the CSCs and further in entire construction projects. However, this study does not rejects the views of Lean and Agile thinkers but reveals the potential of Lean and Agile to work together with the conjunction to the application of knowledge communication and specifically transfer and share Tacit Knowledge to improve the construction process at the individual task, activity, sub-process and further mega process levels.

7.1.4 Findings from literature and data analysis

This critical analysis of literature highlighted that the construction industry needs to consider the process-based view seriously with the application of both Lean and Agile principles and Knowledge Communication within Lean and Agile processes if the desired supply chain performance improvements are to be achieved.

As since, there has been a considerable amount of skill loss in the sector since 1990’s downturn and the industry is still not recovered. Unfortunately, the UK construction industry is now experiencing the ongoing economic recession, leading to stagnation of construction sector in its growth in terms of employment, innovation, business capabilities and exports (BIS, 2013a). On top of that, current recession is adding up the skill loss and questioning the capabilities of the UK construction sector (Baldauf C & Hubbard, 2011). Answer to that, recently, BIS (2013c) revealed that there is a lack of awareness of seeking skills and expertise. And, the construction SMEs have seen continuous increase in negative response in, skills of workforce, increase turnover by exploiting skills, reduce cost by increasing productivity of workers, develop and launch new products, employ more staff, increase leadership capabilities and exports, revealed by (BIS, 2011, 2013a, 2013b, 2013c, 2013d, 2014; HM Government, 2010; Rhodes, 2012).

Earlier, Latham (1994), Egan (1998, 2002) Wolstenholme (2004) and BIS reports all emphasised on the construction supply chain development while integrating teams, integrating processes, quality and capability development and skills development. But, there has been a general absence of awareness, understanding and research about the roles and contributions that Knowledge Management (KM) plays in collaboration and integrated approach in CSCs and Lean and Agile process as well as the importance and efficiency of CSCs. The latest reports by BIS in 2012 and 2013 revealed that, the construction organisations do not have adequate awareness of the availability of knowledge and support from government in terms of skill development.

7.1.5 Challanges

This study highlights that fragmentation in construction sector is because of several causes. The critical analysis of literature lead this study to the root causes such as, lack of partnering and collaboration and lack of process integration within CSC. These causes are preserving negative impact of fragmentation. Further, the study highlights that, lack of collaboration and partnering within CSCs is because of the lack of knowledge management systems. Which is further supported by lack of trust among organisations and lack of motivation among organisations and individuals. In this study following six main challenges are found in terms of transfer and share tacit knowledge in CSCs.

1) Lack of understanding and importance of transfer and sharing of Tacit Knowledge
2) Lack of trust among the organisations in Construction Supply Chains
3) Insufficiency of motivation for organisations in Construction Supply Chains
4) Short term supply chain relationship among partners of Construction Supply Chains
5) Contractors have traditional way of doing business
6) Fragmented nature of construction sector

Investigation into challenges concludes that, there is a gap in knowledge communication specially transferring and sharing tacit knowledge within CSCs. For these reasons, the CSCs remains fragmented and less efficient to produce desired results.

To investigate the findings from literature review, a systematic data collection approach is adopted to collect quantitative data through survey questionnaire. The respondents were recruited based on the job roles and experience in relevant fields. The data is categorised as ordinal scale to run nonparametric analysis in SPSS. Including, Frequency, Kruskal-Wallis H test and Spearman's Correlation analysis, an interpretive analysis is also done to establish the preceding and following challenges based on correlation coefficient rank order.

Data analysis reveals that the foremost challenging factor is the 'traditional ways of doing businesses' because of the lack of understanding and importance of transfer and share Tacit Knowledge.

There could be many reasons by which contractors have traditional ways of doing business in CSCs. Such as, more than 99% of small and medium firms (BIS, 2011), lack of skills in construction sector (BQF, 2013 and Guo, 2012), lack of adequate support to grow (BIS, 2011, 2013b; Schulz, 2012) and lack of learning capacity and capabilities (Baets, 2005; Tsai, 2001).

This study also argue that fragmented nature of construction sector is not the foremost challenge. If tacit knowledge can be effectively transferred and shared within CSCs it would bring partnering and collaboration within CSCs.

7.1.6 Tacit Knowledge

When we talk about tacit knowledge and especially transfer and share tacit knowledge the first name we consider is Michael Polyani. The most important work of Polanyi (1958), 'Personal Knowledge' is widely cited for positivist account of science and personal knowledge. Polanyi's view of about tacitness is something personal. It is an ability or skill to resolve problems or to do something that is based on persons own experience. In this book he claims that the knowledge rely on personal judgements. He also contended that, no matter how the knowledge is formulised it is relied upon commitments of person. In his work, his perception was that, a person experience the world by integrating the subsidiary awareness and focal awareness. Later in his other book 'The Tacit Dimension', (1966) he spoke more about the knowing instead of knowledge. He contended that 'we can often know how to do things without even knowing or without being able to articulate to others.' Recently Grant, (2007), revisited Polanyi's work and found that his work is often misunderstood since 1950's till date. He argued, *Polanyi's work reflects that tacit knowledge is highly personal and how individuals can gain knowledge and share it.* Moreover, in his work *Polanyi did not suggested that tacit knowledge cannot be transferred*. Rather he suggested that some kind of knowledge have limited capability to transfer. Grant (2007) concluded that *Polanyi's work is 23% misinterpreted in overall work in total of 52 most cited papers*.

In this study, I have looked at work of, Francis Becon, Thomas Hobbs, Cartesian, Descartes, Plato, Polayni, John Locke, Peter Drucker, Peter Senge and other mixed modern perspective of knowledge and especially Tacit Knowledge. Investigation of those views lead this study to conclude that, tacit knowledge can be transferred and share if the right tools are used even though it is hard to articulate. This require, individual capabilities (observation, absorption, communication and presentation) to articulate the Tacit Knowledge.

7.1.7 Critical Success Factors to Transfer and Share Tacit Knowledge

Further this study investigated the critical success factors associated with the effectiveness of transfer and sharing of tacit knowledge in the both lean and agile construction process. The literature review highlighted a total number of ten critical success factors. Among those, ‘Trust among construction organisations’ is identified as the foremost. Moreover, this critical success factor is correlated with others such as, motivation, leadership capabilities, business strategies and organisational and individuals capabilities.

The literature review highlights following ten (10) critical success factors.

1. Trust among the organisations in Construction Supply Chains
2. Motivation to share Tacit Knowledge
3. Leadership Capabilities of clients and main contractors to encourage sharing Tacit Knowledge
4. Business Strategies aligned to Share Tacit Knowledge in organisations within Construction process
5. Organisations within Construction Supply Chain must have Capabilities to Share Tacit Knowledge
6. Individual involved in construction process must be capable to share Tacit Knowledge
7. Identification of process improvement opportunity by managers
8. Identification of type of Knowledge to Share
9. Identification of Source of Knowledge
10. Identification of Knowledge recipient

Again, to validate the factors coined from literature review a systematic research methodology is adopted to collect quantitative data through survey questionnaire.

The study concluded, that, ‘identifying source of Knowledge’ is the foremost CSF which highly require and followed by ‘identification of type of knowledge’ and further, ‘identification of knowledge recipient’.

This also establishes that, ‘leadership capabilities’ calls for ‘aligned business strategies’ and further requires ‘capabilities of individuals’ to Transfer and Share Tacit Knowledge within the construction processes. This further highlights that, ‘identification of process improvement opportunity’ is an essential CSF that is essentially required, before identifying type, source and recipient of knowledge it is vital to identify the process improvement opportunity by managers.

7.1.8 Framework Development

Based on the findings from literature review and quantitative data analysis below framework is designed.

At stage A is a six steep process to identify the positioning the knowledge communication. The stages are given in below table.

Table 1: Tasks to Identifying Positioning of KM Framework

Tasks	Variables
Step (A1) Selecting Process : Identify Process Improvement Opportunity	• Increase Flow • Generate Value • Improve Quality • Problem Solving • Developing Partners • Integration
Step (A2) Choose Type of Tacit Knowledge Required to Enhance Selected Process	• Propositional • Personal • Procedural
Step (A3) Identify Source of Knowledge	• Organisation • Person • Collective
Step (A4) Identify Knowledge Recipient	• Person • Organisation
Step (A5) Improve Process	• Validation • Feedback
Step (A6) Integrate with other Processes	• Repeat Step 1 To 5

Stage (A2)

This stage is to identify which type of tacit knowledge is required to enhance the specific process and more importantly which principles. One or more of the three types of tacit knowledge namely, personal, procedural and propositional knowledge should be defined.

Stage (A3)

The third stage is to identify the source of knowledge within the Lean and Agile CSC. If for example, the type of knowledge the procedural knowledge, in case the sources of knowledge could be more likely an individual or an organisation. Sources of knowledge are as personal knowledge, organisational knowledge or collective knowledge. Knowledge source could be the organisation or an individual person who holds the tacit knowledge.

Stage (A4)

The fourth (A4) stage is to identify the recipients, who have the observation, absorptive, conversational, application, routing, and explanation and dissemination capability to receive the tacit knowledge from the source. However, having the same capabilities is important for the knowledge source, to support the smooth knowledge transfer and share. But, this research suggests that, the main source of knowledge should have at least observational, articulation, communication and explanational capability, to observe (tasks & Activities), articulate (new knowledge) and communicate and explain new tacit knowledge to the recipient. The reason, why recipient should have the explanational capability, because on the next stage of KC the recipient will act as the source and will require explanational capability to transfer and /or share the knowledge further upstream in the Lean or Agile process and SC.

Stage (A5)

At stage five, once stage A1 to A4 are identified, those should be validated to ensure the functionality of this process. This validation will also provide feedback and offer improvement to the process.

Stage (A6)

At this stage, the integration opportunities with other processes is to be defined in a view to initiate collaborative working environment with other processes.

Once the strategies, resources and positioning of KM framework is defined, section B of proposed framework needs to be implemented in a lean or agile process. Section B explains how the knowledge communication process should be implemented. Again in this part KM strategies need to be defined based on the process.

7.1.9 ***Stage (B) Knowledge Communication Implementation***

Once above stages (A1 to A6) are finalised, it is important to identify how knowledge communication should be initiated among the source and the recipient of knowledge. At this stage KC is seen as a continuous process on which the transferred and shared knowledge is being flowing through the different processes. This stage of framework is designed based on the input – output model, where the input is the raw tacit knowledge and output is the refined knowledge. The reason of using this model is because this is a qualitative technique which is significantly correlated with KC and interviewing source of knowledge to observe and record knowledge.

At this stage, input (#1) critical success factors (see above) to initiate knowledge communication. This involves defining tools and techniques to transfer and share knowledge, leadership capabilities, motivational tools and techniques and skills required for knowledge source and knowledge recipient.

In KC implementation process this study argues that the knowledge from source must be bias laden because of the nature of Tacit Knowledge being based on the experience. As the source of knowledge would require skills and training on observational, and explanational capabilities to ensure the smooth transfer or sharing of tacit knowledge. However, in terms of knowledge sharing more capabilities such as absorptive and conversational would be require for knowledge source. On the other side knowledge recipient will require both set of capability because in the next stage recipient will act as a secondary source of knowledge.

After each step of Knowledge transfer and sharing knowledge feed should be routed to the experts for feedback and reliability and validation. If in case, captured knowledge does not match with aim and objectives, the process A and B both should be fine-tuned and revised again.

As, the knowledge source often observe processes or an activity and thoughts are being developed with the certification of past experience. In regards, it is natural that the knowledge extracted from its source would be bias laden context specific knowledge. The knowledge conversion (within the mind) and application (within process) would also be bias laden. But, on the recipient side, the first stage is to ask questions and absorb the knowledge from the source with a bias free approach. If in this stage the recipient’s approach is bias laden, then, the extracted knowledge may not be as pure as the source have.

Implementation of this framework should be at the task level, but, the entire KC process must be supported with the SC design, and project strategy must involve CSFs.

7.1.10 Stage (C) Implication of Knowledge Communication in Lean and Agile Supply Chain

As discussed earlier that, Lean, Agile and Knowledge Management must be implemented as embedded in each other to get the best results. This proposed framework do not see Lean, Agile and KM as separate functions to create value in CSCs. Section (C) of proposed framework explains how and where knowledge communication framework should be implemented. Lean and Agile and KC should be embedded within each task of an activity and further sub-process and major and mega process of a SC. As a construction supply chain is a setup of multi-organisational supply chains, this study recommends that this framework should be implemented in all organisations such as main contractors (Tier 1), sub-contractors (Tier 2) and the following Tiers of CSC if the origin of knowledge is organisation or collective instead of personal.

If this proposed KM framework be applied to all tiers of CSC then it can bring collaboration and partnering and improve the level efficiency in SC and further would help to reduce the negative effect of fragmentation on a construction project.

7.2 Invitation Letter

[DATE]

Contact Name
[Company Name]
Address

Zip/Postal Code

Subject: Invitation to Participate in Research

Dear {FIRSTNAME}

I am a PhD student at the University of Salford, College of Science and Technology, School of Built Environment, has been researching to develop a framework of Transferring and Sharing Tacit Knowledge in Construction Supply Chains (CSCs) in context of Lean and Agile Processes and has thus seeking participants with extensive expertise in Knowledge Management, CSCs, and Lean & Agile Construction Processes.

This research seeks to develop a Knowledge Management framework and a set of guidelines within the context of Lean and Agile principles to improve awareness and understanding in Construction Supply Chains.
By reviewing the opinion of respondents on Knowledge Management, Supply Chain Management and Lean and Agile processes, within Construction Supply Chains, its contributions and challenges associated with effective Knowledge Management and identify the critical success factors, to investigate the contributions made to Construction Supply Chains, especially in terms of efficiency and improvements through the application of transferring and sharing tacit knowledge in the context of Lean and Agile processes.
This proposed framework would allow

- To increase awareness of application of transferring and sharing tacit knowledge in Lean and Agile processes and further in construction supply chains
- To increase efficiency of CSC in Lean and Agile construction processes

I invite you to participate in this research to share your views and expertise. Please find attached additional documents. These can also be found/downloaded by clicking the below link.

Thank you for your time.

Sincerely,
Mandeep Saini (MBA, MSc)
PhD Student
Room 433
University of Salford

Maxwell Building
Salford
M5 4WT
United Kingdom
Email: m.saini@edu.salford.ac.uk
Phone: 07506674011

Documents Attached:

1) Consent form
2) Questionnaire

Disclaimer

This email is intended only for the person to whom it is addressed and/or otherwise authorised personnel. The information contained herein and attached is confidential and the property of Mandeep Saini, Room 433, University of Salford, Maxwell Building, Salford, M5 4WT. If you are not the intended recipient, please be advised that viewing this message and any attachments, as well as copying, forwarding, printing, and disseminating any information related to this email is prohibited, and that you should not take any action based on the content of this email and/or its attachments. If you received this message in error, please contact the sender and destroy all copies of this email and any attachment. Please note that the views and opinions expressed herein are solely those of the author and do not necessarily reflect those of the company. While antivirus protection tools have been employed, you should check this email and attachments for the presence of viruses. No warranties or assurances are made in relation to the safety and content of this email and attachments. I accepts no liability for any damage caused by any virus transmitted by or contained in this email and attachments. No liability is accepted for any consequences arising from this email.

7.3 RESEARCH CONSENT FORM

Name of Researcher(s) *Mandeep Saini*
Title of study **A Framework To Transfer and Share Tacit Knowledge in Construction Supply Chains, in the Context of Lean And Agile Processes**

Please read and complete this form carefully. If you are willing to participate in this study, ring the appropriate responses and sign and date the declaration at the end. If you do not understand anything and would like more information, please ask.

• I have had the research satisfactorily explained to me in verbal and / or written form by the researcher.	**YES / NO**
• I understand that the research will involve semi-structured *interview and <u>it would be recorded with an audio recording device and notepad and the time involved will be approximately 30 mins.</u>*	**YES / NO**
• I understand that I may withdraw from this study at any time without having to give an explanation. <u>This will not affect my future care or treatment.</u>	**YES / NO**
• I understand that all information about me will be treated in strict confidence and that I will not be named in any written work arising from this study.	**YES / NO**
• <u>I understand that any audiotape material of me will be used solely for research purposes and will be destroyed on completion of your research.</u>	**YES / NO**
• I understand that you will be discussing the progress of your research with others at the University of Salford.	**YES / NO**

I freely give my consent to participate in this research study and have been given a copy of this form for my own information.

Signature: …………………………………………………………………………..………….

Date: ………………………………………………………………………………………

7.4 Interview Questions

Semi Structured Interview Questions

On commencing the interview:

- Explain the purpose of the interview,
- Express the importance of their views and experience,
- Give an assurance of confidentiality,
- Ask the interviewee's permission to record the interview if appropriate.

Section (B) Main Questions

This section is to examine the contribution of tacit knowledge in the application of Lean and Agile within Construction Supply Chains.

7.4.1 Questions

To what extent tacit knowledge contributes in the application of Lean and Agile in Construction Supply Chain.

A. Could you please explain the contribution of Tacit Knowledge in the application of Lean and Agile in Construction?

Following Questions

B. Based on your experience which one of them is most important?
C. Could you please tell me why transferring and sharing tacit knowledge is becoming important in construction supply chains in the context of Lean and Agile?

7.4.2 Section (2)

This section is to investigate the challenges associated with effective transferring and sharing tacit knowledge through the application of Lean and Agile principles in Construction Supply Chains.

Questions

A. What are the essential factors which hinders the sharing of Tacit Knowledge?

Following Questions

B. Which of them is most challenging factor?
C. What are the challenges which hinders the transfer of Tacit Knowledge?
D. Which of them is most essential?
E. In those which are much influencing factors in the application of Lean and Agile

7.4.3 Section (3)

This section is to identify the critical success factors associated with effectiveness of transferring and sharing tacit knowledge in Construction Supply Chains through the application of Lean and Agile principles.

Questions

A. What are critical success factors which helps to increase effectiveness of sharing Tacit Knowledge?

Following Questions

B. Please tell me which of them is most important?
C. What are the absolutely necessary factors required to transfer tacit knowledge?
D. Please tell me the most important factor among them?

7.4.4 Section (4)

This section is to receive the feedback and validation of framework.

A. In your view what modifications should be required in this framework?
B. In your opinion can this framework be applied in other industries?

7.4.5 Section (5) End of Interview

Thanking participant for taking part in the study and for their time and assistance. Assure participant that all information obtained is confidential. If participant wishes to receive the findings of study. Ask for their business card of fill the information below. Assure them that these details will be stored separately from the interview responses in order to maintain confidentiality.

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