NETWORK LEARNING IN GLOBAL ENGINEERING SERVICES

By

TRAN CONG THANH

A thesis submitted to

The University of Birmingham

For the degree of

DOCTOR OF PHILOSOPHY

Department of Management

Birmingham Business School

College of Social Science

The University of Birmingham

1st October 2018

ABSTRACT

This study develops an integrated framework to improve understanding of network learning and value creation in global engineering services (GES). Network learning is the process that enhances firm performance through better knowledge and understanding.

Prior research has developed GES network learning and value creation as a set of independent processes with customers, suppliers or intra-firm engineering units. Their practices have been fragmented, facilitating either inter- or intra-firm network learning and focusing on either GES efficiency or innovation. The absence of an integrated approach to network learning makes it difficult for researchers to understand, and for GES firms to manage. A more holistic understanding of GES network learning is urgently needed for firms to compete effectively in an ever-changing global market.

This research develops the theory of integrated GES network learning and value creation through a multiple case study. It integrates existing insights from multiple streams of research, and builds on these to explore network learning within three GES firms. The empirical study reveals an integrated network learning process adopted across customers, suppliers and intra-firm engineering units which enhances GES efficiency, flexibility and innovation. It clarifies the interrelated knowledge acquisition and development processes and supporting boundary spanning mechanisms within network learning. These processes and mechanisms are integrated in a framework that offers a more holistic view of GES network learning. The framework contributes conceptually to the literature on network learning in GES and offers managerial implications for firms to facilitate integrated network learning for effective GES value creation.

ACKNOWLEDGEMENTS

This PhD thesis could not have reached this point without the support of many people, to whom I am greatly indebted. I would like to express my gratitude to my lead supervisor, Dr. YuFeng Zhang, who has inspired me from the beginning of this research and guided me to this point, and to my second supervisor, Prof. John Bryson, who has advised me in overcoming many challenges of this complex work. Their never-ending constructive questioning, insightful comments and encouragement have been sources of inspiration for my additional efforts. I am honoured to have been guided by such talented and supportive supervisors. I would also like to thank my former second supervisor, Dr. Pamela Robinson, for her valuable advice and support during the early stages of this PhD before she left the university.

In the industrial sectors, I would like to thank all the managers and engineers who have generously spent their precious time to participate in my research and have shared their insights, which has helped me to realize my case studies.

I would like to thank my friends and colleagues who have provided me timely support over the course of my PhD project. Special thanks to Tuan, Arjun, Gopal, Heng and Steve, who were always attentive with encouragement and help.

Last but not least, this PhD would not have been possible without the huge support of my family, my parents, sisters and cousin. Their endless love and encouragement for life-long learning have helped me to overcome all the challenges of this PhD. This thesis is dedicated to them.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

KEY WORDS AND ABBREVIATIONS

Key words:

Global Engineering Services (GES)

Network learning

Boundary spanning mechanisms

Value creation

Abbreviations:

BSM	Boundary Spanning Mechanisms
BST	Boundary Spanning Tools
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CAR	Case Study Reports
CAS	Cambridge Alliance Service
CEO	Chief Executive Officer
CMMI	Capability Maturity Model Integration
CoE	Centre of Excellence
COO	Chief Operating Officer
CPFR	Collaborative Planning, Forecasting, and Replenishment
CTO	Chief Technology Officer
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
GES	Global Engineering Services
GIN	Global Innovation Network
GVR	Grand View Research
HRM	Human Resource Management
IP	Intellectual Property
ISG	Information Service Group
IT	Information Technology
KB	Knowledge Boundaries
KG	Knowledge Governance

KPI	Key Performance Indicators
LC	Learning Coordination
MATLAB	Matrix Laboratory
M&A	Mergers and Acquisitions
NFC	Near Field Communication
NL	Network learning
PhD	Doctor of Philosophy
QA	Quality Control
QC	Quality Control
RFID	Radio-Frequency Identification
R&D	Research and Development
SAP	Systems Applications and Products
TA	Technical Architect
TM	Technological Mechanisms
TMMI	Test Maturity Model Integrated

1. CHAPTER 1: INTRODUCTION

This thesis examines network learning processes and firm value creation in global engineering services (GES). The ways in which firms manage GES network learning for enhanced operations are explored through three case studies. A holistic view of GES network learning processes has been developed for enhancing firm competitiveness in changing operations contexts.

1.1. Global Engineering Services (GES) Firms and the Changing Global Landscape

Global Engineering Services (GES) firms provide through life-cycle services to support customer businesses around the world (Mathieu, 2001; Kujala et al., 2010; Zhang et al., 2016). Based on a people-centric approach, they deliver GES in different types of projects that create customised solutions driven by customers (Turner & Keegan, 2001; Kaiser & Ringlstetter, 2010). GES firms operate in various industries and specialise in different engineering areas, such as engineering research, design and development, manufacturing engineering and support services (Zhang et al., 2011; GVR, 2017; Kaiser & Ringlstetter, 2010; Zhang et al., 2016). Their operations have been increasingly globalised in response to client demand changes and new concepts of operations. Table 1.1 provides some examples of GES firms which have engineers and engineering facilities located around the world to deliver GES knowledge intensive services.

Table 1-1: Global engineering services firms

GES firms (Headquarters)	Employees (000s)	Revenue ($bn)	Number of offices	Countries with a firm presence
SNC-Lavalin (Canada)	50	9.5 (C$)	361	50
Atkins (UK)*	18	1.8 (£)	153	25
AECom (USA)	35	17.4	620	60
Jacobs (USA)	45	8.4	160	20
CH2M Hill (USA)	23	5.0	250	32
AMEC Plc (UK)	22	4.7	247	30
Tetra Tech (USA)	16	2.8	400	22
Parsons Brinckerhoff (Canada)	36	5.9	413	34
Ericsson (Sweden)	100	201.3 (SEK)	130	180
ABB (Switzerland)	136	34	1076	102
IBM (USA)	380	79.1	Not available	177

Source: Company websites & Wikipedia (updated 2017)
* Atkins was acquired by SNC-Lavalin in July 2017

Over the last two decades, GES firms have increasingly distributed their engineering resources around the world to compete more effectively (Fernandez-Stark et al., 2010; ISG, 2016; Wise & Baumgartner, 1999). On the one hand, they have offshored/outsourced parts of their service operations to emerging countries to reduce costs, and to developed countries to access specialist expertise (ISG, 2013, 2016; GVR, 2017). On the other hand, engineering service operations have been located close to local clients to enhance engineering customisation (Malhotra & Morris, 2009; Abdelzaher, 2012). The tendency of global networks of engineering service provision has enhanced the operational and management complexity of GES firms (Zhang et al., 2014).

In recent years, the GES industry has changed rapidly. Global spending on engineering services was estimated at around USD 750 billion in 2004 (Fernandez-Stark et al., 2010), USD 930 billion in 2012 (ISG, 2013) and expected to increase to USD 1.49 trillion by 2025 (GVR, 2017). Notably, this trend has occurred in parallel with recent technological advances, such as the internet of things, digital technologies and artificial intelligence (ISG, 2016). New GES firms have been on the rise (CAS, 2014; ISG, 2016a). At the same time, manufacturing firms have increasingly recognised that service provision may produce higher margins than stand-alone products (Wise & Baumgartner, 1999; Oliva & Kallenberg, 2003). More and more manufacturing firms have transformed or "servitized" their traditional product-centric businesses to service-centric ones to gain competitive advantage (Daniels & Bryson, 2002; Neely et al., 2011). Additionally, new GES firms have emerged not only in developed countries but also in emerging ones to meet growing global demands (Fernandez-Stark et al. 2010; GVR, 2017; ISG, 2013, 2016). Although this "servitization" trend may bring many benefits to manufacturing firms (Baines et al., 2009; ISG, 2013), research has shown that not all GES firms can create value effectively as they transition towards service-oriented operations (Neely et al., 2011; Valtakoski, 2017).

The changing global context places competitive pressures on GES firms. Customers around the world increasingly expect them to offer high-value engineering services, innovative technologies and long-term business relationships (GVR, 2017; ISG, 2016a). These changing demands encourage the firms to shift their business models towards operations excellence and contractual innovation with fixed pricing; outcome-based operations; and risk-reward sharing with customers, instead of the traditional staff augmentation models (ISG, 2016a).

All the above trends have not only intensified the competitive pressure on GES firms, but have also given rise to new ways of creating value.

1.2. GES Network Learning and Value Creation

It has been increasingly recognised that network learning is an important process, assisting GES firms to create value in the management of their global operations (Brady & Davies, 2004; Galbraith, 2014; Moore & Birkinshaw, 1998; Zhang et al., 2016). GES network learning can be considered as an intra- and inter-firm process that enhances GES network operations through better knowledge and understanding (Fiol and Lyles 1985; Kotlarsky et al. 2014). It occurs when knowledge is created and/or reused across the operations of network members to enhance firm performance (Jaakkola & Hakanen, 2013; Zhang et al., 2016). Moore and Birkinshaw (1998, p.82) argue that for GES firms, “competitive advantage is gained not through the sharing of activities but through the transfer of intangible assets from country to country”. In today’s digital business world, GES network learning is even more important for enhancing operational efficiency and effectiveness because “technology is always changing — knowing where to start is not obvious, and the learning process never ends” (Ernst & Young Survey Report, 2018, p.2).

Research on GES network learning has been undertaken in operations, supply chain and industrial marketing management, and organisational learning. In the operations management literature, the emphasis has been on the important roles played by different operational functions and their contributions to GES network learning and value creation (Moore & Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016). However, these studies have not clarified the contributions that customers and suppliers make to GES network learning across different intra-firm engineering units. The literature on industrial marketing management and supply chain management highlights customers and suppliers as key contributors to GES network learning and value creation (Brady & Davies, 2004; Jaakkola and Hakanen, 2013; Coghlan & Coughlan, 2014; Galbraith, 2014), but the role of intra-firm engineering units in inter-firm GES network learning with customers and suppliers has not been highlighted (Windahl & Lakemoon, 2006; Galbraith, 2014). In a few exceptional studies attempting to identify the interrelations between inter- and intra-firm GES network learning and value creation (e.g. Brady & Davies, 2004; Salonen et al., 2018), their findings are too preliminary and unstructured to provide comprehensive understanding of the linkage between network learning with customers, suppliers and intra-firm engineering units. In the organisational learning literature, the concept of network learning is focused predominantly on intra-organisational matters, while network learning across firm boundaries is underdeveloped (Knight, 2002; Knight & Pie, 2005; Gibb et al., 2017). In brief, prior research has not offered an overall understanding of GES network learning, which should be viewed as an intergrated process involving customers, suppliers and service providers (Grönroos, 2011; Vargo & Lusch, 2008; Lusch et al., 2010).

Additionally, identified mechanisms supporting network learning are inconsistent, facilitating either inter- or intra-firm network learning and focusing on enhancing either service efficiency or innovation (Brady & Davies, 2004; Jaakkola & Hakanen, 2013; Galbraith, 2014; Kotlarsky et al., 2014; Zhang et al., 2016). These fragmented mechanisms make it difficult for researchers to understand, and for practitioners to implement GES network learning. Salonen et al. (2018) have recently stated that we know little about the learning of GES firms in capturing and leveraging engineering knowledge for effective service delivery. An integrated approach to GES network learning is urgently required to address these knowledge gaps.

1.3. Research Objectives

This research is to examine GES network learning through an integrated approach, considering the contributions of customers, suppliers and intra-firm engineering units. A main research question has been formulated to guide the investigation - **"How do GES firms manage network learning to create value in global service operations?"**

The analysis focuses on two key aspects of network learning as articulated in the following sub-questions that will be carefully elaborated in the literature review chapter:

> **Sub-question 1: How does GES firms' network learning with customers, suppliers and intra-firm engineering units contribute to value creation?**
>
> **Sub-question 2: What mechanisms should GES firms use to facilitate network learning with customers, suppliers and intra-firm engineering units? When and why?**

In answering these questions, this research is expected to achieve the following objectives:

- Exploring network learning practice with customers, suppliers and intra-firm engineering units for value creation.

- Analysing interactions among these three areas of practice and identifying the key mechanisms to facilitate network learning.
- Developing an integrated framework for network learning to illustrate the essential theoretical constructs as well as revealing their linkages.

1.4. Research Approach

This research adopted a theory building approach supported by case study methods (Ketokivi & Choi, 2014; Miller & Tsang, 2010). Case studies enabled a detailed analysis of network learning practice through applying, verifing, and modifing pre-assumed theories in real contexts (Barratt et al., 2011; Ketokivi & Choi, 2014). Three GES firms were identified for the case studies. These three firms differ from one another in terms of their technological areas (software, aerospace and pharmaceutical solutions), and value creation strategies (efficiency, flexibility or innovation). They enable comparison between different GES network learning practices and value creation which enhance theoretical replication (Yin, 2003; Eisenhardt & Graebner, 2007). The units of analysis are network learning episodes with customers, suppliers and intra-firm engineering units. These multiple units of analysis contributed to an analysis of different interrelated inter- and intra-firm network learning processes and their linkages. Data collection and analysis was supported by pre-assumed frameworks based on a focused literature review of over 200 research articles on organisational learning and knowledge management, GES network learning and value creation.

The data collection process applied a triangulation approach to gather complex information about GES network learning from various data sources (Yin, 2003; Denzin, 1978). Interviews were the main method for data collection. 31 informants across the three cases participated, sharing their insights and experiences of GES network learning and value creation. They were intentionally selected to include respondents at different management levels, and with different engineering functions and geographical locations (Eisenhardt & Graebner, 2007). The informants included senior global managers, project managers, senior and junior engineers, and business analysts, directly engaged in capturing, creating and disseminating knowledge across organisational and geographical boundaries. A semi-structured interview protocol was prepared to guide open conversations with them.

In addition to interviews, over 20 company documents, 11 company archives, and more than 30 public company articles were collected and triangulated with the interviews, including corporate annual reports; corporate operations annual/quarterly reviews; brochures on company services; training programmes; consortium meetings; company presentations; organisational and process charts; and company articles on new services/ technologies/ products, best practices, and new partnership announcements. Interviews and company documents were combined with site visits for direct observation and experience.

Data analysis was conducted simultaneously along the data collection, using various coding and pattern matching techniques to extract and link data with pre-assumed frameworks. These methods enabled the researcher to compare and contrast empirical evidence with the preliminary framework and across cases. Case data analysis therefore refined and validated the preliminary framework, facilitating theory evaluation and development.

1.5. Overview of the Findings and Research Contributions

The current literature has presented GES network learning as a set of independent knowledge acquisition, development processes and boundary spanning mechanisms, either with customers, suppliers or intra-firm engineering units (Jaakkola and Hakanen, 2013; Kotlarsky et al., 2014). By integrating the existing theories and applying them into real GES network contexts, this study has explored a more holistic network learning process that contribute to GES value creation. Its observations show that GES firms manage their network learning by incorporating customers, suppliers and intra-firm engineering units to acquire knowledge for learning and innovation. Network learning with customers, intra-firm engineering units and suppliers are indeed interrelated rather than independent processes that have been the case in the existing literature. GES network firms can manage network learning processes with customers, suppliers and intra-firm engineering units in an integrated manner to acquire, transform and exploit knowledge for GES efficiency and innovation.

The analysis of this study has resulted in an integrated framework for GES network learning and value creation. The framework includes three interrelated elements - (1) network learning with customers; (2) network learning with intra-firm engineering units; and (3) network learning with suppliers. Each element contributes to providing knowledge to the others for GES operations enhancement in terms of efficiency, flexibility and innovation. Their interactions form an integrated network learning process which includes a set of knowledge acquisition processes across customers, suppliers and intra-firm engineering units. Knowledge acquisition processes comprise knowledge reuse for innovation, knowledge creation and knowledge reuse, which are combined in various ways to create value. These processes are driven by changing customer needs/demands, the knowledge gaps between intra-firm engineering units, and the capabilities of suppliers, and are facilitated by a set of boundary spanning mechanisms. Various centralised and decentralised boundary spanners and formal and informal governance mechanisms can be employed across network learning with customers, suppliers and intra-firm engineering units to enhance the knowledge acquisition processes. Customers, intra-firm engineering units, suppliers, knowledge acquisition processes, and boundary spanning mechanisms form an integrated network of learning and value creation.

This integrated framework thus contributes conceptually to the field of GES operations management by providing a holistic view of network learning for GES value creation. It expands the existing literature by highlighting that customers, suppliers and intra-firm engineering units can together contribute to GES network learning and value creation, rather than just intra-firm engineering units, as has been the case in prior research. The framework also clarifies the knowledge management mechanisms that facilitate the integrated network learning of GES firms. It supports the argument that GES network learning requires a combination of various knowledge management mechanisms. However, it enriches the literature by elaborating the boundary spanning mechanisms that contribute to not only intra-firm but also inter-firm GES network learning.

The study also adds to the literature on innovation management. In contrast to previous research, which has undertaken less exploration of GES network learning that contribute to performance enhancement, this research clarifies an integrated GES network learning process including interrelated knowledge acquisition processes and supporting mechanisms that facilitate idea generation, knowledge transformation and exploitation, leading to performance enhancement. This process provides evidence that GES innovation can be achieved through integrated inter- and intra-firm network learning.

In addition to theoretical insights, the developed framework provides managerial implications for firms to facilitate integrated network learning. The framework offers a set of knowledge management mechanisms that promote knowledge reuse and creation across customers, suppliers and intra-firm engineering units. Effective GES network learning relies on formal and informal mechanisms to encourage knowledge sharing and transfer across different actors. It requires the employment of boundary spanners and governance mechanisms to bridge the knowledge gaps between customers, suppliers and intra-firm engineering units.

1.6. Overview of the Thesis

This thesis comprises seven chapters (Figure 1-1). The first three chapters shape the foundations for the empirical research. The following four empirical chapters present the research results, and theoretical and managerial implications.

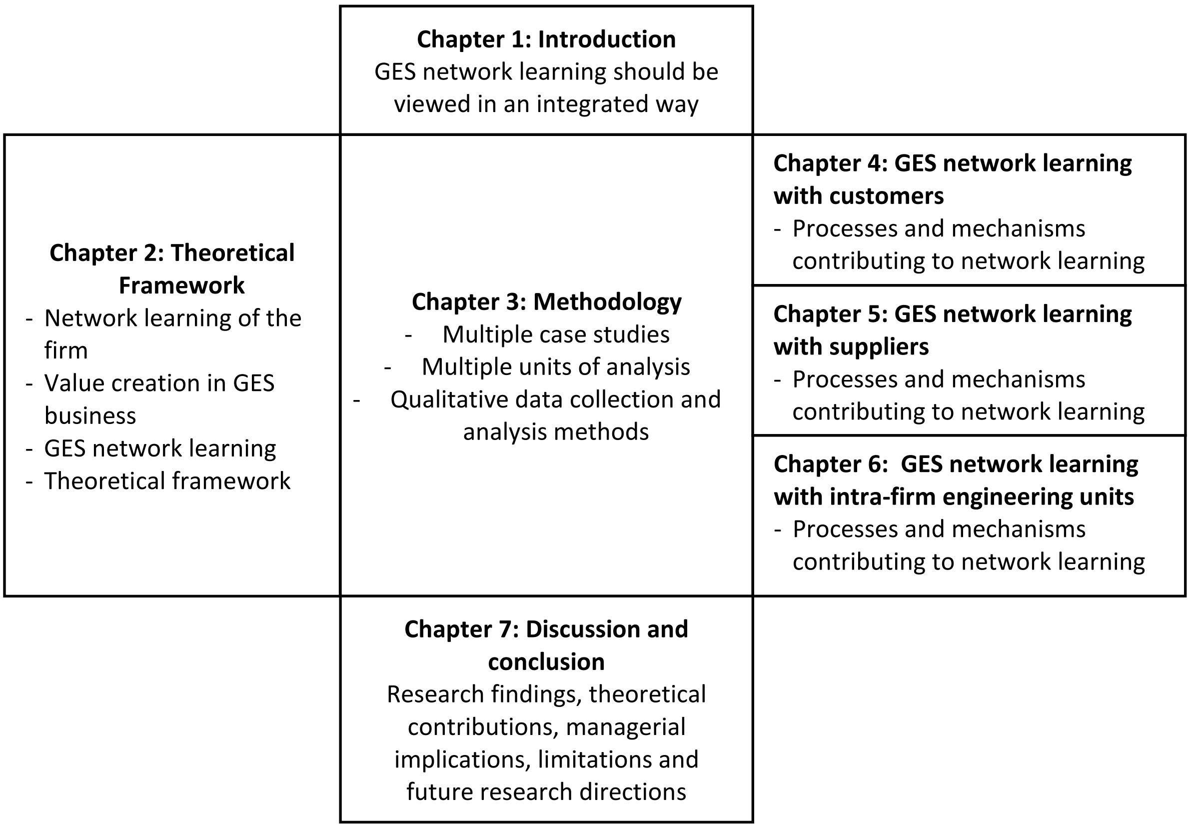


Figure 1-1: Thesis structure

After this introduction chapter, Chapter 2 develops a preliminary framework of GES network learning and value creation. The framework guides the research design, data collection and analysis. It had been iteratively developed, refined and validated during the case studies.

Chapter 3 justifies the research approach, research settings and methods to answer the research questions. The chapter explains how research findings presented in the next chapters were achieved.

Chapter 4 presents network learning practices GES firms adopt in collaboration with customers to create value. The analysis clarifies the roles of customers in GES network learning, highlighting the processes, knowledge management mechanisms and the linkage between customer-focused network learning and intra-firm, supplier-focused network learning.

Chapter 5 explores network learning practices with suppliers that contribute to GES value creation. It clarifies different processes, knowledge management mechanisms and the linkage between supplier-focused network learning and intra-firm and customer-focused network learning.

Chapter 6 focuses on network learning practices with intra-firm engineering units that contribute to GES value creation. It clarifies the processes, knowledge management mechanisms and the linkage between intra-firm and inter-firm network learning that lead to GES value creation in terms of efficiency, flexibility and innovation.

Chapter 7 integrates the findings from chapters 4, 5 and 6, drawing out an updated theoretical framework for GES network learning and value creation, clarifying the theoretical and practical implications, discussing the research limitations and suggesting future study directions.

2. CHAPTER 2: THEORETICAL FRAMEWORK

2.1. Introduction

Chapter 1 presented the motivation for studying GES network learning with an integrated approach, considering the roles of customers, suppliers and intra-firm engineering units. This chapter continues to develop the research background and constructs a preliminary framework, which is iteratively verified and modified in empirical settings. Figure 2-1 presents the overall structure of this chapter.

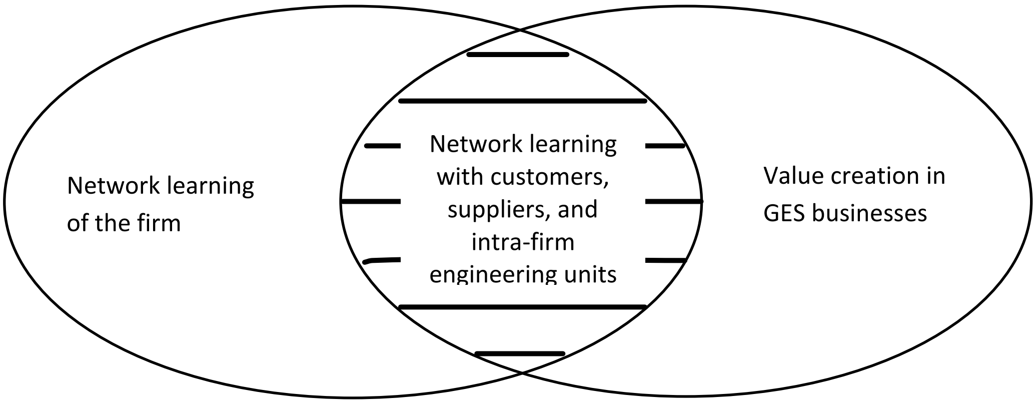


Figure 2-1: Literature review boundaries

The chapter begins by conceptualising firms' network learning. Subsequently, it focuses on the value creation of GES firms, which can be created through network learning. The chapter continues by reviewing the literature on GES network learning with customers, suppliers and intra-firm engineering units, in order to understand the current debates on the practices that contribute to value creation. Finally, exisiting network learning practices are integrated into a preliminary framework, shaping a foundation for the empirical research design, implementation and theory development.

2.2. Network Learning of the Firm

2.2.1. Network Learning Literature

Network learning is increasingly recognised as an important process for network firms to enhance network operation performance within intra- and inter-firm learning contexts (Brady & Davies, 2004; Dyer & Nobeoka, 2000; Harryson et al., 2008). Although network learning has been of interest to business management scholars since the late 1990s, Knight and Pie (2002, 2004, 2005) are among the early authors who developed the concept of network learning as the fourth level of organisational learning.

In their view, network learning is generally “the learning of a group of [autonomous] organizations as a group” (Knight, 2002, p. 427). Network learning is not the sum of the learning of individuals (I), groups (G) and organizations (O) that constitute the network, but is a collective process embedded across network members (Knight, 2002). In this regard, network learning, on the one hand, is distinguished from the other levels of organisational learning (individuals, groups, organisations, and dyad (D)) as a network collective process crossing all network individuals, groups and autonomous organisations. On the other hand, it differs from the learning processes between two organisations (dyad) and the learning between the other levels within inter-firm learning networks (I-O). Figure 2-2 positions network learning in the intra- and inter-organisational learning contexts.

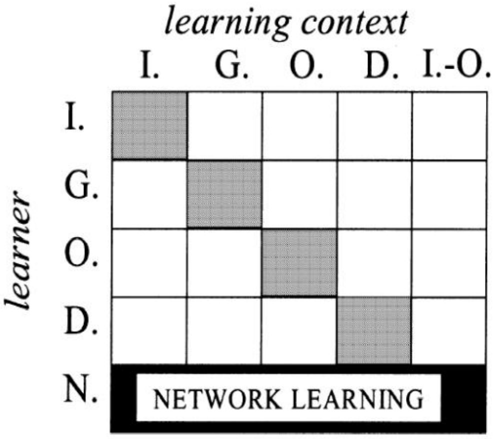


Figure 2-2: Positioning of network learning in different learning contexts

Source: Knight (2002, p. 439).

Shared cognition across network?

Coordinated practices across network?

	No	Yes
No	No network learning	Cognitive network learning
Yes	Behavioural network learning	Integrated network learning

Figure 2-3: Network learning outcomes

Source: Knight (2002, p. 445).

Network learning outcomes can be recognised through network shared cognition and practice changes (Figure 2-3). If there is no shared cognition and coordinated practices across network members, there is no network learning (Knight, 2002). Similar to organisational learning, network changes can be sequential (Crossan et al., 1995). Over time, behavioural or cognitive network learning may lead to integrative network learning, which includes the changes in both cognition and behaviour across network members. They may result in no learning taking place if behavioural or cognitive changes mean there is no shared cognition or coordinated practices across network member (Crossan et al., 1995; Knight, 2002). As such, only network learning processes that lead to network changes (e.g. network structure, interpretation and practices) may be considered as network learning (Knight & Pye, 2005).

Network learning research literature is sparse (see *Appendix 1* for a summary of the literature on network learning of the firm). Most existing conceptual studies focused on inter-organisational network learning and the social mechanisms that facilitate the cognition and behaviour changes of inter-organisational networks. Intra-firm network learning practices are diverse, and there is no consensus in the findings of previous studies. Knight (2002) argues that network learning, whether inter- or intra-firm, can only be captured within a network learning episode in which learning goals, actors and activities should be specified.

Knight and Pye (2005), from the perspective of strategic network changes and social actions, identify a network learning model including network learning context, content, and process to approach network learning. The network learning context refers to many facets of the outer and inner contexts that drive and affect network learning processes and network learning content. Network learning content refers to network learning outcomes - “key changes to network level properties occurring within and between the episode’s temporal boundaries, which are relevant to the focal topic of the episode”, while the network learning process refers to “the actions and interactions through which network-level changes occur” (Knight & Pie, 2005, p. 379).

Despite being an important process for firm innovation, existing intra-firm network learning practices are fragmented in various contexts. The model of inter-firm network learning (context – process – outcome) can be used as the starting-point for operationalising the network learning of the firm from the information processing perspective (Huber, 1991; March, 1991). In this view, network learning refers to any process that enhances network activities through better network knowledge and understanding (Argyris & Schön, 1978; Cyert & March, 1963; Dyer & Nobeoka, 2000; Fiol & Lyles, 1985). The literature on organisational learning and knowledge management provides a rich source of knowledge to examine the network learning of the firm.

2.2.2. Network Learning of the Firm

2.2.2.1. Network Learning Drivers

Changing technologies and markets. Network learning is considered as a vehicle for firms to gain competitive advantage (Powell et al., 1996; Dyer & Nobeoka, 2000). It is increasingly recognised that intra- and inter-firm networks are a source of knowledge (Kogut, 2000; Westerlund & Rajala, 2010). The literature shows that firms are driven to adopt learning with inter-firm networks when industrial knowledge is complex and expanding, and the market is highly dynamic (Lusch et al., 2010; Powell et al., 1996; Teece et al., 1997). Firms rely on network learning with external firms to create value and to survive in changing environments characterised by emerging technologies and changing customer demands (Teece et al., 1997).

Intra-firm knowledge gaps. In intra-firm network learning, the key driver for network learning is to bridge the knowledge gaps between dispersed operations (Chai et al., 2003; Criscuolo & Narula, 2007). Dispersed business units cope with similar or unknown problems. They are motivated to use network learning for knowledge reuse between them and to capture the knowledge that they need for operational efficiency (Kotlarsky et al., 2014). Dispersed business units can collaborate with each other through network learning to combine their knowledge and thus create new knowledge together (Criscuolo & Narula, 2007).

2.2.2.2. Network Learning Processes

From the perspective of organisational behaviour, Knight and Pye (2005) perceive network learning content with a broad view, referring to the changes in network practices, formal organisational structures, and network interpretations. In contrast, operations management scholars perceive network learning as the knowledge processing processes for network performance improvement (Dyer & Nobeoka, 2000; Fiol & Lyles, 1985; Zhang et al., 2016). In fact, firms practise network learning to enhance performance through knowledge exploitation or reuse, and exploration or creation (March, 1991; Criscuolo & Narula, 2007; Dyer & Nobeoka, 2000; Zhang et al., 2016). To exploit existing knowledge (knowledge reuse) and explore new knowledge (knowledge creation), firms need to implement a set of supporting processes such as knowledge acquisition, knowledge distribution, knowledge interpretation, and organisational memory (Huber, 1991).

Knowledge reuse. Knowledge reuse refers to organisational changes in response to dynamic environments (Argote & Miron-Spektor, 2011; Cyert & March, 1963; Daft & Weick, 1984). In this regard, knowledge reuse is mainly associated with experiential learning, in which organisational experiences are selectively developed, stored in organisational memory, and transferred to organisational members for use (Argote, 1999; Levitt & March, 1988; Winter & Nelson, 1982). This experiential learning is attributed to 'single loop' learning, which is the changes in behaviours based on past history, paradigm, and frames, without changes in underlying norms (Argyris & Schön, 1978; Fiol & Lyles, 1985). Knowledge reuse can be a formal or informal process.

In the context of intra-firm organisational learning, formal knowledge reuse is the transfer process by which an entity's knowledge is captured by others (Argote & Ingram, 2000; Szulanski, 2000). Organisational knowledge transfer processes can be considered as active and centralised knowledge reuse. In this regard, knowledge reuse may include knowledge acquisition, communication, application and assimilation (Gilbert & Cordey-Hayes, 1996); formation of transfer seed, decision to transfer, first day of use, achievement of satisfaction performance (Szulanski, 2000); or just simply being aware of knowledge sources, and capturing and transferring them to others (Chai et al., 2003). In these processes, for example, knowledge is usually recognised, probably at the headquarters, in many ways, such as from new individuals with new knowledge, continuous searching and interpreting (Gilbert & Cordey-Hayes, 1996). The knowledge then is processed and sent to subsidiaries. This active process is a one-way transfer process, its intention being to increase efficiency in sharing best practices or knowledge benchmarking across the organisation. The transfer mechanisms (processes and methods) vary depending on the characteristics of the knowledge transferred (e.g. explicit or tacit) (Szulanski, 1996) and/or relational factors (e.g. knowledge boundaries) within the firm (Easterby-Smith, Lyles, & Tsang, 2008).

Informal knowledge reuse is the learning process of the application of best practices into a specific situation or "helping others solve common technical problems" (Markus, 2001, p. 59). Markus (2001) identified four situations in which the knowledge reuse of the firm may occur. First, the knowledge producers may document their own experience for their own future reuse. Second, knowledge may be shared and reused among practitioners who practise their professions in different settings. The third situation is associated with novices occasionally searching for expertise to solve ad-hoc problems. Finally, knowledge reuse occurs when the reusers mine the knowledge, perhaps from various disciplines, to answer new questions and generate innovative solutions (Majchrzak et al., 2004).

Markus (2001) proposes a four-stage process of knowledge reuse. It starts with a process in which knowledge is either intentionally or unintentionally captured (e.g. documented) for later reuse. The second stage involves a process of packaging knowledge through a classification scheme. It is then distributed to users in many ways, by either passive or active mechanisms, depending on the characteristics of the knowledge reused (Filieri & Alguezaui, 2015; Fruchter & Demian, 2002). Passive actions may be the publication of newsletters or updating knowledge on repositories for users to browse. Active actions involve meetings, electronic alerts and so on. The final stage is knowledge reuse, involving a process of defining the search question, searching for and locating experts or expertise, selecting from these experts or expertise, and finally applying the knowledge selected (Markus, 2001). Interestingly, each stage may be implemented by the same groups or individuals. They are either knowledge producers, knowledge intermediaries, or knowledge consumers (Markus, 2001).

Knowledge creation. Knowledge creation is related to organisational information processing processes that solve organisational problems (Daft & Weick, 1984; Newell & Simon, 1972). Such processes result in both cognitive and behavioural changes (Gond & Herrbach, 2006). The cognitive learning process is perceived as a “double loop” learning process, which involves changes in both behaviour and cognition (Argyris & Schön, 1978).

Knowledge creation processes contribute to exploratory organisational learning (March, 1991). The literature on knowledge creation processes that lead to organisational learning is largely founded in the work of Nonaka (1994, 1995), and his highly influential theory on the management of knowledge creation. Nonaka (1994) argues that knowledge is created through continuous dialogue between tacit and explicit knowledge. He proposes four key processes through which knowledge can be created: socialisation, externalisation, combination, and internalisation (Figure 2-4).

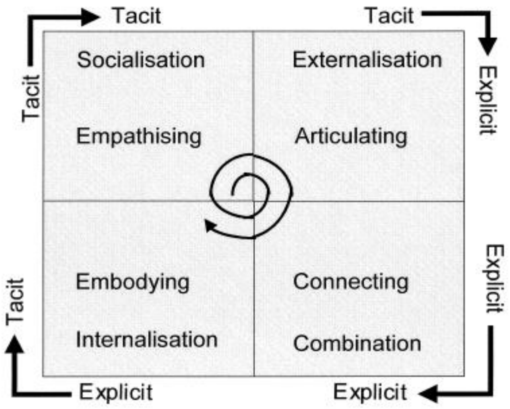


Figure 2-4: Knowledge creation process

Source: Nonaka et al. (2000, p. 12)

Socialisation is the process of sharing experience between individuals to create new tacit knowledge. There are different kinds of interactions between individuals, including verbal and non-verbal ones. *Externalisation* is the process of articulating tacit knowledge into explicit knowledge. New tacit knowledge accumulated from the socialisation process and held by individuals to be made explicit, allowing it to be shared by others (conceptual knowledge or disciplinary knowledge). This process is often initiated and facilitated by using a metaphor to enable team members to articulate their perspectives, and share tacit knowledge with others, which is hard to communicate (Nonaka, 1994).

Combination is the process of converting explicit knowledge into more complex and systematic sets. In this process, explicit knowledge is collected from inside or outside the organisation and then combined, modified and processed to form new knowledge. This is then disseminated among the members of the organisation (Nonaka et al., 2000). *Internalisation* is the process of embodying explicit knowledge into tacit knowledge. The process is closely related to "learning by doing", and once internalised knowledge becomes a part of individuals' tacit knowledge in the form of shared mental models and technical know-how. Although knowledge reuse and creation are based on different approaches, incremental and radical learning, they are viewed as complementary (Miner & Mezias, 1996) and can be implemented simultaneously (Gupta et al., 2006).

In short, network learning content refers to the knowledge reuse and creation processes that enhance network operation performance. In order for network learning to occur, firms need to have knowledge reused or created across network members, which leads to enhanced network performance. Firms can use different practices to facilitate knowledge reuse and creation for network learning and performance enhancement.

2.2.2.3. Knowledge Boundaries

The networks in which network learning occur can be classified into three types: industrial districts, strategic alliance, and intra-corporate networks (Inkpen & Tsang, 2005). Industrial districts include many legally autonomous firms collaborating to address a common industrial network problem (Gibb et al., 2017; Morris et al., 2006). Strategic alliances can be vertical, relating to business networks collaborating to achieve a common business goal (Coghlan & Coughlan, 2014; Dyer & Nobeoka, 2000). They can also be horizontal innovation networks, in which network members collaborate to develop new technologies, processes or services (Powell & Grodal, 2005; Scarbrough & Amaeshi, 2009; Tödtling et al., 2009). Intra-firm networks are mainly associated with networks of business operations within firms, e.g. manufacturing, R&D and service networks (Chai et al., 2003; Zhang et al., 2008). The diversity of networks and their diverse network members create knowledge boundaries between the learner network (network firm) and other learning network members that impede network learning (Ayala et al., 2017; Carlile, 2004; Kotlarsky et al., 2014).

Carlile (2002, 2004) identifies three complexity levels of knowledge boundaries: syntactic, semantic and pragmatic boundaries. According to Carlile, a syntactic boundary refers to the condition in which knowledge actors have the same logic, value and perspectives, but use different lexicons. A semantic boundary is a more difficult situation, in which knowledge actors have different worldviews or interpretations, while a pragmatic boundary is the most challenging situation, in which knowledge actors have different lexicons, interpretations and interests. However, the greater the differences the knowledge actors have, the greater the originality of the collaborations they generate, and the more complex the knowledge management that is required (Carlile, 2004; Hislop, 2009). In fact, knowledge boundaries, on the one hand, hinder knowledge sharing and learning across boundaries. On the other hand, they require knowledge management to foster knowledge transfer, translation and transformation across networked organisations.

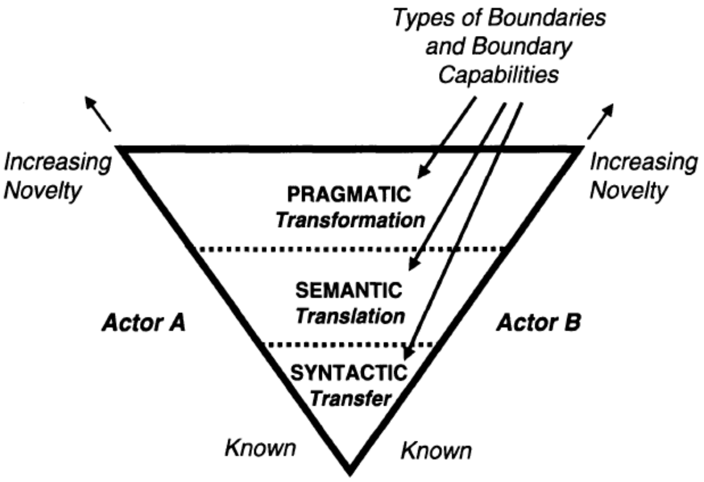


Figure 2-5: Knowledge boundaries and knowledge management processes

Source: Carlile (2004, p. 558)

Figure 2-5 shows different types of knowledge boundaries that require different knowledge management interventions for knowledge sharing and transfer. Syntactic boundaries are the least complex level, at which knowledge is straightforwardly transferred. However, knowledge agents may be different in terms of their absorptive capacity[1], transfer capability, and the motivation to teach and to learn, which hinders the knowledge transfer among them (Dyer & Nobeoka, 2000; Easterby-Smith et al., 2008). Semantic boundaries cause more difficulties due to the differences in interpretations, and require more translational efforts for learning. Pragmatic boundaries are the most challenging situations, in which knowledge management needs to cope with differences not only in lexicon and meanings, but also with the different interests between knowledge actors. Knowledge transformation mechanisms are needed to facilitate knowledge transfer and learning (Carlile, 2004).

Empirical research on intra-firm network learning has identified knowledge boundaries in different network learning contexts. Intra-firm network learning often needs to cope with geographical, technological and cultural differences, which cause difficulties for knowledge sharing and learning between different business functions (Criscuolo & Narula, 2007; Inkpen & Pien, 2006; Lam, 1997; Sirmon & Lane, 2004). Geographical distance may cause national culture, language and identity differences (Sirmon & Lane, 2004), while

---

[1] Cohen and Levinthal (1991, p.128) define absorptive capacity as the ability "to recognize the value of new, external information, assimilate it, and apply it to commercial ends".

technological differences prevent divisions from communicating and collaborating in an effective manner (Criscuolo & Narula, 2007). Organisational or cultural differences may create organisational inertia because there may be conflicts of interest between autonomous organisations (Criscuolo & Narula, 2007; Lam, 1997). These interest differences or pragmatic boundaries between knowledge agents may cause problems such as free riding or opportunism, knowledge spin-over fear, and holdup (not willing to invest in learning) (Coopey, 1995; Foss, 2007; Osterloh & Weibel, 2009). These problems are especially intense when firms engage in inter-firm collaborations/networks (Dyer & Nobeoka, 2000; Scarbrough & Amaeshi, 2009). If they arise in knowledge transactions between firms, the firms may be at risk of organisational hazards such as knowledge appropriation failure, knowledge accumulation or knowledge leakage (Nickerson & Zenger, 2004; Scarbrough & Amaeshi, 2009). Knowledge boundaries are therefore the barriers to network learning that require network firms to have boundary capabilities to boost network learning.

Knowledge complexity. In addition to its boundaries, the knowledge itself is a barrier to network learning. Knowledge is the "information given meaning by knowledge agents" (Fleck, 1997, p.348). Knowledge can exist in many forms. For example, Davenport and Prusak (1998, p.5) specify it as "a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information". Furthermore, knowledge is contextually dependent (Fleck, 1997; Argote, 2011). For example, Leonard and Sensiper (1998, p.113) perceive it as "information that is relevant, actionable, and based at least partially on experience".

Organisational knowledge has multi-facets that make it complex to transfer (Easterby-Smith et al., 2008). To characterise knowledge, Polanyi (1966, p.4) emphasises the tacit dimension of knowing by arguing that "we know more than we can tell". In this regard, knowledge has two key elements: tacit and explicit. While explicit knowledge pertains to the know-what, objective, articulable or documentable (Brown & Duguid, 1998; Doz & Santos, 1997), tacit knowledge is more complex and ambiguous, including aspects such as conceptual and technical elements (Nonaka, 1994). Conceptual elements refer to the abstract aspect of knowledge such as mental models, schemes and frameworks (Argyris & Schön, 1978), while technical elements comprise know-how, skills and heuristics (Alavi &

Leidner, 2001; Fruchter & Demian, 2002; Szulanski, 2000). Other authors emphasise the embeddedness dimension of knowledge. In this regard, knowledge is valid in the complex social contexts where it is situated and grown, namely being embedded or encultured knowledge (Granovetter, 1985). This type of knowledge is only meaningful in a specific context and not valid in all circumstances (Doz & Santos, 1997). Doz and Santos argue that knowledge embeddedness and tacitness make it complex to transfer. The more tacit and embedded the knowledge is, the more complex it is for firms to acquire and transfer it. The degree of knowledge tacitness and embeddedness determines whether the knowledge can be captured through teaching, coaching, observing or codifying ,and hence provides implications for network learning (Doz & Santos, 1997; Zander & Kogut, 1995, Chai et al, 2003).

In addition to the multi-facet aspect, knowledge also has multi-layers within the context of organisations. It may reside within individuals, groups, organisations or at the network level. Spender (1996) outlines four types of knowledge in organisations based on individual and organisational levels and the tacit-explicit characteristics of knowledge (Figure 2-6). He argues that firms possess a mixture of these types of knowledge. While a firm relies on its employees' skilled practices, automatic skills and intuitions, it also uses objectified knowledge, such as science, established standards and practices, as well as collective knowledge, such as routines, norms and cultures to create rents.

	Individual	Organisational
Explicit	Conscious	Objectified
Tacit	Automatic	Collective

Figure 2-6: Different types of organisational knowledge

Source: Spender (1996, p. 52)

The multi-faceted and multi-layered characteristics of organisational knowledge have implications for network learning (Doz & Santos, 1997; Easterby-Smith et al., 2008; Spender, 1996; Szulanski, 2000). While explicit knowledge is perceived as being more precise and easier to acquire and transfer, tacit knowledge is thought to be contextually dependent and highly abstract, which make it hard to transfer and absorb (Doz & Santos, 1997; Lam, 1997; Nonaka, 1994). Furthermore, knowledge is embedded not only within organisational memory but also within that of individuals. Network learning mechanisms therefore should be designed according to the characteristics of knowledge to economise knowledge transfer across networks (Chai et al., 2003; Moore & Birkinshaw, 1998). At the same time, they must ensure that knowledge sharing occurs at individual, group, organisational and network levels (Foss, 2007).

2.2.2.4. Boundary Spanning Mechanisms

Boundary spanning mechanisms refer to the methods, procedures and processes firms use to overcome the knowledge boundaries between learning actors and to ensure that network learning occurs. They help to economise knowledge sharing and thus facilitate network learning (Grant, 1996; Kogut, 2000). The knowledge management literature has paid much attention to strategies firms can employ to facilitate knowledge transfer and learning across knowledge boundaries.

Boundary spanners. Brown and Duguid (1998) found that knowledge boundary spanners are important for developing social relations and fostering knowledge sharing across various communities. They are either strategic translators or knowledge brokers. While the brokering role is relevant in facilitating the mutual understanding of similar or related knowledge, the translating role is more efficient in situations where there is no common knowledge between communities (Hislop, 2009). This role is more complex than the brokering role because translators must be “knowledgeable about the work of both communities to be able to translate” (Brown & Duguid, 1998: p.103).

Boundary spanning tools. Another mechanism that facilitates knowledge sharing across boundaries is knowledge boundary spanning tools or “boundary objects” (Brown & Duguid, 1998; Carlile, 2002). Boundary spanning tools are physical or symbolic in character, including repositories, standardised forms/methods, objects/models, and maps (Hislop, 2009). Carlile (2002) argues that using boundary spanning tools is effective in facilitating common understanding, and thus knowledge sharing and learning. However, each level of knowledge boundary may require different boundary spanning tools. Syntactic boundaries can be mitigated through shared repositories, while standardised forms and methods, models, and maps are useful for overcoming semantic and pragmatic boundaries (Hislop, 2009).

Learning coordination. Network coordination is acknowledged as an important mechanism for economising knowledge sharing and production (Grant, 1996; Kogut & Zander, 1992; Nickerson & Zenger, 2004). Hansen et al. (1999) propose two knowledge coordination strategies: codification and personalisation.

Codification refers to "the compression of knowledge and experience into a structure, involving the use of codes and models to translate rules and actions into procedures, guidelines, specifications, and documents" (Whitaker et al. 2010, p. 19). In this way, codification develops centralised information systems for documenting, storing and disseminating reusable codified knowledge (Hansen et al., 1999; Zack, 1999). Codification strategies are especially efficient in transferring explicit knowledge, because they facilitate the reach of information to many organisational members and thus obtain economies of scale (Chai et al., 2003; Hansen et al., 1999). Alvesson and Kärreman (2001) identify two types of codification strategies: enacted library and enacted blueprint. Enacted library plays the supporting role for knowledge agents by channelling information and analytical tools through information systems so that they can acquire the necessary information for knowledge interpretation and creation (e.g. explicit knowledge combination and reuse) (Durcikova et al., 2011; Liao et al., 2012; Markus, 2001). Enacted blueprint controls the learning behaviours of knowledge agents through knowledge management systems, which provide templates and guidelines to direct knowledge sharing and reuse actions (Earl, 2001; Zack, 1999).

Personalisation strategy emphasises the creation of "social networks for linking people so that tacit knowledge can be shared" (Hansen et al., 1999, p.3). This strategy facilitates economies of scope and is especially useful in supporting knowledge creation which relies highly on tacit knowledge sharing (Hansen et al., 1999; Nonaka, 1994). Personalisation mechanisms are efficient because they enable knowledge agents to capture rich information, which is necessary for the understanding of complex knowledge (Chai et al., 2003; Doz & Santos, 1997). Alvesson and Kärreman (2001) propose two types of personalisation strategies for supporting organisational learning: communities and normative control. Communities are the mechanisms related to social intervention for open knowledge sharing and innovation, which greatly support exploratory learning (Earl, 2001; Leonard & Sensiper, 1998; McDermott, 1999). Normative control refers to control functions over knowledge sharing to ensure that knowledge agents engage in such sharing and learning (Alvesson & Kärreman, 2001; Foss, 2007).

In the personalisation approach to organisational learning, codification may be necessary, but is only moderately important because expert collaboration is dominant in these contexts. For example, in the case of the automotive industry, the frequency of knowledge sourcing and reuse in knowledge repositories negatively affects the creativity of individuals (Cheung et al., 2008). The low-quality of presentation and design of knowledge repositories may be the causes of frustrations for users and reduce creativity (Filieri & Alguezaui, 2015).

Research has shown that in many situations codified knowledge is incomplete because it may not include all the tacit aspects, and hence requires more interactive efforts for the knowledge sources to be fully articulated (Fruchter & Demian, 2002; Goffin et al., 2010). Knowledge codification may need to include the codification of the knowers, which enables the knowledge users to interact with the sources of knowledge (Kotlarsky et al., 2014).

Knowledge governance. Knowledge agents may be willing or unwilling to learn and to teach. This requires complementary knowledge governance mechanisms[2] to direct learning behaviours at micro levels (Foss, 2007; Foss & Michailova, 2009). For example, codification relies on people who are good at reusing knowledge and are rewarded for using and contributing to document databases (Hansen et al., 1999). As such, the design of the knowledge content and presentation within organisational repositories will affect the learning motivation of network members (Filieri & Alguezaui, 2015). Firms may need a sufficient degree of information structure design to facilitate the learning behaviours of knowledge users (Zack, 1999). For example, research has found that the quality of knowledge presentation and design affects the application time and frequency of reuse (Gray & Meister, 2006). It also affects the creativity of knowledge users (Cheung et al., 2008). Additionally, encouraging policies may facilitate knowledge reuse, but the rate of reuse varies across different industries and sectors (Ettlie & Kubarek, 2008).

---

[2] Foss (2007) refers to knowledge governance as an approach firms can take to facilitate knowledge processes, such as knowledge sharing, reuse and creation. Knowledge governance mechanisms affect knowledge processes at not only the macro level (organizational outcomes) but also the micro level (individual actions).

In personalisation, learning relies on people who like problem solving, share knowledge, and are best trained through mentoring (Hansen et al., 1999). Relational mechanisms such as reciprocal routines, trust and other rules are important tools for enhancing knowledge sharing and learning across boundaries (Capaldo, 2014; Dyer & Nobeoka, 2000). Furthermore, knowledge governance mechanisms are strategically critical for guiding the learning behaviour of diverse individuals. They may include HRM practices, incentives (e.g. rewards), identity formulation, social relations processes and ideology to create shared values, beliefs, and norms (Alvesson & Kärreman, 2001; Hansen et al., 1999).

In the context of exploratory learning, knowledge sharing is effectively supported by motivational solutions rather than strategic solutions[3] because knowledge agents' learning behaviours are driven by the intrinsic motivation of the learners (Osterloh & Weibel, 2009). For example, the working environment has an impact on individual and team creativity (Amabile et al., 1996). A working environment that favours creativity contains elements such as encouragement of creativity through organisational encouragement, supervisory encouragement, and work group support; autonomy and freedom; sufficient resources; and pressures relating to the level of the challenge and workload (Amabile et al., 1996). Encouragement for creativity (e.g. normative control) is positively associated with exploitation innovation, and autonomy (e.g. communities) encourages exploration innovation (Durcikova et al., 2011).

Technological mechanisms. Various technologies have been increasingly adopted by firms for capturing, processing and disseminating information for organisational learning (Afify & Pham, 2005; Bose & Mahapatra, 2001; Zack, 1999). Examples are found in the field of machine learning such as big data mining (Bose & Mahapatra, 2001; Montavon et al., 2013), artificial intelligence, knowledge discovery from databases (Afify & Pham, 2005; Wuest et al., 2016). Information and communication technologies are combined with other technologies to enhance information processing and hence organisational learning (Baines & Lightfoot, 2013; Zhang et al., 2016).

---

[3] Osterloh and Weibel (2009) identify three strategic solutions, the long-term outlook, selective incentives and modularisation, that are commonly used to facilitate exploitative learning. However, effective exploratory learning requires intrinsic motivational solutions such as minimizing managerial control and monetary incentives, encouraging flexible and supportive job design, incentives and communication.

2.2.2.5. Network Learning Outcomes

In the operations management literature, network learning outcomes are mainly related to enhancement of firm performance (Dyer & Nobeoka 2000; Coghlan & Coughlan 2014). While inter-firm network learning fosters technology innovation (Powell et al., 1996; Powell & Grodal, 2005) and operational improvement (Dyer & Nobeoka, 2000), intra-firm network learning facilitates knowledge transfer, reuse and creation between network units, which enhance firm efficiency and effectiveness (Criscuolo & Narula, 2007; Kotlarsky et al., 2014; Moore & Birkinshaw, 1998). By adopting network learning, firms enhance their performance through knowledge reuse and creation and thereby create value (Zhang et al., 2016).

2.2.3. Summary

Figure 2-7 summarises the key constructs of the network learning of the firm. The context, processes and boundary spanning mechanism framework provides a tool for the understanding of different network learning practices. To capture these practices, it is essential to examine the network learning context, processes and boundary spanning mechanisms.

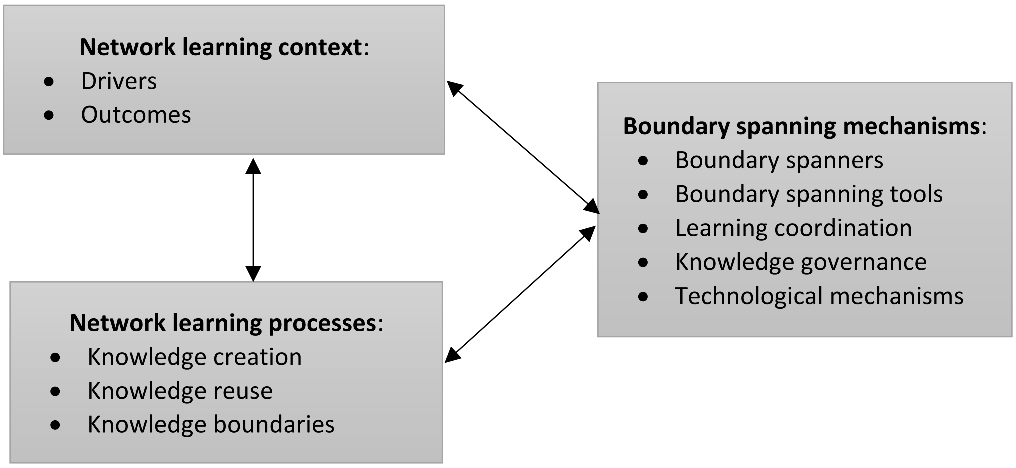


Figure 2-7: Framework of the network learning of the firm

The network learning context includes the following factors:

- Network learning drivers: the internal and external factors that motivate firms to practise network learning in order to enhancing network operation performance. External factors are associated with the dynamics of the market and competition, while internal factors relate to the dispersion of firms' knowledge and their competitive strategies (e.g. efficiency or effectiveness).

- Network learning outcomes: network performance enhancements through better knowledge or understanding.

Network learning processes include knowledge creation and reuse processes and the challenges of their implementation because of the knowledge boundaries between learning actors:

- Network knowledge reuse: the stage at which the learner network effectively responds to the changes in the external environment by exploiting the existing knowledge embedded within the learner network and/or external actors.
- Network knowledge creation: the stage when the learner network explores new knowledge that is unknown to the market.
- Knowledge boundaries: the differences in knowledge languages, interpretations and interests between the learner actors, which hinder knowledge sharing, reuse and creation. Knowledge boundaries are intensified when the knowledge transferred is complex, requiring management interventions to economise the cost of knowledge transfer (Carlile, 2002; Szulanski, 2000).

Network learning practice refers to the actions firms adopt to facilitate knowledge sharing and transfer across knowledge boundaries (Carlile, 2004; Szulanski, 2000). The knowledge management research literature suggests that firms can adopt five key boundary spanning mechanisms:

- Boundary spanners: strategic individuals responsible for developing social relationships and knowledge sharing across communities. They are either knowledge brokers or knowledge translators.
- Boundary spanning tools: the entities that are common to a number of communities within the organisation (Hislop, 2009). They are either physical or symbolic in character, including repositories, standardised forms/methods, objects/models, and maps (Hislop, 2009).

- Knowledge coordination mechanisms: formal, hybrid and informal organisational mechanisms designed by firms to facilitate learning across autonomous communities, including intra- and inter-organisation networks.
- Knowledge governance mechanisms: formal and informal organisational mechanisms that control and/or encourage the learning behaviours of the organisation and its individuals towards an organisational learning objective.
- Technological mechanisms: not only information and communication technologies, but also other technologies that facilitate information sharing, capturing and processing for organisational learning.

2.3. GES Value Creation and Network Learning

2.3.1. Engineering

Engineering generally refers to the application of science and design (Rogers, 1983; Smith, 1988). Applied science is attributed to analysis, while design is associated with synthesis (Smith, 1988). Koen (2003, p.28) specifies engineering as “the use of heuristics to bring about the best change in a poorly understood situation within the available resources”. In this view, heuristics are the rules that guide engineering actions, referring to a variety of activities such as problem-solving, goal-directed approaches, need fulfilment activity, applied science when appropriate, trial and error, resource allocation based on engineering costs, use of feedback to stabilise engineering design (Durbin, 1991). Kirby (1990) emphasises engineering as the application of empirical knowledge for the development of artefacts which contribute to human well-being. In this view, he refers to engineering as “the art of the practical application of scientific and empirical knowledge to the design and production or accomplishment of various sorts of constructive projects, machines and materials of use or value to man” (Kirby, 1990, p.2). Therefore, engineering is a combination of scientific application and design for the benefit of human beings.

Although engineering activities involve applied research and manufacturing for the development of artefacts, it is fundamentally different from research and manufacturing. Indeed, engineers “focus on the future, looking back mainly to calibrate progress, […] drafting plans for the next generations of artefacts, and seeking to achieve what has not been done before” (Petroski, 1992, p.523). Engineering research and manufacturing are oriented to the development of new artefacts for practical use and changes, being related to discipline design methods, and conducted in tool-intensive contexts (Sicilia et al., 2009). Engineering relies on intangible knowledge, targets the solving of one-off problems, and requires cross-functional collaborative teams to respond to changes quickly (Zhang et al., 2014a).

Firms use engineering to develop new products, e.g. product research and development (R&D) (Subramaniam et al., 1998), to enhance manufacturing performance (Shi & Gregory, 1998), or to create engineering solutions that support customer actions (Davies, 2004; Kujala et al., 2010). Depending on the engineering outcomes, engineering firms are classified into either product-based or service-based companies (Payne et al., 1996).

2.3.2. Service

Service is traditionally defined as any activities, processes or performances that create solutions for customers (Gronroos, 1990; Zeithaml et al., 1996). In this view, service is characterised as anything distinct from manufacturing and featuring Intangibility, Heterogeneity, Inseparability and Perishability (the IHIP framework) (Sasser et al., 1978; Zeithaml et al., 1985). Service involves customisation, in which customers engage in operations as input suppliers (Chase, 1981; Goldstein et al., 2002; Kellogg & Nie, 1995; Sampson & Froehle, 2006). Service outcomes are difficult to measure and can be recognised as a change in the condition or state of an economic entity (or thing) cause by another (Hill, 1977) or as pay for performance (Spohrer & Maglio, 2008). By conceptualising service separately from manufacturing, traditional service research literature pays scant attention to the synergy of services and manufacturing in manufacturing services (Lovelock & Gummesson, 2004; Metters & Marucheck, 2007).

A seminal paper on Service Dominant Logic (SDL) (Vargo & Lusch, 2004) shed light on this shortcoming. SDL provides theoretical premises capable of explaining the service phenomena emerging in manufacturing industries (Daniels & Bryson, 2002; Oliva & Kallenberg, 2003; R Wise & P Baumgartner, 1999). According to Vargo and Lusch (2004), service is the application of competencies (such as knowledge and skills) by one party for the benefit of another. In this way, service (not goods) is the fundamental basis of all economic exchanges, and goods (and their manufacture) are the distribution mechanism for service provision (Vargo & Lusch, 2004, 2008).

2.3.3. Global Engineering Services

Global engineering services (GES) can be viewed as “the application of engineering knowledge (including engineering technologies, skills, and expertise) possessed by an engineering services firm in effective problem-solving for the benefit of customers in a global context” (Zhang et al., 2016, p.81). GES have been widely discussed within the literature on solution business and operations management. While the operations management research literature highlights the delivery processes, resources and outcomes at firm level, the solution business management research literature studies GES in a broader context – solution networks, incorporating customers and suppliers in GES processes, and their roles and activities in co-creating engineering solutions with the GES firm.

At firm level, GES include three interrelated stages: corporate technology planning, technology development, and product development. Corporate technology planning is the most complex and valuable activity, directing the operations of the following stages. Technology and product development are more operational, involving engineering research, design and development, and manufacturing engineering. Details of engineering service processes related to the three stages are presented in Table 2-1. GES firms tend to distribute engineering services in many countries to serve customers worldwide (Fernandez-Stark et al., 2010) and/or to enhance engineering efficiency and effectiveness (ISG, 2016).

GES are delivered in different project forms at the firm facilities or customer sites (Kaiser & Ringlstetter, 2010); customers may be integrated into projects for the purposes of customisation (Malhotra & Morris, 2009; Zhang & Zhang, 2014). The primary resources for GES projects are engineers, who apply their engineering knowledge to solve customer problems (Payne et al, 1996; Zhang et al., 2014b). GES firms employ diverse engineers with different backgrounds, skills and experiences, and integrate them into specialised engineering units for GES operations (Malhotra & Morris, 2009; von Nordenflycht, 2010).

Although GES involve product life-cycle development for the benefits of customers, Breidbach and Malgio (2016) clarify two types of engineering solutions that GES firms produce in their projects: process-oriented and output-oriented. Process-oriented engineering solutions are created only when the engineers are deeply embedded within the customer organisational context to be able to capture customer process problems and co-create engineering solutions through the eyes of the customer (Davies, 2004). Output-oriented solutions are mostly created separate from the customer organisational context and rely on service provider specialised expertise, involving the delivery of artefacts as the mechanisms for service (Vargo et al., 2008; Galbraith, 2014). In particular, GES projects generate either mechanical hardware or electronics, or software and embedded software products to support customer businesses (ISG, 2013).

Table 2-1: Value adding activities in GES

Key stages		**Mechanical & hardware product development**	**Electronics, software and embedded software product development**
Corporate technology planning	**High**	• Intellectual property management • Technology planning • Research and development strategy planning • Research and development standards and architecture	• Intellectual property management • Technology planning • Research and development strategy planning • Research and development standards and architecture
Technology development	**Enterprise value added/ Complexity of interaction**	• Applied research • Product requirement definitions • Engineering tool selection and development • Engineering change management	• Applied research • Engineering tool selection and development • Engineering change management system analysis • Requirement gathering
Product development	**Low**	• CAE/CFD analysis • Full product development • Prototype build & testing • Manufacturing support • Value analysis/value engineering • Documentation • Safety testing • Patent management	• Algorithm development • Software design and coding • Chip design and board design • Prototyping V&V testing • Integration testing • Performance/reliability testing • Safety testing • Production support • Patent management

Source: Adapted from ISG (2013, p.7).

At the solution network level, GES involve customers and suppliers, who co-create engineering solutions with GES firms (Davies et al., 2007; Kujala et al., 2010). Customers and suppliers may engage with GES firms in projects (Brady & Davies, 2004; Windahl & Lakemoon, 2006; Jaakkola & Hakanen, 2013) and/or other relationships such as consortiums, supply networks or forums (Galbraith, 2014; Tidd, 2006). Solution operations are conducted in collaboration with customers and suppliers to address customer process problems (Davies, 2004; Helander & Möller, 2007; Kujala et al., 2010). Customers engage with GES firms through a relational process including definition of requirements, customisation and integration, deployment and post-deployment (Jaakkola & Hakanen, 2013; Tuli et al., 2007). Suppliers are integrated into GES to co-create the solutions required by customers, providing complementary knowledge for GES operations (Davies et al., 2007; Jaakkola & Hakanen, 2013). It can be seen from the literature that GES is an all-encompassing process involving customers, suppliers and engineering units, who contribute to technology planning, development and product development for the benefits of the customers.

2.3.4. Firm Value Creation and Network Learning

Firm value. Producers and customers have different perceptions on value (Miles, 1985). In the marketing management research literature, value is defined through the eyes of the customers, referring to their overall assessment of the utility of a product/service based on their perceptions of what is received and what is given (Zeithaml, 1988). What is received are the benefits customers perceive from the performance of the product/service offered and the relationship with the producer (Zeithaml, 1988; Wilson & Jantrania, 1994; Ravald & Gronroos, 1996). What is given pertains to the monetary and non-monetary costs customers are willing to pay in exchange for the product/service (Reddy, 1991; Anderson & Narus, 1998).

For the firm, value can be perceived as “a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer” (Womack & Jones, 1996, p.311). In this regard, firm value has two main components: use value and exchange value (Bowman & Ambrosini, 2000). While use value is “defined by customers, based on their perceptions of the usefulness of the product on offer [the firm capability]”, and can be measured by “the [monetary and non-monetary] amount the customer is prepared to pay for the product”, exchange value is “the amount paid by the buyer to the producer for perceived use value [the price]” (Bowman & Ambrosini, 2000, p. 4). Firm value therefore can be viewed as use, monetary and non-monetary values. Firms create use value for customers and receive monetary and non-monetary values. To create use and exchange value, firms must increase product/service functions and/or reduce the cost and time of production (Miles, 1961). In other words, firms need to enhance their capabilities of producing products/services in order to create use and exchange value.

Firm value creation. The traditional perspective views firm value creation as a process in which the firm create new use value within it for the consumption of customers and to capture exchange value (Miles, 1961; Bowman & Ambrosini, 2000). The firm value creation process starts with value identification (Sirmon et al., 2007; O'Cass & Ngo, 2011). Firms identify value content (utility, cost and time) based on its core competencies and value creation strategy, which is the value known by both customers and firms (Moller, 2003).

Value creation strategy is identified through an assessment of external factors and internal value creation sources. One external factor is market dynamism. Internal sources of value creation may: (1) be innovation culture oriented, (2) include human resources: knowledge of heterogeneous and entrepreneur labour (Bowman & Ambrosini, 2000; Lepak et al., 2007, Pitelis, 2009); (3) involve external network resources: customers, suppliers and competitors (Moller & Rajala, 2007); and (4) include firm resources: capabilities and configurations (Araujo et al., 2003; Zhang et al., 2007). Firm value creation can be viewed through a value chain (Porter, 1985). This chain is not only a heuristic, but is also an analysis tool to identify by whom and where value is created and distributed (Kaplinsky & Morris, 2000).

There are different ways for firms to create firm value. Edwards et al. (2004) propose three pathways to value creation inside a firm: (1) adopt better practices; (2) innovate product/ service, but remain at the same position in the value chain; and (3) value innovation. Bowman and Ambrosini (2007) classify five type of value creation activities: (1) product creation activities; (2) value realisation activities; (3) input procurement activities; (4) capital stock-creating activities, and (5) firm maintenance activities. Firms adopt different approaches to firm value creation depending on social and economic factors; for example, workforce skills, investment and management commitment to long-term changes.

Firm value creation and network learning. The literature on the value creation of network firms indicates that they can adopt network learning processes to create firm value (Dyer & Nobeoka, 2000; Harryson et al., 2008). Most of the studies on the network learning of the firm focus on network learning practices within intra-firm operation networks. Network learning facilitates knowledge transfer and sharing across intra-firm business units and thereby enhances intra-firm network operation efficiency (Chai et al., 2003; Dyer

& Nobeoka, 2000) and new product development (Criscuolo & Narula, 2007; Hoegl & Schulze, 2005).

There is evidence that network firms can create firm value through learning with external partners (Powell et al., 1996; Westerlund et al., 2010). Research has identified different network relationships that firms may engage to innovate firm products and processes with external partners through learning (Normann & Ramirez, 1993; Moller & Rajala, 2007; Powell & Ghodal, 2005; Tidd, 2005). For example, network firms can use network learning to enhance production performance with upstream sub-tier suppliers (Dyer & Nobeoka, 2000) and/or facilitate product innovation with horizontal business partners (Harryson et al., 2008).

Although past research has explored the process through which the network learning of firms with intra and inter-firm networks can create firm value, most studies mainly focus on the network learning that creates use value and captures exchange value inside firms for the consumption of customers (Dyer & Nobeoka, 2000; Harryson et al., 2008). Network learning that creates value in GES businesses has been underdeveloped. There is increasing evidence that firms create value in terms of service improvement and technology innovation through GES network learning (Brady & Davies, 2004; Jaakkola & Hakanen, 2013; Kotlarsky et al., 2014; Zhang et al., 2016). However, we do not have a good understanding of how firms manage GES network learning to create firm value in GES business environments.

2.3.5. GES Firm Value Creation and Network Learning

GES value. The SDL literature indicates that the value that firms create in GES is value-in-use, recognised as an improvement in system well-being, and measured by “a system’s adaptiveness or ability to fit in its environment” (Vargo et al., 2008, p. 149). By create value-in-use as perceived by customers, GES firms capture exchange value (Vargo et al., 2008). The notion of GES value is widely debated within the industrial marketing management research literature. Jaakkola & Hakanen (2013) argue that it is perceived differently by customers, suppliers and GES firm involved in GES. GES value can be viewed as the benefits and sacrifices [cost] solution network actors perceive when they are involved in producing GES offerings and their related exchanges (Jaakkola & Hakanen, 2013).

For customers, GES is valuable when the engineering solution offerings of service providers enhance their business processes (Kujala et al., 2010; Mathieu, 2001). Additionally, customers perceive GES value not only through the value-in-use of the engineering solutions that the GES providers offer, but also the operational capability, cost and the relationships the GES providers can provide (ISG, 2016). For suppliers, Jaakkola & Hakanen (2013) point out that they can benefit from GES with a service provider in terms of revenue, new market access, external R&D investment, customer learning and service innovation. However, they may need to invest upfront in R&D and share risk or cost with the service provider.

For GES firms, GES value is the benefits and sacrifices they receive in offering and exchanging solutions with customers, and in the collaborations with suppliers (Jaakkola & Hakanen, 2013; Coghlan & Coughlan, 2014). The benefits are not just new use and the exchange value of the service offerings, but also other non-monetary benefits such as business innovation, differentiation from competitors, risk reduction and long-term relationships with customers (Jaakkola & Hakanen, 2013). Recent research has provided evidence on firm learning and business innovation as the key benefits manufacturing firms can gain in providing GES offerings and exchanges with customers and suppliers (Brady & Davies, 2004; Sallonen et al., 2018). Furthermore, firms can establish long-term relationships with customers and suppliers by delivering GES (Windahl & Lakemond, 2006). In many situations, the GES providers may share costs and the efforts put into service development and operational risks with customers, sacrificing profit for learning and relationships (e.g. market access) as benefits in GES (Miller et al. 2002; Brady & Davies, 2004; Hakanen & Jaakkola, 2012). Therefore, when offering GES, firms can gain many benefits other than the use and exchange value co-created with customers and suppliers, such as learning, innovation and external relationships (Brady & Davies, 2004; Sallonen et al., 2018).

Although GES firm value has been discussed within the marketing management research literature in terms of the benefits and sacrifices firms receive and make, the value perceived by them when engaging in GES has not clearly discussed within the engineering service operations management literature. Spohrer and Maglio (2008) argue that service is pay for performance of the service provider, highlighting the monetary aspect of service value. However, GES firm value can be different to the monetary benefits captured in collaborations with customers and suppliers. It can be non-monetary value such as knowledge (learning), business innovation and relationships (Jaakkola & Hakanen, 2013). GES firm value therefore should be viewed as both monetary and non-monetary values.

GES firm value creation. GES value creation requires firms to understand how value is created through the eyes of customers (Davies, 2004: p.733). In this regard, they need to understand customer business needs before developing the engineering capabilities to offer products and services that customers perceive as valuable for their businesses. GES value creation therefore emphasises the performance of the service providers in their relationships with customers, not the goods offerings. There are three ways firms can focus on creating value:

- Efficiency: the operational abilities that help GES firms outperform their rivals through implementing their engineering tasks with fewer resources.
- Innovation: the operation abilities that help GES firms create novel engineering solutions for customers.
- Flexibility: the abilities that help GES firms quickly respond and adapt to changing demands (Zhang et al., 2016).

To create GES value, firms focus on enhancing GES efficiency, flexibility and innovation and thus maintain firm competitive advantages (Moore & Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016). The solution business and operations management research literature has focused on the characteristics of the GES value creation process.

GES value creation process. Customers can be the value-in-exchange co-creators and suppliers can be value-in-use co-creators for the service provider (Vargo & Lusch, 2008). GES firm value creation is therefore an all-encompassing co-creation process involving customers, service provider and suppliers (Grönroos, 2011; Grönroos & Helle, 2010). The service provider creates new use value and captures exchange value in its relationships with customers and suppliers through learning (Lusch et al., 2010; Windahl & Lakemond, 2006). In other words, the service provider creates new use value and realises exchange value with customers and suppliers in an all-encompassing value creation process.

In GES businesses, value creation has two parallel processes (Figure 2-8): engineering solution commercialisation and industrialisation (Storbacka, 2011). In the solution commercialisation process, GES firms co-create engineering solutions with customers and suppliers and realise new value (Johnstone, Dainty, & Wilkinson, 2009; Storbacka, 2011; Tuli et al., 2007). Customers co-create perceived value-in-use (the solutions) with GES firms and their suppliers and assess firm exchange value in a relational process that includes requirement definition, customisation and integration, deployment and post-deployment (Jaakkola & Hakanen, 2013; Tuli et al., 2007). Co-creating value-in-use with customers enables GES firms to recognise the potentials of the solutions offered through the opportunities to study, develop and verify value-in-use as perceived by customers.

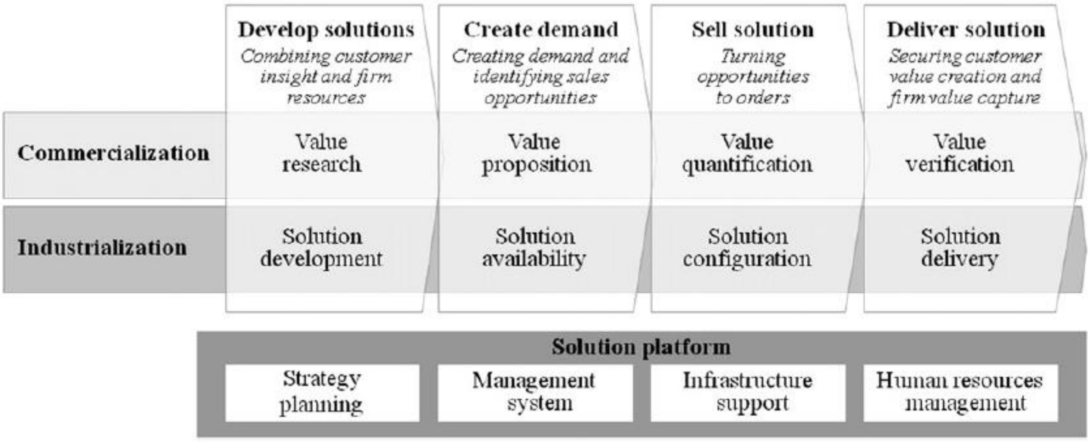


Figure 2-8: Value creation framework for GES businesses

Source: Storbacka (2011, p. 703).

Along with the commercialisation process, GES firms need to develop solution capabilities to industrialise the solutions co-created with customers (Miller et al., 2002). The industrialisation process consists of solution development, availability, configuration and delivery (Storbacka, 2011). The commercialisation and industrialisation processes require a solution platform that facilitates strategy planning, and provides a management system, infrastructure support and human resource management (Storbacka, 2011; Salonen et al., 2018).

Operationally, solution co-creation with customers requires GES firms to clarify their solution creation strategies and link these with solution operations in terms of organisational structure, processes, rewards and people (Galbraith, 2002). Solution creation strategies can be associated with customer-focussed strategies, the scale and scope of solution offerings, the complexity of the integrated solutions, and the solution performance orientations of the firm (Davies, 2004; Galbraith, 2002; Zhang et al., 2016). The solution organisational structure may need a hybrid front-back structure that includes customer-centric solution units and internal operations units to develop valuable solutions (Galbraith, 2002). This hybrid structure requires many processes to link these units together for solution development and fulfilment. Zhang et al. (2016) identify that GES firms organise engineering units in network forms (Kotlarsky et al., 2014). Network organisations provide GES firms with the ability to create solutions effectively in terms of novel solution generation, operational efficiency and flexibility (Galbraith, 2014; Zhang et al., 2016).

Further to customers and GES networks, suppliers are important in providing complementary resources for value-in-use creation of GES firms (Davies et al., 2007; Windahl & Lakemond, 2006). Suppliers include various types, from profit to non-profit organization, e.g. research institutes, universities (Tödtling et al., 2009), or from information to material providers, e.g. consulting, IT firms, and physical service providers (ISG, 2013, Windahl & Lakemond, 2006). Partners/suppliers may collaborate with GES firms in value co-creation projects with customers (Jaakkola & Hakanen, 2013) or in strategic alliances for joint technology development and operational enhancement (Harryson et al., 2008; Morris et al., 2006; Scarbrough & Amaeshi, 2009).

GES value creation and network learning. Research has indicated that GES network learning processes can be used to foster GES value creation in terms of engineering efficiency, flexibility, and innovation (Brady & Davies, 2004; Kotlarsky et al., 2014; Zhang et al., 2016). There are evidences that GES network learning processes can be employed within GES networks with different intra-firm engineering units (Moore & Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016) or solution networks including customers and suppliers (Brady & Davies, 2004; Jaakkola & Hakanen, 2013; Sallonen et al., 2018). GES network learning creates different value, either monetary value through efficiency, flexibility, and innovation (Kotlarsky et al., 2014; Zhang et al., 2016) or non-monetary value such as business innovation, relationship and knowledge or learning (Brady & Davies, 2004; Windahl & Lakemoon, 2006; Hakanen & Jaakkola, 2012).

Although GES network learning is increasingly recognised in inter- and intra-firm network contexts, we do not have a clear understanding on a GES network learning process across customers, suppliers, and engineering units that contribute to GES value creation (Brady & Davies, 2004; Moore & Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016). It is unclear on how customers, suppliers, and intra-firm engineering units contribute to GES network learning and value creation in terms of efficiency, flexibility and innovation (Brady & Davies, 2004; Zhang et al., 2016). The literature on service innovation research has highlighted that knowledge-based service firms can create value through a set of inter-related knowledge acquisition processes with external and internal business actors including knowledge sourcing, knowledge transformation and knowledge exploitation (Birkinshaw & Hansen, 2007; Love, Roper, & Bryson, 2011). However, previous research in this field has mainly focused on network learning and value creation within business services while those for GES remains unexplored. Furthermore, the mechanisms supporting innovation processes are unclear.

It is argued that network learning can only be understood within a network learning episode which clarify learning goals, actors, and interactions (Knight, 2002; Gibb et al., 2016). In the following three sections, literature on GES network learning episodes with customers, suppliers, and intra-firm engineering units is examined based on the framework built in section 2.1. They aim to explore GES network learning drivers, processes, barriers and boundary spanning mechanisms, clarifying the roles of customers, suppliers and intra-firm engineering units and their links within GES network learning and value creation.

2.4. GES Network Learning with Customers and Value Creation

In the solution business research literature, GES network learning with customers and value creation is increasingly being recognized (Brady & Davies, 2004; Jaakkola & Hakanen, 2013; Galbraith, 2014). This section reviews GES network learning with customers and value creation to explore different practices and the links to network learning with suppliers and intra-firm engineering units.

2.4.1. Network Learning Drivers

New technologies and changing customer demands are the main drivers for GES firms to learn with customers (ISG, 2016; Windahl & Lakemond, 2006). Under greater pressure from consumers, businesses and regulators, customers are constantly changing their demands for innovative, efficient and collaborative GES (GVR, 2017; ISG, 2016). Customer demands can be for a new service (Brady & Davies, 2004), new expectations for better operations and technologies (Johnstone et al., 2009), or a new product (Galbraith, 2014). These changing demands require a GES model that delivers customer-focused, outcome-based and high-value solutions with partnership relationships, rather than the traditional model based on cost, scale and skills advantages (ISG, 2016; Davies et al., 2007). Firms are forced to collaborate with customers to co-create GES solutions that customers want, and at the same time enhance GES performance and value creation (Windahl & Lakemoon, 2006; Jaakkola & Hakanen, 2013).

2.4.2. Network Learning Processes

In general, GES firms collaborate with customers through a relationship learning process. This process is “a joint activity between a supplier and a customer in which the two parties share information, which is then jointly interpreted and integrated into a shared relationship-domain-specific memory” (Selnes & Sallis, 2003, p. 80). It comprises four stages: requirement definition, customization and integration, deployment, and post-deployment support (Tuli et al., 2007). Customers collaborate to reach a mutual agreement with GES firms on operational goals, resource investment, information and risk sharing, rewards and responsibilities, and joint problem solving (Soosay et al., 2008). In collaborative relationships, customers and GES firms to some extent jointly make decisions, maintain standardised operations, and share knowledge, processes and activities and measurement of their performance (Barratt, 2004; Soosay et al., 2008).

GES firms may have to “take over the risks and responsibilities for performing activities previously handled in-house by their customers and create innovative ways for components to work together as a whole to increase the overall value of the solution for the customer” (Davies, 2004, p. 733). They may collaborate with many similar customers in formal and informal networks to develop new products and technologies (Galbraith, 2014; Tidd, 2005). Customers contribute to relationship learning by customer process adaptiveness, political counselling and operational counselling (Tuli et al., 2007). Customer adaptiveness refers to the willingness to adapt business processes with the solution offerings of GES firms. Customers may need to counsel GES firms on their political and operational systems so that they are able to generate valuable solutions to their business problems (Tuli et al., 2007).

Knowledge creation and GES efficiency. GES firms co-create process-oriented solutions with customers in projects (Brady & Davies, 2004; Windahl & Lakemoon, 2006). This can be the case when GES firms co-create a service that they have never provided before with a new customer (Brady & Davies, 2004). Firms form GES project teams to tailor their existing products and/or services through the eyes of customers to create new solutions that fit into customer organisational processes (Galbraith, 2002; Hakanen & Jaakkola, 2012; D. Miller et al., 2002). The relationship learning process may include customer task allocators, who proactively decide, select and allocate tasks to the service provider. Customer staff play the roles of enablers, assisting the service provider's consultants in completing the assigned project tasks (Breidbach & Maglio, 2016). By co-creating solutions with customers and suppliers in projects, GES project teams create new knowledge that can be reused to enhance service performance in later projects and thus create GES efficiency value (Brady and Davies, 2004, Salonen et al., 2018).

Knowledge reuse for innovation. GES firms can collaborate with particular customers in the same industry to transform their existing technologies into new products, processes and technologies as solutions for customers (Galbraith, 2014; Tidd, 2005). The innovation research literature indicates that customers and service providers jointly develop new products, services and technologies in various relationships, such as supply chains, joint project development and consortiums, in which different firm engineering groups share knowledge and perspectives with customers on a technological topic, new product or process concept (Chiesa, 1998; Tidd, 2005; Todtling et al., 2009). Breidbach & Maglio (2016) identify that in co-creating output engineering solutions, customers play the roles of governors and quality controllers, while the firm engineering teams are the conductors and experts. In solution co-creation processes, customers provide information which helps GES firms to transform their existing products/services and to verify the quality of the solutions offered (Breidbach & Maglio, 2016). The results of relationship learning are new products, processes and technologies that are perceived as valuable to customers (Galbraith, 2014).

2.4.3. Customer Knowledge Boundaries

GES network learning with customers deals with customer knowledge boundary challenges. GES firms offering horizontal engineering solutions[4] or process-oriented solutions may collaborate with customers in various industries and co-create solutions within customer organizations through the eyes of the customers (Brady & Davies, 2004; Galbraith, 2002; Breidbach & Maglio, 2016). Those GES firms offering industry-specific vertical solutions may need to satisfy the needs of customers in several related industries or a single one for the creation of product-based solutions (Galbraith, 2002, 2014; Johnstone et al., 2009; Turner & Keegan, 2001). The greater the number and range of customers that GES firms collaborate with to co-create engineering solutions, the greater the resources they need to invest in interacting with customers, and the less efficient the operations will be (Barratt, 2004; Chase, 1981; D. Miller et al., 2002). Diverse customers in various industries often focus on their own businesses and have no interest in GES firm operations, which create various knowledge boundaries and hinder knowledge transfer and learning (Hakanen & Jaakkola, 2012; Ayala et al., 2017).

The solution business research literature emphasises the importance of customer interest in learning and value co-creation with GES firms (Cagliano et al., 2006; Hakanen & Jaakkola, 2012; Malhotra et al., 2005; Wiengarten et al., 2010). Research has pointed out that not all customers are willing to adopt the solutions offered by firms and to share information, which cause difficulties for GES network learning (Cornet et al., 2001; Hakanen & Jaakkola 2012). Without customer cooperation in sharing information about, for example, their goals, needs and expectations, it is challenging for GES firms to clarify customer problems, the scale of solutions, and the degree to which customers wish to analyse their problems (Hakanen & Jaakkola, 2012; Mathieu, 2001). Therefore, firms should be careful in selecting customers for learning in GES (Cornet et al., 2001). According to Cornet et al., to identify, create and capture value with customers, GES firms should selectively collaborate with customers who have strong relationships, high motivation to innovate, possible short-term benefits from the solution offerings, shared problems with many other customers, and the potential for capability development.

---

[4] Galbraith (2002) defines horizontal solutions as generic solutions which can be applied across many diverse industries, while vertical solutions are industry-specific.

2.4.4. Boundary Spanning Mechanisms

Boundary spanners. The solution business literature identifies a variety of boundary spanners who engage in transferring, translating and transforming different knowledge domains between GES firms and various customers. Central strategic taskforce groups or project teams set up by the headquarters are found to be the boundary spanners of manufacturing firms who wanted to "servitise" their existing manufacturing business (Brady & Davies, 2004; Windahl & Lakemond, 2006). The project teams are often decentralised and autonomous from the rest of the manufacturing networks. One example is the Turnkey Project Group in the case of Ericsson (Brady & Davies, 2004). This taskforce group is an example of an expert group which was strategically set up to create new services for a new turnkey project market. The strategic taskforce independently collaborates with customers and internal and external suppliers to create new services for the customers and for the firm (Brady & Davies, 2004). Eventually, when service becomes the main business, Ericsson's expert groups are the main boundary spanners who capture, interpret and disseminate knowledge across projects.

Breidbach & Maglio (2016) identify different proactive and reactive roles of boundary spanners for value co-creation in either process-oriented or output-oriented service projects. In process-oriented services, boundary spanners can be the proactive facilitators who independently trigger tasks to both customers' task allocators and enablers and internal performers, who reactively respond to customer requests. In output-oriented services, boundary spanners can be proactive conductors who independently trigger tasks to customers' governors and quality controllers, while collaborating with internal engineering experts to reactively respond to customer requests.

In the case of the IBM company, Galbraith (2014) found that it had established independent research centres to collaborate with lead customers in a specific industry in order to develop new applications. For example, IBM established an Insurance Research Centre (IRC) in La Hulpe, Belgium, who reports directly to IBM research labs and insurance industry group. At IRC, IBM research engineers work with forty lead customers to develop insurance application architecture for the immigration of legacy systems to the internet and to the cloud. The development of insurance application architecture also involves IBM hardware, software and services units, together with those of partners, to create solutions.

Boundary spannning tools. The solution business literature identifies various boundary spanning tools that GES firms employ to facilitate knowledge sharing and learning with customers. Common platforms are important to facilitate communication and knowledge sharing for value co-creation across GES providers and diverse customers (Storbarka, 2011). New technology, products and process concepts can be the platforms to connect customers and GES firms for value co-creation (Tidd, 2005; Galbraith, 2014). In value co-creation projects, defining a common engineering requirement is important to direct the collaboration between different customers and the GES provider, and should be the innitial step in relationship learning with customers (Tuli et al., 2007; Windahl & Lakemond, 2006). Research indicates that clear engineering requirements with an anticipated working procedure across learning actors facilitate network learning between diverse learning actors (Scarbrough & Amaeshi, 2009; Windahl & Lakemond, 2006). Common information systems are useful in obtaining real-time updates of the co-creation process (Johnstone et al., 2009; Kristjánsson et al., 2012).

Learning coordination. Coordination mechanisms for relationship learning with customers have been widely discussed in the industrial marketing management literature. Project personalisation supported by communication technologies is common in solution co-creation with customers (Breidbach & Maglio, 2016). The interaction mechanisms vary depending on the solution outcomes and their development processes. In process-oriented engineering solutions, Windahl and Lakemond (2006) explore the process through which customers and service provider discuss both the commercial and technological aspects of a project at an early stage and develop product and business approaches in parallel. The success of a project is determined by the stable involvement of dedicated individuals from start to finish and the strong support of top management (Jaakkola & Hakanen, 2013). Moreover, the strength of the relationships affects the quality of the relationship learning (Windahl & Lakemond, 2006). Interactions often follow systematic activities, mapped processes, and straightforward integration due to the clear division of solution components (Jaakkola & Hakanen, 2013). Interactions are intensive at all levels of employees within GES firm and customer divisions (Breidbach & Maglio, 2016).

The frequency and patterns of interactions are less intensive in output-oriented engineering services (Breidbach & Maglio, 2016). In these, most interactions occur at top management level, while employees on both sides work independently, with little interaction. Negotiation meetings, technical and business requirement workshops and co-team operations with customers, enabled by digital technologies, are common team coordination mechanisms in projects (Helander & Möller, 2007).

When GES firms co-create technologies and products which are new to customers and the firms, personalisation mechanisms are not neccesarily formal. In fact, coordinating customers in developing a new product or technology for an industry is more flexible and informal. Customers and GES firms may be informally coordinated within consortia, networking or joint research and development (R&D) (Scarbrough & Amaeshi, 2009; Storbacka, 2011; Tidd, 2006). These informal coordination mechanisms allow GES firms and customers to share risks and facilitate innovation effectively (Chiesa, 1998). In the case of IBM, for example, the company formed a consortium with 40 leading insurance companies to develop a new technology which is new to the insurance industry (Galbraith, 2014).

Recent research has found that platform-based modular solution designs are mechanisms which can integrate learning with various customers (Salonen et al., 2018). Customer solutions are coordinated into solution components and gradually developed into modules which are stored within a corporate platform for learning.

Knowledge governance. Customer openness and engagement in service operations are essential for engineering solution creation (Hakanen & Jaakkola, 2012; Tuli et al., 2007). Customers should be willing to adapt their processes to the co-created solutions, share information, and help GES firms to understand customer business, political and operational systems, and assign reliable employees to engage in service operations (Breidbach & Maglio, 2016; Hakanen & Jaakkola, 2012). To encourage customers to share knowledge, their selection is key to the success of the knowledge creation of GES firms; it is suggested that they select customers with strong relationships, under pressure of innovation, with the potential to gain short-term higher margins, to develop reusable solution modules, and with geographical dispersion for capability building (Cornet et al., 2001; Brady & Davies, 2004; Storbarka, 2011). Research has also found that GES firms can use social structure and power mechanisms, such as requirement framing and network positioning, to enhance common understanding and actions (Peters et al., 2016; Windahl & Lakemond, 2006) or relational mechanisms such as encouragement of reciprocal communication, the building of trust, and reputation (Capaldo, 2014; Mathieu, 2001).

For individuals who engage in both customer and firm interactions, socialisation tactics may be necessary to facilitate knowledge sharing and contributions on both sides (Husted & Michailova, 2009). Incentives for knowledge sharing, and top management support and commitment, are required to facilitate knowledge reuse and creation, for individuals in projects as well as in network learning (Goffin et al., 2010; Osterloh & Weibel, 2009). Furthermore, customers are also important in developing knowledge by sharing their experiences and feedback on service offerings (Tuli et al., 2007).

Technological mechanisms. Digital technologies play a cental role in facilitating GES network learning with customers. Recent research has found that GES firms use digital technologies to foster remote communication, inter- and intra-firm connection, information sharing, and learning (Cenamor et al., 2017; Zhang et al., 2016). Many firms have adopted flexible information systems with open interfaces that allow them to connect with clients, facilitate remote communication, and monitor service operations (Baines & Lightfoot, 2013; Breidbach & Maglio, 2016). Digital technologies enable GES firms and customers to share in order to create multiple modular solution platforms that promote solution flexibility, efficiency and innovation (Cenamor et al., 2017; Eloranta & Turunen, 2016) and to enhance digital learning through simulation and analytic tools (Montavon et al., 2013; Zhang et al., 2016).

2.4.5. Values

GES firms collaborate with customers to co-create new use value or new solutions that meet changing customer demands (Windahl & Lakemond, 2006; Jaakkola & Hakanen, 2013). The new use value can be a new process-oriented and/or product-oriented solution (Breidbach & Maglio, 2016). By creating solutions through the eyes of customers, GES firms capture exchange value (Stobarka, 2011; Jaakoola & Hakanen, 2013). Research has shown that GES firms also capture other non-monetary values, such as business innovation, knowledge and relationships in collaboration with customers (Brady & Davies, 2004; Hakanen & Jaakkola, 2012; Galbraith, 2014).

2.4.6. A GES Network Learning Episode with Customers and Value Creation

From the literature review, a framework can be constructed to understand GES network learning practices with customers that contribute to value creation (Figure 2-9). The framework include three stages: network learning (NL) drivers, processes and created values.

Network learning is driven by changing customer needs and demands. The processes involve horizontal or vertical customers, and various engineering units such as project teams or research groups. They engage in knowledge creation and reuse for innovation processes, in which engineering units need to cope with diverse customers with different interests, interpretations and languages. Boundary spanning mechanisms are adopted to eliminate knowledge boundaries and to facilitate network learning processes. The outcomes of network learning with customers are primarily new use values or solutions that satisfy changing customer needs and demands. Other non-monetary values can be customer relationships or new knowledge.

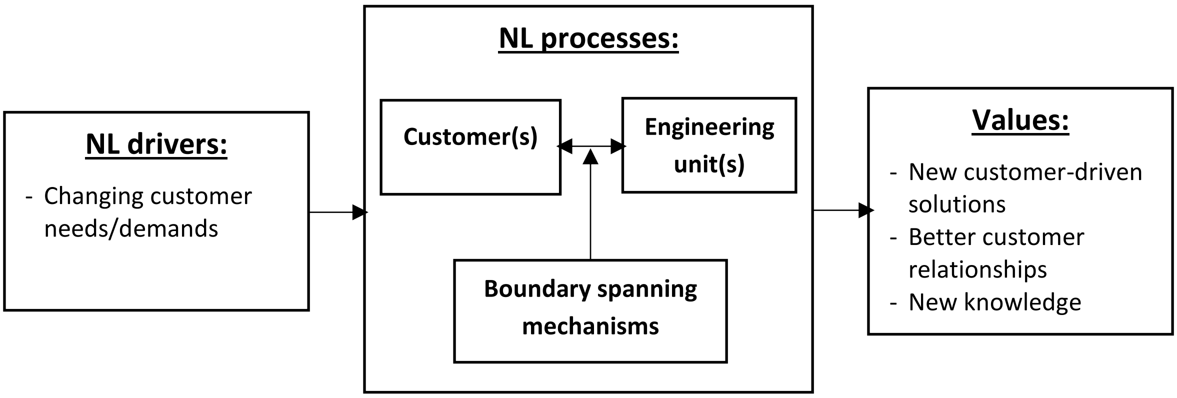


Figure 2-9: GES network learning with customer(s) and value creation

2.4.7. Links to Supplier-Focused and Intra-Firm Network Learning and Value Creation

GES network learning with customers contributes to value creation by creating customer-driven solutions, capturing new knowledge, and building relationships with customers (Windahl & Lakemoon, 2006; Jaakkola & Hakanen, 2013; Galbraith, 2014). Although network learning with customers creates knowledge that can be reused in other projects for efficiency (Brady & Davies, 2004; Salonen et al., 2018), the process linking customer-focused learning to intra-firm network learning is unclear. The relations between network learning with customers and supplier-focused network learning are mainly highlighted within the context of a solution project, where suppliers may engage with the project teams to co-create solution with customers (Brady & Davies, 2004; Jaakkola & Hakanen, 2013). It is not clear how customer-focused network learning affects supplier-focused network learning and value creation, and vice versa. Although the literature shows that GES firms employ different boundary spanning mechanisms for customer-focused network learning, they are mainly employed to bridge the knowledge gaps between customers and the GES firms in their solution projects (Brady & Davies, 2004; Jaakkola & Hakanen, 2013; Galbraith, 2014). In the following section, the literature on GES network learning with suppliers is reviewed to further explore the role of suppliers in GES network learning and value creation, and its links with customer-focused and intra-firm network learning.

2.5. GES Network Learning with Suppliers and Value Creation

It has been increasingly recognised that suppliers play a key role in contributing to GES network learning and value creation (Windahl & Lakemoon, 2006; Coghlan & Coughlan, 2014; Salonen et al., 2018). This section examines a GES network learning episode with suppliers to explore supplier-focused network learning practices and their contribution to value creation.

2.5.1. Network Learning Drivers

GES firms collaborate with various sub-tier suppliers and technology partners to create solutions for customers (Brady & Davies, 2004; Windahl & Lakemond, 2006; Coghlan & Coughlan, 2014). By integrating suppliers into solution networks, GES firms exploit their capabilities and are thus able to fulfil customer demands (Windahl & Lakemond, 2006; Davies et al., 2007, Jaakkola & Hakanen, 2013). The industrial "clockspeeds"[5] have been accelerating and driving firms to collaborate with competent suppliers to co-develop their business and to survive (Fine, 1998; Teece et al., 1997; Meijboom et al., 2007). New technologies give rise to innovation and therefore create uncertainty, new competitors, and technological changes (Fine, 1998). Under these hypercompetitive conditions, firms needs to collaborate with various suppliers to have complementary capabilities and facilitate innovation (Childerhouse & Towil, 2011; Meijboom et al., 2007).

---

[5] Various evolution rates in different industries (Fine, 1998).

2.5.2. Network Learning Processes

In general, supplier-focused network learning is conducted within two main processes: backward and forward integration (Cagliano et al., 2006; Frohlich & Westbrook, 2001; Trent & Monczka, 1998). While forward integration processes facilitate physical flows of deliveries, relating to the coupling of production systems and purchasing practices, backward integration processes aim at coordinating information and data flows from GES firms to suppliers for activity adjustment and operational improvement (Cagliano et al., 2006).

GES network learning with suppliers starts with backward integration processes, in which GES firms directly receive requirements from customers and communicate them to suppliers for supplier solution production (Jaakkola & Hakanen, 2013; Mathieu, 2001; Windahl & Lakemond, 2006). Forward integration processes follow, and may involve the customers of GES firms in evaluating the production results (Jaakkola & Hakanen, 2013; Mathieu, 2001). Suppliers may sometimes be incorporated in teams with GES firms to work with customers (Hakanen, 2014; Mathieu, 2001). In these knowledge exchange processes, GES firms play the role of integrators, while suppliers are the respondents (Davies, Brady, & Hobday, 2007; Windahl & Lakemond, 2006). Integrated information technologies are important for information sharing and learning (Childerhouse & Towill, 2011; Frohlich & Westbrook, 2001). Shared information may include design and development, process management, planning and control, technology adaptation, resources and risks (Bagchi & Skjoett-Larsen, 2003). Two main processes of GES network learning with suppliers are discussed in the literature.

Knowledge creation. Sub-tier suppliers can co-improve operations and products with GES firms to enhance GES firm solution performance to fit customer requirements (Windahl & Lakemoon, 2006; Davies, 2007). Knowledge created can be supplier-enhanced service performance (Coghlan & Coughlan, 2014) or new product co-development, e.g. new software that combines with GES firm solutions (Windahl & Lakemond, 2006). Suppliers may need to engage with customers to co-create supplier solutions effectively (Jaakkola & Hakanen, 2013). Any knowledge co-created can be reused across other suppliers and/or intra-firm units and thus enhance firm efficiency (Dyer & Nobeoka, 2000).

Knowledge reuse for innovation. GES firms may combine supplier technologies to transform their own technologies and develop new products for customers. In these situations, suppliers are integrated in various ways to help GES firms to transform their existing products and services. Chiesa and Manzini (1998) identify a variety of integration forms that GES firms can adopt to reuse their existing knowledge with suppliers (see descriptions in Table 2-2).

Table 2-2: Organizational modes for technological collaboration

Mechanism	Description
Acquisition	A company acquires another company in order to access a technology (or technological competence) of interest.
Educational acquisition	A company recruits experts in a certain technological discipline or acquires a smaller company, to obtain people familiar with a certain technological or managerial competence.
Merger	A company merges with another one that possesses a technology (or technological competence) of interest, and a new company emerges from the two existing companies.
Licensing	A company acquires a license for a specific technology.
Minority equity	A company buys an equity in the source organization in which a technology (or technological competence) of interest is embedded, but does not have management control.
Joint venture	A company establishes a formal joint venture with equity involvement and a third corporation is created, with a specific objective of technological innovation.
Joint R&D	A company agrees with others to jointly carry out research and development on a specific technology (or technological discipline), with no equity involvement.
R&D contract	A company agrees to fund the cost of R&D at a research institute, university or small innovative firm, for a specific technology.
Research funding	A company funds exploratory research at a research institute, university or small innovative firm to pursue opportunities and ideas for innovation.
Alliance	A company shares technological resources with other companies in order to achieve a common objective of technological innovation (without equity involvement).
Consortium	Several companies and public institutions combine their efforts in order to achieve a common objective of technological innovation (without equity involvement).
Networking	A company establishes a network of relationships, in order to keep up to pace with a technological discipline and to capture technological opportunities and evolutionary trends.
Outsourcing	A company externalizes technological activities and then simply acquires the relative output.

Source: Chiesa and Manzini (1998, p.200)

Each relationship mechanism for solution co-creation with suppliers has different characteristics in terms of the level of integration, specific asset, formality, focal firm control, set-up time and flexibility (Table 2-3). M&A is the most integrated and formal mode of knowledge reuse. Joint ventures and alliances may be formal or informal, depending on the levels of ownership structure and the contractual agreement terms the parties impose on the collaboration. Outsourcing and R&D contracts are the most flexible forms of knowledge reuse, with low levels of integration, control and impact on firms.

Table 2-3: Characteristics of GIN modes

Organizational mode	Level of integration	Level of equity	Level of formality	Impact on the firm	Time horizon	Control	Setup time/cost	Flexibility
Acquisitions & mergers	Highest	Highest	High	Highest	Long	Highest	Highest	Low
Joint venture; minority equity	Fairly high	Fairly high	Low/ high	Fairly high	Fairly long	Fairly high	Fairly high	Medium
Alliances; networking; joint R&D	Medium	Medium	Low/ high	Medium	Medium	Medium	Medium	Fairly high
Outsourcing; research contracts	Low	Low	High	Low	Short	Low	Low	Highest

Source: Adapted from Chiesa and Manzini (1998).

2.5.3. Supplier Knowledge Boundaries

GES firms collectively select and integrate diverse suppliers into their GES to co-create solutions with customers (Windahl & Lakemond, 2006; Jaakkola & Hakanen, 2013). Past research has identified two types of suppliers that GES firms integrate with for learning purposes. The first type contains vertical or sub-tier suppliers within business networks, which supply raw materials and collaborate with GES firms for incremental innovation (Coghlan & Coughlan, 2014). They may share a common interest in co-improving processes and products and rely on a high degree of collaboration rather than an arm’s length relationship (Coghlan & Coughlan, 2014; Windahl & Lakemond, 2006). Collaborative processes require resource investment and commitment, as well as a learning culture in which GES firms, to some extent, align activities, processes, decision making, and performance measurement with suppliers (Barratt, 2004). For continuous improvement, GES firms should maintain standardised operations, joint planning and investing, and share knowledge and processes, synchronising and interfacing with suppliers (Soosay et al., 2008). Information and information technologies should be the same or compatible, e.g. common EDI, ERP, CAD/CAM and CPFR (Bagchi & Skjoett-Larsen, 2003).

The other suppliers are horizontal, encompassing both similar and/or dissimilar strategic actors at the same level of the supply chain, but combining their complementary capabilities to purposively develop technologies and/or solutions to fulfil customer demand (Dittrich & Duysters, 2007; Powell & Grodal 2005). They may include engineering service providers, software partners, business consultants or research organizations (Windahl & Lakemond, 2006; Zhang et al., 2016). Suppliers provide different products and services such as technical support, maintenance software and engineering services (Jaakkola & Hakanen, 2013). Diverse horizontal suppliers create knowledge boundaries because they operate different businesses and may not have the same interests as GES firms (Davies, 2004; Matthyssens & Vandenbempt, 2008; Ayala et al., 2017). GES firms need to have different mechanisms to guide and facilitate supplier knowledge sharing and learning (Coghlan & Coughlan, 2014).

2.5.4. Boundary Spanning Mechanism

Boundary spanners. In collaboration with sub-tier suppliers, GES firms may need to employ a decentralised division for capturing local supplier knowledge (Coghlan & Coughlan, 2014; Dyer & Nobeoka, 2000; Moore & Birkinshaw, 1998). Centralised functions only assist to capture and disseminate knowledge across multiple dispersed suppliers (Dyer & Nobeoka, 2000). In addition to formal division, voluntary and problem solving teams/taskforces can be effective mechanisms for capturing and disseminating tacit knowledge that addresses common problems across supply networks (Coghlan & Coughlan, 2014; Dyer & Nobeoka, 2000).

In technology development, research has found that the employment of researchers and/or experienced engineers is important for enhancing the knowledge interactions of GES firms with research and engineering suppliers (Tödtling et al., 2009). It is argued that these people have a high degree of absorptive capacity to assimilate new knowledge and disseminate it across GES networks (Moore & Birkinshaw, 1998). Galbraith (2014) studied IBM, and found that the company had established independent global research centres in which engineers collaborate not only with lead customers and internal engineering units, but also with external suppliers to develop new technology for a specific industry.

Boundary spanning tools. There are many tools that GES firms use to facilitate knowledge sharing and exchange with suppliers. Coghlan and Coughlan (2014) show that common topics or problems across supply chains can be used to direct action learning for operational innovation across supply network members. Peters et al. (2016) argue that common frameworks play a key role in facilitating not only common understanding, but also actions across different suppliers in solution projects. Recent research has found evidence that GES firms use digital solution platforms to integrate suppliers' solutions, thereby enhancing the development of not only core GES firm modules, but also peripheral modules that are associated with suppliers' capabilities (Salonen et al., 2018). These platforms, along with other mechanisms, enable GES firms to capture relationship learning with various strategic suppliers for future reuse (Eloranta & Turunen, 2016).

Learning coordination. There are many ways to coordinate suppliers' knowledge. Supply associations, multi-lateral and bilateral forums, seminars and workshops, supplier clusters, supplier learning teams, and supplier visits are among the mechanisms that GES firms can use to capture supplier knowledge for performance improvement (Chai et al., 2003; Coghlan & Coughlan, 2014; Dyer & Nobeoka, 2000). For supplier technology co-development in GES projects, GES firms coordinate supplier knowledge systematically with clearly mapped processes, divisions of solution components, and transaction-based relationships (Windahl & Lakemond, 2006; Jaakkola & Hakanen, 2013).

Recent studies have increasingly recognised the role of modularisation as an effective method to coordination knowledge created with suppliers (Cenamor et al., 2017; Salonen et al., 2018). GES firms need to have the ability to modularise relationship learning with suppliers into modules which are linked with their core modules (Salonen et al., 2018). Effective modularisation relies on top management support, strategic partner selection, integrative platform architecture, and interfaces that facilitate integration (Salonen et al., 2018).

Knowledge governance. Peters et al. (2016) note that the framing of understanding across the supply chain within a project enhances common understanding, knowledge sharing and creation. They also demonstrate that social mechanisms such as expertise respect, trust and protection, as well as network position development, are effective mechanisms to develop social powers that facilitate knowledge sharing and learning. Similarly, Scarbrough and Amaeshi (2009) argue that partner selection, scope of collaboration and trust are important to ensure effective knowledge sharing and creation in open innovation networks and to avoid exchange hazards among network members. Husted and Michailova (2009) recommend that different socialisation tactics should be adopted in the context of R&D collaboration to encourage different types of R&D employees with different interests to share knowledge. Furthermore, motivation solutions are effective in enhancing creativity and knowledge creation across engineering suppliers (Osterloh & Weibel, 2009). IP protection and transparency are also important in supplier collaborations. Shared vision, with detailed legal and business practices, should be mutually agreed between GES firms and their suppliers (Salonen, Rajala, & Virtanen, 2017).

Dyer and Nobeoka (2000) found that structural mechanisms such as routines (e.g. association meetings, site visits, access to network knowledge, and an open culture are useful in building the identity of the knowledge sharing supply network. However, the focal firms may need to create formal and informal rules for the network relating to the rewards, sanctions, procedures and measurement of knowledge sharing and learning across the supply network (Capaldo, 2014; Dyer & Nobeoka, 2000). These mechanisms are necessary to develop social capital, such as trust, reputation and network culture (Capaldo, 2014), which require a long period of joint working to develop (Coghlan & Coughlan, 2014).

Technological mechanisms. The literature emphasises global portals as knowledge centres for global operations with suppliers (Kristjánsson, Helms, & Brinkkemper, 2012b). They are also useful for knowledge sharing across diverse suppliers within technology development projects (Scarbrough & Amaeshi, 2009). Effective customisation across partners can be achieved through digital technologies and their flexibility for updating additional applications, strengthening communication and knowledge flows with key partners, and creating inter-organisational interfaces for network learning (Salonen et al., 2017).

2.5.5. Values

The final outcomes of collaboration with suppliers are the solutions that customers want (Windahl & Lakemond, 2006; Davies et al., 2007; Jaakkola & Hakanen, 2013; Galbraith, 2014). GES firms select suppliers with clear predefined roles in solution co-creation with customers (Davies et al., 2007; Jaakkola & Hakanen, 2013). Suppliers contribute to solution creation by providing their complementary products and services for GES operations (Coghlan & Coughlan, 2014; Windahl & Lakemond, 2006) or complementary technology or service knowledge for innovation (Dittrich & Duysters, 2007; Powell & Grodal 2005). Research also indicates that collaborating with suppliers generates new knowledge and strengthens supplier relationships (Salonen et al., 2018; Coghlan & Coughlan, 2014; Windahl & Lakemond, 2006).

2.5.6. A GES Network Learning Episode with Suppliers and Value Creation

A framework of GES network learning with suppliers has been created based on the literature review (Figure 2-10). The framework include three stages: network learning (NL) drivers, processes and values.

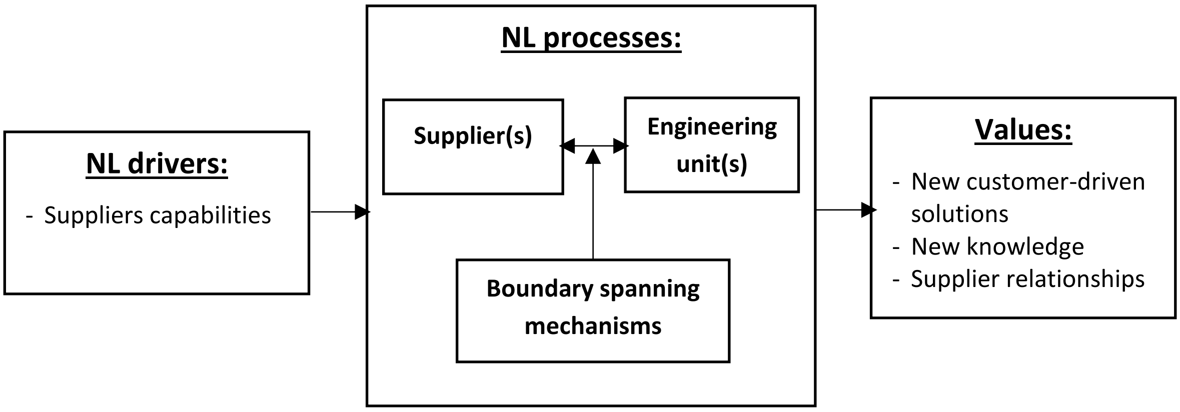


Figure 2-10: GES network learning episode with supplier(s) and value creation

Network learning drivers refer to the supplier capabilities that may contribute to enhancing the solution creation performance of firms. The network learning processes involve sub-tier suppliers and technology partners who collaborate with different intra-firm engineering units in their knowledge creation and knowledge reuse for innovation. In these processes, diverse suppliers with different interests, interpretations and languages create various knowledge boundaries that require boundary spanning mechanisms to facilitate network learning processes. The outcomes of network learning with suppliers are primarily new use value or solutions for changing customer needs and demands. Other non-monetary value can be obtained, such as customer relationships and new knowledge.

2.5.7. Links to Customer-Focused and Intra-Firm Network Learning

Collaborating with suppliers helps GES firms to create solutions more effectively and to generate new knowledge that enhances firm performance (Coghlan & Coughlan, 2014; Brady & Davies, 2004). Suppliers can be sources of knowledge and combine with GES firm technologies to generate new products and technologies that benefit customers (Tidd, 2006; Galbraith, 2014). Although network learning with suppliers contributes to firm performance enhancement and may facilitate customer-focused network learning within a solution project (Windahl & Lakemoon, 2006; Jaakkola & Hakanen, 2013), the relations between supplier-focused network learning and customer-focused and intra-firm network learning are unclear. GES firms employ various boundary spanning mechanisms to enhance supplier knowledge transfer; the literature shows that they mainly focus on eliminating supplier knowledge boundaries without clear evidence of their links to network learning with customers and intra-firm engineering units. In the following section, the literature on GES network learning with intra-firm engineering units is reviewed to further explore the role of engineering units in GES network learning and value creation and their links to customer-focused and suppler-focused network learning.

2.6. GES Network Learning with Intra-Firm Engineering Units and Value Creation

Intra-firm engineering units are important in providing knowledge for operation efficiency, flexibility and innovation (Kotlarsky et al, 2014; Zhang et. al., 2016; Johnstone et al., 2009). Engineering units can be projects (Kotlarsky, Scarbrough, & Oshri, 2014), engineering centres (Zhang et al., 2016), and individual engineers (Criscuolo & Narula, 2007). In this section, the literature on GES network learning with intra-firm engineering units is reviewed to examine its practices and connection to inter-firm network learning and value creation.

2.6.1. Network Learning Drivers

Engineering units are increasingly dispersed and there are knowledge gaps between them that need to be bridged to enhance operational performance and innovation (Moore & Birkinshaw, 1998; Kotlarsky et al., 2014). In the GES industry, competitive advantage is determined by a firm’s capability to transfer intangible knowledge embedded within different globally dispersed engineering units from country to country (Kogut & Zander, 1993; Moore & Birkinshaw, 1998). GES network learning with engineering units economises knowledge sharing between them (Hansen, 2002) and helps transfer intangible knowledge across dispersed engineering units (Malhotra & Morris, 2009; Kotlarsky et al., 2014). There are two ways in which network learning fosters knowledge transfer and sharing and enhances engineering performance, either through knowledge reuse or creation (Kotlarsky et al., 2014; Zhang et al., 2016).

2.6.2. Network Learning Processes

Knowledge reuse. GES firms can exploit knowledge from different project teams who co-create new services with customers (Brady & Davies, 2004; Kotlarsky et al., 2014). Relationship learning in one project can be captured, codified and reused in other projects (Kotlarsky et al., 2014; Salonen et al., 2017). The processes of capturing relationship learning with customers may start during or at the end of the relational learning processes within projects (Goffin et al., 2010; Salonen et al., 2018). Capturing relationship learning across projects involves a variety of knowledge codification and personalisation processes (Goffin et al., 2010).

Brady and Davies (2004) show that learning can be transferred across project teams to enhance firm project capabilities (Figure 2-11). Network knowledge created with customers and suppliers in projects is captured into organisational memory and reused in other projects to reduce efforts and cost. These two network learning processes can be implemented in parallel in GES operations (Goffin et al., 2010; Kotlarsky et al., 2014). Although Brady and Davies indicated a link between projects and business learning, their study emphasises the role of inter-project learning for business innovation from manufacturing to service, without elaborating GES network learning processes and mechanisms. It is unclear about a GES network learning process across customers, suppliers and GES firms that creates new services for firms.

The knowledge transfer of firms across similar engineering sites has been widely discussed. Best practices in one manufacturing site may be recognised and transferred to other sites (Chai et al., 2003), while knowledge created in one R&D centre can be documented and reused across other R&D centres (Hoegl & Schulze, 2005). There are centres of excellence whose knowledge is used by others (Criscuolo & Narula, 2007; Reger, 2004).

Knowledge reuse for GES is selective and frequently related to idea reuse rather than application of the entire knowledge components into diverse service project contexts (Ettlie & Kubarek, 2008; Fruchter & Demian, 2002; Tidd & Hull, 2006). To exploit existing knowledge in a new project, its abstract dimension is useful for generating new solutions for clients (Kotlarsky et al., 2014; Majchrzak et al., 2004). The context dimension entails experiences that can be adapted into new situations (Argote & Miron-Spektor, 2011; Fruchter & Demian, 2002; Kotlarsky et al., 2014; Markus, 2001).

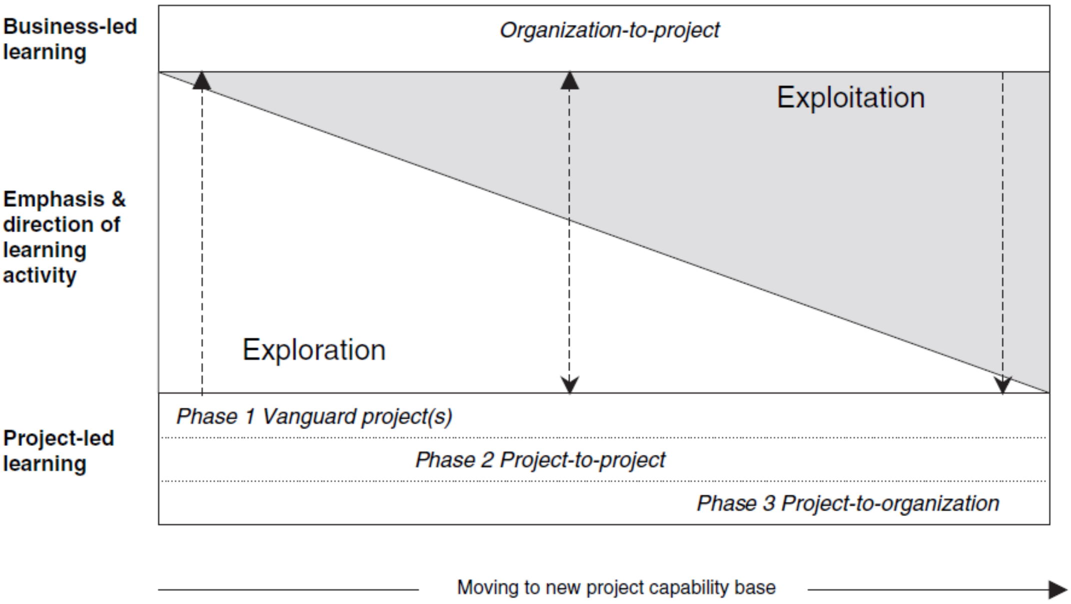


Figure 2-11: From project learning to network learning

Source: Brady and Davies (2004)

Knowledge creation. The literature on R&D networks indicates that the knowledge creation process within intra-firm engineering centres involves the coordination processes of network members (Nonaka, 1994; Reger, 2004). These processes are diverse, varying between the formal, hybrid and informal, to internal market processes (Criscuolo & Narula, 2007; Reger, 2004). By coordinating different R&D centres for learning, GES firms create new products that address customer problems (Hoegl & Schulze, 2005; Zhang et al., 2016). Details of how GES firms coordinate engineering centres for knowledge creation is discussed in the learning coordination context in the following section.

2.6.3. Intra-Firm Engineering Unit Knowledge Boundaries

Network learning barriers. Knowledge creation and reuse across different engineering units face many challenges relating to engineering unit differences and the complexity of engineering knowledge. Engineering service units[6] are diverse and operate in an integrated manner (ISG, 2013; Zhang et al., 2016; Malhotra & Morris, 2009). Manufacturing engineering networks may be either hosting or active networks, which have a medium to high degree of centralised communication, innovation and people mobility (Vereecke et al., 2006). These networks are globally coordinated manufacturing plants linked to geo-

---

[6] See engineering service activities in table 2-1 for more details of engineering operations units.

integrated value-added chains or plants for global product development (Shi & Gregory, 1998; Vereecke et al., 2006).

Research on the international R&D networks of global engineering firms has shown that global R&D firms have restructured their R&D functions into global centres of excellence[7] to minimise the cost of learning (Reger, 2004); these centres are distributed and decentralised globally based on their capabilities (Von Zedtwitz et al., 2004). The centres are highly internationalised and have global responsibility for technology and product development (Criscuolo & Narula, 2007); the global network structures assist firms to enhance global synergy and learning across many locations (Gassmann & Von Zedtwitz, 1999, Criscuolo & Narula, 2007). Birkinshaw (2002) identified three types of R&D centre in terms of the nature of their knowledge assets, the attributes of the centres, the R&D centre mandate, and network organizational structures (Table 2-4). It is noted that the more tacit the knowledge, the more autonomous and less integrated the R&D centres are.

Table 2-4: Characteristics of R&D centres in global firms

R&D network	Self-contained R&D centre	Modular R&D centre	Home-based R&D centre
Nature of knowledge			
Observability (explicit)	High	Low	Low
Mobility (embedded)	Low	High	Low
Role of centres	Unique role: no other centres with similar capability	Non-unique role: there may be other centres with similar capability	Unique role
Form of specialisation	Vertical specialisation	Horizontal specialisation	Vertical specialisation
Network structures			
Level of autonomy	Relatively high	Relatively low	Relatively high
Level of integration	Relatively low	Relatively high	Relatively high

Source: Birkinshaw (2002)

Different engineering centres are the main challenges to knowledge integration, sharing and learning. Zhang et al. (2007) found that communication difficulties, and economic, social and psychological barriers, were among the challenges for the network learning of engineering network firms. In fact, technological, organisational and geographical differences between R&D centres are the causes of communication difficulties and may lead to organisational inertia, which is a situation in which people have interest conflicts

---

[7] Centres of excellence can be individuals, a group of individuals (Moore & Birkinshaw, 1998) or an organisational unit (e.g. subsidiaries) (Frosgren & Pedersen, 1999). They are similar in their possession of strong competencies, and the recognition and use of such competencies by the internal members within the firm.

and do not engage in network learning, e.g. knowledge transfer, reuse and creation (Criscuolo & Narula, 2007).

In GES operations, firms replicate their global engineering value chain to deliver service projects to various clients across countries (Abdelzaher, 2012). On the one hand, GES firms set up their engineering operations across the globe for efficiency and effectiveness, but integrate them to serve customers from country to country (Abdelzaher, 2012; Moore & Birkinshaw, 1998). On the other hand, they follow key clients by setting up a number of temporary and permanent offices close to client sites for customisation (Abdelzaher, 2012; Malhotra & Morris, 2009). Such organisational behaviours create "spider web" structures in GES operations (Abdelzaher, 2012).

Notably, GES production and consumption occur simultaneously and vary from customer to customer (Zhang & Zhang, 2014). This type of operation results in a number of network layers representing various projects and individual engineers, which are assigned to serve customers across the globe (Abdelzaher, 2012; Von Zedtwitz et al., 2004). Project operations intensify the complexity of GES network learning. GES networks may have various expert groups with diverse engineers in multiple disciplines that create knowledge boundaries and thus require knowledge management to facilitate knowledge sharing and network learning (Kotlarsky et al., 2014).

Knowledge complexity. Another barrier is the intangible and complex nature of engineering knowledge (Malhotra & Morris, 2009; Zhang et. al., 2014). Engineering knowledge is "a specific kind of knowledge that […] is typically related to discipline design methods, and takes place in tool-intensive contexts" (Sicilia et al., 2009, p. 309). Engineering knowledge can be engineering standards, best practices or experience (Zhang et al., 2016); services, operating procedures, or know-how (Moore & Birkinshaw, 1998); expertise and the capacity to act (Kotlarsky et al., 2014); or scientific and practical knowledge (Tödtling et al., 2009).

Fruchter and Demian (2002, p.128) characterise engineering knowledge as "knowledge in context"; that is, the knowledge occurs in a designer's personal memory, typically being rich, detailed and contextual. They dichotomise engineering knowledge into systemic and abstract dimensions. The systemic dimension (multi-disciplinary aspect of the artefact) refers to the technical and social systemic structure of engineering knowledge. It is associated with products and production processes that shape the context of engineering knowledge and relate to discipline design methods (the know-how) (Dias, 2007; Doz & Santos, 1997; Fruchter & Demian, 2002). The abstract dimension (the component abstraction of the artefact) refers to the scientific and practice-based development of engineering knowledge and is related to historical knowledge (Dias, 2007; Fruchter & Demian, 2002). Additionally, engineering knowledge is highly dispersed within global engineering units, which makes it more difficult to capture.

GES operations are customer-focused and thus their accumulated intangible experience is contextually embedded, heterogeneous, and perishable across many projects (Malhotra & Morris, 2009; Zhang & Zhang, 2014). Knowledge users may not see and feel the tacitness, nor the abstraction or systemic aspects of the knowledge, embedded within diverse project contexts (Fruchter & Demian, 2002; Kotlarsky et al., 2014). Such knowledge complexity creates challenges for knowledge transfer across similar and diverse intra-firm engineering units and the network.

2.6.4. Boundary Spanning Mechanisms

Boundary spanners. Moore and Birkinshaw (1998) identified three types of centre of excellence (CoE) as boundary spanners to facilitate intangible knowledge transfer across GES projects: charismatic, focused and virtual CoEs. Charismatic CoEs are individuals who are internationally recognized for their knowledge or expertise in a certain area. They are deployed to disseminate new knowledge and assist knowledge creation across GES networks. Focused CoEs are small groups of people who identify, build and make emerging knowledge available globally across projects or through training and developing materials. Virtual CoEs are large groups of people in multiple locations, who build and leverage leading edge practices through a formalised information system.

CoEs contribute to GES network learning with intra-firm engineering units in many ways. They engage in problem solving and knowledge reuse with network members in projects (Kotlarsky et al., 2014) and technology planning and knowledge creation for GES firms (Adenfelt & Lagerström, 2006). Kotlarsky et al. (2014) describe CoEs as knowledge boundary translators, who bridge the knowledge differences between expert groups. In their study of global software development network, CoEs are the mechanisms that connect the knowledge gaps between different expert groups or projects. They are involved in the knowledge reuse process as advisors, providing abstract explanations for knowledge applications in different contexts (Kotlarsky et al., 2014). CoEs can be grouped within international teams, who work together to identify technological platforms and to review the knowledge development plans of intra-firm engineering units (Adenfelt & Lagerström, 2006; Criscuolo & Narula, 2007).

Boundary spanning tools. Past research has identified various boundary spanning tools that engineering network firms use to facilitate communication, and knowledge sharing and transfer across highly dispersed and diverse engineering units. Kristjánsson (2012) emphasises the importance of a global information systems as knowledge centres to facilitate explicit and tacit knowledge integration across onshore/offshore GES projects. A global information system provides dispersed engineers with a platform to manage communication, knowledge codification and sharing. Recent research has shown that GES firms tend to adopt a digital solution platform which is designed to enhance the flexible integration of different actors, products, services and solutions in value co-creation (Cenamor et al., 2017; Thomas et al., 2014). In addition to common information system and digital platforms, standards play a key role in knowledge sharing and learning. Engineers share knowledge according to templates and procedures to enhance network learning (Goffin et al., 2010; Kotlarsky et al., 2014). To facilitate knowledge sharing and creation across different engineering sites, technology platforms are used to integrate diverse knowledge sources to create network knowledge (Criscuolo & Narula, 2007; Reger, 2004).

Learning coordination. A large amount of engineering operation management literature studies the coordination of engineering units for knowledge reuse and creation. International R&D centres can be coordinated through formal, hybrid or informal mechanisms (Reger, 2004; Von Zedtwitz et al., 2004). Formal/structural mechanisms refer to centralised coordination mechanisms that are routinized and standardised, such as R&D budgets, engineering councils, engineering planning and programing. Hybrid mechanisms refer to strategic coordination mechanisms which facilitate knowledge creation across dispersed autonomous global R&D centres, such as taskforces, international teams and strategic projects. Informal mechanisms refer to personal relationship and socialisation mechanisms that facilitate knowledge sharing and transfer culture across autonomous

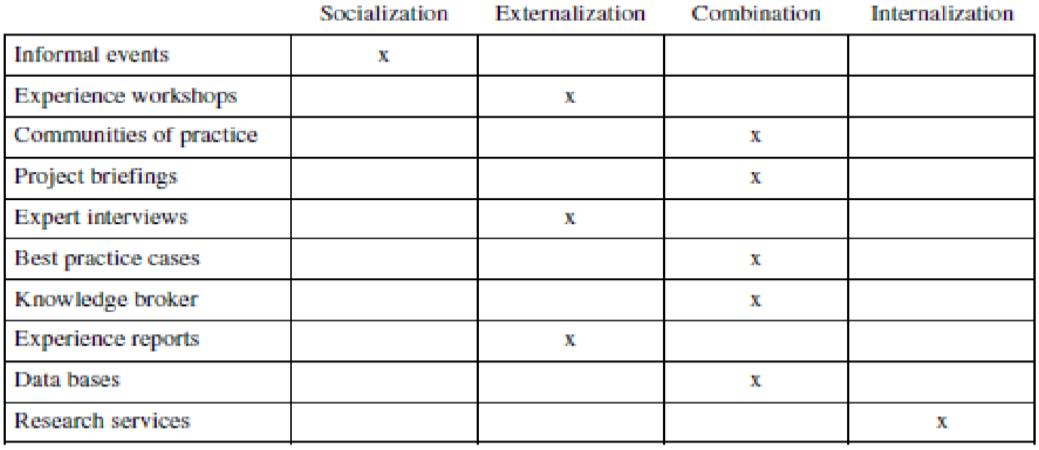
R&D centres. Finally, R&D centres can use internal markets to coordinate knowledge for learning.

Reger (2004) proposes that informal and hybrid mechanisms are more relevant to project organisations, decentralised decision making, and foreign-based competences with a low degree of cultural difference, while formal and internal markets more closely fit structured production organisations, centralised decision making, and home-based competences with a high degree of cultural difference. Operationally, the first two mechanisms support operations with high degree of novelty, unstructured tasks, tacit knowledge and reciprocal communication, while the second two should be used for operations involving a low level of the factors described above (Reger, 2004).

In global new product development firms, formal and hybrid coordination mechanisms, such as company cross-disciplinary review boards, and cross-border and cross-disciplinary projects, are key mechanisms in facilitating knowledge creation across global R&D units (Criscuolo & Narula, 2007). The transnational review board may play the roles of coordinating R&D centres, budgeting, establishing programmes/policies and creating technology platforms that guide knowledge creation and sharing among network members (Adenfelt & Lagerström, 2006). Informal mechanisms, such as socialisation events, cross project workshops, and temporary and long-term assignments, are effective in inter-unit knowledge transfer (Reger, 2004).

In cross-project learning, while formal global functions facilitate knowledge transfer across a broad range of R&D projects, company taskforces help to develop and disseminate a specific knowledge area (e.g. common technology platforms) across R&D networks (Criscuolo & Narula, 2007). However, centralised knowledge management functions, despite being effective in disseminating general knowledge, are not always useful in situations where specialised knowledge is required (Söderquist, 2006). In this case, local functional knowledge management or expert groups are more effective in transferring knowledge across projects than global functions (Söderquist, 2006).

Hoegl and Schulze (2005) identify ten key formal and informal learning coordination mechanisms that international R&D firms adopt for knowledge reuse and creation across projects (see Figure 2-12). Each mechanism contributes to a specific stage of the knowledge creation process in new product development projects (Nonaka, 1994); they can be either codification or personalisation mechanisms. While codification mechanisms include best practice cases, experience reports and databases, personalisation ones are informal events, experience workshops, communities of practice, project briefings, expert interviews, knowledge broking and internal research services.



	Socialization	Externalization	Combination	Internalization
Informal events	x			
Experience workshops		x		
Communities of practice			x	
Project briefings			x	
Expert interviews		x		
Best practice cases			x	
Knowledge broker			x	
Experience reports		x		
Data bases			x	
Research services				x

Figure 2-12: Supporting mechanisms for knowledge creation in NPD projects

Source: Hoegl and Schulze (2005, p. 271).

Goffin et al. (2010) argue that post-project reviews are important for GES firms to benefit from lessons learned from new product development projects. However, reports from post-project reviews are not sufficient to transfer tacit knowledge across firms. Instead, firms should combine codification with interpersonal mechanisms such as knowledge broking, cross-project learning and codification updating to enhance network learning. Kotlarsky et al. (2014) echo this argument, providing empirical evidence that GES firms combine codification and personalisation mechanisms to optimise knowledge sharing and creation across dispersed and diverse expert groups. Notably, in the GES network learning context, CoEs are involved with different expert groups to provide advice that can solve their common issues (Kotlarsky et al., 2014).

Recent research has emphasised the role of the modularisation approach to learning coordination across projects with customers (Eloranta & Turunen, 2016; Palo & Tähtinen, 2011; Storbacka, 2011). This approach generally refers to "building a complex product or process from smaller subsystems that can be designed independently yet function together as a whole" (Baldwin and Clark, 1997, p. 84). Modularisation solutions involve the development of product modules (Mikkola, 2003; Simpson, Siddique, & Jiao, 2006), service modules (Palo & Tähtinen, 2011; Pekkarinen & Ulkuniemi, 2008) and information/solution modules (Javier Cenamor, Sjödin, & Parida, 2017; Salonen et al., 2017). GES firms tend to coordinate these modules into a digital solution platform, which is designed to enhance the flexible integration of different actors, products, services and solutions in value co-creation (Cenamor et al., 2017; Thomas et al., 2014).

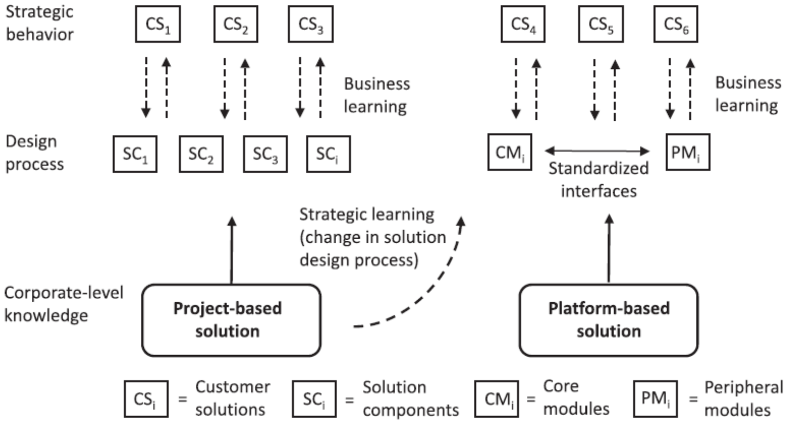


Figure 2-13: Modular solution building process

Source: Salonen et al. (2018, p. 15)

The design of blueprints for standardised modules is important for project learning coordination. Modules are also classified in specialised service porfolios or capabilities (Cenamor et al., 2017). Salonen et al. (2018) found that the modular solution approach facilitates network learning through two stages: project-based integration of solutions (e.g. knowledge creation with customers), and platform-based solution reuse (Figure 2-13). At the first stage, customer solutions are created in initial projects, which are then developed into solution components (Cenamor et al., 2017; Palo & Tähtinen, 2011). These components, after being continuously constructed within a few projects, are then transformed into core and peripheral standardised modules that are incorporated within a solution platform (Salonen et al., 2018).

The development of "blueprints" for standardised modules involves both front-end and back-end units (Javier Cenamor et al., 2017). While front-end units seek opportunities and develop new modules with customers, back-end units collaborate with front-end ones to standardise modules for future reuse (Breidbach & Maglio, 2016). Developing modular knowledge across various units requires GES firms to facilitate coordination through mechanisms such as diversity, cross-disciplinary learning and reuse methods, and through various individuals and teams with different learning roles (Breidbach & Maglio, 2016; Goffin et al., 2010; Zhang et al., 2016).

Knowledge governance. Knowledge governance is equally important for facilitating knowledge agents to share knowledge effectively (Foss, 2007). In engineering network learning, knowledge governance mechanisms can be formal or informal. Formal mechanisms can be related to Human Resource Management (HRM), rewards and management policies to guide knowledge sharing behaviours, while informal mechanisms may be the art of creating trust and the feeling of learning as a culture (Argote & Kane, 2009; Garvin et al., 2008; Pedler et al., 1991). Argote & Kane (2009) emphasise the importance of shared superordinate identity in facilitating knowledge creation and transfer at a network level. Hansen et al. (1999) argue that HRM policies towards knowledge reuse or creation play a key role in guiding employees to engage in network learning. While formal strategic solutions such as identity creation, monetary incentives, and modularisation of works are useful for exploiting exiting knowledge, formal and informal motivation solutions such as supportive leadership and the encouragement of managers are more effective for explorative learning (Osterloh & Weibel, 2009). Creating innovative working cultures, encouraging creativity and diversity, and pursuing perfection will foster risk taking and knowledge creation across GES networks (Zhang et al., 2016).

Technological mechanisms. Recent research has identified new technologies which are being adopted for GES network learning. Digital technologies facilitate remote learning through simulation and information update (Zhang et al., 2016) and big data, the internet of things and machine learning technologies are applications that may facilitate operational performance in many business situations (Montavon et al., 2013; Wuest, Weimer, Irgens, & Thoben, 2016). Despite their availability for GES network learning, previous studies have not yet provided a comprehensive understanding of how technological mechanisms can be adopted to contribute to GES network learning and value creation.

2.6.5. Values

GES network learning with intra-firm engineering units contributes to enhancing engineering operations in terms of engineering efficiency, flexibility and innovation (Moore & Birkinshaw, 1998; Zhang et al., 2016). It bridges the knowledge gaps between project teams and thus enhances project efficiency (Kotlarsky et al., 2014; Moore & Birkinshaw, 1998). Intra-firm network learning also helps to coordinate different engineering centres for knowledge creation and reuse, which enhances both operational and technological development (Zhang et al., 2016). It also facilitates new product development collaboration between individual engineers (Criscuolo & Narula, 2007).

2.6.6. A GES Network Learning Episode with Intra-Firm Engineering Units and Value Creation

A framework of a network learning episode with intra-firm engineering units and value creation has been developed from the literature review (Figure 2-14). The episode involves three stages: network learning drivers, the network learning process, and values.

A network learning episode with intra-firm engineering units is initiated when there is a knowledge gap between the units. The network learning processes involve knowledge creation and/or knowledge reuse between engineering units to enhance their efficiency, flexibility and innovation. The units are diverse and may have different interests, interpretations and language that can hinder their intangible knowledge transfer in knowledge reuse and creation processes. Boundary spanning mechanisms are employed to facilitate knowledge transfer and learning between units.

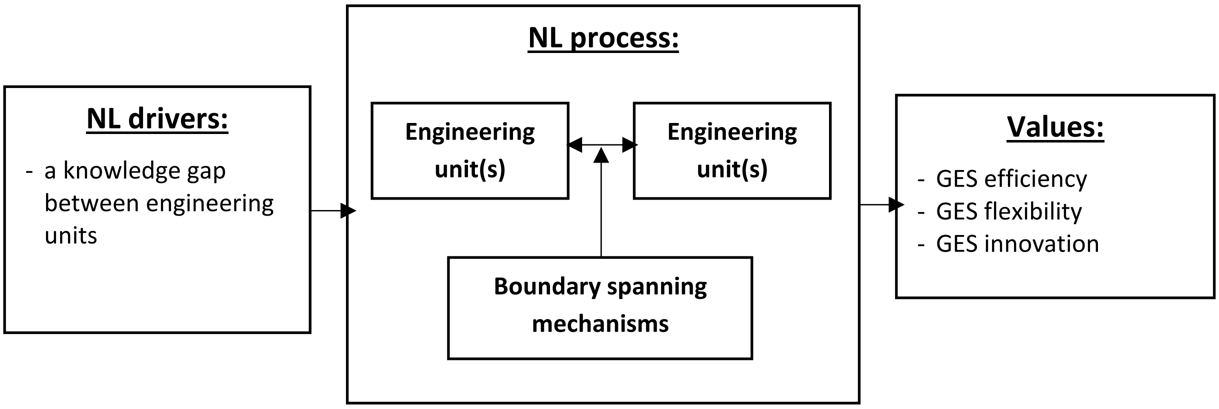


Figure 2-14: GES network learning episode with suppliers and value creation

2.6.7. Links To Inter-Firm Network Learning

Past studies on intra-firm network learning mainly highlight the knowledge creation and reuse processes between different engineering units (Moore & Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016). They do not clarify the roles of suppliers and customers in intra-firm network learning and value creation. Various boundary spanning mechanisms have been identified, but the connection between these and those employed within inter-firm network learning is unclear. Therefore, it can be seen from the literature that there is no link between GES network learning and customers, suppliers and intra-firm network learning.

2.7. Preliminary Framework

2.7.1. The Missing Links between GES Network Learning with Customers, Suppliers and Intra-Firm Engineering Units

The literature on GES network learning with customers, suppliers and intra-firm engineering units shows that there is no clear connection between them. A few studies have attempted to demonstrate that they contribute to service innovation (Brady & Davies, 2004). However, the key concern of these studies is business innovation and transformation and thus they do not pay sufficient attention to the integrated GES network learning practices with customers, suppliers and intra-firm engineering units. Recent studies focus on such GES network learning through modularisation and platform approaches (Eloranta & Turunen, 2016; Salonen et al., 2018). However, the focus of these studies is on a business method for business transformation and therefore they do not clarify the connection between inter-firm and intra-firm network learning. Furthermore, the existing boundary spanning mechanisms that facilitate GES network learning are fragmented, supporting either inter- or intra-firm network learning and focusing either on efficiency or innovation. These inconsistent practices need an integrated framework to clarify the contributions of different GES network learning practices to value creation.

GES network learning can be viewed as an integrated approach, incorporating the roles of customers, suppliers and intra-firm engineering units (Birkinshaw & Hansen, 2007; Love et al., 2011). Such an approach will offer better understanding of how network learning contributes to GES value creation. This study therefore aims to develop an integrated framework to capture the fragmented current theories and building on these to develop an integrated GES network learning with customers, suppliers and intra-firm engineering units in real GES network operations contexts to provide better insights into GES network learning and value creation. A preliminary framework will provide implications for theory development and effective practical implementation.

Also, the literature review shows that GES firms use a set of boundary spanning mechanisms to facilitate GES network learning with customers, suppliers and intra-firm engineering units. However, their integrated practices are not clear. Thus, the second sub research question raised in chapter 1 can be specified: *"What boundary spanning mechanisms do GES firms use to facilitate network learning with customers, suppliers and intra-firm engineering units? When and why?"*

2.7.2. Preliminary Framework

Three GES network learning episodes and preliminary framework

The literature review enables the development of a preliminary integrated framework of GES network learning and value creation (Figure 2-15). The literature on GES network learning and value creation has shown that GES firms can create value through GES network learning with customers (Brady and Davies, 2004; Windahl & Lakemoon, 2006), suppliers (Coghlan & Coughlan, 2014), and intra-firm engineering units (Zhang et al., 2016). Past research has developed GES network learning with customers, suppliers, and intra-firm engineering units as a set of independent knowledge acquisition processes which should be linked to create value (Hansen and Birkinshaw, 2007; Love et al., 2011). Empirical research thus is needed to examine their linkage and contributions to value creation.

It is recommended that network learning practices are only understood in a network learning episode in which the learning goals, actors and interactions are specified (Knight, 2002; Gibb et al., 2017). To understand how GES firm's network learning contribute to value creation, three network learning episodes should be considered. They include unrelated GES network learning with customers, suppliers, and intra-firm engineering units.

The literature review reveal that GES network learning with customers is triggered by changing customer demands that lead to learning episodes between customers and engineering units which are supported by a set of boundary spanning mechanisms and lead to monetary and non-monetary values. GES network learning episodes with suppliers are driven by supplier capabilities. GES firms tend to integrate suppliers to enhance performance and innovation. Collaborating with suppliers therefore helps firms to enhance value creation. In the episode of network learning with intra-firm engineering units, the knowledge gaps between engineering units result in knowledge reuse and creation between them that lead to engineering performance enhancement. These three independent episodes can help to develop a preliminary framework to study integrated GES network learning, examining their linkage and interactions that contribute to GES value creation in terms of efficiency, flexibility and innovation. Figure 2-15 exhibits the preliminary framework of GES network learning and value creation.

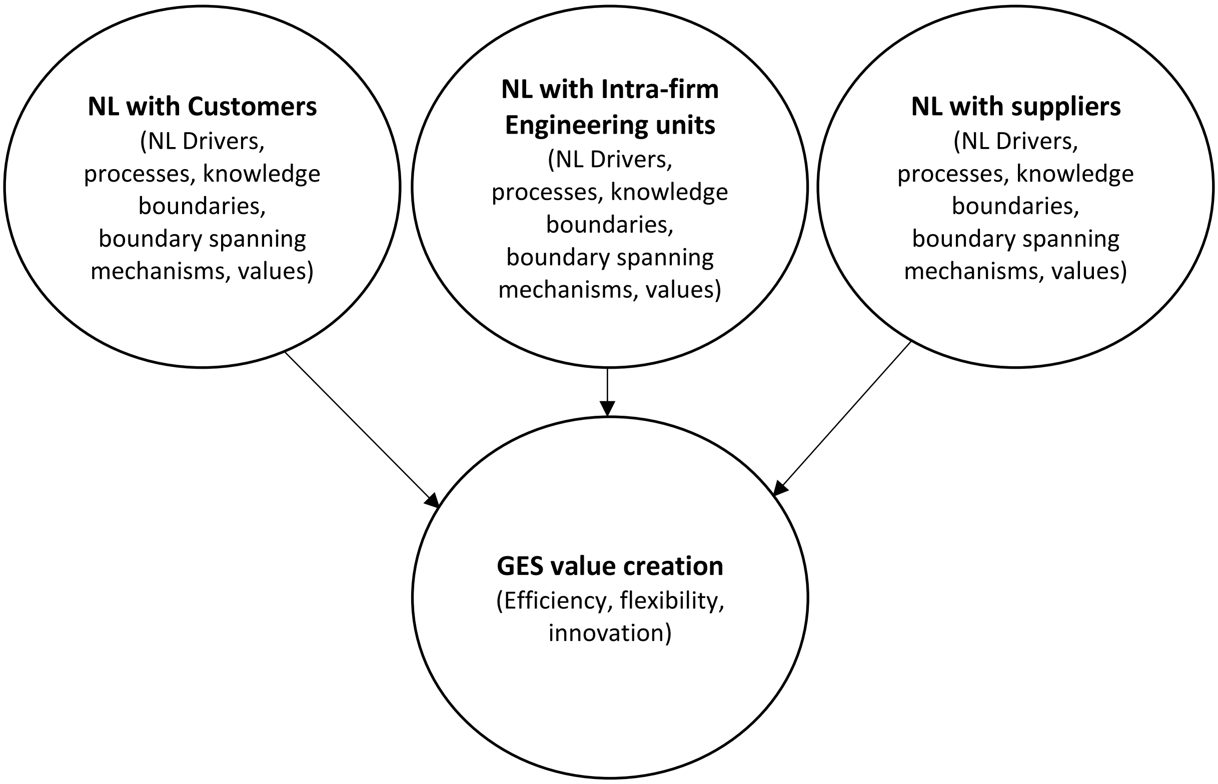


Figure 2-15: Preliminary framework for GES network learning and value creation

The framework includes three unrelated network learning episodes with customers, suppliers and intra-firm engineering units that contribute to GES value creation. Three learning episodes form the foundations for empirical research and enables to explore the inter-relation between the three episodes that contributes to value creation. From the literature review, the episodes comprise different network learning drivers, processes, knowledge boundaries, boundary spanning mechanisms, and created values.

- Network learning drivers refer to the factors that trigger network learning practices (Knight, 2002), including changing customer demands, good supplier capability, or a knowledge gap between engineering units.

- Network learning processes are either knowledge reuse or creation, which lead to an enhancement in GES performance. Knowledge reuse may be knowledge transfer (Argote & Ingram, 2000), selective knowledge reuse (Markus, 2001), or knowledge reuse for innovation (Majchrzak et al., 2004).
- Knowledge boundaries refer to the knowledge differences between network actors in terms of interests, interpretations and languages, which may hinder knowledge sharing and transfer between them (Carlile, 2002, 2004).
- Boundary spanning mechanisms refer to the methods, procedures and processes that firms use to address the issues of knowledge boundaries and therefore facilitate network learning. They include boundary spanners (Brown & Duguid, 1998), boundary spanning tools (Carlile, 2002), learning coordination (Reger, 2004), knowledge governance (Foss, 2007), and technological mechanisms (Brown & Duguid, 1998; Zhang et al., 2016).
- Values refer to the benefits and sacrifices firms experience in service offerings and related exchanges. Values can be monetary ones, such as use and exchange values, or non-monetary ones such as knowledge, relationships or differentiation.
- Efficiency: the operational abilities that help GES firms outperform their rivals through implementing their engineering tasks with fewer resources.
- Innovation: the operational abilities that help GES firms create novel engineering solutions for customers.
- Flexibility: the operational abilities that help GES firms quickly respond and adapt to changing demands (Zhang et al., 2016).

These various elements provide the primary categories, sub-categories and key issues for empirical research (for more details about these categories and key issues, see Appendix 2).

2.8. Conclusion

This chapter has developed a preliminary integrated framework of GES network learning and value creation, which should be viewed as an integrated approach for better understanding. The chapter has also reviewed the literature on network learning, GES value creation, and GES network learning with customers, suppliers and intra-firm networks to integrate the fragmented knowledge into a framework.

The literature review shows a missing link between GES network learning with customers, suppliers and intra-firm engineering units; GES value creation is an all-encompassing process involving all three. As such, GES network learning should be viewed in an integrated way, incorporating customers, suppliers and intra-firm engineering units in its processes. Current theories enable the construction of a preliminary framework which integrates different practices into three network learning episodes with customers, suppliers and intra-firm engineering units. The framework forms a foundation for the empirical research to clarify GES network learning and value creation. The following chapter presents the research approach, design and implementation to achieve the research objectives.

3. CHAPTER 3: METHODOLOGY

3.1. Introduction

In chapter 2, the literature review resulted in a preliminary framework, including three independent network learning episodes. The framework shapes the foundations for empirical research to explore their linkage and contributions to value creation. This chapter justifies the rationale of the empirical research approach, design, settings and methods used to answer research questions.

It begins with the theoretical foundations for the research approach. Subsequently, it describes the research design and settings and highlights the key methods selected to collect and analyse the data. Finally, it evaluates the research quality achieved through the selected research design and practices. The research results obtained from the empirical research are presented in chapters 4, 5, and 6.

3.2. Research Approach

All social researchers start their research with an ontological and epistemological stance (Bryman, 2015; Grix, 2002). Ontology refers to the “claims and assumptions about what social reality is, while epistemology refers to the possible ways of gaining knowledge of social reality” (Blaikie, 2000). In fact, researchers believe that what is known is either objective (realism perspective) or subjective (nominalism perspective) to the human mind (Blaikie, 2007; Easterby-Smith, Thorpe, & Jackson, 2012). In this study, a critical realism stance is taken to approach the knowledge of GES network learning and value creation (Miller & Tsang, 2010; Reed, 2005; Sayer, 2000). This worldview stems from the fact that there is increasing evidence that GES network learning facilitates value creation, and observations of this social phenomenon are rapidly evolving, but are inconsistent and fragmented within different knowledge domains, e.g. service operations and industrial marketing.

Critical realism first needs “a realist ontology” that perceives the existence of the social world as independent from researchers’ knowledge of it (Miller & Tsang, 2010; Sayer, 2000). However, it relies on a “fallibilist epistemology” in which the knowledge of the researchers is shaped by social constructions (Bhaskar, 2013; Miller & Tsang, 2010). In this regard, critical realism acknowledges the limitations of researchers and practitioners in producing absolute objective knowledge of the world (Miller & Tsang, 2010). The critical realism perspective is relevant to theory building in organisation and management studies that focus on generating an overarching explanatory framework and logic for diverse, complex and dynamic social phenomena (Miller & Tsang, 2010; Reed, 2005). Critical realism philosophy is also useful for verifying, falsifying and integrating diverse, inconsisten, or conflicting theories on the social phenomena in question (Miller & Tsang, 2010).

Within critical realism, the truth of social reality is determined by the "consensus between different viewpoints" (Easterby-Smith et al., 2008, p. 62). In fact, critical realists view social reality through a stratified model of reality containing three different related, but not reducible, domains: the real, actual and empirical (Leca & Naccache, 2006; Miller & Tsang, 2010). The real domain consists of generative mechanisms external from human minds. These mechanisms give rise to events in the actual domain, which may or may not be experienced by social actors (Miller & Tsang, 2010). The empirical domain entails the events experienced and perceived by social actors, which can be observed directly or indirectly by researchers (Leca & Naccache, 2006).

From the stratified model of reality, explanations of social reality emerge based on a philosophical framework that is made up of causal mechanisms in the real domain, sensitive to the interactive relationships of domains, and capable of capturing and changing with the facts or observations in the empirical domain (Miller & Tsang, 2010; Reed, 2005; Sayer, 2000). The consideration of contextual conditions is crucial for the development of a philosophical framework (Leca & Naccache, 2006; Miller & Tsang, 2010; Sayer, 2000). Here, a stratified view of reality may be useful to simplify and direct research to those causal mechanisms relevant to the social phenomena in question (Miller & Tsang, 2010). Although critical realists cannot see causal mechanisms, and only access the empirical domain to observe experienced events within the actual domain, their aim is to "seek explanations for contingent relations, understood in terms of causal mechanisms" (Miller and Tsang, 2010: p. 145). Theory development within critical realism is therefore mainly associated with evaluating the presence of causal mechanisms (the real domain) in empirical settings.

Adopting a critical realism stance, this study acknowledges the existence of GES network learning mechanisms external from researchers' knowledge of them. Although these mechanisms are invisible to researchers, they may be partially recognised through various observations of previous researchers, as well as the experiences of practitioners. At the same time, the assumption taken in this study is that the best way to understand GES network learning is through the interpretation of informants' viewpoints and experiences, in spite of their limitations in capturing objective knowledge of social realities (Miller & Tsang, 2010).

The philosophical stance, the complexity of GES network learning, and the inconsistency of current theories require an intensive or qualitative research design (Barratt, Choi, & Li, 2011; Edmondson & McManus, 2007; Ketokivi & Choi, 2014; Miller & Tsang, 2010). Miller & Tsang (2010) argue that "intensive designs" address the diversity of cases and enable the identification of generative mechanisms (e.g. various structures and causal powers) occurring in particular cases, which is not feasible through "extensive designs" or quantitative research designs adopted for theory testing (Leca & Naccache, 2006). Furthermore, qualitative research designs enable the collection of detailed qualitative data within a few cases. Case studies, an ethnographic approach, grounded theory and action research are among possible choices for qualitative research designs (Miller & Tsang 2010).

3.3. Research Design

Qualitative case research is selected because this research design is relevant to theory building or the elaboration of GES network learning (Eisenhardt 1989; Yin 2003; Edmondson & McManus 2007). The literature review in chapter 2 indicates that theories on GES network learning are independent within either inter- or intra-firm network learning contexts. It is important to approach GES network learning and firm value creation with a holistic view, integrating both inter- and intra-firm network learning.

Ketokivi and Choi (2014) argue that theory elaboration[8] with case research design enables researchers to apply a pre-assumed general theory into real contexts; not to test its

---

[8] Ketokivi and Choi (2014) clarify three modes of case research design: theory generation, theory testing and theory elaboration. They differ in the degree to which knowledge is either situationally grounded or generally sensed. While theory generation requires a great deal of empirical data, and theory testing relies mostly on generalisation, theory elaboration needs balanced attempts between formulating a general theory and grounding it in an empirical context.

generality, but to verify or challenge it. This type of case research design aims to use empirical evidence to enrich or modify the logic of a general theory constructed from competing theories and/or phenomena (Barratt, Choi, & Li, 2011; Ketokivi & Choi, 2014). Moreover, a qualitative case research design is useful to address the “how” question and the investigation of contemporary phenomena when researchers have limited control (Yin, 2003).

In operations management research, qualitative case research is “empirical research that primarily uses contextually rich data from bounded real-world settings to investigate a focused phenomenon” (Barratt et al., 2011, p. 329). Qualitative case research design allows the researcher to capture rich data from a few cases, which enables understanding of a complex social phenomenon (Edmondson & McManus, 2007; Eisenhardt, 1989; Yin, 2003).

Case research design for theory elaboration starts with preconceived ideas formulated from existing theories (Eisenhardt, 1989; McCutcheon & Meredith, 1993; Voss, Tsikriktsis, & Frohlich, 2002). A general theory with pre-assumed causal mechanisms should be established from these theories before it can be iteratively triangulated and modified with particularly empirical contexts (Barratt et al., 2011; Ketokivi & Choi, 2014; Voss et al., 2002). In this regard, the preliminary framework of GES network learning constructed in chapter 2 is the starting point for the research design, setting and implementation (Barratt et al., 2011).

In the four types of case research design, whether single or multiple case study designs and units of analysis (Yin, 2003), embedded multiple case design is the most suitable type to cover the diversity of GES firms, as well as their embedded network learning practices (network learning episodes). Multiple case design allows the researcher to compare various network learning practices of diverse GES firms in many industries (K. D. Miller & Tsang, 2010). Multiple units of analysis enable the understanding of different practices in network learning episodes. Multiple case studies and units of analysis thus increase external generalisability of the research findings (Yin, 2003).

3.4. Research Settings

The literature review provides a basis for case definition, sampling and units of analysis. GES firms are generally defined as ones which provide through life-cycle services to support customer business activities in a global context (Turner & Keegan 2001; Kujala et al., 2010; Zhang et al., 2016). They are common in delivery forms: project business, people-centric, global dispersion of engineering operations and engineering solution offerings. However, GES firms are different from each other in terms of solution outcomes (Breidbach & Maglio, 2016), engineering services (Zhang et al., 2011) and value creation strategies (Zhang et al., 2016).

GES firms in various engineering industries may have different engineering services, such as engineering research (Galbraith, 2014), product development engineering (Johnstone et al., 2009), and process-oriented engineering (Brady & Davies, 2004; Windahl & Lakemond, 2006). They also compete in different value creation strategies, for example engineering efficiency, flexibility or novel solutions (Zhang et al., 2016). Furthermore, GES firm solutions may be different, perceived as either process-oriented or output-oriented engineering solutions that contribute to enhancing the customer business process (Kujala et al., 2010; Breidbach & Maglio, 2016). Different GES firms may have different network learning practices and therefore research sampling should address their heterogeneity to capture a comprehensive understanding of GES network learning.

Case sampling. The research sampling was intentional, based on an intensive case study approach (Miller and Tsang, 2010; Eisenhardt and Graebner, 2007) and a theoretical replication logic (McCutcheon & Meredith, 1993; Yin, 2003), targeting coverage of diverse GES firms that might have different network learning practices for value creation (Ketokivi & Choi, 2014; Yin, 2003). The theoretical framework guided the identification and selection of potential cases for the research, which sought GES firms that met the following criteria:

- Network learning context: (1) the firm competed through a value creation strategy such as engineering efficiency, flexibility and novel solutions, and had a good financial performance and/or was well-known as strongly performing companies within an industry; (2) the firm applied engineering advice, expertise and capabilities to address various customer problems; and (3) the firm might update new services, technological capabilities and products annually.
- Network learning processes and mechanisms: (1) the firm operated in an engineering industry, offering product life-cycle development solutions services (engineering research, product design and process development) to customers

around the world ; and (2) the firm had engineering resources (engineering suppliers/partners, engineering facilities, offices, supporting technologies and key engineers) dispersed and/or operating around the world to serve customers.

The process of identifying and selecting cases for the empirical study was conducted before and during the data collection process, from February to December 2016. A number of potential companies were identified that met the research criteria by studying their company websites. Company contacts were obtained through various channels, such as the London Stock Exchange website, company contacts in the university alumni network databases, company representatives attending local engineering exhibitions, conference and industrial associations, and other social, and research professional networks. However, one of the greatest challenges was accessibility to the cases. Social, industrial and professional networking was the most useful approach to obtain key contacts and access the potential cases.

Research inquiries were sent to 12 potential companies through the contacts obtained, mainly through social, industrial and professional networks. Six companies refused to participate in the research after the first interview because they found it difficult to commit time and to seek the relevant informants for the research. The other six companies agreed to participate in the research with the assistance of senior management staff. Interviews, company document collection, and direct observation were later intensively conducted at the six companies from August to December 2016.

However, by the end of December 2016, three of six companies were dropped because the information collected was not sufficient for the analysis of their network learning processes and boundary spanning mechanisms. In two of the case companies, there were only two interviewees that could be reached in each case. The other involved five interviewees, but they were mainly junior and middle managers and located just at one site. Therefore, the information collected was insufficient to capture their network learning on a global scale. Furthermore, studying six GES firms at the same time was time and cost consuming due to the dispersion of engineering sites and interviewees, the limited time and funding of the research, and the lack of research resources.

Number of cases. Because this study adopted an intensive design approach and aimed to achieve theoretical generalisation, not statistical generalisation, to explore GES network learning and value creation, three cases were therefore intentionally selected to ensure robust in-depth understanding of the diverse and complex network learning practices that create value in GES (Eisenhardt & Graebner, 2007; Siggelkow, 2007). The three cases selected contained different value creation strategies and thus ensured the representation of the diversity of network learning for GES value creation. They enabled to capture in-depth insights into specific network learning practices in each case and address the differences across cases which could be not feasible for extensive design (Yin, 2003; Eisenhardt & Graebner, 2007; Miller and Tsang, 2010).

Table 3-1 summarises the main characteristics of the three case companies, covering different aspects relating to the GES network learning context, processes and mechanisms. The cases were given the pseudonyms OSCOM, APPCOM and RECOM due to the confidentiality agreement with them. More details of the three cases are given in Appendices 3, 4 and 5.

Table 3-1: Theoretical characteristics of the three case companies

Network learning features		OSCOM	APPCOM	RECOM
Context	**Engineering applications**	Software development	Sub-system engineering applications for aerospace, energy, automotive and medical devices	Physiologically based pharmacokinetic (PBPK) modelling & simulation
	Solutions	IT advisory, bespoke software development and business process outsourcing solutions	Sub-system engineering solutions for aerospace, energy, automotive and medical devices	Innovative bio-simulation solutions for customer decision making in new drug development
	Strategic orientation	Efficiency	Flexibility	Innovation
	Revenue (£ m/ 2016)	10	2,000	-
Process & mechanism	**Global engineering centres and offices**	A network of two engineering offshore captive centres and eight offices in the UK, Europe, the US and Asia Pacific	A network of five competence divisions with over 50 manufacturing and engineering sites located in North America, Europe, UK and Asia Pacific	A network of one engineering research centre in the UK and 19 offices worldwide
	Engineers (2016)	1500	11,000	400 (150+ PhD)
	Customers	Numerous customers in diverse industries	A few large customers in aerospace, energy, medical device and automotive industries	Numerous customers within the pharmaceutical industry
	Suppliers	A few technological suppliers	Numerous component and technology suppliers	Numerous knowledge and technology suppliers

The case companies offered relevant theoretical contexts to explore GES network learning. They all applied engineering knowledge for the benefit of customers, had globally dispersed engineering resources, customers and suppliers, delivered project solutions, and had been profitable in recent years. Although RECOM was a university spin-over company, emerging in recent years, it was perceived as a well-known innovative firm by industrial experts in the pharmaceutical industry. However, it kept its financial performance confidential. Despite their common features, the three companies were different from each other in terms of:

- Value creation strategy: while OSCOM competed through engineering efficiency, APPCOM relied on engineering and technology flexibility to gain competitive advantage and RECOM focused on novel solutions to create value.
- Engineering knowledge applications: OSCOM focused on creating bespoke IT systems for customers in diverse industries; APPCOM offered sub-system design and development customised to diverse customer demands for excellent operations and innovative technologies in the aerospace, energy, automotive and medical equipment industries; while RECOM conducted engineering research to create novel bio-simulation platforms that addressed new drug development challenges of customers in the pharmaceutical industry.
- Engineering solution outcomes: while OSCOM provided process-oriented solutions, APPCOM offered both product and process-oriented solutions, and RECOM focused mainly on novel products licenced to customers.

These differences might provide theoretical insights into GES network learning. Different value creation strategies, engineering services, and engineering solution outcomes might rely on different GES network learning patterns (Eisenhardt & Graebner, 2007).

Unit of analysis. Defining clearly the unit of analysis determines the boundaries of the theories explored (Barratt et al., 2011). Prior research indicates that network learning can be only captured in a clearly defined network learning episode, including network learning drivers, learner networks, network learning processes and outcomes, performance implications and related interactions of network units (Knight 2002; Gibb et al., 2017). In this research, a GES network learning episode is a learning event of a GES network with external customers, suppliers or with network engineering units, which leads to GES performance enhancement or value creation. The literature review in chapter 2 identifies three GES network learning episodes that contribute to GES value creation: network learning with customers, suppliers and intra-firm engineering units. Each episode has its own network learning drivers, processes, knowledge boundaries between learning actors, and boundary spanning mechanisms to create value as the network learning outcomes. The three network learning episodes are the units of analysis in each case studied to capture their practices and sequential linkages.

3.5. Research Process

The research process begins with the development of a preliminary framework that facilitates case research design, data collection, analysis and theory building (Miller and Tsang, 2010). In this research, the preliminary framework was constructed based on the literature review of over 200 articles on organisational learning and knowledge management, GES value creation and network learning (see chapter 2 for more details). The framework incorporated existing theories, highlighting key theoretical elements and exposing the knowledge gaps that the case studies are intended to address (Eisenhardt, 1989; Voss et al., 2002, Christensen et al., 2002). The case studies involved data collection and analysis that enabled the researcher to repeatedly verify and refine the preliminary framework. These deductive and inductive processes were iterated until no further elements were revealed and resulted in a new integrated framework and theories (Figure 3-1).

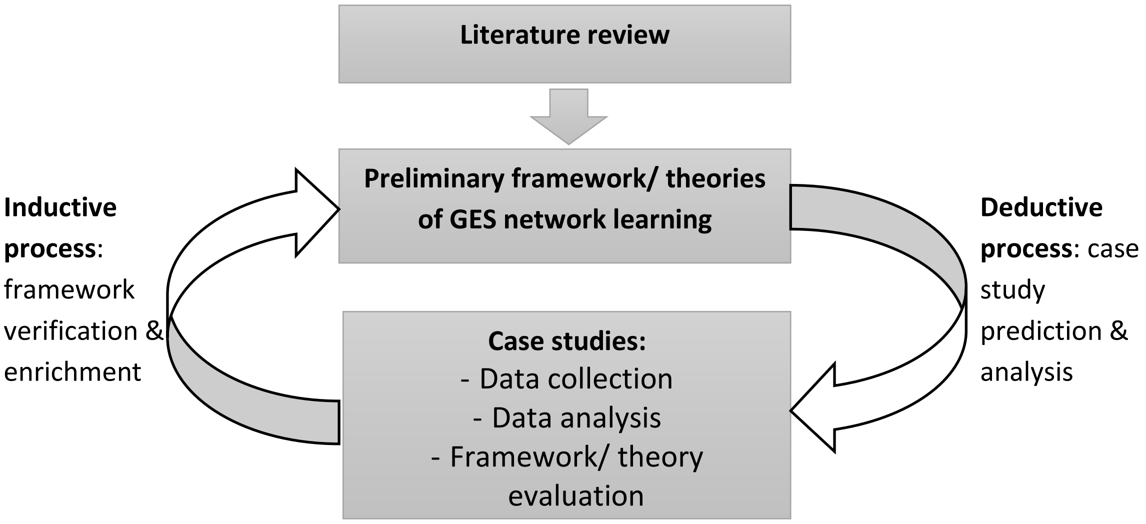


Figure 3-1: Research process

Source: adapted from Christensen et al. (2002)

Table 3-2 presents the main activities and outcomes of the case study process. The data collection was conducted from July 2016 to the end of 2017 and involved activities such as interviews, site visits, company document collection, observation and the participation of six companies. These processes aimed to capture information about GES network learning drivers, processes, knowledge boundaries, boundary spanning mechanisms and outcomes in collaboration with customers, suppliers and intra-firm engineering units. By January 2017, three case companies had been formally selected for in-depth analysis because of their depth and completeness of data sources and the limitations of research resources and time. Further data collection within the three selected cases was conducted on an ad-hoc basis during 2017 to capture more data for data analysis.

Table 3-2: Research stages, activities and outcomes

Research stage	Research activities	Outcomes	Time frame
Literature review	Literature review Website search and study Case company identification and contact for research invitation Preliminary company website study	Preliminary framework/ theories Knowledge gaps Criteria for case identification and selection Protocols for data collection Guidelines for data analysis	2015 (Jan)-2016 (Sep)
Data collection	Detailed company website study Semi-structured interviews Site visits, observations, and learning Company document collection Preliminary data analysis	Interview data Company documents Observation notes Press and public social media records Preliminary data analysis Preliminary findings Protocol and framework adjustment	2016 (Feb)-2017 (Dec)
Data analysis	Data source analysis Within case analysis Cross-case analysis Literature/preliminary framework comparison	Network learning drivers, processes, knowledge boundaries, boundary spanning mechanisms, and values of the three case companies Framework, theory development and refinement	2016 (Sep)-2017 (Dec)
Writing up	Framework assessment Theoretical and practical evaluation of research findings Case study report	Integrated framework Theoretical contributions Practical implications Limitations and future directions	2017 (Sep)-2018 (Sep)

Sources: Adapted from Yin (2003), Eisenhardt (1989) and Voss et al. (2002)

Data analysis was conducted simultaneously with data collection. It included single and cross case data analysis in which the data sources were read, coded and aligned with preliminary categories for comparison and refinement (Yin, 2003). The analysis enabled the updating of the data collection protocol, the exploration of different GES network learning practices and value creation, the refinement of the preliminary framework, and the development of new theories on GES network learning. The following sections present the data collection and analysis methods and implementation in more detail.

3.6. Data Collection

Various data collection methods were employed to capture a rich source of information about GES network learning practices in the case companies. Among the six types of data collection methods in case research - documentation, archival records, interviews, direct observation, participant observation and physical artefacts (Yin, 2003) - interviews were the main method used to capture empirical data. They were complemented and triangulated by documentary information (e.g. company reports, annual operational reviews, presentations and internal newsletters), archival records (e.g. organisational charts, process charts and lists of engineers), direct observations (e.g. site visits), and participant observation (e.g. attending knowledge sharing meetings). Denzin (1978) argues that the data triangulation approach enhances the validity and reliability of research findings because any weakness in a data source can be compensated by the strengths of the other data. Various data sources and the triangulation strategy were important for the study because GES network learning is a complex phenomenon involving external and internal actors at different levels, which requires the combination of various information sources to yield comprehensive understanding.

The data collection processes were based on the preliminary framework (network learning with customers, suppliers and intra-firm engineering units) to predict what data needed to be collected and observed (Christensen et al., 2002). Table 3-3 highlights the key themes that were identified through the literature review and that directed the data collection and analysis processes. The researcher gathered data related to network learning drivers, outcomes, processes, knowledge boundaries and boundary spanning mechanisms adopted by the case companies in their three network learning episodes – network learning with customers, suppliers and intra-firm engineering units.

- Network learning drivers refer to internal and external factors that motivate firms to practise network learning.

- Network learning outcomes refer to network performance enhancement through better knowledge or understanding.
- Network knowledge reuse refers to the process of exploiting existing knowledge embedded within the learner network and/or external actors.
- Network knowledge creation refers to the process of exploring new knowledge that is unknown to the market.
- Knowledge boundaries refer to language, interpretation and interest differences between learner actors that hinder knowledge sharing, reuse and creation.
- Boundary spanners are strategic individuals responsible for developing social relationships and knowledge sharing across communities. They are either knowledge brokers or knowledge translators.
- Boundary spanning tools are the entities that are common to a number of communities within the organisation. They are either physical or symbolic in character, including repositories, standardised forms/methods, objects/models and maps.
- Knowledge coordination mechanisms refer to formal, hybrid and informal organisational mechanisms designed by firms to facilitate learning across autonomous communities, including intra- and inter-organisation networks.
- Knowledge governance mechanisms refer to formal and informal organisational mechanisms that control and/or encourage the learning behaviours of the organisation and its individuals towards an organisational learning objective.
- Technological mechanisms are not only information and communication technologies, but also other technologies that facilitate information sharing, capturing and processing for organisational learning.

All the data sources were searched to enrich these themes in the three network learning episodes, namely network learning with customers, suppliers and intra-firm engineering units. The details of the data collection processes are presented below.

Table 3-3: Key themes for data collection and analysis

Elements of a network learning episode	Descriptions of operational characteristics
Network learning context (Triggers for learning & learning outcomes)	- Drivers - Outcomes (Values)
Network learning processes (Learning actors, their interactions and complexity)	- Knowledge creation - Knowledge reuse - Knowledge boundaries
Boundary spanning mechanisms (Mechanisms supporting knowledge creation and/or reuse)	- Boundary spanners - Boundary spanning tools - Learning coordination mechanisms - Knowledge governance mechanisms - Technological mechanisms

Interviews. Interviews enabled the researcher to directly capture various types of GES network learning information, including facts, opinions, experiences and insights, from original sources (Yin, 2003). Interview methods also allowed the researcher to explore rich and complex causal explanations through probing, which is not possible in survey and experiment strategies (Yin, 2003). Furthermore, this method is powerful in revealing the real situations step by step by referring to the sources of information back and forth. It helps to reach information that may be viewed as sensitive by the insiders through confidentiality insurance (Easterby-Smith et al., 2012).

31 interviews (Appendix 7) were conducted within the three cases selected for the research during the period July 2016 to November 2017. There were seven OSCOM informants, five from APPCOM and 19 from RECOM. Several informants were interviewed several times due to their hectic schedules. They included corporate senior managers, business managers, site managers and engineers who designed and/or were engaged directly in GES network learning for value creation. Details of the informants and interviews are presented in Table 3-4.

In the case of OSCOM and APPCOM, it was challenging to reach a large number of informants due to the limited accessibility to new and existing informants in terms of time and space. The informants had tight working schedules and often travelled to global projects. They only committed a limited fixed time for the interviews; sometimes the interview arrangement took up considerable time as the informants' working schedules had changed. Besides, the informants were located at different sites, either in the UK, Asia or other countries, and were often on business trips. Such dispersion of the informants required the use of different communication tools to communicate with them instead of face to face interviews, e.g. phone, Skype and WebEx.

Table 3-4: List of informants and other data sources

Company	Site	Primary source (Time)	Number/(total hours)	Communication channel	Other information sources
OSCOM (7 interviewees)	UK	**Chairman** (Oct. 2016)	1 (1 hour)	Phone	1 corporate annual report 2 internal documents 1 service catalogue 1 training brochure Public information on company website, blogs and social media videos, field notes
		Onsite business analyst (Oct. & Nov. 2017)	2 (1.5 hour)	Face to face	
	Asia	**Managing director** (June-Oct. 2016)	3 (3 hours)	Skype	
		CTO (Nov. 2016)	1 (1 hours)	Skype	
		Quality manager (Sep-Oct. 2016)	2 (3 hours)	Skype	
		Delivery manager (Nov. 2016; Sep. 2017)	1 (2 hour)	Skype/ site visit (1 day)	
		Presales manager (Nov. 2016)	1 (1 hour)	Skype	
APPCOM (5 interviewees)	UK	**Group CTO** (Nov. 2017)	1 (1.5 hours)	Site visit (1 day)	4 presentations 3 internal documents (organization charts) Annual/quarterly group operations review (since 2008) 1 group introduction for graduates Public information on company websites and social media videos Field notes
		Group quality manager (Nov. 2016)	1 (1 hour)	WebEx	
		Group supply chain manager (Sep. 2016)	1 (4 hours)	Site visit (1 day)	
		NPD project manager (Nov. 2016)	2 (1 hour)	Phone	
	Asia	**Engineering project manager** (Sep. 2017)	1 (1.5 hour)	Phone	
RECOM (19 interviewees)	UK	**VP of R&D** **Division managers** (3) **Senior research scientist** (3) **Principal scientist (line manager)** (2) **Research scientist** (3) **Scientific advisor** (1) **Research associate** (2) **IT manager** (1) **HR officer** (1) **Librarian** (1) (Nov. 2016)	30m – 2 hours (each interviewee)	Site visit (1 week)	1 internal document Public reports Annual reports Presentations Blogs Social media videos Field notes

Six OSCOM informants were interviewed through Skype, one by phone, and it was only possible to conduct three interviews directly. In the case of APPCOM, only two interviews were conducted through face to face meetings, while the other two interviews took place by phone and through WebEx. In the case of RECOM, it was easier for the researcher to approach the informants (nineteen interviewees participated in the research) because he obtained a week’s internship at the company engineering research centre, where most of their key engineers were located.

The process of gathering interview data began with invitations sent by email to potential informants, informing them about the objective, content and procedure of the research, and asking for their participation with a consent form. In the case of RECOM, during the internship week, invitations were sent to all engineers at the company's engineering research centre and nineteen interviews were arranged and conducted with the research scientists on their site. For OSCOM and APPCOM, at the end of each interview, informants were asked to recommend contacts with any other informants who might have knowledge and experiences of GES network learning and would be relevant for participation in the research. The communication protocol package included a brief introduction of the study with a clearly defined context, objectives, theoretical and practical benefits, a research information sheet, consent and withdrawal forms, and an interview protocol (Appendix 6).

A loosely semi-structured interview protocol was designed to capture the interview data. This interview protocol was based on the preliminary framework of GES network learning constructed in chapter 2, focusing on the following themes (Table 3-3):

(1) The interviewees and the businesses.
(2) *Network learning context*: network learning drivers and outcomes (values).
(3) *Network learning processes*: the knowledge reuse and creation processes and the complexity of customers, suppliers and engineering network actors.
(4) *Boundary spanning mechanisms*: such as boundary spanners, boundary spanning tools, learning coordination, knowledge governance and technological mechanisms.

These themes aimed to guide and facilitate an open conversation with informants rather than structured queries to capture diverse facts, experiences and insights about GES network learning and value creation (Yin, 2003). The early versions of interview protocol were piloted with two senior managers within an IT engineering service company to test their capability to capture information on firms' GES network learning, and resulted in the preliminary interview protocol (Appendix 6).

The preliminary interview questions were developed during the field research and tailored to fit the various interviewee roles, positions and perceptions of network learning. Top ranking managers often had a general and comprehensive view about network learning, while middle managers and engineers possessed local and more detailed knowledge. In fact, not all informants had a full understanding of network learning practices due to the scope of their work. However, their different experiences provided complementary information for the understanding of GES network learning. Figure 3.1 exhibits an example of an interview protocol tailored for interviewing a senior manager who manages engineering network learning for technologies development of APPCOM.

Network learning for engineering innovation

1. Could you help me understand better your company engineering network?
   Prompts: engineering service areas of your company, market position, number of subsidiaries with engineering functions and their locations.
2. What are the drivers for innovating engineering solutions at your company?
   E.g. customer problems/demands, supplier technologies, and intra-firm innovation strategies?
3. Does your company use internal and/or external resources for engineering innovation? How does your company coordinate these engineering resources for engineering innovation?
4. Who are the external partners? How does your company work with them to create new technologies? Does your company reuse partner knowledge or collaborate with them to create new ones? Could you describe the reuse and/or collaboration processes?
5. How do internal engineering divisions collaborate to create new technologies for the company?
6. What are the knowledge sharing challenges in the collaboration processes?
   E.g. the complexity and abstraction of knowledge, organizational, technological and cultural differences.
7. What are the knowledge management mechanisms your company uses to facilitate engineering innovation?
   - Who are the people involved in engineering innovation processes?
   - What do they do to capture, interpret and disseminate knowledge across the engineering network?
   - What are the coordination mechanisms your company uses for engineering innovation projects?
   - How does your company govern the knowledge sharing behaviours of engineers in technology development projects?
   - Does your company use supporting tools for technology development projects?

Intelligent manufacturing (extra questions)

8. What is intelligent manufacturing technology at your company?
9. How does intelligent manufacturing help to capture, interpret and disseminate knowledge across engineering network to enhance engineering performance of the whole network?
10. What are the challenges of using intelligent manufacturing for network operations?
11. What can your company do to effectively adopt intelligent manufacturing across engineering networks?

Figure 3-2: Interview protocol with the CTO – APPCOM

The researcher combined some interviews with a site visit. This combination strengthened the information provided by the informants through the triangulation of interview information and direct observations. All the informants who participated in the research allowed the researcher to record the interviews so that handwritten notes did not need to be taken. After the interviews were conducted, the data were transcribed, resulting in a total of 436 pages of text which were then input into Nvivo software for data analysis.

Documentary information. Company documents were important sources for the study. Indeed, the case companies compete through innovative solutions and operational excellence, and such business strategies motivate them to generate and openly share a great deal of operational information on their website portals about their service business, strategies and best practices. Offline and online company documents included business profiles, group annual reports, group operational reviews, best practice case studies, training programme brochures, service capabilities, new technologies, business and operational blogs, and press articles. These documents were all relevant to this study as they provided information relating to the drivers, processes, challenges and mechanisms of network learning that contributed to companies' competitive advantages. Such information was crucial to augment the research themes and triangulate them with other types of data sources. Company documents were collected systematically through the case companies' websites and during the site visits (see details in Table 3-4).

Archival records. Internal documents such as presentations, organisational diagrams, internal lists of engineers and process charts were collected during the site visits with the permission of the case companies. These archival records augmented other data sources to enrich the research themes. Notably, public archival records could be found on social media channels. For example, many events, service facts and presentations were uploaded by the companies and other organisations and published Youtube. These social media records offered information to corroborate with other data sources. Internal archival records such as process maps, organisational charts and directories were all relevant to further understanding of the GES operations and network learning of the case companies. Some documents about projects stored in information systems and customer information were confidential, so it was not allowed to take notes or to copy them. Archive records were important data sources to corroborate and complement the interview and company document data.

Observation and participation. During the field research, there were opportunities to visit key engineering sites of the three case companies. Two visits were made to APPCOM sites in the UK, one at the group advanced research and technology function and one at the group operations function. Along with the interviews, lectures and conversations on engineering supply networks and machine learning with two senior managers in these sites, there was the opportunities to observe the intelligent manufacturing laboratory and how this technology can contribute to network learning to improve engineering operations. In addition, visiting group research and operations sites provided first-hand experience of how group taskforces work to facilitate network learning at APPCOM.

One day was spent visiting an OSCOM engineering centre in Asia to interview a senior manager and observe the operations of their offshore development centres (project teams) and other software development project teams. This visit provided first-hand experience of how their engineering project teams were organized, and how they operated and collaborated with the entire network to effectively create solutions for customers. A one week internship at the RECOM engineering hub for bio-simulation technology in the UK was also offered to learn about their network learning practices. During the internship, along with nineteen interviews, it was possible to directly observe cross-functional learning practices (e.g. individual research, seminars, engineering meetings and journal clubs), the design of learning spaces, research activities, and the application of information systems/ technological tools. The chance was also provided to attend cross-functional seminars during the internship week to have first-hand experience of how diverse research scientists learned expertise from each other to generate innovative models for the company. All the experiences and notes gained from of these direct observations enriched the research themes and were used for triangulation with the other data sources.

Data management. The interview data were managed to avoid respondent bias and inaccuracies (Yin, 2003). First, an interview protocol package was prepared to address these issues. In each interview, the researcher checked and signed a consent form with the informants to ensure that they had read and understood the objectives and content of the research project before attending the interviews. Second, various engineers at different management levels, engineering functions, and geographical locations were interviewed (Eisenhardt & Graebner, 2007). Third, the researcher also emphasised the confidentiality, risks and the benefits of participating in the research before the interviews. This eliminated the concerns of informants relating to trade secrets and/or intellectual property and facilitated open conversation during the interviews.

The interview research questions highlighted contemporary events and experience. The researcher tried not to use academic terminologies that were unfamiliar to the informants. Instead, he adopted terms that were understandable to them. Furthermore, multiple informants were approached who were located at different organizational levels, either at corporate functions or engineering sites, to capture diverse information on GES network learning. These interview data were triangulated with documentary information, archival records, observation and participation experience to ensure the alignment of different groups of interview data. These, together with the other sources of each case company, were stored in separate folders for tracking and cross-referencing (Yin, 2003).

3.7. Data Analysis

The data analysis process extracted relevant information from the various data collected to gain insights into GES network learning and value creation in the three case companies. The rich data from various sources provided a variety of information relating to network learning drivers, processes, knowledge boundaries, boundary spanning mechanisms and outcomes (values) within the three network learning episodes. Data analysis was conducted to capture the data that fitted with the network learning episodes and their related research themes. The data analysis methods enabled the researcher to draw new frameworks from the data, which were subsequently compared with the preliminary framework for theory development.

The data were analysed at two levels: single and cross case (Yin, 2003). The single case analysis identified the GES network learning practices that were typical for a specific value creation strategy such as efficiency, flexibility or innovation, while the cross-case analysis aimed to achieve theoretical replications across the three cases (Yin, 2003). Figure 3-2 shows the sequences of single and cross case analysis activities in the research

Data analysis was facilitated through data coding and pattern matching techniques. Open, axial and selective coding[9] techniques (Strauss & Corbin, 1998) were adopted to identify and align various information within data sources with the preliminary categories in the three network learning episodes, such as GES network learning drivers, processes, knowledge boundaries and boundary spanning mechanisms, and values (Table 3-3) (Christensen et al., 2002). These techniques helped to link the data with the preliminary themes and therefore enable identification of GES network learning practices within a single case (Christensen et al., 2002; Yin, 2003).

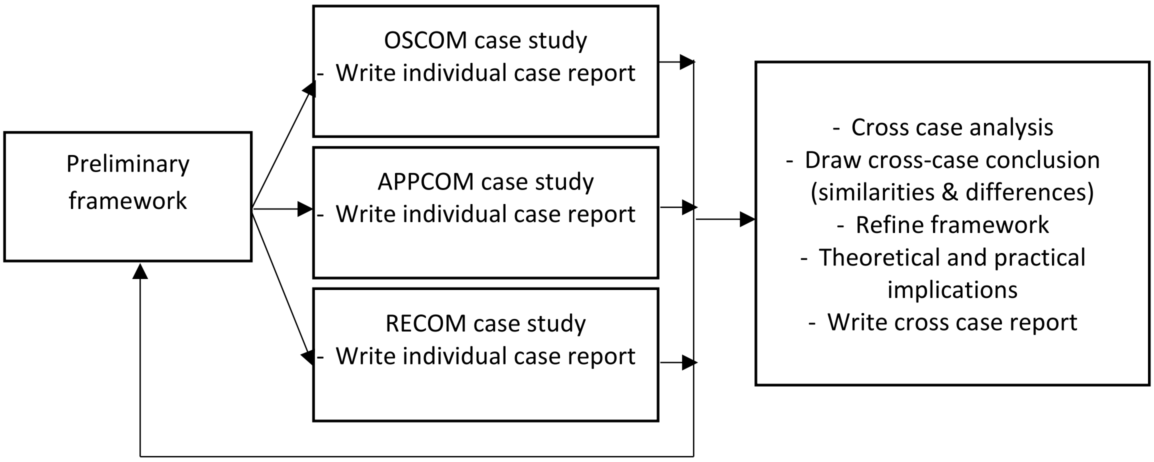


Figure 3-3: Data analysis process

Source: Adapted from Yin (2003, p.50)

Pattern matching techniques were adopted for both the single and cross-case analysis (Yin, 2003). The aim was to link the data and research findings with the preliminary conceptual frameworks, evaluating whether the emerging framework confirmed or altered the preliminary one. In single case analysis, pattern matching assisted comparison of the research findings of a single case study with the preliminary framework. In the cross-case analysis, pattern matching helped to compare different frameworks found in the three cases, which enabled the exploration of similar and different GES network learning patterns (Yin, 2003).

---

[9] According to Strauss and Corbin (1998), open coding is the analytic process through which concepts are identified and their properties and dimension are discovered in data. Axial coding refers to the process of relating categories to their subcategories; the term “axial” is used because the coding occurs around the axis of a category, linking them at the level of properties and dimensions. Selective coding is the process of integrating and refining the theory.

Developing categories and episode frameworks for data analysis. To assist the data analysis, the literature review developed key categories of network learning, three network learning episode frameworks, and a preliminary framework highlighting their independent contributions to GES value creation. The network learning context, processes and boundary spanning mechanisms (Table 3-3) not only helped to predict and capture data from various data sources, but also assisted data coding processes (Christensen et al., 2002). The network learning episode frameworks were the patterns for analysing the GES network learning data in order to verify or refine the patterns (Yin, 2003). Figure 3-3 presents an example of an episode framework used to analyse the data of network learning with customers. Ultimately, the preliminary framework of GES network learning and value creation enabled analysis of the research findings within and across cases (see chapter 2 for details of the preliminary framework).

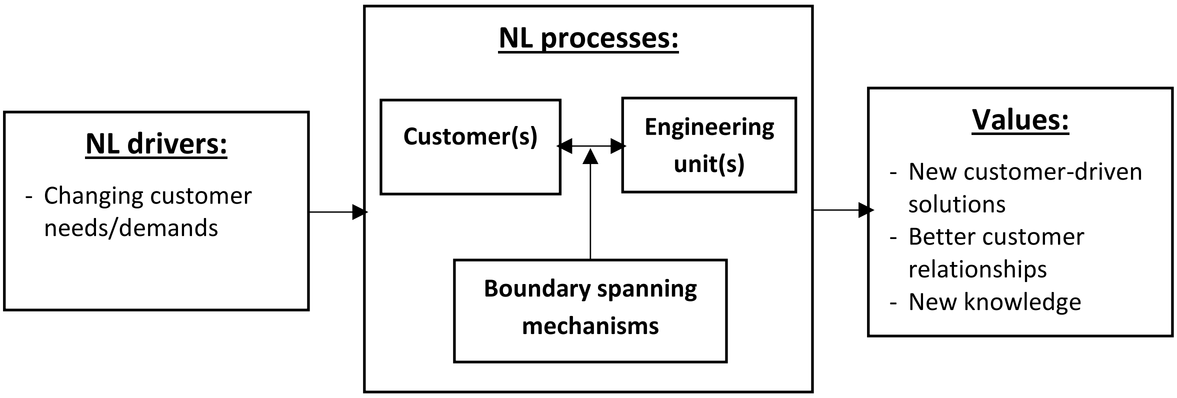


Figure 3-4: Example of a network learning episode framework for case analysis

Identifying network learning practices. In the single case studies, the interview data, documentary information, archival records, observation notes and other related data were read and coded with reference to the preliminary categories (M. B. Miles & Huberman, 1994). Both open, axial and selective coding were simultaneously and iteratively employed to align the data with the preliminary categories and aggregate them into the common themes across the three cases. This helped to compare and contrast the GES network learning drivers, processes, knowledge boundaries, boundary spanning mechanisms, and outcomes (values) across the network learning episodes and cases. For example, the various themes on GES network learning drivers were classified into changing customer needs/demands, supplier capabilities, and intra-firm knowledge gaps; GES network learning processes were grouped into knowledge reuse for innovation, knowledge creation, and knowledge reuse (transfer and/or selective reuse); knowledge boundaries included interest differences or shared interests; and boundary spanning mechanisms were distinguished in terms of centralised/decentralised boundary spanning resources and formal/informal governance. The structure of emerging themes along the preliminary categories changed constantly during the analysis processes. Selective coding subsequently arranged the codes into common themes which explained different GES network learning for value creation across the three learning episodes and cases. Interview data coding was assisted by Nvivo - version 11. Nvivo is a qualitative data analysis software produced by QSR International, providing a set of tools that assists researchers to manage data sources, ideas, data analysis and reporting (Bazeley and Jackson, 2013). In this study, the software facilitated the extraction, creation and integration of various codes from interviews into preliminary and emerging categories. It helped to enhance the summary and reduction of data into categories that revealed insights into GES network learning and value creation.

Identifying the relationships. Based on the aggregated themes and their linkages which emerged from data, it was possible to draw the similarities and differences between the GES network learning practices across the three cases. The preliminary framework was subsequently used to interpret the findings, explaining the differences between the emerging framework and the previous one. The emerging framework could be the tool to explain the variation between the three cases. At this stage, data collection and analysis reached a saturation point, at which further data did provide additional interesting insights into the phenomena in question. The results of the data analysis were compared with the current literature to verify and establish the theoretical contributions and practical implementation.

3.8. Quality of the Research

From a critical realism stance, the quality of this research is determined by a set of qualitative research methods and their rigor in assuring maximum measurement reliability and theory validity (McCutcheon and Meredith, 1993). Good case study research should ensure that research methods are selected to increase research validity, reliability and generalisability[10] (Easterby-Smith, 1991). Yin (2003) clarifies that research validity and generalisability[11] can be measured by the identification of accurate constructs, the possibility of generating reliable theories, and the ability to generalise constructed theories. Research reliability can be tested through the replicability of research operations with the same results (Yin, 2003).

In this study, three representative cases and their key units of analysis were rigorously selected. By applying the same preliminary categories and frameworks for the analysis of multiple case studies, external validity was achieved. In fact, the preliminary themes of the network learning episodes guided the data collection and analysis. The analytical and conceptual frameworks were developed through the literature review and verified and refined through the case studies. These frameworks facilitated pattern matching and theoretical replications across the three cases studied and thus increased the external validity of the theories on GES network learning for value creation (Yin, 2003).

Construct and internal validity were fostered by various qualitative research methods. The selection of these methods was based on an intensive literature review in which preliminary measures were constructed through various sources of evidence. These measures guided the design of data collection and analysis methods. Various data collection methods such as interviews, documentation, archival records, direct observations and participation over a long period of time were adopted to triangulate and complement each other. The triangulation approach to data collection and analysis increased the construct validity by providing different and connected sources of empirical evidence and ensuring that biases could be eliminated (Denzin, 1978). Diverse literature and empirical data sources enhanced the validity of the constructs.

Internal validity was facilitated by the adoption of the preliminary frameworks in the single case studies. This research approach fostered pattern-matching and explanation building

---

[10] Easterby-Smith (1991) argues that research quality can be measured by three criteria: (1) validity: whether full access to the knowledge and meanings of informants has been obtained; (2) reliability: whether similar observations are achieved by different researchers on different occasions; and (3) generalisability: how ideas and theories generated in one setting will also apply in other settings.

[11] Yin (2003) identifies four criteria to test research quality: (1) construct validity: the identification of correct operational measures for the concepts being studied; (2) internal validity: the ability to establish cause and effect relationships; (3) external validity: the ability to apply findings in other populations; and (4) reliability: the ability to repeat the operations of the study with the same results.

within these studies, validating the predicted framework and theories. It also increased rival explanations through theory comparison across cases (Yin, 2003).

Reliability was assured through a preliminary research protocol (Appendix 6). The aim was to ensure that the data gathered was accurate and to avoid informant and interviewer bias. The introduction to the study provided a general perception of GES network learning issues and the benefits of the study to companies. This information facilitated informants to provide relevant information relating to the research themes. The research procedure and confidentiality agreements on use of confidential information, techniques and products enhanced the openness and accuracy of the information provided by the informants. In the study, the confidentiality issues were clearly stated and explained to the research participants in the form of a participant information sheet which was attached to each research invitation. The issues then were repeated before each interview to ensure that the informants understood and consented to participate in the research. Understanding and consent were confirmed through a signed consent form. Data were collected at different management levels, engineering functions and geographical locations to reduce respondent bias (Eisenhardt & Graebner, 2007). The data gathered were managed within a secure database and the interview transcripts were coded and stored along with company documents, archival records and field notes in separate folders for data analysis.

In the case of RECOM, the company and researcher signed a deed of confidentiality to protect any confidential company information which may have been encountered during the field research period at the company. With regard to OSCOM, the company required a guarantee letter from the supervisors in order to agree to participate in the research. As for APPCOM, the informants asked to be sent all the information relating to the study before granting permission for interviews. Regarding data confidentiality, it was clearly stated that confidential information would not be divulged and that although direct quotes would be used in the thesis, these will be anonymised and anything which could identify the participant or the company would be removed. This was important to ensure an open conversation between the researcher and the informants.

Flexible research questions on key themes of GES network learning generated open conversations without taking informants through structured queries. This flexible approach allowed the researcher to capture the information emerging from the views of the informants on the research themes. Such an approach to the interview data also ensured the objectivity of the research findings and eliminated interviewer bias.

3.9. Conclusion

This chapter has justified the methodology used to understand how firms manage GES network learning to create value in global service operations. It clarifies the empirical research approach, case study design and methods employed in the thesis.

From a critical realism stance, GES network learning can be understood through a theory building approach with case research design. A multiple case studies and units of analysis are relevant to address the complexity and variation of GES firms and their network learning. Three typical cases were intentionally selected to compare and contrast different aspects of GES network learning that contribute to efficiency, flexibility and GES innovation. Case study process was guided by the preliminary frameworks constructed through the literature review and verified and refined through the case studies. The data collection adopted a triangulation approach, using various sources of information to capture GES network learning practices, while the data analysis involved single and cross case analysis supported by preliminary frameworks for pattern matching and theoretical replication purposes. The quality of the research was ensured through a set of methods in collecting and analysing the data.

The above empirical research design and practices enabled the researcher to explore complex GES network learning practices in different GES contexts and thus to address the research problem. In the following chapters, the results from the empirical research process are elaborated to present the evidence of GES network learning and value creation in the three cases studied.

4. CHAPTER 4: GES NETWORK LEARNING WITH CUSTOMERS

4.1. Introduction

This chapter clarifies the roles of customers in GES network learning and value creation, highlighting their contributions to supplier-focused and intra-firm network learning. The chapter begins with an introduction to an episode framework characterising key elements and stages of GES network learning with customers and value creation. Subsequently, it presents the results of the case analysis, clarifying the customer-focused network learning drivers, processes, knowledge boundaries and boundary spanning mechanisms that result in value creation. Finally, the roles of customers in GES network learning and value creation are exemplified and concluded.

4.2. A GES Network Learning Episode with Customers

In this research, a network learning episode with customers identified within the literature review and verified during the case studies is adopted to analyse and present the case studies. It includes three key stages – network learning drivers, processes and values. The first stage is related to emerging customer business problems that change customer needs and demands for firm engineering solutions and trigger a network learning process (Brady and Davies, 2004; Jaakkola and Hakanen, 2013). Customers may need a new engineering solution and/or demand the same systems with better performance. Network learning processes with customers begin to address changing customer needs and demands through either knowledge creation or knowledge reuse (Brady and Davies, 2004).

- Knowledge creation: the stage when the learner network explores new knowledge that is unknown to the market (Nonaka, 1994).
- Knowledge reuse: the stage when the learner network effectively responds to changes in the external environment by exploiting the existing knowledge embedded within the learner network and/or external actors (Argote & Ingram, 2000; Gilbert & Cordey-Hayes, 1996; Majchrzak et al., 2004; Markus, 2001).

Knowledge creation and reuse require customers to share their information and knowledge with engineering units for network learning to occur. But knowledge sharing may be challenging due to the customer knowledge boundaries that hinder its transfer. GES firms need to employ various boundary spanning mechanisms to eliminate customer knowledge boundaries and thereby facilitate network learning with customers (Hakanen and Jaakkola, 2012; Breidbach and Maglio, 2016; Ayala et al., 2017). The literature indicates five boundary spanning mechanisms that firms can use:

- Boundary spanners: strategic individuals responsible for developing social relationships and knowledge sharing across communities. They are either knowledge brokers or knowledge translators (Brown and Duguid, 1998).
- Boundary spanning tools: entities that are common to a number of communities within the organization (Hislop, 2009). They are either physical or symbolic in character, including repositories, standardised forms/methods, objects/models and maps (Hislop, 2009).
- Learning coordination mechanisms: formal, hybrid and informal organisational mechanisms designed by firms to facilitate learning across learner actors (Reger, 2004).
- Knowledge governance mechanisms: formal and informal organisational mechanisms that control and/or encourage the learning behaviours of the organization and its individuals towards an organisational learning objective (Foss, 2007).
- Technological mechanisms: not only information and communication technologies, but also other technologies that facilitate information sharing, capturing and processing for organisational learning (Zhang et al., 2016).

The outcomes of network learning with customers are process-oriented and/or output-oriented engineering solutions for the customers, which help firms to capture exchange value (Breidbach and Maglio, 2016). Furthermore, network learning outcomes can be non-monetary values such as partner relationships and new knowledge, which can be useful for future exploitation (Brady and Davies, 2004), as well as new customer information for future development (Galbraith, 2014). Figure 4-1 presents common characteristics of a learning episode with customers identified through the literature review and verified through the case studies.

The network learning episode framework (Figure 4-1) is used to analyse and present GES network learning with customers in the three cases studied. The following sections present the customer-focused network learning drivers, processes, boundary spanning mechanisms, and values at OSCOM, APPCOM and RECOM, clarifying the roles of customers in GES network learning and value creation. At the end of the chapter, their learning practices are compared and contrasted to identify GES network learning patterns with customers.

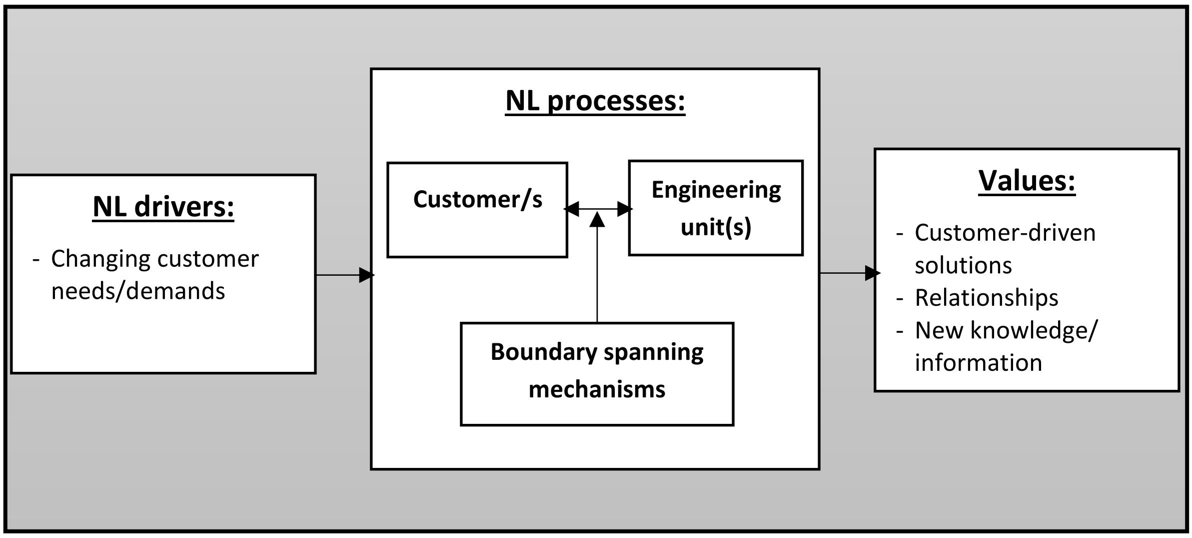


Figure 4-1: Characteristics of a GES network learning episode with customer/s

4.3. OSCOM Learning with Customers and GES Efficiency

OSCOM (see Appendix 3) provided Information Technology Outsourcing (ITO) services to customers worldwide, competing through GES efficiency. The company delivered IT solution projects to customers through a network of two engineering centres in Asia and 10 offices around the world. OSCOM customers operated in various industries and businesses and were globally dispersed. This section presents the OSCOM GES network learning with customers that contributed to GES efficiency.

4.3.1. Network Learning Drivers

Changing customer needs

Technologies and global markets were are changing rapidly, which forced customers to change their needs for IT systems constantly. The OSCOM engineering service business model depended greatly on addressing changing customer needs in order to be competitive. The CEO asserted that *"[OSCOM] are selling today what businesses need. But [OSCOM] is having to think of what businesses will need at the same time*" (OSCOM, interviewee 001). Most OSCOM customers already had an IT system, but their IT systems or engineering resources might have been be unable to meet their current or future business needs. They needed OSCOM to advise them what should be changed and at the same time undertook these changes, such as re-developing or enhancing their systems (OSCOM, interviewee 007).

Customer demands for high-quality and low price solutions

In addition to changing needs, customers demanded high-value IT solutions. A senior manager stressed that "*customers know what they want, and they want to have a cost-effective solution to address their needs*" (OSCOM, interviewee 002). He added that "*[customers] have a fixed budget to do a project, they want to find a partner who can solve their problems within a fixed budget, so they can transfer the risk. Customers sometime cannot find qualified resources at a reasonable price in their location, they look for partners who can provide resources at reasonable prices*" (OSCOM, interviewee 002).

Competition intensified customer needs for low price IT solutions. An onshore business analyst asserted that "*In this ITO industry, there are many providers in China, India, and recently western countries such as Romania […] customers will select suppliers firstly for the solutions they need. The second criterion is nearshore, offshore or onshore. And another issue is price over quality or quality over price. Sometimes customers seek solution providers with prices as low as possible because they have a limited budget. However, they rarely accept a quality trade-off over price*" (OSCOM, interviewee 007).

For customers, quality meant on-time delivery and skilful engineers. A quality manager noted that "*customers may not care about how we do provided that we deliver services on time with high quality*". He added "*In outsourcing business, customers may not require a high degree of innovation but skill, in order to provide defect-free solutions*" (OSCOM, interviewee 005).

Cooperative relationships

Because of rapidly changing technologies, customers wanted a partnership relationship with OSCOM in which they expected that it would co-develop its business with that of the customers, support them and make everything transparent. Customers wanted to know what OSCOM did and to make sure that OSCOM operations benefitted their projects. This trend was described by an onshore business analyst, who noted that "*for the UK market,*

[…] the customers want a partner who will go along with them over the entire business cycle […] you can imagine that a customer is not specialised in IT. They have an IT system and many business problems. If [OSCOM] just steps in, consults and goes away, they will struggle to find their own ways for IT changes and they do not want that. They want to have a company who carries out those changes and of course cost and quality should be good. It is multiple value" (OSCOM, interviewee 007).

Changing needs and diverse demands for quality, cost and long term relationships, along with rapidly changing technologies and increasing competition were driving OSCOM to learn with customers to adapt to changes. A senior technology manager highlighted the changing global market that impacts OSCOM learning: "*our company is a global company covering services in many countries in the world. Each country has different technological trends […]. In order to adapt to these demands, we must constantly update new knowledge for our engineers […]. Because technologies have changed continuously and customers come from many countries in the world, we have to constantly learn to meet this challenges*" (OSCOM, interviewee 003).

4.3.2. Network Learning Processes

Knowledge reuse for innovation – capturing future customer needs

OSCOM annually conducted a CEO survey to identify technology trends around the world (Company document, 2017). This survey provided information for OSCOM senior technology and operation managers (e.g. the CEO, general director, CTO, quality managers) to work out the key technology targets the company should focus on. These targets directed project teams to capture information on customer needs and helped OSCOM to identify what technology the company should develop with the technology suppliers who generated the technologies that customers wanted (OSCOM, interviewee 003, 005). Thus, "*We have been collecting information about customers' requirements on necessary skills in recent times […] so that we can set the future directions on which technologies our R&D team should focus or in which areas we should develop more skilful resources*" (OSCOM, interviewee 002).

Knowledge creation of onshore-offshore project teams

OSCOM co-created IT solutions with customers at customer sites with the engagement of onshore-offshore integrated project teams. The solution co-creation included five phases: requirement, architecture and design, development, testing, and deployment (OSCOM internal documents). Solution co-creation with customers began with the pre-bidding process, acquiring customer requirements for bidding. In this process, customers provided information to on-site/onshore business analysts (BA) and technical architects (TA) to draw up conceptual solution designs. The design plans were sent to offshore engineering centres for bidding and then software production. Offshore centres took onshore solution plans to prepare detailed proposals and established project teams including developers, testers and business analysts to cooperate with onshore BA, TA and customers for IT solution co-creation. Customers then continued to collaborate with the onshore and offshore teams in the development, testing and deployment processes to ensure that the produced solutions met their requirements.

The importance of customer cooperation

Project learning occurred primarily in the phase of capturing customer requirements. In fact, different customers had different requirements for technologies and operational performance to address their needs. To create solutions for customers effectively, OSCOM needed to understand customer requirements so that it could apply its IT knowledge to benefit customer needs (OSCOM, interviewee 002). A business analyst highlighted the importance of customer cooperation for the project team learning: "*depending on customer technology maturity, OSCOM want customers to cooperate with OSCOM in providing their requirements. That is, firstly, 'what do you want us to do for you?' This means that customers must clarify their requirements*" (OSCOM, interviewee 007).

In relationship learning with customers, onshore BA and TA collaborated closely with customers to co-create solutions. When customer requirements were new and complex, OSCOM had to send offshore BA and TA to customer sites. These engineers were experts in their areas, sent to learn about the customer's IT systems and technologies, which informed decisions regarding what technologies should be used, what platforms should be adopted, and how to code (OSCOM, interviewee 007).

Relationship learning with customers at the customer sites resulted in many benefits. On the one hand, it facilitated the creation of frameworks that guided offshore development teams. On the other hand, it saved time communicating by phone, enhancing observation, interaction and knowledge creation, facilitating resource selection, and developing new skills for OSCOM (OSCOM, interviewees 002, 007). The knowledge creation processes between customers and OSCOM continued during the implementation phases, which involved offshore development teams, and the solutions developed were transferred to customers. Customers then played the roles of information providers and collaborated to verify solutions with offshore and onshore teams, making sure that the solutions produced met their requirements. In some projects, customers might have requested OSCOM to ask suppliers to join in on projects to verify the solutions co-created with customers (OSCOM, interviewee 005). This relationship with customers might have lasted for a long time.

The project teams might have become Off-shore Development Centres (ODC), conducting many projects with customers (OSCOM, interviewee 002). Thus, "*Customers want to utilize [OSCOM] resources and consider them as their departments [offshore]. [The offshore teams] include engineers with diverse backgrounds and skills working according to customer assignments and packages. For example, a customer buys our services to have an ODC with 20 engineers working for them. They will assign projects within that ODC. ODC may implement a big project or they may undertake many projects for the customer*" (OSCOM, interviewee 002).

Knowledge capture for future reuse

OSCOM project teams not only co-created solutions with customers but also captured the lessons learned in the relationships with them (OSCOM, interviewee 005). Knowledge created with customers was first captured by onshore BA and TA, who worked directly with customers. They generated high-level engineering architecture frameworks that addressed customer requirements and guided offshore operations (OSCOM, interviewees 002, 007). During project implementation, customers collaborated with onshore-offshore teams to provide feedback and additional requirements, from which OSCOM project teams could learn. Such frameworks and lessons learned in the relationships with customers were captured through the documentation within projects (OSCOM, interviewees 001, 005). The CEO asserted that "*What we do when we are in the development process - we are capturing* *the framework of what we do and modularising those frameworks on a constant basis. That learning enables us to reduce the cost of the future development for business and for clients and to increase the flexibility and efficiency of our teams*" (OSCOM, Interviewee 001).

The frameworks and lessons learned were different in terms of business domains, and technical and process knowledge. A senior manager explained that "*For domain knowledge such as banking and finance, enterprises, manufacturing, retailing and so on, each domain differs from the others and we capture each of them. For technical knowledge, all customers have their own requirements for different technologies such as .NET, Java, database and so on and we also capture each of them*" (OSCOM, interviewee 002).

4.3.3. Customer Knowledge Boundaries

Customer business complexity

OSCOM customers were diverse, running various businesses in different industries, either non-IT businesses or IT solution vendors who were specialised in a specific IT platform (OSCOM, interviewees 005 and 007). They could be public or private businesses which engaged with OSCOM as the end-users or vendors. In the words of an onshore business analyst, "*[OSCOM] works with all industries. Customers can be public or private businesses […] whoever has a need to build or manage or maintain their IT systems or need consulting and design solutions for their these systems*" (OSCOM, interviewee 007).

Interpretation and language differences. Diverse customers in different industries meant there were knowledge boundaries that hindered knowledge transfer. A senior manager described the knowledge boundaries between OSCOM and its customers in this way: "*Some customers have ideas on what they need, but they don't know how to describe it in the language that can help engineers to turn it into the solutions. For some clients, they don't have knowledge of engineering, they just know what they need, so they need a partner who can consult them on the solution, architectures and then can help them to turn it into solutions*" (OSCOM, interviewee 002).

Customer Interest differences

Diverse customers had their own specific technologies, processes and interests that OSCOM had to follow. For example, "*Customers who dictate [OSCOM] on technology requirements are often solution vendors. They already have specific technologies or* *platforms. OSCOM must follow those technologies […]. In some governmental organizations, they also use a specific technology. They are constraints for OSCOM. However, these constraints are driven by objective reasons, not by the customers imposing them [OSCOM]*" (OSCOM, interviewee 007).

Diverse customers and their knowledge boundaries caused many challenges for both OSCOM and customers in solution co-creation processes. As the CEO noted, "*Customers are not regularly working with the remote teams. And they do not know how to work with the remote teams, particularly in today's digital technologies […] most clients do not quite understand the technique of running an agile development [process]. They are necessary in the digital world. One more challenge at the end, that is, offshoring the remote team, faces the challenge of relating to customers' needs because they are far away*" (OSCOM, interviewee 001).

4.3.4. Boundary Spanning Mechanisms

Boundary spanners (BS)

Centralised onshore/offshore BA and TA teams. OSCOM strategically employed a small number of BAs and TAs who were located both within international offices close to customer sites and in offshore centres. These engineers interacted with local customers to understand their complex requirements and made a development plan for the offshore engineering centres to request information and/or proposals. They then reviewed the offshore proposals together with the offshore bidding support teams to ensure that the proposals were accurate and practical. A senior manager explained that "*Onshore engineers work at high levels, being responsible for customer interaction and technical architecture design. They are the engineers who do not focus on the details of software development*" (OSCOM, interviewee 002).

The onshore BAs knew how to collect business and functional requirements. They had backgrounds in information technologies and experience in software development. They supported sales teams to capture customer requirements and design solutions for them. BAs were also engineers who collaborated with customers when necessary. When a project was large and constantly progressing, BAs might follow that project from the beginning to the end. They even supported customers in deploying the IT systems (OSCOM, interviewee 007).

The onshore TAs had deep insights into information technologies and system design. They collaborated with the onshore BAs to consult customers on where to go and what to do with their IT systems. They worked with customers in different businesses and projects and at the same time collaborated with offshore engineering centres for software development work. An onshore business analyst commented on the role of the onshore TAs in this way: "*Technical architects are like 'gurus', joining us to solve difficult problems. They engage in projects to provide technical solutions […]. They do not work full time on a specific project, but work on a number of projects at the same time and are only involved in solution design works. They may review projects to make sure development teams follow solution plans. They are often released from projects before they are completed*" (OSCOM, interview 007).

When customer requirements were new and difficult, meaning that onshore TAs might not understand them, offshore centres would send skilled BAs and TAs to study customer requirements and technical problems with onshore BAs and TAs. Thus, "*When we have a difficult project in which the [onshore] team may not understand everything, the [onshore] team will inform the [offshore] centres to implement a discovery phase. [Offshore] centres will send business analysts and technical engineers to talk with customers directly*" (OSCOM, interviewee 002). Offshore BAs and TAs were knowledgeable and had the ability to learn fast, which helped them to shorten the research and development phases (OSCOM, interviewee 003). Onshore and offshore BAs and TAs collaborated closely with each other to establish customer requirements, technology approaches and to estimate contract prices (OSCOM, interviewee 007).

Boundary spanning tools (BST)

Pre-defined solution frameworks. OSCOM served many customers with differing business contexts, technologies and interests. To facilitate learning across knowledge boundaries, customer requirements had to be translated by boundary spanners into solution frameworks that created a common sense of shared interests and a willingness to share knowledge (OSCOM, interviewees 002, 005, 007). Solution frameworks were co-created between onshore/ offshore BA and TA and customers and sent to offshore development teams. These frameworks were the boundary spanning tools for customers and OSCOM project teams to guide knowledge sharing, bridging the differences in interests, interpretations and languages.

Global project management system. OSCOM adopted a common virtual portal for customers and OSCOM to interact during the implementation of solution projects. In fact, the company had a global intra-firm/inter-firm information system to manage not only past project information, but also current projects. The company used this system as a boundary spanning tool to connect customers with remote production teams in related projects. Customers were granted an account to access their project portals that facilitated the communication and control of solution production between customers and offshore project teams. Through these portals, customers could easily share and capture information with remote teams and thereby enhance mutual understanding in the collaboration processes. In the words of a senior manager, "*We only have a portal to interface with clients. We upload necessary data and customers can do the same, to provide input for us. However, there are projects where customers co-develop a software with offshore teams. Customers will be granted an account to log into the company project management system. This system is just for the management of that project*" (OSCOM, Interviewee 002).

Learning coordination (LC)

Onshore-offshore project coordination. OSCOM and its customers coordinated in projects for solution co-creation. The coordination process began with customer requirement understanding, solution planning and pricing in the pre-bidding phase. The process involved OSCOM sales, and BA and TA teams working with customers in workshops at customer sites to reach a common plan for project formulation. In the bidding phase, onshore and offshore bidding teams worked on project proposals that met customer requirements. Project terms and contracts were often established after offshore engineering centres, onshore offices and customers came to agreement on prices, technologies, production processes and solutions. Once project bidding was set, customers and OSCOM assigned resources to undertake the project (OSCOM, interviewees 002, 007). Project teams could be employed as an OCD, which conducted many projects for customers on a regular basis.

Knowledge documentation. Another mechanism for learning coordination across OSCOM and its customers was documentation. Onshore teams documented relationship learning with customers into solution frameworks that were used to guide learning coordination between the company and its customers during the later phases of projects. Integrated onshore and offshore teams continued to learn with customers and capture customer learning through documentation of lessons learnt following CMMI standards; e.g., processes of knowledge sharing and templates for documentation (OSCOM, interviewees 002, 004).

Knowledge governance (KG)

Customer contact points. Customer knowledge sharing was important for OSCOM project operations. In projects, customers might have had to formally set up a contact point or an IT team to share knowledge with OSCOM during implementation. They might have shared knowledge with onshore and offshore BA, TA, developers and testers on a regular basis about issues and emerging requirements during the solution production process. An onshore analyst asserted that *"[Customers] must provide OSCOM with their resources. They must assign a project manager or project owner as the contact point to work with the project team, addressing issues or queries arising during the implementation phases of the project. If the customers have IT teams who also have the same IT knowledge, OSCOM wants them to verify the solution proposed by them. They must confirm that they agree with it*" (OSCOM, interviewee 007).

Trust & long-term relationship. Trust was another important mechanism to facilitate knowledge sharing because customer cooperation was key for learning. An onshore business analyst emphasised that customers increasingly expected OSCOM to become a long-term trusted partner who could go along with them in the long run (OSCOM, interviewee 007). For example, "*[OSCOM] has worked with a customers over 10 years […]. Most of the knowledge accumulated is stored at [the OSCOM offshore team]. [The OSCOM offshore team] is very important for them because their knowledge is here*" (OSCOM, interviewee 002).

Third party certifications. To build up trust with customers, OSCOM had to obtain certifications of well-known industrial third parties such as CMMI (for process standards), TMMI (testing standards), ISO 27001 (security standards), Microsoft technology certification, and Amazon technology certification. These certifications were the signals to demonstrate to customers that OSCOM had the abilities to implement and manage IT solution projects. Thus, *"[CMMI] is a level of maturity has tools and processes to help project managers to be confident in confirming whether the projects are in good or bad conditions and predict if are there any problems in the future"* (OSCOM, interviewee 002).

Operational transparency & IP protection. Operational transparency was important to build trust with customers. Customers wanted OSCOM to be transparent with what it did so that they knew that the company was doing things that benefitted them (OSCOM, interviewee 007). Furthermore, intellectual property protection was important in building trust. A senior technology manager emphasised the rule of protecting customer knowledge within OSCOM: "*There is a committee which reviews and approves [lessons learned] before they are public or not. What are approved firstly are not related to clients because clients' intellectual properties must be protected, and are not for sharing*" (OSCOM, interviewee 002).

Technological mechanisms (TM)

Data mining technologies. Cloud and analytic technologies assisted OSCOM and its customers with managing project information. These technologies allowed the company to capture, analyse and disseminate real-time project information from both customers and project teams on a global scale. Project statuses were constantly updated on dashboards and therefore provided on-time operational information for decision making (OSCOM, interviewees 001, 002).

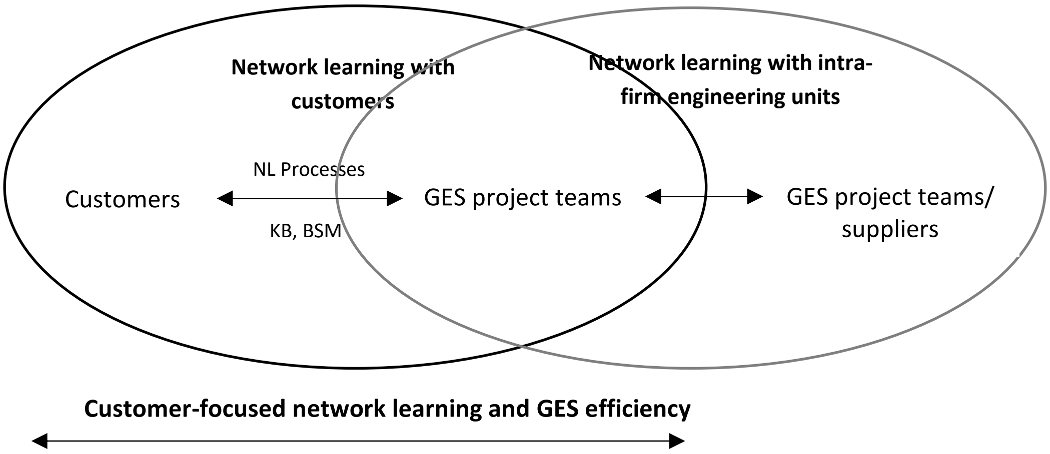
4.3.5. Values

OSCOM network learning with customers generated cost-effective IT solutions that satisfied a specific customer need. Besides, it generated solution frameworks and lessons learned that could be reused for future operations. The company set up fixed-price CoEs to learn with new customers and/or about difficult problems with the purpose of learning and service innovation. In fixed-price CoE projects, learning and building relationships with new customers were the key values of project teams, rather than profits (OSCOM, interviewee 002). Additionally, customer information regarding their future needs were collected in the collaboration processes to guide future technological research and development with suppliers.

4.3.6. GES Network Learning With Customers and GES Efficiency

Customer-focused network learning is driven by changing customer needs for cost-effective solutions. It is enabled through a cooperative relationship with customers. The network learning process firstly focuses on knowledge reuse for innovation, involving future customer needs capture for future technology development. Knowledge reuse for innovation occurs at both corporate and project levels. While corporate senior management teams capture customer trends to set engineering targets for the learning of project teams, the teams themselves directly contact and capture future customer needs for the firm’s future development. Another process is the knowledge creation between a project team and a customer in the solution co-creation process. This includes two moments of learning: the first being knowledge co-creation and the second knowledge capture for future reuse. Knowledge creation and reuse often occur at customer sites because the solutions need to be created in customer business contexts. The challenge is that customers may have different interests, interpretations and languages that hinder network learning. It is important for firms to use dispersed centralised functional teams and formal governance mechanisms to eliminate customer knowledge boundaries. These teams operate across many projects, directly collaborating with customers to generate common frameworks that direct the knowledge creation between the project teams and customers. The created values are not only the cost-effective solutions that satisfy emerging customer needs, but also customer long-term relationships, firm engineering targets, new knowledge for future operations, and information for firms’ future R&D. Figure 4-2 illustrates customer-focused network learning practices and their links to intra-firm and supplier-focused network learning that contribute to GES efficiency.

Past research highlights customer collaborations and new service capability development in solution networks (Brady and Davies; 2004; Windahl and Lakemoon, 2006; Jaakkola and Hakanen, 2013). However, most of the studies do not clarify how customer-focused network learning contributes to GES network learning and firm value creation. This study clarifies that customers provide information about their future needs which are the inputs for knowledge creation and innovation inside the firm and/or with suppliers. Furthermore, customers co-create new knowledge with project teams in solution networks that can be reused in intra-firm network learning for efficiency. Customer-focused network learning therefore helps to create not only customer-driven solutions and to capture exchange values, but also to enhance cooperative relationships with customers, and capture information for future development and new knowledge for future reuse. The following section examines the case of APPCOM to explore its network learning with customers for flexible GES.



Network learning drivers:
- Changing customer needs for cost-effective solutions

Network learning processes:
- Knowledge reuse for innovation (with customers) & knowledge creation (intra-firm/suppliers)
- Knowledge creation (with customers) & Knowledge reuse (intra-firm)

Values:
- Engineering targets
- Cost-effective solutions
- New knowledge for future reuse
- Future customer need understanding
- Customer relationships

Knowledge boundaries (KB):
- Customer interest, interpretation, and language differences

Boundary spanning mechanisms (BSM):
- Centralised charismatic CoE (knowledge reuse for innovation)
- Centralised functional teams (project-based knowledge creation)
- Customer business and technology trends, customer project requirements; uniform global information systems and data mining technologies
- Formal knowledge coordination and standardised project-based knowledge sharing procedures and routines

Figure 4-2: Customer contributions to GES network learning and efficiency

4.4. APPCOM Learning with Customers and GES Flexibility

APPCOM (see Appendix 4) provided integrated product-service solutions and competed through flexible GES in the aerospace, energy, automotive and medical device industries. The aerospace industry was the dominant market, in which customers were consolidated and centralised. In this industry, APPCOM provided components and sub-system solutions to two end customers, Airbus and Boeing, and their “tier 1” suppliers, who directly supplied engines and systems to the two companies. APPCOM delivered GES flexibility through a network of over 50 engineering sites across the globe. It learnt with customers to enhance its service performance and address changing customer demands. This section presents APPCOM’s learning with customers for GES flexibility.

4.4.1. Network Learning Drivers

Changing customer demands

The global aerospace market was growing, creating more business pressures on APPCOM customers. To cope with the changing and growing global airline market, customers were demanding better operation performance and technologies. Thus, “c*ustomers were quite fragmented in their approach to the supply chain until relatively recently. Now they are becoming much more joined up. They are more demanding contractually, operationally and in terms of communication. Multiple points of contact on bids and programme management have been replaced by central procurement and engineering teams*” (CEO, APPCOM Annual Review, 2015).

High demands for operational quality, delivery and cost

Customers demanded high-performance engineering services. A senior project director noted that “*The aerospace industry is different from other industries in the way that it establishes very high standards […]. If we are not an approved vendor, it is difficult to access the aerospace market*” (APPCOM, interviewee 005). High quality and just-in-time delivery were the standards APPCOM customers always wanted. Thus, “*Customers want zero quality escapes and they want their products on time. It is what they are paying for. We must manage our processes to minimize risk to their programmes”* (Senior VP Operations, APPCOM Annual Review 2015).

Product quality in the aerospace industry is measured by Piece per million (PPM), which is the number of defective products per million delivered. Customers expected that APPCOM would deliver no defect products, because aircraft should be safe and stable when flying; therefore, the lower the PPM, the better. Just-in-time delivery was equally important. A senior project manager noted that “*big aircraft manufacturers have orders for 10 years from now on. The assembly lines therefore cannot be delayed because customers expect on* *time delivery*” (APPCOM, interviewee 005). Another expectation was cost reduction. That was why APPCOM had located some of its operations to Asia. To meet changing customer expectations for excellent operations, APPCOM had to assure high quality, on time delivery and cost reduction operations on a global scale (APPCOM, Annual Review 2015).

High demands for technology innovation

APPCOM customers increasingly expected that the company was committed to continuous technology development, as they were innovating from one technology to another due to the increasing pressures from consumers, business customers and regulators. In the aerospace industry, customers require the technologies provided to be developed at levels that could be integrated into products for commercialisation. Thus, “*in the past, sometimes the industry has come unstuck when it changed from one technology to another. In consequence, our customers want to see products developed to a higher state of readiness before they award programmes*” (CEO, APPCOM Annual Review 2015). Moreover, APPCOM faced high competition from other “tier 1” and “tier 2” suppliers. In the aerospace industry, customers want to have many similar suppliers who compete with each other so that they can capture value.

Cooperative relationships

Customers and APPCOM had strong relationships, which facilitated APPCOM learning with its customers. Their relationships might have been risk/revenue sharing partnerships rather than one-way benefit. In the words of a senior project director, “*We are like partners in our collaborations. If [the customers] want to be successful, they must help us to be successful and vice versa […]. These relationships are very close*” (APPCOM, interviewee 005).

Changing customer demands for better performance, innovation and partnership relationships drove APPCOM to learn with customers in order to align their operations with customer demands and standards and to maintain its suppliers of choice in customer systems. In fact, the company was learning with customers to transform its global organisation into a capability-based engineering group with a common working approach across all businesses. Furthermore, APPCOM had to constantly develop its technologies to be relevant to customers, who were forced to innovate their technologies to address consumer, business and regulatory pressures for safety, hyper-efficient engines and low-weight components and airframes.

4.4.2. Network Learning Processes

Knowledge reuse for innovation

APPCOM engineering sites learned with customers at both corporate and site levels. At the corporate level, APPCOM business managers negotiated commercial terms with customers' senior procurement managers and captured customer requirements. They agreed with supply relation managers what should be done over the coming years. Customer requirements may have been be gathered into packages, which may have included engineering, performance, and quality requirements, and cost challenges for different internal strategic business units (APPCOM, interviewee 002).

Customer requirements were then processed by central functional teams to transform APPCOM knowledge into new knowledge that met changing customer requirements. For example, "w*e had a detailed conversation with [a customer] about how [APPCOM production system] are processed […]. We aligned [APPCOM production system] with [customer standards] […]. That is great. Our quality and delivery requirements are generally their quality and delivery requirements. That is how we work*" (APPCOM, interviewee 002). APPCOM also collaborated with customers in industrial working groups and associations to share and develop common industrial standards. The company met with customer representatives quarterly or annually to discuss common problems and standards for the aerospace industry.

For technological requirements, APPCOM was expected to co-develop technologies with customers, who tended to change from one technology to another over a period of time. Customers expected that APPCOM would innovate its technologies to fit with their technology roadmaps in order to be awarded programs. To meet with customer expectations, APPCOM's central R&D team captured customer technology roadmaps at the corporate level and based on them created technology platforms to guide the learning of engineering sites in their collaborations with customers.

Knowledge creation of engineering sites

After customer requirements were agreed at the corporate level, they were subsequently broken down into lower levels – APPCOM engineering sites. The requirements were often specific and written within contracts and orders and were passed to the design divisions for product research and development. In the design process, the design team worked with customers to understand what they wanted and to create samples for customer feedback. After customers had agreed with the samples and the new product designs were complete, the design engineers passed the new products to the process engineers to design the manufacturing processes and supply chain. After the new products had been manufactured, commercialised and accepted by customers, they were maintained and developed (APPCOM, interviewee 005). During project operations, customers and APPCOM engineering teams collaborated to design, develop and manufacture new products that satisfied customer requirements. In this collaboration process, customers co-created knowledge with APPCOM engineering sites relating to engineering practices and customer business problems (APPCOM, interviewees 002, 005).

Best practice capture for knowledge reuse

During the collaboration with customers, they gave feedback on site performance and maybe helped APPCOM to fill its knowledge gaps for performance enhancement (APPCOM, Interviewee 005). In fact, customers had their own operational standards and knowledge from which APPCOM could learn. Customers often visited APPCOM engineering sites to audit engineering operations and were able to help APPCOM to develop its operations. In the words of a project director, "*Customers frequently visit our site to monitor our operations. They want to see if what they flowed down are implemented as we informed them. They also help us to identify the gaps in our works. That is a form of supplier development*" (APPCOM, interviewee 005). Best practices and standards sharing benefitted both APPCOM and customers as the end-users (APPCOM, interviewees 002, 003). APPCOM created a group production system which was employed across its engineering sites and their supply chains to reuse best practices captured in the collaborations with customers (Company documents, 2015).

Customer problem capture for knowledge creation

Additionally, engineering sites independently contacted customers and received feedback, so therefore had the opportunity to capture customer business problems. In fact, engineering sites were the best units to capture customer problems, which was important for both corporate central teams and engineering sites to develop the right future technologies that addressed customer business problems (APPCOM, Annual Review 2015; interviewee 001).

4.4.3. Customer Knowledge Boundaries

Customer interest differences

APPCOM was the sub-tier supplier of several large customers in related industries. Customers were only interested in developing their businesses and expected that APPCOM would co-develop its business accordingly. They wanted APPCOM to display good performance and commit to co-development with them. Thus, *"they [customers] want a capability-based engineering group at [APPCOM] to talk to their capability-based engineering group*", as the CTO noted (APPCOM, Annual Review, 2015).

Technological, organisational and geographical differences

Although APPCOM customers were operating in the same or related businesses, their capabilities differed from APPCOM in terms of technologies, geographies and cultures. APPCOM customers could be aircraft manufacturers or engines producers, while APPCOM was an expert in braking, sensing, monitoring systems and thermal management solutions. Their customers focused on different platforms and technologies. In addition to technological differences, customers were globally dispersed and had different cultures in terms of working approaches, operations and management styles. The CEO asserted that "*Our customers are becoming more and more international – they come from different countries and cultures and we need to be able to tune into a range of different management styles and approaches*" (APPCOM, Annual Review 2015).

APPCOM customers were large organisations, which made collaboration difficult. Thus, "*When you have a very large customer […] what conversations happen [at corporate level] may not always be based on the same conversations at a lower level, from site to site. The challenge is "how do you take things to corporate level?*" (APPCOM, interviewee 002).

Engineering capability maturity differences. For engineering collaboration, customers may have been at a higher level of engineering capabilities. Thus, "*When [customer requirements] is about to our sites, the sites may be different in terms of levels of maturity and the abilities to achieve those requirements that we agreed at corporate level. The customer thinks everything is going to come through at one level and it cannot because it is depending on your journey of improvement; how much does it cost in yourself?*" (APPCOM, interviewee 002).

Customer knowledge complexity. The tacitness and embeddedness of engineering knowledge intensified knowledge transfer. In the aerospace industry, technological and business knowledge is often embedded within the heads of the engineers and organisational systems. Such tacit embedded knowledge requires frequent contact in order to capture it. Thus, "*We have a very capable central technology team but the businesses will always know at least as much or more about their own technologies and how they might be developed to the customer's advantage. They have regular access to our customers' engineers in their capabilities and what are they thinking about. They know what problems they are trying to address and how we might help them. That cannot be done as well by the central team as it can by those who have that regular contact*" (CEO, APPCOM Annual Review 2015).

4.4.4. Boundary Spanning Mechanisms

Boundary spanners (BS)

Corporate central teams. At the corporate level, corporate CTO, COO and business senior managers were formed in central teams, working directly with customers in capturing customer engineering requirements and designing solution plans that were subsequently transferred to engineering sites (APPCOM, interviewees 002, 005). They were technology and operation leaders in a specific business area of APPCOM. Most possessed a PhD degree or had many years of experience in their areas, with a deep understanding of customers' businesses and the industry. As the CEO highlighted, "*The central [technology team] act as my portfolio manager, identifying the technologies we are capable of pursuing and where we think we have a good idea [at engineering sites]*" (APPCOM, Annual Review 2015).

In technology development, the technology central team, which included corporate and business senior managers, captured customer technology roadmaps, created company technology platforms and collaborated informally with engineering sites, who worked closely with customers in programs to identify the technologies APPCOM needed to develop to meet customer technology roadmaps (APPCOM, Annual Review 2015). For operational improvement, APPCOM had functionally-focused centres of excellence which created common group working approaches and standards and frequently visited customer sites, collaborating with them to align APPCOM production system with their standards. They also collaborated with all APPCOM sites and even suppliers to co-improve and align APPCOM engineering operational standards with customers (APPCOM, internal document, interviewee 003).

At engineering site level, engineers captured new knowledge co-created with customers for future reuse and customer business problems for future development. Local engineers were experts, with a deep insight into customer requirements and business problems (APPCOM, Annual Review, 2015). They were in the best position to capture customer feedback and information for future reuse and development.

Boundary spanning tools (BST)

Customer operational standards. Customer standards reflected in their engineering and performance requirements were the key boundary spanning tools for operational improvement and learning between APPCOM, customers and even suppliers. The APPCOM production system needed to align with changing customer requirements or standards in order for them to be awarded programs. As a global supply chain manager noted, "*Customers' requirement packages, they can be huge, they are engineering requirements, they are package requirements, they are performance requirements, they are quality requirements, they are cost challenges […] then we put [customer requirements] in different departments*" (APPCOM, interviewee 002).

Integrated information systems. In addition to customer standards, common integrated information systems such as virtual assembly systems were adopted to facilitate information sharing between customers and APPCOM. Virtual designs from APPCOM could be captured by customers for inspection. Customers then sent evaluations and changes back to the APPCOM systems (APPCOM, interviewee 002). These information systems mainly helped customers and APPCOM to transfer information for resource planning, scheduling and decision making (APPCOM, interviewee 004).

Technology platforms. For technology co-development, customer technology roadmaps were important boundary spanning tools for APPCOM technology development (APPCOM, Annual Review 2015). Customer technology roadmaps provided directions for APPCOM to develop not only what customers currently wanted, but also what they would want (APPCOM, Interviewee 001). For example, customer technology development plans for gas turbines and aircraft within the next 15 to 20 years were the foundations for APPCOM to set up technology platforms for transforming its existing technologies, such as thermal management systems, air systems, smart composite systems, health monitoring, fire protection and landing systems. All APPCOM sites were based on these platforms to search for their technology development ideas with customers and suppliers (APPCOM, company documents).

Learning coordination mechanisms

Formal corporate negotiation meetings. Senior corporate managers periodically met customers to capture their requirements. In these meetings, customers negotiated with corporate managers on engineering requirements and plans for APPCOM operations and technology development in the coming years (APPCOM, interviewee 002). Customer requirements were then processed by central excellence teams to draw up technology platforms and operational standards that would guide the development of engineering sites.

Formal program coordination. Customers collaborated with engineering sites to co-create solutions by providing feedback on APPCOM performance (APPCOM, interviewee 002). In the operational process, customers might send people to APPCOM sites to audit APPCOM operations, search for knowledge gaps and maybe help APPCOM to improve. Customer visits might have occurred monthly, as stated by a project manager, "*we have meetings with customers at least once per month. Why? Because we work as a team.*" (APPCOM, interviewee 005). Similarly, APPCOM central teams sometimes visited customer sites as well as supplier sites for engineering co-improvement (APPCOM, interviewee 003).

Documentation. As elaborated above, design solutions were documented and sent to customer sites through integrated information systems to obtain customer feedback. Integrated virtual assemblies allowed APPCOM and customers to coordinate learning with each other, facilitating decision making and solution tracking.

Customer staff grafting. Customer business understanding could be gained through grafting staff who used to work for customers. APPCOM employed experts who had insights into what customers did and their business problems in order to work out what customers wanted and therefore set the directions for future technology development that fitted customer strategies. Thus, "*We actually employ people who used to work at [a client's company] […]. We bring customers in but it knows as the staffs because they can help*" (APPCOM, Interviewee 001).

Knowledge governance mechanisms

Trust – committing with continuous innovation. APPCOM built trust with customers to obtain orders and knowledge sharing by investing in operational excellence and technology leadership programs. It established its reputation with customers transparently through improvement programs for operations excellence and self-funded technology development projects. Thus, "*The objective of [APPCOM production system] implementation is to earn the unwavering trust of any [APPCOM] customer in the ability of any of our businesses to deliver on time and to the required specification*" (CEO, APPCOM Annual Review 2015). Within the aerospace industry, trust is important to create an eco-system in which partnership relationships help both customers and APPCOM to be successful (APPCOM, interviewee 005). Trust must be maintained through the reputation of APPCOM operational excellence and technology leadership (APPCOM, Annual Review 2015).

Points of contact. Operationally, APPCOM used formal mechanisms to regulate knowledge sharing with customers in contracted projects. Various interfaces with customers were controlled by identifying who did what and when, and defining the responsibilities of engineers and customers. This was because "*There are many large programmes that may last for several years and involve many people and companies. Therefore, it is critical to know who does what and how, who are the supporters. This should be regulated very carefully*" (APPCOM, interviewee 005).

Technological mechanisms

Data mining technologies. The only technologies APPCOM used to capture customer data for engineering services were enterprise resource planning (ERP) and data management technologies (SAP), which established customer requirements during the programs conducted. Customer requirements were captured through integrated ERP and data management systems for the purposes of resource planning and operational monitoring. Integrated software technologies, e.g. common virtual assembly, allowed APPCOM to monitor project operations, supporting decision making in engineering resource planning and operations (APPCOM, interviewee 004). In addition, integrated software facilitated APPCOM collaboration with customers, such as in capturing, analysing and disseminating customer feedback on designs and engineering operations in current and future programs (APPCOM, interviewee 002)

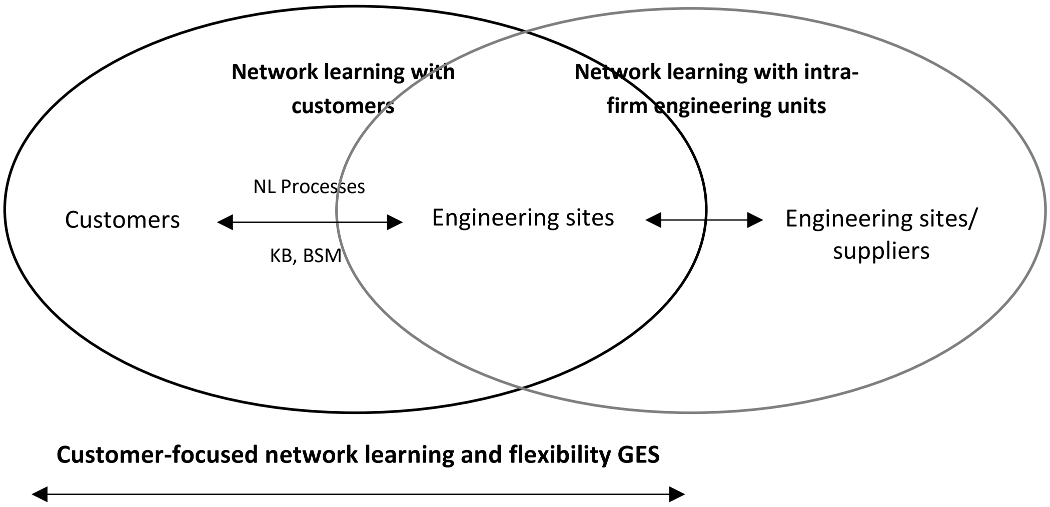
4.4.5. Values

APPCOM engineering sites learnt with customers how to deliver high-performance operations and innovative technologies which addressed changing customer demands. The learning of engineering sites was supported by corporate operational frameworks and technological platforms. Engineering sites co-created solutions with customers and captured best practices for future reuse with intra-firm sites and their sub-tier suppliers where applicable in order to enhance group performance (APPCOM, Annual Review 2015; interviewees 002, 003).

For technology development, the technology central team created group technology platforms based on customer technology roadmaps that guided engineering sites in searching for specific customer problems in their solution programs. This information helped the engineering sites to come up with new ideas for technology development within intra-firm engineering sites and with technology suppliers (APPCOM, Annual Review, 2015; interviewees 001, 002). Besides, customer-focused network learning enhanced the relationships with customers through better performance and trust.

4.4.6. GES Network Learning with Customers and GES Flexibility

Customer-focused network learning is motivated by changing customer demands for better service performance. Customers need to cope with greater pressures from their markets and constantly change their demands for service and product solutions. Network learning therefore occurs at both corporate and engineering site levels. Corporate central teams capture customer engineering requirements and technology roadmaps and generate operational standards and technology platforms for engineering site learning. Engineering sites collaborate with customers to co-create best practices for future reuse and capture customer business problems for future technology development. Customers, however, have different interests, technologies and operations and often impose their own requirements that GES firms must follow. Firms therefore have to adopt a set of boundary spanning mechanisms to address customer differences. Figure 4-3 illustrates the contributions of customers to network learning and GES flexibility, highlighting the role of boundary spanning mechanisms in facilitating network learning processes.



Network learning drivers:
- Changing customer demands for better performance

Network learning processes and links to intra-firm/ suppliers:
- Knowledge reuse for innovation (with customers) & knowledge creation (intra-firm/suppliers)
- Knowledge creation (with customers) & Knowledge reuse (intra-firm/suppliers)

Values:
- New engineering standards, technology platforms driven by customers
- New knowledge for future reuse
- Customer problems understanding
- Better performance
- Strengthened relationships with customers

Knowledge boundaries (KB):
- Customer interest, interpretation, and language differences

Boundary spanning mechanisms (KBM):
- Centralised charismatic CoE (knowledge reuse for innovation)
- Centralised functional teams (program-based knowledge creation)
- Customer operational standards and technology roadmaps; Uniform global information management systems, data mining technologies
- Formal knowledge coordination and standardised knowledge sharing procedures and routines

Figure 4-3: Customer contributions to GES network learning and flexibility

Previous research highlights customers as key players in integrated solution development, but does not clarify how customer-focused network learning contributes to GES network learning and GES flexibility (Johnstone et al., 2009). The case analysis shows that customer-focused network learning not only helps to create better solutions, but also information for future innovation within the firm and with suppliers, and new knowledge within contracted programs for future reuse and efficiency. It also clarifies different boundary spanning mechanisms that the firm can use to eliminate customer knowledge boundaries and thus enhance network learning with them. In the following section, the RECOM case is examined to explore network learning practices with customers and GES innovation.

4.5. RECOM Learning with Customers and GES Innovation

RECOM (Appendix 5) created novel pharmacological models embedded within a bio-simulation platform that was licenced to pharmaceutical companies, research institutions and regulatory agencies. The company delivered its innovative solutions through a network of four scientific competence divisions located in the UK and 21 offices located worldwide. The key RECOM customers were commercial pharmaceutical companies who developed new drugs to treat human diseases. Other customers were granted licences free of charge for non-profit purposes only, e.g. teaching and learning (RECOM, interviewees 003, 016). This section studies RECOM network learning with customers for GES innovation.

4.5.1. Network Learning Drivers

New drug development and changing customer expectations

New drug development is a costly and time consuming process for pharmaceutical companies. Such a process starts with a new compound discovery that has the potential to cure a disease. The compound is then tested in animals to check its toxicity. The next stage involves three phases of human trials. Phase one involves testing with healthy people. Phase two comprises experiments in a small disease population, while phase three is submission onto the market. A research scientist commented that sometimes a drug development process might take 10 years to reach phase three and might cost a billion dollars (RECOM, interviewee 017). Furthermore, it is very risky. He added that only approximately 10% of new drugs were able reach phase three during the past thirty years, and that the challenge of the pharmaceutical industry is how to predict at the very early stages of the drug development process if a new compound will be able to pass to phase three and obtain approval from the regulatory agencies (RECOM, interviewee 017).

Drug development processes are challenging, high-risk and time-consuming. Thus, "*[The clients] can use the software instead of doing a clinical study […]. It saves time and money and they can answer the questions that they might probably struggle to answer without using the software […]. It is not only nice to know but it is nice to use" (*RECOM, interviewee 003).

In fact, it is ineffective for pharmaceutical companies to develop similar software in-house, as the costs associated with recruiting in-house experts are high. Thus, "*some companies have tried [to do in-house] but the maintenance of the software is difficult for them […]. For each company to put in people to do the same thing, they haven't got enough money to do so. Even if they have got enough money, it's not efficient. We do that for companies, which is more efficient than all the companies doing it themselves*" (RECOM, interviewee 002).

Solution benefits to customers

Customers used RECOM solutions because their bio-simulation software was more accurate, enhancing the efficacy of drug development and enabling customers to obtain approval from regulatory bodies. In the words of a scientific advisor, "*what we're trying to do, as far as client consent is concerned, is different things that the client wants; sometimes they just want to get understanding of how their compounds behave. But I think increasingly they are asking more regulatory questions"* (RECOM, interviewee 009).

Consortium cooperative relationship

Customers develop new drugs to cure diseases and because of the rapid changes in science. As new drug discoveries emerge, customers constantly change their expectations for a new RECOM solution. Thus, "*every year a consortium of top pharmaceutical and biotechnology companies meets to discuss the scientific advancements or wish list items in the area of modelling and simulations and these consortium members drive the future simulators*" (RECOM, interviewee 019).

RECOM was motivated to learn with consortium customers to explore the scientific problems customers faced in their new drug development processes and to create new functions for its future bio-simulation platforms (RECOM, Annual Report; interviewees 016, 013, 019). Furthermore, customers could be the sources of experimental data for solution verification, as RECOM did not conduct experiments in-house.

4.5.2. Network Learning Processes

Knowledge reuse for innovation of research scientists

RECOM research scientists captured the problems of the key customers within RECOM consortiums. At the time of this study, RECOM had two consortiums involving leading pharmaceutical companies around the world. These acted as the consulting teams, providing RECOM directions for future technology development within the firms and suppliers. They also offered experimental data and information for the co-development of new bio-simulation solutions they were interested in. In exchange, the consortium members were granted RECOM solution software licences free of charge. In addition to consortium collaboration, RECOM collaborated with various commercial and non-commercial customers and suppliers in workshops to understand how the solutions benefitted customers and suppliers (RECOM, interviewees 002, 009, 016).

Consultancy projects

RECOM might reuse knowledge for innovation in formal consultancy service projects in which customers shared their particular interests, problems and data, for its solution development (RECOM, interviewee 016). Customers experienced their own problems in developing new drugs using RECOM bio-simulation technologies, problems that they may not have understood, or did not know how to use the RECOM software to solve them. They sometimes used RECOM consultancy services to solve these problems. Collaborating with customers in consortia, workshops and consultancy projects provided RECOM with information that guided future development inside the organisation and with suppliers.

4.5.3. Customer Knowledge Boundaries

Customer interest differences

In the pharmaceutical industry, customers might not engage in network learning if they are not interested in the firm’s solutions. Thus, *“[Clients] wouldn't share the data on compounds they're not interested in anymore; they don't share things which are highly* *confidential"* (RECOM, interviewee 002). To take into consideration customer interests in RECOM technologies, the company had to establish consortia for network learning, in which member pharmaceutical companies and affiliate research institutes shared the same interests of developing RECOM bio-simulation software. The company collaborated with consortium members within workshops and consultancy projects to co-develop common solutions of interest.

Customer interpretation and experiment differences

For customers who shared common interests with RECOM, different interpretations might cause variations in customer data. Customers might provide experiment data which were not useful, because they might not ask the right questions about the problems they faced (RECOM, interviewee 003). To create bio-simulation models for customers, RECOM needed to exchange scientific knowledge with them to understand their experiment data, research questions and approaches, and the scope of the models that concerned customers (RECOM, interviewee 016). Customer knowledge boundaries required RECOM to employ a set of mechanisms to manage knowledge sharing and learning between RECOM research scientists and its customers.

4.5.4. Boundary Spanning Mechanisms

Boundary spanners

Centralised senior research scientists. The senior research scientists and advisor scientists were RECOM boundary spanners who contacted customers to translate and transfer knowledge between them and RECOM. They had backgrounds in pharmacy, biology and chemistry. These scientists collaborated with customers to explore their areas of interest, drug research and development problems, and requirements for bio-simulation solutions. The company also employed other junior, mathematical and statistical research scientists and IT engineers, but they were not directly involved with clients. They might have attended workshops and conferences with customers for the purposes of training and knowledge transfer, without engaging in customer drug development processes.

The boundary spanners were grouped into focused centres of excellence. They were specialised within a scientific area, e.g. quantitative systems pharmacology, translational science, or modelling and simulation. All the boundary spanners who were interviewed possessed a PhD degree and had experience of working in the pharmaceutical industry. They had in-depth understanding of customer drug development processes, including experiment operations, and worked closely with customers' scientist researchers in consortia and consultancy projects for mutual understanding and solution designs. Their knowledge was published in academic journals and they were well-known within academic and industrial societies. A senior principal scientist asserted that "*We build the models, obviously, and the programs, and we are keeping up with the recent literature, but I see it more and more that we are influencing the literature*" (RECOM, interviewee 003). Some boundary spanners used to work at universities; they were employed to develop new knowledge for the company, capturing industrial challenges and generating scientific solutions that were new to the market.

Boundary spanning tools

Company simulation models and databases. The bio-simulation products themselves were the boundary spanning tools between customers and RECOM. Pharmaceutical and academic customers used RECOM platforms for their new drug development processes. Models and databases embedded within the platforms were verified and expanded by the customers and shared with RECOM to co-develop the software, enhancing its predictability and validity. Thus, "*It [a new platform software] will be accessible to the clients of the consortium. We also have a small consortium with four or five pharma companies and we will build together with them the system of interests and then in return the companies will get the software to use but we will also use it for our purposes […]. We can market it further*" (RECOM, interviewee 016).

Customer engineering challenges. Another boundary spanning tool was the customer engineering challenges, which were the topics discussed within consortium meetings, workshops and consultancy service projects in order to devise common platforms for co-development, such as customer wish lists (RECOM, interviewees 006, 016, 019). These common agreed topics guided the future development of models and databases within the bio-simulation platforms. They also guided solution development in workshops and consultancy service projects.

Learning coordination mechanism

Formal consortium coordination. Customers and RECOM scientist researchers met once per year for an annual review and agreed with each other what would be co-developed in the following year. For example, at the time of this study, RECOM was managing a consortium as a research centre including 36 of the largest bio-pharma companies, and affiliating universities and regulatory agencies to co-develop a bio-simulation platform. RECOM organised annual workshops for consortium customers to present and discuss scientific advances and set the future directions for technology development. Consortium customers also played the role of consulting teams and collaborated with RECOM to co-develop technologies that they desired to be agreed within the consortium meetings.

Periodic informal workshops. Commercial and non-commercial customers were coordinated through various informal workshops to share their experiences of using new solutions. The company provided various workshops throughout the year in many countries, such as the UK, Europe, Asia, China, and Japan, for the purposes of training and learning. These would perhaps focus on a specific area, such as modelling best practices, drug research and development supporting tools or related science areas, or be more general. The workshop attendees included senior managers and scientists working both in industry, academia and research institutes. The workshops were designed to provide the necessary understanding and skills to simulate and predict how drugs behave within animal and human bodies. They comprised lectures provided by leading experts in the field and small group discussions with peers and expert tutors. In the words of a research scientist, "*we go and do workshops and people from other companies, pharmaceutical companies they come to the workshops and they learn what we've done with the software and what the new capabilities of the software are. They learn and then of course they all share their experiences so we learn from them as to what benefits them*" (RECOM, interviewee 015).

Ad-hoc consultancy projects. Customers would sometimes use RECOM consulting services to address their engineering problems. These were organised in projects which may have involved weekly meetings between customers and RECOM research scientists through tele-conferences to discuss their research interests, research problems, scope of modelling and solutions for their problems (RECOM, interviewee 016). Furthermore, informal conferences and workshops were events in which customers and RECOM scientists presented their work and learnt from each other.

Knowledge governance mechanisms

Free-of-charge licences. To encourage customers to share knowledge, RECOM provided consortium customers free access to the latest versions of its software and its training programs. In this way, customers were willing to engage in co-developing the software with RECOM to validate existing technologies and ensure that future technology developments were relevant to the needs of consortium members. The members provided feedback that validated the reliability of the software, experimental data to develop new models, and wish lists to guide future directions.

Trust building through the reputation of research scientists. The reputation of research scientists was another mechanism to encourage customers to share knowledge with RECOM, as the leader in the field. Reputation was created through publications. All the information that went into software would be published if clients consented (RECOM, interviewee 016). "*If you publish the information and you are the author of that, then you get recognition in your field of research, and people will ask you more questions*" (RECOM, interviewee 006).

Trust building through third-party affiliation. Reputation could be signalled through third parties. The affiliation of academic institutes and most regulatory agencies enhanced the reputation of RECOM and the reliability of its products. More and more clients would pay attention to the company and share knowledge with it to learn and improve the software because regulatory agencies had accept its results. For example, more than 100 new drug labels had been approved by FDA - the US Food and Drug Administration.

Technological mechanisms

Internet open sources. Although RECOM provided customers with the tools to help them to predict drug behaviours within their research and development processes, the company did not use any technologies which supported knowledge capture, analysis and dissemination between customers and RECOM. The main technology to capture customer data were the public databases on the internet. Pharma companies publish their research and development results every year and this is a source of customer knowledge that OSCOM could capture for its operations.

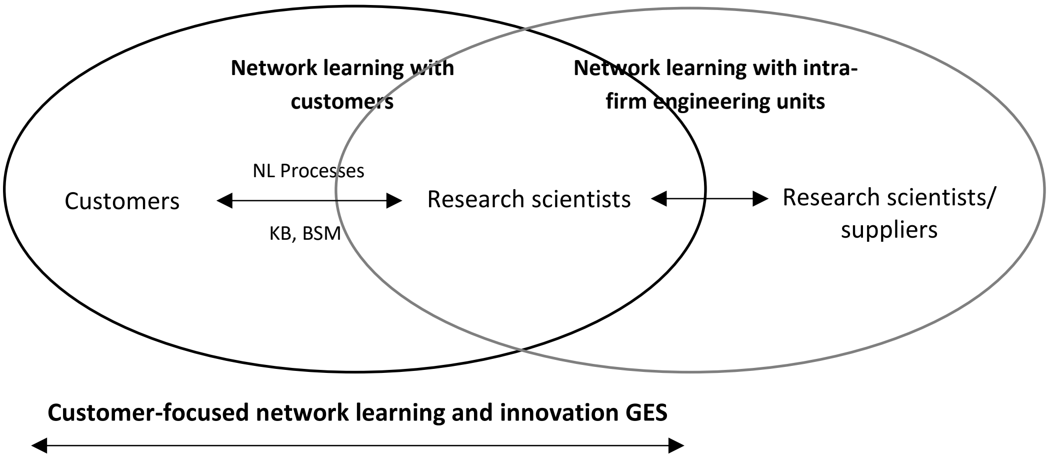
4.5.5. Values

Network learning with consortium customers not only enhanced existing solutions, but, more importantly, generated customer wish lists that guided future solution development inside the organisation and with suppliers. On the one hand, customers provided feedback on how RECOM technologies benefitted them in consortium meetings, informal workshops and consultancy projects, and therefore verified the quality of the product. On the other hand, they gave RECOM their expectations for future development of the company software by collaborating with senior research scientists to finalise their wish lists for future novel solution development. Additionally, collaborating with customers helped RECOM to build up trust and relationships with them. The number of consortium members had increased over the previous 10 years and more and more research institutes and regulatory agencies had joined RECOM consortiums and workshops to co-develop the company software.

4.5.6. GES Network Learning with Customers and Innovation

Customer-focused network learning is driven by changing customer expectations for novel solutions that address customer engineering challenges. This is enabled by close, shared interest relationships with customers in consortia and consultancy projects. The network learning process involves knowledge sharing activities between individual senior engineers and customers in formal events such as consortium meetings, workshops and ad-hoc consultancy projects. Network learning with customers not only helps the firm to understand how its existing technologies benefit customers, but also explores their problems and creates common topics of interest that direct its future development. Customers, however, have different interests, interpretations and experimental practices. Network learning therefore relies on centralised individual senior engineers who have the expertise and industrial experience to understand complex customer practices and problems. Their interactions with customers should be supported by formal governance for effective knowledge sharing and learning. Figure 4-4 illustrates the key network learning practices with customers and their links to intra-firm and supplier-focused network learning that contribute to innovation GES.

Past research has increasingly recognised that customers can be key contributors to novel solution generation (Galbraith, 2014; Todtling et al., 2009; Tidd, 2006). However, most studies fail to provide clear understanding of how customers contribute to the GES network learning process and value creation. This study provides evidence that customers share their engineering challenges, which helps the firm to come up with scientific topics of interest with customers, e.g. customer wish lists for future novel solution development inside the organisation or with suppliers. It also clarifies different boundary spanning mechanisms that contribute to eliminating customer knowledge boundaries and thus facilitates knowledge reuse for innovation with customers.



Network learning drivers:
- Changing customer engineering challenges

Network learning processes and links to intra-firm and suppliers:
- Knowledge reuse for innovation (with customers) & knowledge creation (intra-firm) & Knowledge reuse for innovation (suppliers)

Values:
- Customer problems understanding (Customer wish lists, interests, scope of problems)
- Customer-driven novel solutions
- Strengthened relationships

Knowledge boundaries (KB):
- Customer interest, interpretation, and operations differences

Boundary spanning mechanisms (KBM):
- Centralised senior engineers (knowledge reuse for innovation)
- Customer engineering challenges; company software
- Formal knowledge sharing coordination and governance (consortium meetings, free of charge licences, research contracts)

Figure 4-4: Customer contributions to GES network learning and innovation

4.6. GES Network Learning with Customers and Value Creation

The analysis is integrated in Table 4-1. The table enable to identify the key features of GES network learning with customers of the three cases. They enable to draw the similarities and differences across cases. Details are discussed below. The analysis also enables to explore the linkages to supplier-focused and intra-firm network learning episodes.

Table 4-1: GES network learning with customers and value creation

Network learning		**OSCOM** GES efficiency	**APPCOM** GES flexibility	**RECOM** GES innovation
Learning Drivers		- Changing customer needs for a cost-effective IT solution - Long-term cooperative relationships	- Changing customer demands for better performance - Collaborative relationships	- Changing customer expectations for a novel solution - Consortium relationships
Learning process	**Key knowledge processes**	- Knowledge reuse for innovation - Knowledge creation	- Knowledge reuse for innovation - Knowledge creation	- Knowledge reuse for innovation
	Process complexity	- Customer interest differences - Business domain, technology, process differences - Geographical distance	- Customer interest differences - Customer engineering maturity differences - Geographical distance	- Customer interest differences - Interpretation/ experiment differences - Customer scientific challenges
Boundary spanning mechanisms	**Boundary spanners**	- Central management teams (CEO, director, CTO, senior managers) - Central focused functional teams (e.g. onshore/offshore BA, TA)	- Central management teams (CTO, COO, senior business managers) - Centralised functional teams (e.g. operational teams aligning firm standards with customers)	- Centralised senior research scientists (to co-create customer wish lists)
	Boundary spanning tools	- Solution frameworks pre-defined with customers - Global project management portals	- Group customer-driven standards/ requirements - Group customer-driven technology platforms - Group integrated information systems (SAP)	- Company software (Existing models and databases) - Customer engineering challenges
	Learning coordination	- Customer survey - Onshore-offshore project coordination - Knowledge documentation/ modularisation	- Customer negotiation meetings - Formal program coordination - Knowledge documentation - Customer staff grafting	- Formal consortium meetings - Periodic informal workshops - Formal consultancy projects
	Knowledge governance	- Customer contact points - Trust (built by third party certifications, operational transparency, IP protection)	- Trust (built by commitments to operational excellence and technology leadership) - Points of contact	- Trust (built by scientist publications; third-party affiliation)
	Technology mechanisms	- Data mining technologies (e.g. cloud and analytics software) - Technology websites	- Common integrated virtual assembly (for co-development)	- Internet open sources

Values	- Cost-effective IT solutions - New frameworks and lessons learned, information on future customer needs - Long-term partnership (e.g. offshore ODC)	- High-performance sub-system package solutions - New standards, technology platforms - Best practices, customer business problems - Supplier of choice	- Customer-driven Innovative solutions - Knowledge on customer interests, problems, scope of solutions (e.g. customer wish lists) - Customer affiliation
Network learning processes and links to network learning with suppliers and intra-firm engineering units	- Knowledge reuse for innovation (links to knowledge creation with suppliers) - Knowledge creation (links to knowledge reuse with intra-firm project teams)	- Knowledge reuse for innovation (links to knowledge creation with intra-firm engineering sites; & knowledge reuse for innovation with suppliers) - Knowledge creation (links to knowledge reuse with intra-firm engineering sites & knowledge creation with suppliers)	- Knowledge reuse for innovation (links to knowledge creation with intra-firm research scientists & knowledge reuse for innovation with suppliers)
Boundary spanning mechanisms across cases	- Central management teams - Centralised functional teams - Formal governance mechanisms - Uniform/global information systems, common frameworks, engineering targets	- Central management teams - Centralised functional teams - Formal governance mechanisms - Uniform/global information systems, common technology platforms and standards	- Central management teams - Formal governance mechanisms - Common technology platforms/ models

Figure 4-5 summarises the common features of intra-firm network learning. Customer-focused network learning is driven by changing customer needs or the demand for firm solutions. In the efficiency case, customers constantly change their needs under the pressure of changing markets and technologies. The flexibility case highlights changing customer demands for better performance, while the innovation case shows that changing customer engineering problems motivate network learning with customers.

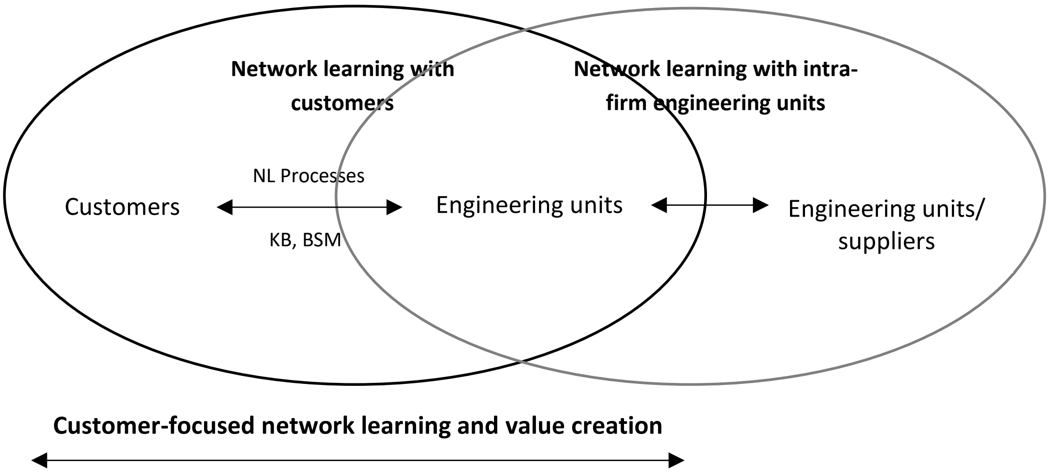
Network learning processes include two main processes:

- Knowledge reuse for innovation: firm interactions with customers to gain understanding about future customer problems, needs and demands, which form the foundations for intra-firm network learning to create targets, platforms and topics for future development within intra-firm units and/or suppliers.

- Knowledge creation: firm engineering units interact with customers to co-create customer-driven solutions and at the same time capture the new knowledge co-created for future reuse inside the firm and thus enhance efficiency.

These processes show the links between customer-focused network learning and intra-firm, supplier-focused network learning.

Customers are diverse and have different business interests. In the efficiency case, they came from different industries and had different businesses. The flexibility case served a few large customers in related industries, while the innovation case dealt with many customers within the pharmaceutical industries. The diversity of customers and their differences in interests forced firms to employ a set of centralised boundary spanners and formal governance mechanisms supported by common information systems, technologies and platforms to address customer knowledge boundaries and thus facilitate network learning with customers. The values created included not only customer-driven solutions but also customer relationship reinforcement and knowledge, customer problem understanding for future reuse, and innovation.



Network learning drivers:
- Changing customer needs/demands

Network learning processes:
- Knowledge reuse for innovation
- Knowledge creation

Values:
- Customer-driven solutions
- Customer problems understanding
- New knowledge
- Customer relationships

Knowledge boundaries:
- Customer interest, interpretation, and language differences

Boundary spanning mechanisms:
- Centralised boundary spanners and formal governance mechanisms
- Common supporting information systems, technology platforms, and technologies

Figure 4-5: Customer contributions to GES network learning and value creation

The analysis finds some variations in network learning practices with customers (Table 4-1). There are two patterns of network learning with customers: efficiency and innovation network learning. They differ from each other in terms of network learning drivers, processes, knowledge boundaries, boundary spanning mechanisms and values.

Efficient network learning addresses changing customer needs/demands for cost-effective and high-performance GES. Network learning processes focus on knowledge co-creation between engineering units and customers, which is captured by engineering units for firms' future reuse and therefore enhances GES efficiency. Customers, however, have different business interests, operational maturities and languages, which make their requirements complex and difficult to capture. Different customers often have their own requirements that firms must follow. Efficient network learning has to rely on a set of boundary spanning mechanisms, as follows:

- Dispersed centralised functional teams: different functional focused centres of excellence are employed to interact with customers at customer sites to capture customer requirements for the solution generation operations of engineering units with customers.
- Centralised, uniform information systems: GES firms use global information systems such as SAP to connect with customers for solution exchange and feedback. For example, APPCOM employs SAP for virtual assembly with customers.
- Centralised, common data analytic software: GES firms use data mining technologies to capture, process project data, and deliver analysis on dashboards for decision making with customers.
- Formal learning coordination: knowledge reuse for innovation and knowledge co-creation with customers is formally based on project and/or program routines and standardised procedures.
- Formal knowledge governance: customers are encouraged to share knowledge through formal industrial standards and project-based procedures.

Innovation network learning focuses on capturing future customer needs and demands for future development. The network learning processes often start with network learning at group or corporate level for identifying general customer needs, demand trends, and engineering challenges. For example, OSCOM conducted annual CEO surveys to identify technology targets for learning with customers. RECOM offered bio-simulation software and had formed a consulting consortium to discuss and identify customer wish lists for software development. Technology targets and platforms would guide the learning of different expert engineering units with customers to capture future customer needs and demands. Capturing customers' business problems, needs and demands, however, is difficult because customers have different interests, interpretations and operations. Therefore, it is important for firms to employ a set of boundary spanning mechanisms, as follows:

- Centralised functional senior management teams: individuals who capture customer business problems and come up with new ideas for technology innovation. They can be CTO, COO, business senior managers, engineering fellows, or senior research scientists based within engineering sites. They may be dispersed and connected with each other through an information system that forms a virtual CoE.
- Customer requirements and challenges: customer problems such as operational performance, technology roadmaps, and engineering challenges that guide the learning of central teams to generate technology platforms and directions for future development of engineering units.
- Internet websites: companies may use technology websites to capture customer demand trends and challenges for network learning.
- Formal learning coordination: knowledge capture is conducted within formal events such as annual customer surveys, program negotiation meetings, and consortium meeting.
- Formal knowledge governance: encourages customers to share their problems; it is important for firms to use formal incentive mechanisms such as free-of-charge licences, partnership cooperative relationships, and reputation of engineers.

4.7. Conclusion

This chapter has examined the roles of customers in GES network learning and value creation. It is not clear in the literature how customer-focused network learning links to other network learning episodes: with suppliers and intra-firm engineering units and with the boundary spanning mechanisms used to facilitate network learning with customers. Three cases have been conducted to clarify these gaps.

The cases reveal that firms are faced with changing customer needs/demands and conduct network learning with customers to capture changing needs for future innovation inside the firms or with suppliers. In their solution co-creation processes with customers, firms' engineering units co-create knowledge with customers for the future reuse of other engineering units to enhance efficiency. These findings highlight the linkage between customers and intra-firm, supplier-focused network learning.

Network learning with customers relies on a set of boundary spanning mechanisms to enhance either GES efficiency or innovation. Efficient network learning occurs in a knowledge co-creation process with customers in formal solution projects and/or programs. Innovation network learning focuses on knowledge reuse for innovation, in which customer information is transferred and translated into common frameworks, standards and platforms that direct the network learning of engineering units. Because customers have different businesses, technologies and processes, network learning needs to employ centralised excellence teams to create new directions for network learning, while central functional teams help to translate customer knowledge for the learning of engineering units. Customer-focused network learning therefore generates not only solutions, but also information and knowledge for future reuse and development.

In summary, customers play a key role in GES network learning and value creation by providing information for intra- and inter-firm network learning for innovation and the co-creation of knowledge for intra-firm knowledge reuse for efficiency. In the following chapters, GES network learning with suppliers and intra-firm engineering units is examined to clarify its links to customer-focused network learning.

5. CHAPTER 5: GES NETWORK LEARNING WITH SUPPLIERS

5.1. Introduction

Chapter 4 revealed that customers contribute by informing firms to collaborate with suppliers in order to address changing customer needs and demands. This chapter presents the research findings on the roles of suppliers in GES network learning and value creation. It explores supplier-focused network learning practices and their links to customer-focused and intra-firm network learning. The chapter begins with a brief introduction to a framework on a network learning episode with suppliers, describing the key elements and stages of network learning with them. It then continues to analyse three case companies in order to understand different supplier-focused network learning practices that contribute to the creation of different values. At the end of the chapter, the role of suppliers in GES network learning and value creation is justified and concluded.

5.2. A GES Network Learning Episode with Suppliers

An episode framework of GES network learning with suppliers is identified through the literature review and case studies. It is used to present supplier-focused network learning in this chapter (Figure 5-1). GES firms are motivated to collaborate with various suppliers to exploit their capabilities for enhancing their performance in the solution co-creation with customers (Brady and Davies, 2004; Windahl and Lakemond, 2006; Galbraith, 2014). The key drivers for collaborating with suppliers are their capabilities that can help firms to enhance their solution creation performance and thus fulfil emerging customer demands (Fine, 1998; Teece et al., 1997; Meijboom et al., 2007). The network learning processes involve backward and forward interaction between suppliers and firms' engineering units to create or reuse firm knowledge (Cagliano et al., 2006; Frohlich & Westbrook, 2001; Trent & Monczka, 1998). These processes are challenging because suppliers have different business interests, engineering interpretations and operations that hinder supplier knowledge transfer and sharing (Ayala et al., 2017). It is important to employ boundary spanning mechanisms to eliminate supplier knowledge boundaries and facilitate network learning (Coghlan and Coughlan, 2014; Peters et al., 2016; Eloranta & Turunen, 2016). Effective supplier-focused network learning results in better solution creation performance, supplier relationships, new knowledge and information for future reuse and development (Salonen et al., 2018).

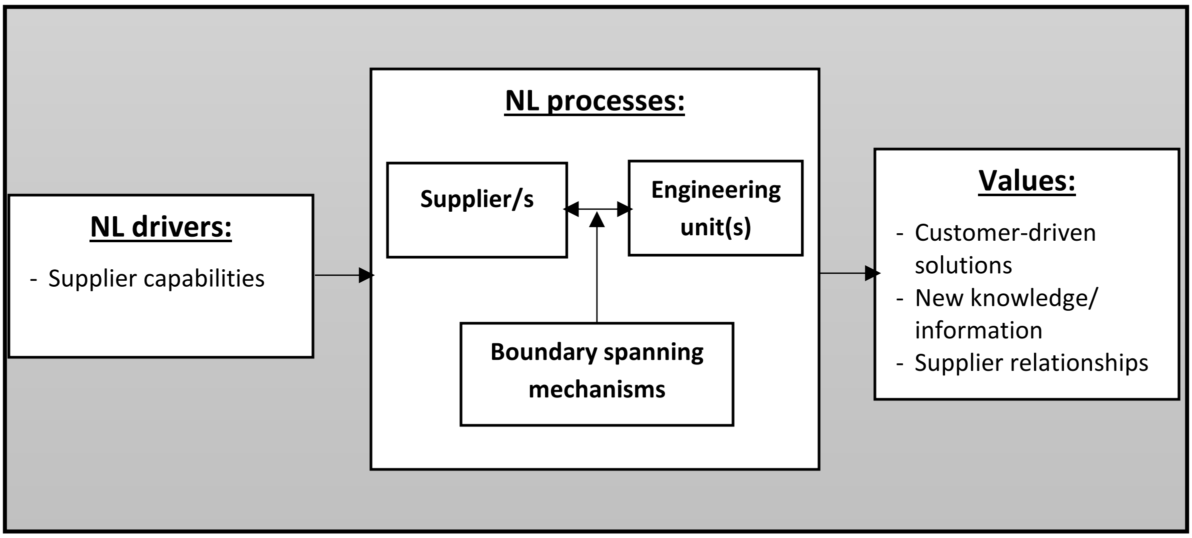


Figure 5-1: Characteristics of a GES network learning episode with supplier/s

The episode framework guides the case analysis and presentation of this chapter. In the following sections, the results of the three case analyses are presented to clarify different supplier-focused network learning drivers, processes and boundary spanning mechanisms that result in value creation. Finally, the network learning of the three cases is compared to identify similarities and differences.

5.3. OSCOM Network Learning with Suppliers and GES Efficiency

The previous chapter showed that customers constantly change their needs for cost-effective IT solutions due to the rapidly changing technologies and markets. OSCOM learned with customers at both corporate level and project team level to capture changing customer needs that guided firm technology development with technology suppliers for future opportunities. In this section, OSCOM network learning with suppliers is examined to explore how supplier-focused network learning contributes to GES network learning and efficiency.

5.3.1. Network Learning Drivers

Company engineering targets

Learning with suppliers was first based on company targets. Annually, OSCOM conducted a CEO survey with customers to identify the global technology and business trends in ITO services, such as investment trends in IT, technological skill needs, and operational issues (Company document, 2017). Based on the CEO survey, the company's management board identified the focuses and targets for the OSCOM project teams to identify specific customer needs and related technologies. For example, "*this year we must focus on ITO services for .NET or for just Asia markets […] or we must develop a specific process in a specific region or quality should be number one […]. To achieve [these targets], 95% of projects should reach a quality standard level and we must focus on particular areas. We must improve some areas and make improvement plans and collect data for assessment*" (OSCOM, interviewee 004).

In project learning with customers, customer needs were gathered by sales and project teams based on top-down technology targets. This information was the input for the knowledge creation of the central functional teams such as R&D and quality teams to identify specific skills that the company had to develop with suppliers to satisfy changing customer needs. OSCOM then sent R&D experts to learn with IT and industrial suppliers to capture the skills the company needed. Thus, "*First, we "smell" technology trends from external sources relating to different areas that the company focuses on. Secondly, from observation of sales support with customers, we study what technology the potential customers need so that we can prepare for it. Preparation does not mean the training for the whole team, but the learning of a few core engineers, who will study that technology first. After they master their skills, they will train the whole team in a short time […]. Because they already have experience, they will articulate their knowledge faster*" (OSCOM, interviewee 003).

Technology partners trusted by customers

OSCOM had several technology partners trusted by customers for updating their technological knowledge. Thus, "*we have many partners. For example, we partner with Microsoft, Amazon Cloud and other IT companies […]. Annually, they have training courses* *for us to get certificates, updating their technologies*" (OSCOM, interviewee 005). The reason to learn with different well-known technology suppliers was explained by a delivery manager: "*when customers require [new skills], we can demonstrate our abilities*" (OSCOM, interviewee 005).

5.3.2. Network Learning Processes

Knowledge creation

OSCOM captured updated supplier knowledge mainly through training courses offered by suppliers. It sent engineers to courses such as workshops or site visits. Some technology suppliers provided training courses annually and issued certificates to OSCOM engineers, assessing OSCOM learning through the number of certificates and customers in order to grant partnerships. In the words of a delivery manager, "*We aim to become a partner of trusted names according to partner criteria such as the number of certificates and customers*" (OSCOM, interviewee 005). With partnership status, OSCOM had many benefits besides training. In some projects in which customers required OSCOM solutions to be qualified by suppliers such as Microsoft, AWS and other IT management international standard organisations, OSCOM involved their partners in projects to review the OSCOM solutions and gave advice on what needed to be improved (OSCOM, interviewee 005).

Supplier knowledge transfer to intra-firm project teams

These certified engineers then transferred their learning to other engineers through internal seminars, workshops and boot camps. Thus, *"[OSCOM] has a technical department doing research and development works. When the engineers in this department explore a new technology trend, they will study to obtain certificates of that technology. Then, they organize training courses for other engineers in seminars, workshops and boot camps*" (OSCOM, interviewee 005).

5.3.3. Supplier Knowledge Boundaries

Sub-tier supplier maturity differences

OSCOM integrated several well-known computer software providers and IT management standard organisations. In particular, it was a partner of Microsoft, Amazon Web Services (AWS), CMMIDEV/5 and ISO27001. These suppliers provided OSCOM with updated high technologies and IT process management knowledge for the company operations. OSCOM had to satisfy supplier requirements in terms of a particular number of certifications and customers served to become their partner (OSCOM, interviewee 005).

Additionally, OSCOM partnered with some well-known research institutes and ITO companies to combine their complementary capabilities in projects. For example, it partnered with a not-for-profit IT management research institute to offer advisory services for customers on IT management. The company also partnered with a Romanian ITO company to enhance the capability of providing progress solutions with more operational options for onshore-nearshore-offshore integrated teams. Thus, "*The aim of partnership is to go with trusted names, to increase reputation. It is not related to a specific project or requirement of customers […]. When you are a partner of a trusted name, you will enclose this name with your company to introduce to customers*" (OSCOM, interviewee 005).

Supplier technology changes

OSCOM's suppliers were international organisations, constantly updating their technologies and frameworks. New computer software and software development frameworks required OSCOM to employ the best engineers to research, capture and then transfer this knowledge to other engineers in project teams. It took engineers time to capture supplier knowledge (OSCOM, interviewee 003). Furthermore, language barriers and training expenses intensified the difficulty of learning with suppliers (OSCOM, interviewee 005).

5.3.4. Boundary Spanning Mechanisms

Boundary spanners

Decentralised functional teams. The CEO noted that the company had a specific team who "*are tasked with learning from outside the company to capture new techniques of technologies, new way of developing, and new way of doing business, and they bring that back into the company*" (OSCOM, interviewee 001). The challenges in learning with technology suppliers were time and cost. Such challenges required OSCOM to employ strategic boundary spanners who had the ability to absorb knowledge quickly in learning with suppliers. Thus, "*In our company, there is an outstanding team. They have in-depth technology insight, troubleshooting and fast learning abilities which facilitate R&D*

activities. For example, they can shorten research time from two months to just one month. To define these engineers, we firstly observe their performance within our company based on their profiles" (OSCOM, interviewee 003).

Most OSCOM engineers resided in Asia, while their suppliers organised their training courses internationally. Overseas training courses might be expensive for OSCOM to attend. "*There are advanced technology seminars organized in Singapore and the US which are very expensive*" (OSCOM, interviewee 005). Such expensive courses posed challenges to the number of engineers who could attend supplier training courses. A managing director noted that the budget for learning was a constraint because it could be reduced if the business had issues. To solve the cost problem, the CTO emphasised that OSCOM only sent core R&D engineers to learn with suppliers and they became the trainers for the other engineers. A delivery manager estimated that R&D boundary spanners with suppliers only accounted for approximately 3% of the engineers within OSCOM (around 45 people).

Boundary spanning tools

Company technology targets. Contrary to the learning with customers who were connected with OSCOM through the firm global project management system, suppliers were linked through technology targets. Top-down technology and business targets created by management and central teams were the platforms guiding the learning of R&D experts with suppliers (OSCOM, interviewees 003, 005). On the one hand, company targets directed the search for technological needs. On the other hand, it determined the investments for network learning with suppliers.

Technology websites. OSCOM did not use any technology to support learning with suppliers. The company only used technology websites and forums as applications to capture updated supplier knowledge. These forums played the role of open source platforms for OSCOM to capture supplier information about new technologies. Thus, "*we often refer to websites on technologies trends or technologies communities, for example Microsoft communities. We have people participating to observe technology trends and discuss with them when we have concerns which need to be solved*" (OSCOM, interviewee 003).

Learning coordination

Periodic training courses. To capture supplier knowledge, OSCOM sent core engineers to attend periodic supplier training courses, seminars and workshops and gained their certificates. An interviewee mentioned that Microsoft annually organised SharePoint training courses to update its new technologies for its partners. Some suppliers granted OSCOM partnerships if the company had sufficient certifications and served the number of customers that met supplier requirements. Partnership status could help OSCOM to receive support from suppliers in using their technologies, frameworks and guidelines in OSCOM projects. Suppliers may have reviewed OSCOM solutions on what should be improved if customers required this.

External expert recruitment. Another mechanism was recruiting external experts to capture their knowledge that OSCOM may not have had. In the words of a delivery manager, "*When [OSCOM] finds out a technology that the company does not have, the company can recruit external experts to train the other engineers*" (OSCOM, interviewee 005).

Knowledge governance

Partnership relationship. OSCOM used its partnership status to encourage suppliers to share knowledge with the company. To become a partner of suppliers, OSCOM obtained their certificates of qualification and had a sufficient number of customers. As a partner, OSCOM benefited from suppliers' policies, such as periodic training courses and solution support. Annually, suppliers shared their updated knowledge with partners through training and issued certificates to OSCOM trainees. If customers required OSCOM solutions to be qualified by trusted suppliers, suppliers, as partners, assisted OSCOM to review solutions, ensuring the success of OSCOM solutions (OSCOM, interviewee 005).

Technological mechanisms

Internet technology websites. The internet is the only technology OSCOM used to capture, interpret and disseminate knowledge in the relationships with suppliers. Information was processed and shared with suppliers on online technology websites. These technologies helped OSCOM to update and capture supplier updated technologies for firm learning.

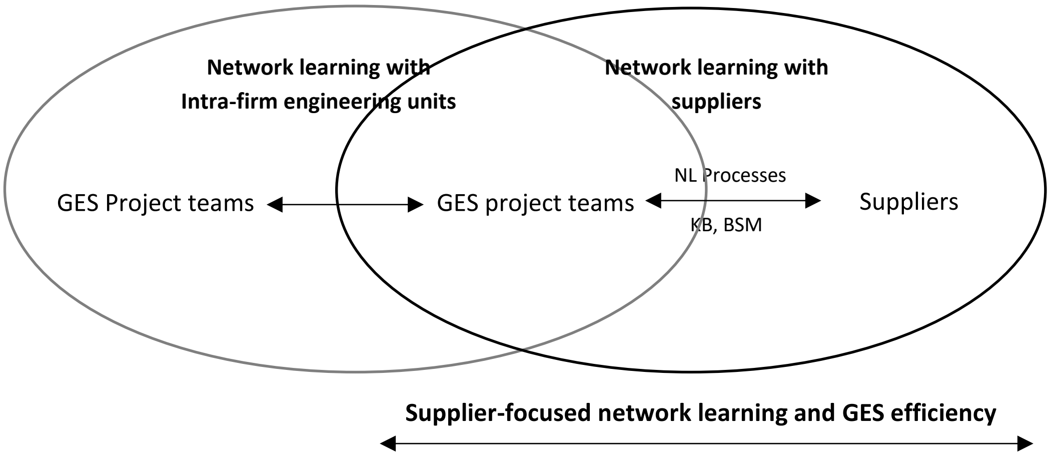
5.3.5. Values

The outcomes of OSCOM learning with suppliers were the updated technologies that customers needed and which were relevant to company strategies. New technologies helped OSCOM to fulfil customer needs when required. The ultimate outcomes were customer-driven solutions in future development. Supplier-focused network learning not only created new knowledge and capabilities for the firm, but also built partner relationships with trusted technology suppliers and thereby consolidated its reputation and obtained other benefits from suppliers in solution creation with customers.

5.3.6. GES Network Learning with Suppliers and GES Efficiency

Efficiency-oriented network learning focuses on knowledge creation with a few high-tech sub-tier suppliers trusted by customers and relevant to firm targets. Knowledge creation with suppliers highlights the capture of updated supplier technologies and subsequent transfer to intra-firm engineering project teams for future operations with customers. Sub-tier technology suppliers share the same interest of developing the technologies with the firm, but have superior, complex and constantly updated technologies that require decentralised expert boundary spanners and informal governance mechanisms to help ease the translation and transfer of supplier knowledge to boundary spanners. Figure 5-2 illustrates the key features of supplier-focused network learning and GES efficiency.

Past research has identified that suppliers engage in providing service providers with technologies for solution co-creation with customers (Brady and Davies, 2004; Windahl and Lakemond, 2006; Jaakkola and Hakanen, 2013). However, most studies have not clarified how suppliers contribute to customer-focused and intra-firm engineering units and thus GES efficiency. This study indicates that sub-tier suppliers provide new knowledge for firms that is transferred to project teams through intra-firm network learning for future development with customers. The suppliers may provide support to verify the solutions co-created with customers and ensure that they meet customer demands. The study also clarifies that suppliers share the same interests of developing technologies with firms, but that decentralised expert boundary spanners and informal governance mechanisms should be employed to capture evolving and complex supplier knowledge. The following section examines the APPCOM case to explore GES network learning with suppliers and GES flexibility. Flexibility is a firm value created through quick response to changing customer demands for both high-performance service and innovative products.



Network learning drivers:
- Technology suppliers trusted by customers

Network learning processes:
- Knowledge creation (with suppliers) & knowledge reuse (intra-firm project teams)

Values:
- New skills
- Supplier partnership and supports

Knowledge boundaries:
- Updated supplier technologies

Boundary spanning mechanisms:
- Decentralised functional teams
- Company engineering targets
- Informal training coordination and knowledge sharing governance
- Supported internet technology websites

Figure 5-2: Supplier contributions to GES network learning and efficiency

5.4. APPCOM Network Learning with Suppliers and GES Flexibility

In chapter 4, APPCOM engineering sites were shown to collaborate with customers in a few related industries to capture customer standards, technology roadmaps, engineering best practices and customer problems. This knowledge informed APPCOM relationships with suppliers to enhance group performance and innovate technologies. In this section, APPCOM supplier-focused network learning for GES flexibility is examined in terms of learning drivers, processes, barriers, boundary spanning mechanisms and outcomes.

5.4.1. Network Learning Drivers

Sub-tier supplier clusters

Collaboration with sub-tier suppliers was a key strategy to reduce the risk of supply failure and to enhance group performance in response to changing customer demands for better engineering performance. *“It allows the supply chain to become more efficient*” (APPCOM, interviewee 002). In particular, supplier-focused network learning minimised supply risks by aligning supplier operations and components with APPCOM standards and technologies. The company expected that its upstream sub-tier suppliers would develop their operations and technologies jointly with APPCOM to match customer operational standards and technology roadmaps. Some strategic upstream sub-tier suppliers were selected as partners to co-develop engineering operations and technologies with APPCOM to align with customer requirements. Only suppliers with high-performance operational capabilities that met APPCOM standards were eligible to be selected for learning. In fact, APPCOM had around 50 high-performance suppliers integrated in clusters for network learning. Therefore, one of the key drivers for co-development with upstream sub-tier suppliers was supplier performance.

Advanced technology partner collaboration

To align its technologies with customer technology roadmaps and problems, APPCOM engaged with a few advanced technology suppliers who provided APPCOM with complementary technological capabilities to solve future challenges that would impact on clients. Thus, “*From an engineering viewpoint, we have direct relationships with multiple engineering research groups around the world in many countries, Singapore, US - fair and UK - huge. And the knowledge we gain from that very often will help us develop our technical approaches to solve the challenges of the next 10, 15, 20 years that the customers put all that directions*” (APPCOM, interviewee 002).

These technology partners were diverse, including universities, governmental technology centres and technological service companies. APPCOM wanted to co-develop technologies with partners that had the abilities to develop technologies at a high level of readiness to integrate into products for commercialisation. Thus, “*technology readiness level (TRL) one to four is very much where universities operate. Four to six is getting close to a product. Once you've got to six, you've got something which is good enough to put into a product. And six to nine is taking it to put into a product to make it real. But we have to de-risk the technologies so the “catapult” centres are there to take any technology that is low TRL and turn it into something more real*” (APPCOM, interviewee 001).

5.4.2. Network Learning Processes

Knowledge creation

Knowledge creation between APPCOM engineering sites and their sub-tier suppliers was guided by the firm production system, which highlighted common engineering practices between APPCOM and sub-tier supplier operations. For example, common topics could have been production control, lean tools or sub-tier management. APPCOM created standardised processes and tools embedded in its production system to direct the collaboration of APPCOM engineering sites with key sub-tier suppliers (around 1400 suppliers). Thousands of suppliers were formally and periodically evaluated through a four-step process to lessen the risk of supplier failure, which involved a vendor questionnaire, risk analysis, working assessment of supplier performance (WASP) and account review.

Collaboration in clusters. The standardised supplier assessment system enabled the company to score, rank and integrate suppliers into the APPCOM production system. At the time of this study, fewer than fifty suppliers were excellent, scoring over 60% (WASP score); these were selected for co-developing operations and technologies jointly with APPCOM engineering sites in supply network clusters. The others (below 60% WASP) had to participate in APPCOM- supported development programs to improve their performance, such as conformance findings (1-2 years), improvement suppliers (1-2 years) and supplier development (3 years +). Selected high-performance suppliers and APPCOM engineering sites formed clusters to share ideas and benefits with the company for operational and technological innovation, selectively being integrated into APPCOM's technology roadmaps and strategic plan.

Knowledge reuse for innovation

Based on the technology platforms developed in the relationships with customers, ideas from engineering sites were annually discussed across the group and approved for investment by the R&D board. Engineering ideas were then implemented, incorporating advanced research partners, to turn APPCOM ideas into new technologies ready to be integrated into products. A technical fellow stated that "*at APPCOM, given its diverse specialist technologies and products, our vitality [revenue from new products] is limited by our ability to link thousands of talented, technically-oriented employees into a continuous* *innovation framework and to integrate open innovation, where we can, with universities and industry*" (APPCOM, Annual Review 2015). Thus, "*there is a group of postgraduate students working together on bringing some of these high-level ideas [APPCOM technology roadmaps] to a level of reality. They are still doing works with universities, but it is more at a practical level*" (APPCOM, interviewee 002). Technology partners interacted with APPCOM engineering sites within formal joint development projects to co-create new technologies for the company. Customers were also involved in the projects as the end-users, providing feedback and verification for the validity of the new technologies developed (APPCOM, Annual Review, 2015).

5.4.3. Supplier Knowledge Boundaries

Sub-tier supplier maturity differences

In the collaboration with the large number of sub-tier suppliers, APPCOM found it difficult to influence and change all of them (APPCOM, interviewee 002). In fact, many upstream sub-tier suppliers which were at different maturity levels might have had a low level of good lean application, and focused solely on the manufacturing arena rather than the back office. Most of them did not understand the benefits of a whole business approach in making the change that was needed. Such differences made collaboration with sub-tier suppliers difficult to implement.

Technology partner boundaries

Technology partners might have operated in different industries or technology areas with different engineering resources. Such differences required close collaboration with research partners to overcome knowledge boundaries. Thus, "*why are they [manufacturing technology partners] good? They have access to fantastic facilities, much better than we have. They are good because they have different people that have not been in the business for so long but have got different open views. But they are limited from the point of view that they do not really understand the industry. They do not really have the experience of the industry. So we have to work quite closely with them*" (APPCOM, interviewee 001).

5.4.4. Boundary Spanning Mechanisms

Boundary spanners

Decentralised functional teams at site level. APPCOM engineering sites had their own functional teams who worked directly with their sub-tier suppliers to enhance quality, engineering and the supply chain. They were the boundary spanners who captured learning with their sub-tier suppliers for intra-firm network learning with central functional teams (APPCOM, interviewees 002, 003). Local functional teams created knowledge with the sub-tier suppliers in clusters based on shared frameworks such as quality, supply chain management and operations. Thus, "*If I look at my colleagues in engineering who are working with a supplier I have never seen, if I can see that that supplier will meet our process quality, commercial requirements and will technically develop them beyond that current capability and our current supply chain can do it, then I will wholeheartedly support what the engineers are doing*" (APPCOM, interviewee 002).

Centralised technology development taskforces. For new technology development with advanced technology partners, APPCOM employed engineering taskforces with a mixture of postgraduate engineers and technical fellows selected by a central R&D team to collaborate with advanced technology partners in joint development projects. Thus, "*We have a mixture of very experienced engineers, people who are engineering fellows, who are the most senior engineers in the company. We also have people that are fresh graduates because they are coming with new ideas and they do not know what is difficult. So they just solve the problems. They think about it differently. And they are not constrained*" (APPCOM, interviewee 001). Engineering fellows had at least 15 years' experience with an impressive record of commercial impact and the respect of their peers, both internally and externally. They developed and maintained external relationships with research institutes, government bodies and the like. They also played a key role in nurturing APPCOM's engineers of tomorrow, such as fresh graduate engineers. Centralised taskforces collaborated closely with partners and were supervised by the central R&D team to develop technologies for APPCOM.

Boundary spanning tools

Integrated information systems. APPCOM used integrated data systems as the boundary spanning tools to integrate sub-tier supplier information for resource planning and engineering collaboration virtually. Information systems might include engineering data systems, quality management systems and packaging systems. A group supply chain manager explained the benefits of integrated information systems with its sub-tier suppliers: "*We have all these data systems around us helping us make decisions and helping us track all of our decisions*" (APPCOM, interviewee 002). However, these integrated information systems were only used for information sharing and resource planning, not for information interpretation.

Shared standards. Operational standards were the key boundary spanning tools between APPCOM sites and their sub-tier suppliers. To be an APPCOM choice, suppliers needed to meet its requirements on a variety of engineering performance standards in terms of quality, delivery, engineering issues and improvement plans, amongst others. Assessment criteria were the boundary spanning tools to align supplier standards with APPCOM standards. Furthermore, common operational standard platforms such as planning and control, basic lean tools, advanced lean tools, new product introduction (NPI), product lifecycle management (PLM), and sub-tier management directed operational improvement across APPCOM and its suppliers. For supplier technology development, selected suppliers were integrated into APPCOM's technology roadmaps and strategic planning. In these cases, the roadmaps were the boundary spanning tools to guide supplier technical planning.

Technology requirements. For technology co-development with diverse advanced technology partners, APPCOM technology requirements were the boundary spanning tools to direct research partners' operations. It seemed that diverse advanced technology partners required more collaborative effort. Thus, "*We are learning how to work with them [technology partners]. So what we do now is what you must never do with them - just give them the requirements for a project and tell them to get on with it. Because that is not good thing to do with any suppliers anyway […]. You have got to work as a partnership*" (APPCOM, interviewee 001).

Learning coordination

High-performance supplier clusters. High-performance sub-tier suppliers were integrated in clusters with engineering sites for co-development. A set of formal assessment tools were developed to understand supplier performance and capabilities and hence identify key suppliers for operational and technological co-development. The evaluation tools included a vendor questionnaire, supplier risk analysis (a combined tool that reviewed the risk of suppliers), working assessment, and an account review agenda (including supplier audits and site visits).

After classifying suppliers according to their maturity levels, a limited number of selected excellent suppliers (fewer than 50) were clustered with APPCOM sites to co-develop a common approach periodically and informally for continuous performance improvement and co-evolved technical planning. Knowledge might have been transferred through training, coaching and site visits across APPCOM engineering sites and their clustered suppliers. Suppliers also joined in industrial associations with APPCOM to co-develop operations standards for the aerospace industry.

Joint development projects. Research partners were formally coordinated with APPCOM engineers in joint development projects. They interacted with each other in a formal routine to co-create new technologies. At the time of this study, APPCOM was leading several joint development projects with advanced technology partners who supplied different services and products to generate technological solutions for specific customers. Customers also joined in projects as the end-users and verifiers.

Merger and acquisition. Another way of coordinating with suppliers was to buy their businesses. APPCOM bought supplier businesses to capture new technologies and new skills, and to expand its businesses. The key reason for acquiring knowledge through M&A was to reduce the risk of developing technology internally. Thus, "*in the past, the way that we developed our technologies was by buying companies that had got the technologies. That is not about ways to develop the technologies. Because if you see somebody that has got something that you want and if it fits your solutions, then you buy it. It has been de-risked. So it might cost you a lot of money but you have got something at a market form; we buy them […], get new skills, get new products and get more value*" (APPCOM, interviewee 001). Since 2002, APPCOM has acquired more than 23 businesses in the aerospace and energy industries. Besides supplier acquisition, APPCOM also disposed of 15 engineering divisions.

Knowledge governance

Supplier assessment. APPCOM wanted to consolidate spending and reduce supplier tail. Only suppliers who met APPCOM expectations and shared responsibilities for continuous operational and technological innovation were selected. To be the choice of APPCOM, suppliers had to conform to the company's quality standards and be willing to share ideas and benefits for co-development. Thus, "*it makes sense for us to share the activity benefits and workloads, just to do more with the same resources. But equally it makes sense for us to send the same message, in this case up to the government, or down to suppliers or just to do the right thing because it is good for the UK economy*" (APPCOM, interviewee 002).

Talented engineers. To encourage supplier knowledge sharing and firm learning, APPCOM recruited talented graduate engineers with fresh ideas and high motivation to learn (APPCOM, interviewee 001). They were combined and supported by senior engineering fellows who were respected by technology partners. These mechanisms fostered knowledge sharing with advanced technology partners who were strong at advanced research but did not have the same industrial experience as APPCOM. Additionally, suppliers were integrated within contracted joint development projects with specific technological requirements and knowledge sharing routines.

Technological mechanisms

Common integrated software. Virtual assembly supported the capture, interpretation and dissemination of designs between APPCOM engineering sites and their suppliers during the development processes. It helped to enhance operational decision making across the supply chain (APPCOM, interviewee 002). In joint development projects, data analysis could be supported by simulation software to help engineers in their learning processes with suppliers (APPCOM, interviewee 001).

5.4.5. Values

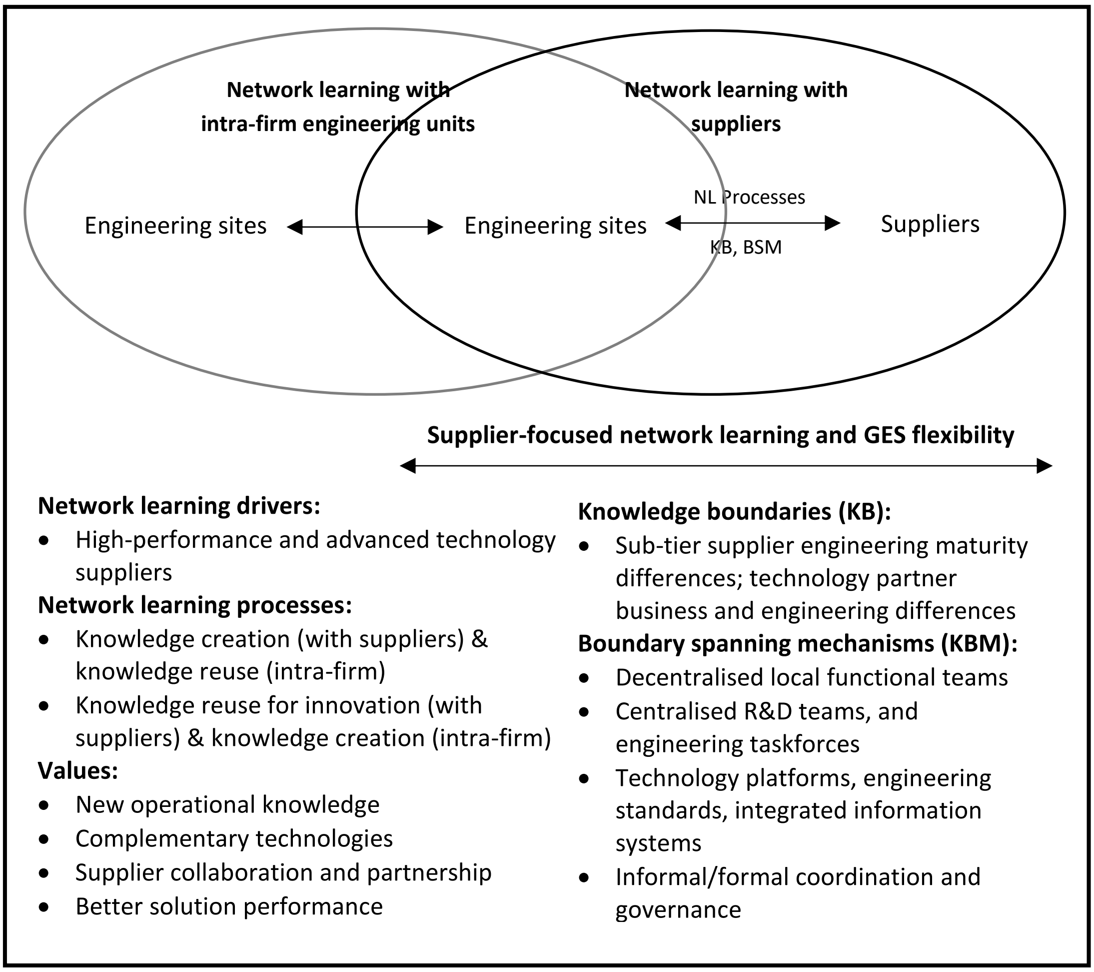
Supplier-focused network learning contributed to better solutions and performance for the entire group. On the one hand, APPCOM set up development programs to help key sub-tier suppliers with lower maturity levels to improve their performance and therefore reduce supply risks. On the other hand, world-class suppliers were integrated into clusters to share their ideas and benefits to enhance performance jointly. New knowledge co-created with suppliers could be reused by other engineering sites for their operations and by suppliers through the company production system (APPCOM, interviewees 002, 003).

For technology development, technology partners were integrated into taskforce projects, providing services and complementary products for new APPCOM technology development. Their complementary technologies and services helped to transform APPCOM ideas and technologies into reality and their knowledge was captured for knowledge reuse for innovation.

5.4.6. GES Network Learning with Suppliers and GES Flexibility

The case indicates that high-performance and advanced technology suppliers are selected to collaborate with firm engineering units for operational and technological co-development. There are two key supplier-focused network learning processes: knowledge creation and knowledge reuse for innovation. Knowledge creation is the interaction with high performance sub-tier suppliers with the same interests in supplier clusters or associations, to co-develop common operational processes and thus enhance intra-firm performance. Knowledge co-created with sub-tier suppliers can be reused by other engineering sites through intra-firm network learning. Knowledge reuse for innovation relates to the interactions with different technology suppliers who provide complementary knowledge for the firm to innovate its technologies. Customers may be involved in this process, but their role is to evaluate the technologies co-developed by the engineering taskforces and their suppliers.

Sub-tier suppliers may be at a higher level of maturity. Decentralised local functional teams are the best mechanisms to capture supplier knowledge. Informal governance mechanisms, such as supplier clusters and associations, are critical in encouraging suppliers to share knowledge, because suppliers share the same interests in co-improving performance with the firm. For technology development, technology partners conduct businesses in different technology fields and they may have different interests, complex technologies and engineering operations. To collaborate effectively with technology partners, centralised R&D teams and engineering taskforces are employed, collaborating closely with suppliers within joint development projects. Supplier-focused network learning results in new knowledge for operational enhancement and complementary technologies for technology innovation that ultimately results in better solution performance. Figure 5-3 illustrates the key features of supplier-focused network learning and their links to intra-firm network learning and GES flexibility.



Network learning drivers:
- High-performance and advanced technology suppliers

Network learning processes:
- Knowledge creation (with suppliers) & knowledge reuse (intra-firm)
- Knowledge reuse for innovation (with suppliers) & knowledge creation (intra-firm)

Values:
- New operational knowledge
- Complementary technologies
- Supplier collaboration and partnership
- Better solution performance

Knowledge boundaries (KB):
- Sub-tier supplier engineering maturity differences; technology partner business and engineering differences

Boundary spanning mechanisms (KBM):
- Decentralised local functional teams
- Centralised R&D teams, and engineering taskforces
- Technology platforms, engineering standards, integrated information systems
- Informal/formal coordination and governance

Figure 5-3: Supplier contributions to GES network learning and flexibility

Different network learning practices with sub-tier and technology suppliers for GES flexibility have been identified in the supply chain management literature (Todtling et al., 2009; Coghlan & Coughlan, 2014; Salonen et al., 2018). However, most current studies have not clarified the contributions of supplier-focused network learning to customer-focused and intra-firm network learning. This study reveals that supplier-focused network learning contributes to the creation of new knowledge that can be reused for solution performance enhancement through intra-firm network learning. It also helps to capture supplier technologies for intra-firm technology transformation. Suppliers and customers may collaborate within joint development projects, but customers mainly play the role of the end users rather than co-creating technologies with suppliers. The study clarifies that decentralised local experts and informal governance mechanisms facilitate network learning with sub-tier suppliers who share common interests in continuous improvement, but may have different levels of engineering capability maturity. Centralised R&D teams and technology taskforces shows their advantages in capturing the different technologies and engineering practices of diverse technology partners to transform internal ideas into solutions that customers want. The following section studies the RECOM case to explore its supplier-focused network learning practices and GES innovation.

5.5. RECOM Network Learning with Supplier and GES Innovation

Chapter 4 revealed that RECOM research scientists engaged with customers in consortia, informal workshops and consultancy projects to capture their interests, problems and data for the creation of novel solutions for RECOM. To create innovative solutions for customers, RECOM research scientists needed to search for data and models generated by research institutes to build their own scientific models. This section presents RECOM network learning with research institutes for GES innovation.

5.5.1. Network Learning Drivers

Model development and supplier information

RECOM scientists exploited the models and data generated by research institutes around the world to develop their own models. These models were created by RECOM research scientists to describe drug absorption, distribution and elimination in the body, which was represented as a series of organs or tissue spaces. Because the company did not conduct any of the laboratory experiments, it relied on the latest publications of the experimentalists of academic institutions and pharmaceutical companies around the world. The company was motivated to capture supplier data and some aspects of suppliers' models to refine and verify its models. Thus, "*It is a massive number of equations [human and animal models]. But equations themselves will not do anything. Everybody can write down equations. But what are more important are the parameters; for example the rates of change [of drugs within human and animal bodies] that you can only determine through the experiments […]. Most of their data [supplier knowledge] are relevant, not all, but still you can get access to some data. So that is one of the parts of the science team here, they* *look at literature, data, and publications to determine the up-to-date values of these parameters*" (RECOM, interviewee 010).

5.5.2. Network Learning Processes

Knowledge reuse for innovation

Literature review. One research scientist described how supplier knowledge contributed to RECOM's new model generation: "*One part is to search for the data that fit into your models, the other part is to search for the literature to verify your models*" (RECOM, interviewee 006). RECOM scientists usually started with open access databases such as PubMed or Google Scholar, together with databases of research institutes, to search for related models and data available in published papers. For example, "*I want to develop a brain model. I know brain physiology. I look at the literature and go to PubMed and search anything on CISS data. If I search for CISS data, there are like thousands of articles which actually come up. I look at those articles within the abstract and see what they have done. If I think what they have done might have data inside, then I get the full text and then try to find the data and then what we have is the tables, the graphs. We have a lot of data and we can digitalize these data and that is how we get them*" (RECOM, interviewee 017).

Most RECOM suppliers provided data and models to RECOM free of charge. The reason was that "*they [academic institutions] populate the databases and everyone can use these models and this knowledge. So there are research institutes which are usually in academic institutions producing products for free. They do not sell them. They cannot do this. They just have to do this for free. […] They get money from grants and from the European Union to exist and to produce the knowledge and accumulate the knowledge. They produce hundreds of databases on different genetics and in metabolomics in different areas, sort of biological sciences*" (RECOM, interviewee 016).

*Client data***.** When RECOM scientists did not find the data they needed within the open access literature provided by academic institutions, they might have asked clients for experimental data because RECOM did not have research laboratories to conduct experiments. In the words of a research scientist, "*we sometime ask our clients: do you have internal data? Can you do an experiment and give us the data? So we ask such kinds of things*" (RECOM, interviewee 017). But commercial companies only provided data if they were interested in RECOM models and if the data were not confidential. Thus, "*it depends on what the project is, what the data is, but sometimes they [commercial companies] do [provide data]... They do not share the things they are working on, some things are highly confidential*" (RECOM, interviewee 002).

Research service. In addition to exploiting supplier knowledge within the literature, RECOM funded some excellent research institutes that used the company's bio-simulation platforms for their doctoral and post-doctoral research. Annually, RECOM invited outstanding research institutes with RECOM licences to apply for research grants provided by the company. The aim was to use the funded research results of academic institutes to verify the validity of RECOM models and/or to gather the data that informed the models. In these research funding processes, clients may have been involved in evaluating supplier proposals to ensure that the supplier research was relevant and contributed to their interests.

5.5.3. Supplier Knowledge Boundaries

Interest differences. The research institutes included universities, research labs, hospitals, governmental agencies, and even clients, such as pharma companies around the world. They had different interests, interpretations and experiments, and were located in different places. Their knowledge might not have been relevant to RECOM. Thus, "*every day I read some papers from this year, last year, the last ten years. But it is still not clear how biology really works. It is a revolution-driven process*" (RECOM, interviewee 16). Suppliers' knowledge might have been new to RECOM and data could have been complex because suppliers might have had different interpretations within their experiments (RECOM, interviewees 015, 016, 006). Different interpretations and experiments might result in knowledge boundaries and make suppliers' scientific knowledge more complex for RECOM scientists to capture.

5.5.4. Boundary Spanning Mechanisms

Boundary spanners

Research scientists. All the research scientists in the four research groups (see Appendix 3.3) engaged in learning with the knowledge published by various research institutes to develop company models. All the interviewees stressed that they learned from the literature and captured data from previous studies, publications and clients. Besides, the research scientists directly contacted various suppliers by themselves through informal contacts and/or events such as industrial and academic conferences.

Boundary spanning tools

RECOM physiological models. The research scientists connected with suppliers through the models they were developing. RECOM models were the key boundary spanning tools for its scientists to search for supplier knowledge for model verification. These boundary spanning tools also guided knowledge sharing between RECOM scientists and their knowledge suppliers. While academic institutes were willing to share their knowledge free of charge, commercial companies only shared their experimental data if they had an interest in RECOM models.

Scientific databases. RECOM scientists used different scientific databases to reach supplier knowledge. The interviewees referred to various public and local databases as the means to collect data and models for their operations. For example, PubMed, some databases from well-known universities, were among the boundary spanning tools RECOM research scientists used to search for supplier data and models.

Learning coordination

Reviewed journals. RECOM formally coordinated knowledge from the literature into its bio-simulation platforms. Because scientific exploration needed to be verified by trusted scientists, only models and data published within peer reviewed journal papers were valid to be added to RECOM models. Thus, "*you cannot use data which is not published […]. When it comes from journals, it is verified. If it is reviewed by scientists who are known in the field of research, they verify the methodology, they verify the calculation of the experimental work, etc*." (RECOM, interviewee 006).

Informal contacts and professional conferences. Besides searching for new knowledge created by academic institutes in internet open sources and experimental data from clients, research scientists might have interacted with research institute scientists in various ad-hoc, informal events such as academic workshops and conferences, professional networks and personal contacts. Thus, "*I find where they are and send the email, tell them what I want to have and so far I would say 90% of the people come back* *and give me the information, and I do it probably, I would say, 10 to 15 times a year*" (RECOM, interviewee 003).

Research project grants. Another way to coordinate knowledge from academic institutes was through annual grants for doctoral and post-doctoral research projects. RECOM called for research applications from research centres of excellence around the world who had successful track records in the area of the proposed research and held a valid license at the time of application. Applications were assessed by an internal panel of experts, along with representatives from RECOM consortium member companies, through a set of criteria such as the feasibility of proposals, the track record of applying institutions, and the relevance to RECOM products and areas of interests. These research contracts enabled RECOM to capture the knowledge of outstanding research partners to verify the performance of RECOM models via clinical studies or to gather experimental data that informed RECOM simulations. Successful research institutes were usually well-known universities around the world.

Knowledge governance

Free licences. RECOM used formal mechanisms to encourage knowledge suppliers to share their knowledge with the company. The company provided the software licences free of charge to academic institutes. In exchange, RECOM asked them to co-develop the company software by using it to solve their research problems, to raise public recognition on websites, to include training in RECOM software in student courses, and to reference RECOM software in academic publications. RECOM also provided updated software licences to commercial consortium member companies, not just to obtain their feedback and orders for future development, but also to encourage them to share experimental data, experience and problems for technology co-development.

Research contract grants. Research centres of excellence sent their proposals to RECOM to develop the company's models. They were encouraged to produce research that informed RECOM models or provided data that verified them. Knowledge sharing was based on a research contracts with grants.

Technological mechanisms

Internet search engines. Public internet search engines enabled RECOM scientists to capture relevant literature and data created by academic and research institutes. PubMed, Google, and other databases within the pharmaceutical industry were search engines that captured knowledge from various research institutes and companies around the world for RECOM research scientists. Public internet tools could be considered as the technologies supporting RECOM scientists' learning.

Data predictive software. When research scientists could not find data from the literature and clients, they may have used predictive software to capture it. But these practices were rarely used because the predicted data might not have been reliable. One scientist revealed that these practices might have accounted for less than 10% of his operations.

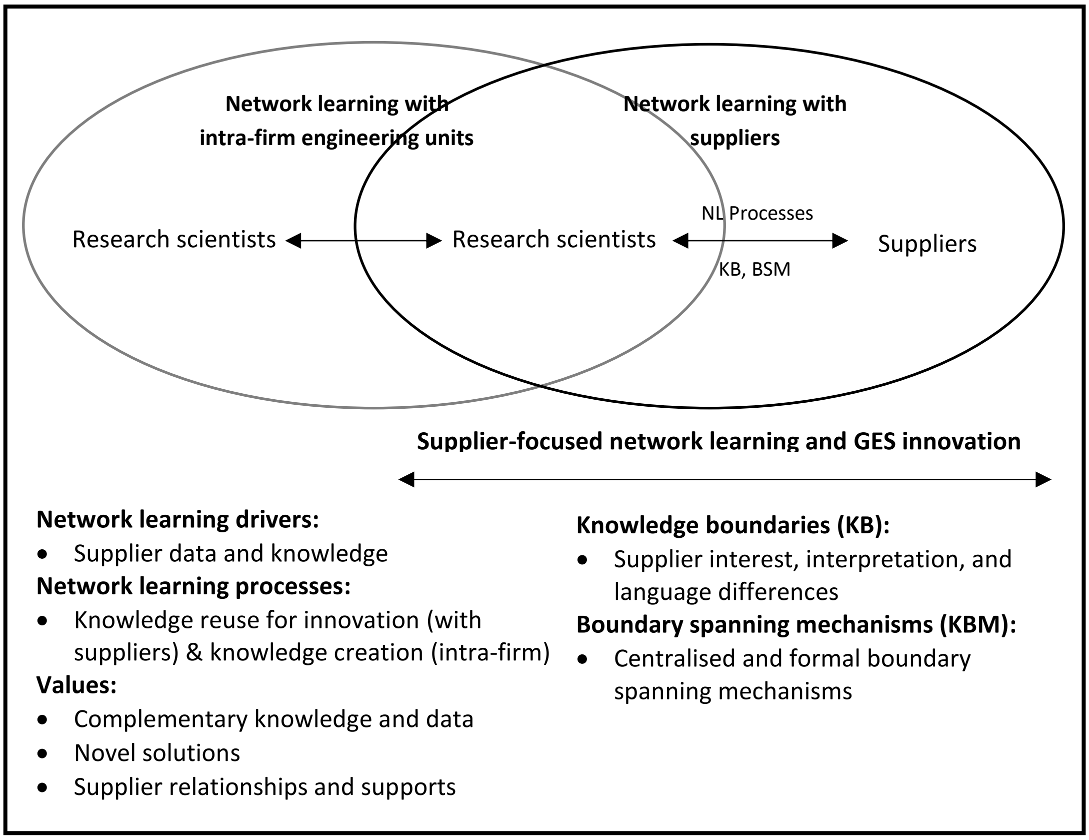
5.5.5. Values

The main outcome of RECOM supplier-focused network learning was the capture of relevant data and models for intra-firm model development. Other benefits were supplier relationships. Supplier-focused network learning helped to enhance the relationships with suppliers and clients as data providers. Furthermore, supplier data and models generated from research projects might have helped to verify and contribute to network learning with customers.

5.5.6. GES Network Learning with Suppliers and GES Innovation

Supplier-focused network learning for GES innovation was driven by the need of the firm to capture complementary information to verify firm solutions. The network learning processes focused mainly on formal interactions, such as individual literature reviews, client data collection and research services, to capture supplier information for intra-firm innovation. The main learning challenge was that suppliers had different interests, interpretations and experiments in their businesses and may have produced information irrelevant to firm solutions. To address this challenge, centralised resources, e.g. project supervisors, proposal committees for research grants and formal governance such as peer review journals, research contracts and licence grants, were important for obtaining the right knowledge for solution development. Figure 5-4 highlights the key features of network learning with suppliers and GES innovation.

Although the literature has emphasised suppliers as key players in co-creating novel solutions with service providers, most studies have not clarified the supplier links to customer-focused and intra-firm network learning that also contribute to GES innovation (Tidd, 2005; Galbraith, 2014). This study clarifies that suppliers provide information that verifies the solutions created inside the firms, informing and reinforcing network learning with customers. Furthermore, it identifies key boundary spanning mechanisms that support network learning with suppliers.



Network learning drivers:
- Supplier data and knowledge

Network learning processes:
- Knowledge reuse for innovation (with suppliers) & knowledge creation (intra-firm)

Values:
- Complementary knowledge and data
- Novel solutions
- Supplier relationships and supports

Knowledge boundaries (KB):
- Supplier interest, interpretation, and language differences

Boundary spanning mechanisms (KBM):
- Centralised and formal boundary spanning mechanisms

Figure 5-4: Supplier contributions to GES network learning and innovation

5.6. GES Network Learning with Suppliers and Value Creation

The analysis of GES network learning with suppliers is shown in Table 5-1. It enables to identify the key features of GES network learning practices with suppliers of the three cases that reveal the similarities and differences in network learning with suppliers across three cases. These similarities and differences will be discussed below.

Also, the linkages and practices between network learning with customers and suppliers are identified by comparing with network learning with customers (Table 4.1, 5.1). The analysis clarifies the linkages between the network learning with customers and suppliers and indicates their linkage to network learning with intra-firm engineering units. It also shows the linkages between boundary spanning mechanisms adopted across customers and suppliers.

Table 5-1: GES network learning with suppliers and value creation

Network learning		OSCOM GES Efficiency	APPCOM GES Flexibility	RECOM GES Innovation
Learning Drivers		Table 4.1: - Changing customer needs for a cost-effective IT solution - Long-term cooperative relationships - Technology suppliers trusted by customers	Table 4.1: - Changing customer demands for better performance - Collaborative relationships - High-performance sub-tier suppliers - Advanced technology partners (TRL suppliers)	Table 4.1: - Changing customer expectations for a novel solution - Consortium relationships - Suppliers with relevant knowledge for model development
Learning process	**Key knowledge processes**	Table 4.1 - Knowledge reuse for innovation (knowledge creation with suppliers) - Knowledge creation - Knowledge creation (supplier knowledge capture, solution verification)	Table 4.1 - Knowledge reuse for innovation - Knowledge creation - Knowledge creation - Knowledge reuse for innovation (Joint technology development projects)	Table 4.1 - Knowledge reuse for innovation - Knowledge reuse for innovation (literature review; client experiment data capture)
	Process complexity	Table 4.1 - Customer interest differences - Business domain, technology, process differences - Geographical distance - Updated supplier technologies - Supplier dispersion	Table 4.1 - Customer interest differences - Customer engineering maturity differences - Geographical distance - Supplier engineering maturity differences - Supplier technology and engineering differences	Table 4.1 - Customer interest differences - Interpretation/ experiment differences - Customer scientific challenges - Supplier interpretation, experiment differences
Boundary spanning mechanisms	**Boundary spanners**	Table 4.1 - Central management teams (CEO, director, CTO, senior managers) - Central focused functional teams (e.g. onshore/offshore BA, TA) - Decentralised functional teams (e.g. R&D experts, BA)	Table 4.1 - Central management teams (CTO, COO, senior business managers) - Centralised functional teams (e.g. operational teams aligning firm standards with customers) - Central management teams (supplier selections and supervision) - Decentralised local functional teams (e.g. supply clusters)	Table 4.1 - Centralised senior research scientists (to co-create customer wish lists) - Central management teams (to select research proposals of suppliers) - All research scientists in four engineering groups (informally contact with suppliers)
	Boundary spanning tools	Table 4.1 - Solution frameworks pre-defined with customers - Global project management portals - Technology targets - Technology online forums/websites	Table 4.1 - Group customer-driven standards/ requirements - Group customer-driven technology platforms - Group integrated information systems (SAP) - Integrated information system (information sharing) - Common shared standards - Technology requirements	Table 4.1 - Company software (Existing models and databases) - Customer engineering challenges - RECOM physiological models - Scientific databases

	Learning coordination	Table 4.1 - Customer survey - Onshore-offshore project coordination - Knowledge documentation/ modularisation - Supplier periodic training course - Informal forums	Table 4.1 - Customer negotiation meetings - Formal program coordination - Knowledge documentation - Customer staff grafting - Supplier clusters, associations - M&A - Joint development projects	Table 4.1 - Formal consortium meetings - Periodic informal workshops - Formal consultancy projects - Supplier research grants - Reviewed journals - Informal contacts - Professional conferences
	Knowledge governance	Table 4.1 - Customer contact points - Trust (built by third party certifications, operational transparency, IP protection) - Partner membership (e.g. number of certificates, customers)	Table 4.1 - Trust (built by commitments to operational excellence and technology leadership) - Points of contact - Supplier assessment for learning integration - Talented engineers (capturing technology supplier knowledge)	Table 4.1 - Trust (built by scientist publications; third-party affiliation) - Free of charge licences
	Technology mechanisms	Table 4.1 - Data mining technologies (e.g. cloud and analytics software) - Technology websites - Internet	Table 4.1 - Common integrated virtual assembly (for co-development) - Virtual assembly - Simulation software	Table 4.1 - Internet open sources - Internet search engines - Predictive software
Outcomes		Table 4.1 - Cost-effective IT solutions - New frameworks and lessons learned, information on future customer needs - Long-term partnership (e.g. offshore ODC) - New technological knowledge - Supplier partnership	Table 4.1 - High-performance sub-system package solutions - New standards, technology platforms - Best practices, customer business problems - Supplier of choice - New knowledge for operational improvement - Complement knowledge for technology development - Supplier relationships	Table 4.1 - Customer-driven innovative solutions - Knowledge on customer interests, problems, scope of solutions (e.g. customer wish lists) - Customer affiliation - Relevant data and models for solution development - Supplier relationships
Network learning processes and links to network learning with suppliers and intra-firm engineering units		Table 4.1 - Knowledge reuse for innovation (links to knowledge creation with suppliers) - Knowledge creation (links to knowledge reuse with intra-firm project teams) - Knowledge creation (links to knowledge reuse with project teams, verification of knowledge creation with customer)	Table 4.1 - Knowledge reuse for innovation (links to knowledge creation with intra-firm engineering sites; & knowledge reuse for innovation with suppliers) - Knowledge creation (links to knowledge reuse with intra-firm engineering sites & knowledge creation with suppliers) - Knowledge creation (links to knowledge reuse with intra-firm engineering sites) - Knowledge reuse for innovation (links to knowledge creation of technology taskforces; customer verification as the end-users)	Table 4.1 - Knowledge reuse for innovation (links to knowledge creation with intra-firm research scientists & knowledge reuse for innovation with suppliers) - Knowledge reuse for innovation (links to knowledge creation with intra-firm research scientists, customer verification of knowledge reuse with suppliers)

Boundary spanning mechanisms across cases	Table 4.1 - Central management teams - Centralised functional teams - Formal governance mechanisms - Uniform/global information systems, common framework, engineering targets - Decentralised functional teams - Informal governance mechanisms - Customised engineering targets, platforms	Table 4.1 - Central management teams - Centralised functional teams - Formal governance mechanisms - Uniform/global information systems, common technology platforms, standards - Central management teams - Formal governance (joint projects for technology development) - Common technology platforms (e.g. technology requirements) - Decentralised local functional teams (to co-develop operations with sub-tier suppliers) - Informal governance (e.g. supplier clusters) - Customised shared standards	Table 4.1 - Central management teams - Formal governance mechanisms - Common technology platforms/ models - Central management teams - Formal governance (e.g. research grant projects) - Common technology platforms/models (e.g. use of company software)

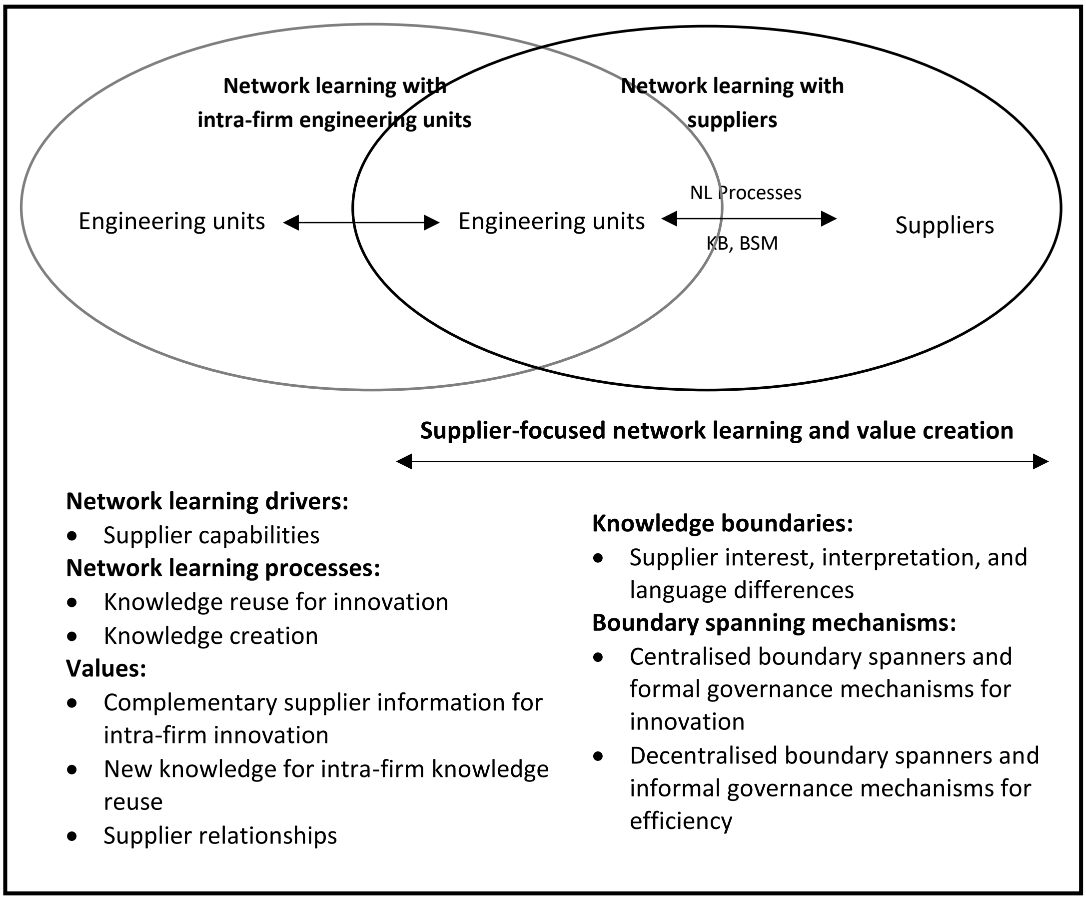
The three case studies reveal common characteristics of supplier-focused network learning and their linkage with intra-firm and customer-focused network learning. Figure 5-5 presents the common features of supplier-focused network learning.

Such learning is driven by customer capabilities. In the efficiency case, the company was motivated to learn with high tech suppliers trusted by customers to gain the skills necessary for their operations. The flexibility case collaborated with high-performance sub-tier suppliers and advanced technology partners to enhance its performance directed by customers. The innovation case indicates that research institutes which conducted experimental research and publish relevant data and models were the target suppliers for firm solution development. There are two main network learning processes:

- Knowledge creation: the interactions with sub-tier suppliers to create new knowledge for future intra-firm reuse and efficiency.
- Knowledge reuse for innovation: the interaction with technology and research suppliers to capture supplier information for intra-firm technology innovation.

These processes show the connections between supplier-focused network learning and intra-firm and customer-focused network learning. Additionally, supplier-focused network learning may involve customers in verifying the benefits of collaboration with suppliers for their businesses.

Suppliers are diverse, which creates knowledge boundaries and impedes network learning. In the case of GES flexibility, sub-tier suppliers may have different levels of engineering capability maturity, while technology suppliers operate in different businesses and have different interests, interpretations and languages. The efficiency case suppliers were high-tech providers trusted by customers and who constantly updated their technologies. The innovation case shows that suppliers could be universities, hospitals or regulatory agencies who provided various data and models that may not have been relevant to firm operations.



Network learning drivers:
- Supplier capabilities

Network learning processes:
- Knowledge reuse for innovation
- Knowledge creation

Values:
- Complementary supplier information for intra-firm innovation
- New knowledge for intra-firm knowledge reuse
- Supplier relationships

Knowledge boundaries:
- Supplier interest, interpretation, and language differences

Boundary spanning mechanisms:
- Centralised boundary spanners and formal governance mechanisms for innovation
- Decentralised boundary spanners and informal governance mechanisms for efficiency

Figure 5-5: Supplier contributions to GES network learning and value creation

To address supplier knowledge boundaries, firms employ a set of boundary spanning mechanisms to eliminate the complexity between suppliers and engineering units. Boundary spanning mechanisms include both centralised and decentralised boundary spanners and formal and informal governance, depending on the differences in interest between suppliers and engineering units. The learning with suppliers contributes to creating new knowledge for future reuse and complementary information for firm innovation.

The case analysis reveals some variations in the network learning with suppliers (Table 5-1). There are two different patterns of such learning found within the three cases studied: efficiency and innovation network learning.

GES firms tend to collaborate with sub-tier suppliers with good capabilities to develop their capabilities for efficiency. The learning process focuses on knowledge creation and informal interactions with suppliers rather than formal network learning processes, because sub-tier suppliers are interested in collaborating with the firms and they share similar technology platforms. Knowledge created will be captured for intra-firm reuse for efficiency. Sub-tier suppliers, despite sharing the same interests, have different engineering capability maturity levels, that require the employment of a set of boundary spanning mechanisms, including:

- Decentralised local functional teams: different independent or local functional teams are employed to interact with suppliers to capture supplier knowledge effectively and for transfer to intra-firm network learning for efficiency.
- Decentralised technology platforms: technology targets, platforms, standards and models are the key boundary spanning tools that guide the learning with suppliers.
- Decentralised technologies: internet-connected forums are among technologies GES firms use to support learning with suppliers.
- Informal learning coordination: independent teams or local engineering sites are integrated within workshops, training courses, clusters and associations to co-create knowledge with sub-tier suppliers.
- Informal knowledge governance: suppliers share knowledge based on industrial standards for continuous innovation. In the aerospace industry, for example, knowledge sharing is one of the important standards for business awards.

Innovation network learning is motivated to capture suppliers’ complementary knowledge for firm’s technology development. The learning processes are associated with knowledge reuse for innovation. Engineering taskforces/groups capture supplier information and knowledge as the inputs for verifying intra-firm technological innovation. The learning processes may be difficult because suppliers may come from different industries and areas and they may have different interests, interpretations and operations. GES firms therefore need to adopt the following set of boundary spanning mechanisms:

- Centralised R&D teams, engineering taskforces/ research groups: firms tend to form development teams to collaborate with suppliers which are under the management of a central team to ensure that suppliers will do what benefits the firm.
- Centralised boundary spanning tools: common technologies are used to support learning with suppliers. For example, RECOM shares common industrial databases with suppliers. Pre-defined frameworks/models are also important to guide learning with technology suppliers.
- Centralised technologies: common simulation and predictive software and search engines are adopted to support supplier-focused network learning.
- Formal learning coordination: Supplier information is captured within projects or followed by a formal procedure to ensure its effectiveness. For example, RECOM only captured data and models in peer reviewed journals and research services.
- Formal knowledge governance: formal mechanisms are employed to encourage knowledge sharing, such as talented graduate engineer recruitment in the case of APPCOM and free-of-charge licences in the case of RECOM.

5.7. Conclusion

This chapter has examined the role of suppliers in GES network learning and value creation. It is not clear how suppliers link to intra-firm and customer-focused network learning, nor the boundary spanning mechanisms that facilitate supplier-focused network learning and value creation. Three cases were studied to clarify these knowledge gaps.

The case analysis indicates that supplier-focused network learning is driven by supplier capabilities, which can contribute to enhancing the firm’s solution performance driven by customers. Suppliers co-create knowledge with firm engineering units, which can be reused in future development and thus enhance firm efficiency. It also provides complementary knowledge for the firm’s technology innovation. Customers may be involved in evaluating the results of supplier-focused network learning to ensure that it benefits them. Suppliers therefore link to intra-firm and customer-focused network learning and value creation.

Suppliers, however, have different interests, interpretations and languages because they operate in different businesses and are at different maturity levels. These cause supplier knowledge boundaries, which hinder network learning with suppliers. This study identifies knowledge boundary mechanisms to address the problems of supplier knowledge boundaries and to facilitate either efficiency or innovation. Efficient network learning focuses on knowledge creation with sub-tier suppliers for future intra-firm reuse and efficiency. Sub-tier suppliers share the same interests in learning and improvement but they have different levels of engineering capability maturity, which are often superior to those of the firm. Efficient network learning therefore relies on decentralised and informal mechanisms to facilitate mutual understanding and learning with sub-tier suppliers. Innovative network learning involves diverse technology partners/suppliers for technology development. Because these suppliers come from different industries and areas and may have different interests in network learning, firms need to employ centralised centres of excellence, engineering taskforces/groups and formal governance mechanisms to address differences in supplier interests.

The chapter has revealed that supplier-focused network learning links to intra-firm, customer-focused network learning in facilitating value creation. It is supported by a set of boundary spanning mechanisms to overcome supplier knowledge boundaries. In the following chapters, intra-firm network learning is examined to clarify its links to inter-firm network learning with suppliers and customers.

6. CHAPTER 6: GES NETWORK LEARNING WITH INTRA-FIRM ENGINEERING UNITS

6.1. Introduction

The previous chapters have highlighted the role of inter-firm network learning, exploring the process by which inter-firm network learning contributes to the creation of knowledge for intra-firm knowledge reuse and to capture customer and supplier information for intra-firm technology transformation. This chapter focuses on intra-firm network learning practices in relation to inter-firm network learning.

The chapter begins with a brief introduction to the framework of network learning with intra-firm engineering units that describes key network learning elements and stages. Subsequently, the case analysis is presented to explore different intra-firm network learning drivers, processes, knowledge boundaries and boundary spanning mechanisms that lead to value creation. At the end of the chapter, the relationship between intra-firm and inter-firm network learning is justified and concluded.

6.2. A GES Network Learning Episode with Intra-Firm Engineering Units

An episode framework of GES network learning with intra-firm engineering units is identified through the literature review and verified within the case studies (Figure 6-1). The episode framework is used to explore different GES network learning practices with various engineering units that contribute to value creation. GES network learning with intra-firm engineering units is practised because there is a knowledge gap between intra-firm engineering units that can be addressed by knowledge reuse and creation processes (Moore and Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016). Learning with intra-firm engineering units therefore included two main processes – knowledge reuse and knowledge creation (Kotlarsky et. al., 2014; Zhang et al., 2016). Knowledge reuse is the exploitation of existing knowledge from one engineering unit to the others to address a similar problem or situation (Argote and Ingram, 2000; Markus, 2001; Chai et al., 2003; Majchrzak et al., 2004), while knowledge creation refers to the process of new knowledge exploration across different engineering units (Nonaka, 1994; Hoegl and Schulze, 2005). The learning process may have to cope with the problems of knowledge boundaries between different engineering units. Engineering units may have different interests, interpretations and operations and they are dispersed globally. GES firms therefore have to employ a set of boundary spanning mechanisms (see chapter 4 for details) to facilitate knowledge transfer and learning between engineering units (Moore and Birkinshaw, 1998; Kotlarsky et al., 2014). Effective intra-firm learning results in new values through enhanced performance in terms of efficiency, flexibility, and innovation (Zhang et al., 2016).

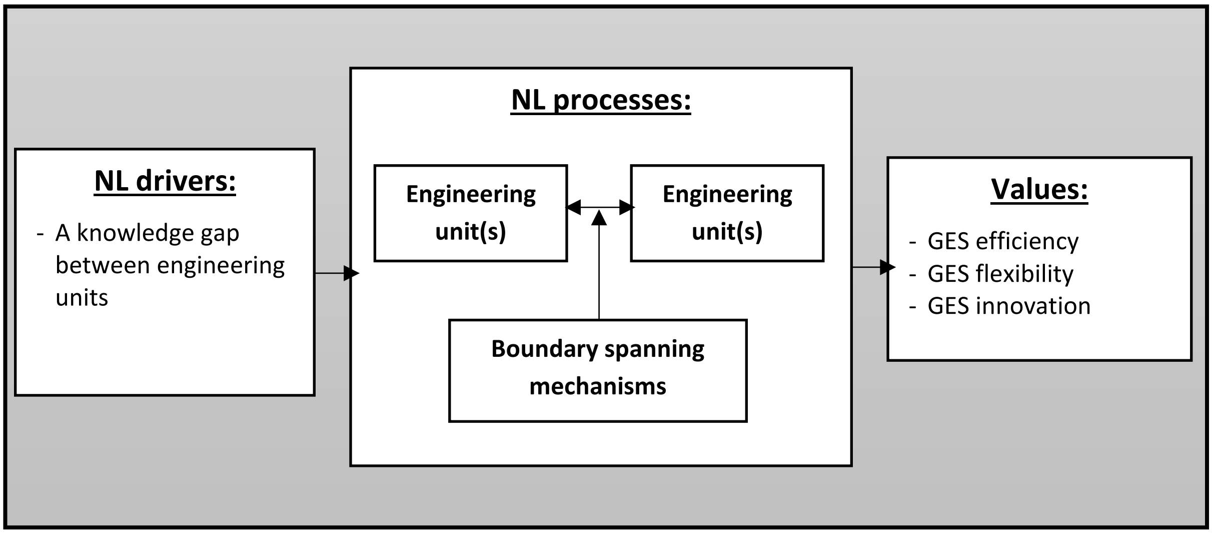


Figure 6-1: Characteristics of a GES network learning episode with intra-firm engineering units

The episode framework guides the case analysis and presentation of this chapter. In the following sections, the results of the three case analyses are presented. Intra-firm network learning in the three cases are compared and contrasted to identify their similarities and differences.

6.3. OSCOM Network Learning with Intra-Firm Project Teams and GES Efficiency

In the previous chapters, it was shown that OSCOM project teams collaborated with customers to create new knowledge for future firm reuse and GES efficiency, and captured customer information for firm innovation. OSCOM sent experts to capture updated supplier technologies informed by customers and transferred it to intra-firm project teams for future solution co-creation with customers. In this section, OSCOM network learning with different dispersed project teams is examined to explore their practices and the links to OSCOM inter-firm network learning.

6.3.1. Network Learning Drivers

Project team knowledge and knowledge creation

OSCOM project teams created knowledge through collaboration with various customers globally, capturing new knowledge for intra-firm knowledge creation and reuse. Thus, "*the important thing in learning inside the organization is to be able to capture [project] learning […] Having your data is one thing, capturing the data quickly as it happens is the second point and then the third point is being able to mine that data to deliver relevant information, to be able to use and improve it*" (OSCOM, interviewee 001). Project team knowledge could help to identify future directions for new knowledge generation inside the firm and with technology suppliers.

Bridging knowledge gaps between project teams

Reuse of knowledge between project teams enhanced engineer capabilities and avoided operational repetition because it was costly if engineers repeated development work already completed in a similar project team. Knowledge reuse across projects optimised operational processes and saved time and effort. Thus, "*if a team wrote many codes and frameworks, so the other teams just need to reuse them in similar projects. But if these [codes & frameworks] are not popularised to other parties, they will re-invent the wheel*" (OSCOM, interviewee 002).

6.3.2. Network Learning Processes

Knowledge creation

There were various frameworks and lessons learned from certain project teams that could be reused by other teams. However, they needed to be processed before they could be reused. For technical and domain knowledge, OSCOM created an internal knowledge management system for engineers to submit lessons learned. These experiences were then reviewed and approved by a central technology committee before they were published for the reuse of project teams. Thus, "*they [the engineers] can submit whatever they learn from their projects. Then there is a committee to review and approve what they submitted to be published in the system for reuse, otherwise it will be removed*" (OSCOM, interviewee 003).

For process improvement, OSCOM adopted an Organizational Performance Management (OPM) process to improve its engineering process performance. The process aimed to identify improvement opportunities within the organisation and to deploy the improvement actions to achieve greater results with the business objectives. The improvement process included three main activities:

- Interactive analysis of the aggregated process performance measurement data.
- Identification of gaps in performance against organisational objectives.
- Selection and deployment of improvements to ensure the organisational objectives are met.

Annually, the OSCOM board of directors set business objectives, including improvement targets. These targets were modelled and specified through measurable data by the quality assurance team. Based on these targets, the quality assurance team searched for improvement opportunities from the firm's operational databases, project case analysis reports (CARs), improvement opportunities provided by the process improvement team, and improvement opportunities from other sources. They searched for opportunities for intra-organisational network learning based on the client co-creation process. Performance gaps and improvement opportunities were identified and evaluated constantly by the board of directors, department heads, and quality assurance team to align the current capacity with the organisational objectives and to ensure these were implemented and achieved.

After improvement opportunities were identified, they might have been tailored to fit with organizational performance objectives. Subsequently, a pilot plan was prepared and implemented by OSCOM departments. The pilot implementation results were collected, hypothesised, validated and approved by the quality assurance management team. The approved improvements were implemented in a broad base and their effects were continuously updated and compared with business objectives. These improvements were then monitored and integrated as part of a sustainability plan. The board of directors monitored and approved all the steps in the OPM process. Thus, "*from the top down, for example, this year we need to develop project process capability in a market. The business objectives set out the targets for quality improvement … To achieve business objectives, 95% of projects need to reach a specific quality level. We will make plans and implement to* *improve specific quality areas, collect related data and evaluate the results*" (OSCOM, interviewee 004).

Knowledge reuse

Project knowledge could be transferred to another project when it started. Knowledge stored within information systems or embedded within centralised functional focused teams was reviewed, selected and reused within this project. New knowledge captured within projects could be shared across projects through experience sharing seminars and workshops across competence departments and projects (OSCOM, interviewees 001, 002, 004). Knowledge reuse between project teams was more related to modularised knowledge transfer; different modules of knowledge could be selectively transferred between different projects which faced the same problems. Thus, "*when OSCOM has a new project similar to the previous projects in which the former project engineers left the company, the new engineers can just pick up existing frameworks documented by the previous ones to build. This helps them to gain about 40-50 percent of the codes within the new project*" (OSCOM, interviewee 005).

Knowledge transfer. Firm knowledge captured in collaboration with customers and suppliers could be disseminated through an education system in which OSCOM organised periodic training courses to transfer standard knowledge and experience to the other project teams. Technology knowledge captured from suppliers could be transferred to project teams through formal seminars, boot camps and coaching. The company needed to educate its employees in different divisions with various skills to co-create solutions effectively with diverse customers who constantly changed their needs and demands for efficient, high quality and innovative IT solutions. Thus, "*we need to keep our engineers up to date with latest technologies in the world. Therefore they can consult onshore teams to sell solutions and to win trust from clients*" (OSCOM, Interviewee 002). For quality assurance, *"[OSCOM] is standardising the input for its projects. Engineers will be educated to be aware of what should be done at the beginning of a project, security issues, and what engineers have the right to access, what should be done when they complete a project*" (OSCOM, Interviewee 004). Standard knowledge transfer was implemented in a more frequent and regular basis (OSCOM, interviewee 002). Thus, "*standard process training* *occurs almost every week because there are one thousand employees come in and out the company"* (OSCOM, Interviewee 004).

6.3.3. Intra-Firm Project Team Knowledge Boundaries

Different interests

There were many differences between OSCOM project teams that impeded knowledge transfer and reuse between them. They differed in terms of their business domains, project types, applied technologies, and project team sizes. They produced IT services such as advisory, bespoke software development, offshore development centres, data processing, and testing. OSCOM project teams applied different technologies; for example .NET, Symphony, Elite, Java and C#, for different customer business problems. Project teams varied in size from a few (3-20) to hundreds of engineers. For example, "*if a customer just requires a small IT system, OSCOM will design a small team for them. If a customer has a big IT system with complex requirements, OSCOM will need a big project team*" (OSCOM, interviewee 007).

A project team generally contained three types of engineers – project manager, developers, and testers (OSCOM, interviewee 007). While developers were the coders, testers ensured the quality of project solutions. OSCOM project engineers came from 14 technology competence divisions and international offices as the talent pools for various projects. Because project teams collaborated with diverse customers in different industries, they created different knowledge in terms of business domains, technologies, and operational processes. Such different knowledge created boundaries between project teams that hindered knowledge sharing and learning between them. For example, "*an engineer attended a seminar about an issue [of a project]. However, this issue he did not have in his on-going projects, or those technologies or skills he did not use or he had not met. In the next projects, he did not have the opportunities to practise that issue. Sometime he attended the seminar just for knowing. Remembering the knowledge or not depends on the memory of each person*" (OSCOM, interviewee 007).

Project dispersion & resistant for learning

In addition to various business, technological and process differences, one barrier that hindered network learning with project teams was the dispersion of project team members within international offices and offshore engineering centres. Their members might not have been interested in sharing knowledge perhaps because "*time for learning is a challenge as engineers are involved in many projects*" (OSCOM, interviewee 003). The dispersion and lack of time for sharing experience intensified the knowledge boundaries and complexity between project teams.

Knowledge complexity

Another challenge was that project knowledge was tacit, embedded within the contexts of project teams. Thus, "*however careful an engineer documents his knowledge, it is impossible to get all of his experiences*" (OSCOM, interviewee 005). In general, there were three types of knowledge captured from project teams for network learning: domain knowledge - the business-related knowledge; technical knowledge; and process knowledge (OSCOM, interviewee 002). The knowledge complexity might cause organisational unlearning when engineers moved out of the company; the higher the turnover rate, the greater the amount of knowledge lost (OSCOM, interviewee 007).

6.3.4. Boundary Spanning Mechanisms

Boundary spanners

Charismatic centres of excellence. There were excellent engineers who were responsible for new knowledge creation for OSCOM. For technology development, the CTO was the person who decided which technological directions the company would develop and what lessons learned were approved to be updated and reused. The CTO was experienced and academically qualified, for example, she possessed a PhD in IT. For other functions, OSCOM had line and functional managers who were competent in a specific area, responsible for creating new knowledge for engineers; for example, quality managers, delivery managers and competency managers.

Central functional teams. Chapters 4 and 5 showed that OSCOM employed onshore/offshore BA and TA to collaborate with customers, who might have joined R&D teams to capture supplier knowledge for solution creation. In intra-firm network learning, they continued to act as the boundary spanners to facilitate knowledge reuse across projects. OSCOM had a BA team who were responsible for disseminating domain knowledge amongst other engineers. Their knowledge could be transferred through training or projects. They supported projects to deal with complex domain problems. Thus, "*the BA team are the people who have mastered domain knowledge in different areas. They hold seminars and training courses to update domain knowledge for engineers according to training schedules defined and planned at the beginning of the year and maybe adjusted monthly*" (OSCOM, interviewee 002).

There were technical teams who conducted technology R&D, supported projects with technical knowledge and were responsible for troubleshooting. They reviewed and updated information for project teams, and captured technical lessons learned. Thus, "*R&D and technical support teams are overhead functions, accounting for around 3% of engineering resources. The people involved in these teams are often excellent engineers in software development processes, who are identified and picked up [from projects] into these teams*" (OSCOM, interviewee 005).

While the R&D team developed new technologies for the company by searching, learning with suppliers and directly engaging with new clients, the troubleshooting team mainly supported similar projects with emerging problems. The company called the technical troubleshooting team the "SWAT" team to refer to its boundary spanner responsibilities. Thus, "*'the SWAT' team are mainly technical architects (TA). They used to be developers. After a period of accumulating experiences, they become TA. They have a good knowledge of different platforms and technologies*" (OSCOM, interviewee 007). Some BA and TA were distributed to onshore international offices to work with customers directly and support offshore teams in fulfilling customer requirements.

For process knowledge reuse, the QA team was the function that disseminated process standards to ensure project quality and captured lessons learned across projects for organisational performance improvement. They rolled in each project to audit project processes, assisted project teams to tailor processes that fitted with customer needs, and collected and logged lessons learned into company databases (OSCOM, interviewee 002). The QA manager was the person who decided improvements in organisational performance management. The QA quality manager noted that "*[QA staff] used to be developers, project managers, testers, or BA. When they work as a QA, they have more knowledge to evaluate*" (OSCOM, interviewee 004). Additionally, OSCOM had a quality control (QC) team, who supported projects with testing. The team disseminated testing knowledge and supported projects in solving emerging problems related to solution testing.

Boundary spanning tools

Centralised information systems. OSCOM employed different central information systems for knowledge creation and reuse across project teams. Jira - a software platform for issue tracking and IT project management - was a heavy system OSCOM used for capturing and sharing project information across customers, and onshore and offshore engineers in projects. A shared wiki library and SharePoint systems contained the company's framework best practice, lessons learnt, and domain knowledge for learning across projects. Source codes were saved and shared within a source code control system (OSCOM, interviewee 002). Besides, the company used a common Curriculum Vitae (CV) system to manage engineers' skills information (OSCOM, interviewee 003). Engineers could contact others through this system for learning purposes.

Industrial standards. In addition to information systems, OSCOM adopted industrial standards as the common norms for learning across projects. Capability Maturity Model Integration (CMMI), an industrial standard for IT process management, was a key boundary spanning tool to ensure project quality and continuous process improvement. Thus, "*CMMI is a standard for quality assurance of IT companies. For example, you must have a plan for projects. However, how to plan depends on each company. Many companies say they adopt CMMI but their templates or procedures are different. [CMMI] only guides you in what should be done, but how to get it done depends on each company*" (OSCOM, interviewee 004). Besides, ISO27001 and TMMI were among the key integrated standards for operational security and testing.

Technologies targets. Technology platforms were also boundary spanning tools for OSCOM learning with project teams. The company had technological targets that guided engineering units to capture and develop knowledge together. Thus, "a*nnually, the company considers current gaps in projects and evaluates which technologies and domain knowledge should be developed […] the company will set specific targets for departments to develop and learn from*" (OSCOM, interviewee 005).

Learning coordination mechanisms

Standardised knowledge documentation. OSCOM set standardised learning coordination processes for knowledge documentation and personalisation. For process knowledge reuse, the company used a CMMI system to build the maturity model for knowledge documentation and organisational performance improvement capability across projects (OSCOM, interviewee 001). Lessons learned within projects were documented into case study reports (CAR), including clients, projects and technology information, and the CARs were saved into the company project information system. CAR was not only a useful tool for organisational performance improvement, but also a tool for expertise coordination across projects. Thus, "*[CARs] are useful if a project deals with a similar technology or industry that other projects used to do. When the project teams search the CAR database, they will know the company used to have similar projects and thereby they will find the people who used to work on those projects to learn from their experiences*" (OSCOM, interviewee 007).

Knowledge modularisation. For domain, technical knowledge reuse, OSCOM adopted a modularisation approach to capture technical knowledge. It developed common frameworks to document and modularise lessons learned in projects. Thus, "[*OSCOM] has developed a set of common frameworks over many years as a good methodology to retain knowledge. For example, when you write a website, there are many components such as user, authentication, and access management. These components do not need to be rebuilt because all projects need them […]. If there is a new project using new components which common frameworks have not had, after the completion of the project, the project team will capture best practices, modularise these components, and submit them to the company system. After being approved [by the technology committee], they will be published*" (OSCOM, interviewee 005).

Formal project-based coordination. In each OSCOM project, functionally-focused centres of excellence were formally coordinated with project teams in project kick-off, implementation and review to disseminate expertise, solve emerging problems and collect lessons learned. During the implementation of projects, project information and knowledge were documented into templates which were formatted by the company (OSCOM, interviewees 005, 007). For example, "*[OSCOM] has a standard bidding process.*

At the beginning of a project, OSCOM always looks back to the past. A project team will work with QA – the party keeping process knowledge and lessons learned. Usually, there is a meeting to discuss how we deliver the project, referring to similar projects to select resources, necessary tools and then conduct the project" (OSCOM, interviewee 005).

Formal training programs. Formal training programs were essential mechanisms to transfer best practices and standards to engineers. OSCOM had various training mechanisms. Fresher training programs were intensive training courses for new recruits to equip them with company standard technical, process and soft skills. Online training was available for engineers who wanted to improve their skills. For experienced engineers, experience sharing seminars and on the job coaching were common mechanisms to transfer knowledge from senior to junior engineers. Senior engineers were invited to organise seminars or training according to their business domain or technology lines. Line managers might have offered on the job training for engineers (OSCOM, interviewees 002, 003, 004, 005, 007).

New technical knowledge accumulated by engineers could be coordinated through ad-hoc or periodic seminars, workshops, meetings and online forums to transfer knowledge for reuse. Thus, "*[OSCOM] has a technical team doing research. When they explore a new technology trend, they will research or learn to obtain a certificate. They will then organize seminars, workshops or boot camps to train other engineers in their new knowledge. Boot camps refer to the events when the company brings some senior engineers out of their projects for one or two weeks to an isolated place just to focus on a technology, maybe self-studying, experimenting some pilot projects to learn*" (OSCOM, interviewee 005).

Knowledge sharing forums. OSCOM issued a periodic e-newsletter as a forum for engineers to share knowledge and disseminate technology trends. Thus, "*[OSCOM] issues a monthly e-newsletter called Tech-insider. There is a professional team editing it […] technical engineers can submit their articles to share their experiences. Additionally, Tech-insider updates technology trends and projects that require new technologies*" (OSCOM, interviewee 005).

Knowledge governance

Standardised knowledge sharing routines. Coordination for learning was only effective when engineers were willing to share their knowledge and to learn. As they were dispersed within projects, they might not have been interested in spending time on knowledge sharing or learning. OSCOM adopted formal and standardised knowledge sharing mechanisms embedded within the company CMMI system to regulate procedures for knowledge sharing. Therefore, "*[CMMI] regulates project management to monitor project status, take actions and manage emerging issues. It is also related to organization and optimization. This means that information on each project is gathered into the company database to define improvements for not only that project, but also the divisions and the company. [CMMI] is a comprehensive system used by all departments"* (OSCOM, interviewee 002). For example, "*one of the CMMI requirements is recording lessons learned [in projects] and knowledge sharing within our organization. All projects always have kick-off and after kick-off processes. After projects complete, there will be "post-bottom" meetings which review whether the projects have succeeded or failed. Why do they succeed? Why do they fail? And during the implementation of the projects, were there any problems? Why and how did the problem arise? How was the problem solved? What were the lessons learned? This is a standard process of CMMI which OSCOM is applying. It is a method to collect knowledge"* (OSCOM, interviewee 007).

Customer intellectual property protection. Although knowledge was formally shared, not all lessons learned were approved for publication in the company system. One of the key conditions for sharing was that customer intellectual properties should be protected. Thus, "*To be approved, lessons learned firstly were not related to customers because customer intellectual properties should not be shared. Secondly, are best practices valuable? And thirdly, are they described understandably?"* (OSCOM, interviewee 003).

Human resource management. OSCOM recruited engineers who tended to have intrinsic motivation for learning. Thus, "*We attract inspired candidates through offering learning and development opportunities in our organization. In addition to learning from customers, there are research and development activities to help engineers to keep their knowledge up-to-date. Additionally, in our working culture and environment, engineers try their best to support each other*" (OSCOM, interviewee 003).

Key Performance Indicators (KPIs). KPIs were widely applied to help engineers to identify their career path development. The company measured the performance of its engineers at four levels, with specific KPIs. Each level had requirements for KPIs in professional knowledge, knowledge sharing and contribution to company communities. For example, "*Annually, managers or principle engineers must study and have three seminars relating to their professional knowledge to share with lower level engineers […] by the end of the year, we will evaluate if they invest time to share knowledge or not*" (OSCOM, interviewee 004).

The KPIs would be informed to all the engineers so that they could make their own implementation plans. Thus, "*Annually, the company has an annual review. Each engineer will be evaluated on their career path development. Line managers not only evaluate but develop their career paths, commenting on the strengths and weaknesses, consulting engineers to develop necessary skills*" (OSCOM, interviewee 005).

Career development. Formal career path development was supported by top management to encourage knowledge sharing and learning. Thus, "*Leadership is important to develop engineer careers. [OSCOM] has an engineering management group who are doing both management and technical jobs to support other engineers in developing their careers. Because any engineers want to be promoted, if they see a clear development path in the company, they will attempt to pass each phase to develop within the organization*" (OSCOM, interviewee 002).

Learning culture. Standardised mechanisms created a quality working culture and organisational identity for OSCOM engineers to commit to learning for excellent quality. Thus, "*Quality procedures here [at OSCOM] are standards of working convention. Coding is like literature writing […] although customers do not examine codes to see what they are, quality should be ensured that the products you produce are able to not only be used at the present, but are also maintained for future use. In coding, there are techniques, requirements, and reviews to ensure nice coding and accurate algorithms. The [OSCOM] quality procedure has all those standards*" (OSCOM, interviewee 004).

Other informal mechanisms. Furthermore, informal mechanisms focused on creating a friendly learning environment for engineers. Direct observation by the researcher showed that OSCOM had an open-space office where people could easily approach each other. There were private spaces for team learning located in the middle of the office. Thus, "*We* *have management office which create friendly policies and a working environment like a family to retain talents and encourage them to share knowledge. Engineers spend most of their time here rather than at their homes so it is important to turn the company into a friendly environment where people feel familiar, like in a family. It is important to retain talents*" (OSCOM, interviewee 002).

Another mechanism was informal events that delivered company symbols and the goal of doing great things. Company events such as IT contests and team building were important to foster a learning culture. A delivery manager noted that "*culture is important. In addition to career development, creating an inspiring culture that makes engineers feel that they are doing something cool will enhance the learning process of engineers*" (OSCOM, interviewee 005).

Technological mechanisms

Data mining technologies. The cloud database and analytics applications assisted OSCOM to collect and analyse project information from the past and present. These technologies allowed OSCOM to predict future trends or to explore knowledge gaps within a set of projects. For example, "*after we have collected data in recent years, we have noticed that defects have been increasing […] or less efforts have been made. We analyse those data to find the causes and make action plans for future operations. That is the data mining applications*" (OSCOM, interviewee 002).

Interestingly, OSCOM adopted an application to predict operational risks in projects. This application allowed analysis of data from projects while they were running to predict risks. After project data such as defects, efforts and scope of work were input into the software, it might predict whether the project would have problems in the future or not, and what should be done. Therefore, "*It [project prediction application] may be applied during the implementation of the project because you need to run the project in a period to have input data. Before the project starts, data is just company standard data. However, when the project is running, it may have some deviations, it is not similar to company standard data. Input data therefore should base on the project information to predict if the project has any problem or not*" (OSCOM, interviewee 002).

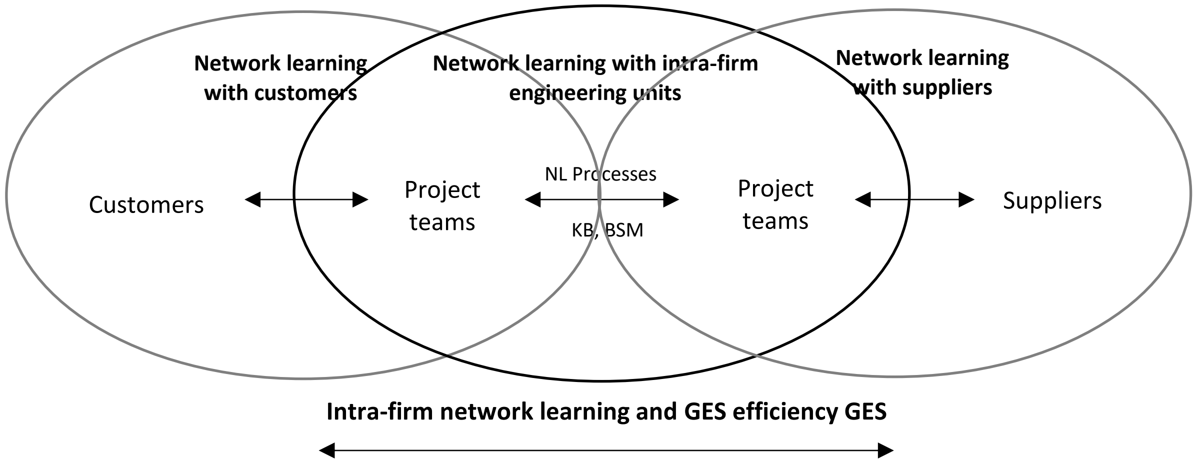
6.3.5. Values

OSCOM network learning with intra-firm project teams helped to capture project team knowledge created in collaboration with suppliers and customers. It assisted in creating new knowledge that was co-created with suppliers and thus enhanced service innovation. Network learning with different project teams facilitated project knowledge transfer to other project teams to reduce the problems of reinventing the wheel and thus enhance efficiency. Ultimately, intra-firm network learning helped OSCOM to innovate its services and enhance project efficiency (OSCOM, interviewees 001, 002, 004). Furthermore, network learning with intra-firm project teams encouraged different teams to share knowledge and commit to learning, enhancing the relationship between the teams and the learning culture within OSCOM.

6.3.6. GES Network Learning With Intra-Firm Engineering Units and GES Efficiency

New knowledge captured with suppliers could be transferred directly from central R&D teams to project teams for their operations with customers. Project teams used knowledge transferred from the central teams to co-create knowledge with customers and transferred their knowledge through network learning to other project teams to enhance efficiency. Because different project teams were highly dispersed and focused on different business domains, technologies and processes, they may not have been interested in learning with the other teams. Knowledge reuse therefore should be based on project-based standardised processes and formal knowledge sharing and training mechanisms. Different central functional teams, centralised supporting information systems, data mining technologies and formal governance mechanisms were critical to bridge the knowledge gaps between different dispersed project teams. Figure 6-2 highlights the key feature of intra-firm network learning for efficiency GES and its relations to inter-firm network learning.

Past research highlights different network learning practices adopted by different intra-firm engineering units to enhance GES efficiency (Moore and Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016). However, most of the studies do not point out their connections with inter-firm network learning with customers and suppliers. This study clarifies that customers provide information for firms to create new knowledge with suppliers. This knowledge is in turn transferred to project teams to co-create knowledge with customers, which is reused by other project teams through network learning and thus enhances efficiency. These findings highlight an all-encompassing inter- and intra-firm network learning process that creates GES efficiency. The case study also highlights the roles of centralised functional teams and formal governance mechanisms in supporting knowledge creation and reuse, as project teams have different interests that hinder network learning. The following section examines the APPCOM case to explore GES network learning with intra-firm engineering sites and GES flexibility.



Network learning drivers:
- Skill shortages, project team emerging knowledge

Network learning processes:
- Knowledge creation (driven by customers), knowledge reuse (exploiting project knowledge with customers and supplier knowledge)

Values:
- Service innovation
- GES efficiency
- Intra-firm relationships and learning culture

Knowledge boundaries (KB):
- Interest, interpretation and experiment differences between project teams

Boundary spanning mechanisms (BSM):
- Central management teams/centralised functional teams for knowledge creation and knowledge reuse
- Common boundary spanning tools and supporting technologies
- Formal coordination and governance

Figure 6-2: Contributions of intra-firm network learning to GES efficiency

6.4. APPCOM Learning with Intra-Firm Engineering Sites and GES Flexibility

The previous chapters indicated that APPCOM engineering sites created knowledge through collaboration with customers and suppliers, which could be used for the engineering performance enhancement of the entire group. APPCOM engineering sites also captured information on customer problems as well as complementary supplier knowledge for future technology development. This section examines APPCOM network learning with intra-firm engineering sites to explore how it relates to inter-firm network learning to create GES flexibility.

6.4.1. Network Learning Drivers

High-performance package delivery and a single global system

Customers were increasingly demanding that APPCOM provide high-performance solutions in packages. In the words of the CEO, "*customers are increasingly looking to us to put together bigger packages of work – sub-systems that solve their problem. These solutions are increasingly less dependent on component A or component B but packages of components and sub-systems sourced from across our group, not just one facility or business unit or division*" (APPCOM, Annual Review 2015). Package solutions required APPCOM engineering sites with different capabilities to collaborate with each other and to align with customer operational standards. The CEO noted that "*[customers] want a capability-based engineering group at [APPCOM] to talk to their capability-based engineering group*" (APPCOM, Annual Review 2015).

To deliver high-performance package solutions for customers, APPCOM needed a single group production system for all engineering sites to deliver what customers wanted on time. A common global system enabled cross-divisional workforce mobility, problem solving, and responsiveness to a range of different international customers with different management styles, approaches and requirements. The CEO explained why a single system helped APPCOM to improve its performance: "*optimising single global systems is preferable to the expense of optimising many. We must move away from reinventing the wheel locally*" (APPCOM, Annual Review, 2015).

Bridging the knowledge gaps between engineering sites

To develop a single global system, it is necessary to ensure all engineering sites are involved. At the time of this study, two thirds of the 50 APPCOM engineering sites were using the system, with one third at stage two of the six stages (the yellow stage). In fact, engineering sites were at different maturity levels of progressing towards the group's highest standards. As bottom-up learning was more appropriate than top-down learning for APPCOM, network learning with engineering sites was important to bridge the knowledge gaps between engineering sites and enhance the performance of the entire group. Thus, "*the factories are steaming ahead but to progress through the next three phases of bronze, silver, and gold, the entire group must be engaged*", as highlighted by the CEO (APPCOM, Annual Review, 2015).

Technology leadership and knowledge creation across all sites

APPCOM's competition strategy was to become a technology leader in the aerospace industry. New technology development was essential for it to be relevant to its customers and even to become their first choice. The CEO noted that "*Aircraft in the next major bid cycle will be developed for a world that is hungrier for resources and more regulated in environmental terms. We are locked into a cycle of ever-decreasing operating costs requiring hyper-efficient engines and low-weight components and airframes that must be designed using a new generation of different technologies and different materials. We need to make sure that we continue to remain relevant to our customers' efforts by building on our core capabilities*" (APPCOM, Annual Review 2015).

To become a technology leader, APPCOM needed to innovate its technologies proactively. Thus, "*we used to work by just talking to our customers and waiting for them to tell us what they wanted. But that is changing. What is happening now is that we have to take a lead to work out what technologies to develop that we think they will want [...]. So what you have to do is to come up with things that they really cannot refuse*" (APPCOM, interviewee 001).

Network learning across all APPCOM sites optimised its knowledge creation by synergising all the expertise dispersed across the group. Therefore, the CTO noted that "*it is no good working alone. We need to harness ideas from across the group, and focus our efforts on the most promising and collaborate across disciplines*" (APPCOM, Annual Review, 2015).

6.4.2. Network Learning Processes

Knowledge creation

APPCOM engineering sites developed a common group production system through both top-down and bottom-up knowledge reuse processes. The APPCOM central team created a common group production system and transferred it to all engineering sites, including a common working approach, standardised processes, continuous improvement practices, lean tools and methods. These were brought from other manufacturing industries to fit with APPCOM operations and were characterised as low volume, high variety, and complex. The company's production system enabled flexibility, scalability and target abilities, which helped all the engineering sites to operate and collaborate with each other, thus improving their performance to a common excellent standard. The APPCOM production system was transferred to engineering sites through training for site leaders on general ideas of common working approaches.

For new technology development, the previous chapters have revealed that the APPCOM central team captured customer technology roadmaps and technologies from partners to guide the company's intra-firm technology development. New technologies were developed internally through both centralised and decentralised processes. The centralised process was conducted by the R&D central team with members selected from APPCOM business units. The R&D central team was responsible for identifying APPCOM technology platforms aligned with customer technology roadmaps to guide the technology development of APPCOM engineering sites. Based on these platforms, ideas for technology development were then proposed by the engineering sites and evaluated by the R&D central team. Selected ideas received group investments to conduct technology development projects.

The decentralised process was associated with knowledge creation within integrated product development teams involved in new product development projects selected by the R&D central team. Thus, "*[Individual businesses] can put in bids to get money and they do that every year. I have a budget which I allocate parts of to the individual businesses for them to undertake research projects. So they do some research themselves, some of which is funded by my group as I have a board which has representatives on each of the businesses. And then we look at all the projects that have requested money and we choose which ones we think are important and fund those. Some research is down here, some research in Switzerland, some in the US*" (APPCOM, interviewee 001).

New technologies had to be at level 6, the point at which they were ready to be offered to a customer. In the words of the CTO, "*If you look at TRL levels, to get something to TRL 6, you have to prepare a lot of things. We go for TRL 6 and TRL 5, which is manufacturing readiness level 5. And I mean before we can hand something out of this group, we have got* *to design, to test plan, to document and to build instructions; we need to work out a supply chain, who can make it, how it can be made.*" (APPCOM, interviewee 001).

Knowledge reuse for innovation

In joint technology development projects, engineers might have reused the knowledge of the other development projects stored within the company information system. However, the knowledge was mainly used as the data for project knowledge creation. Thus, "*[the database system] will hold all of the records of the builds of the product and how they came together. Obviously we have all the information, it is all on the website for that product and you could look around and everything is captured there. You have all of the novel design tools and methodologies that you expect around it. So do you have anything else in terms of sharing the knowledge around? In the end, it will come to a list of all the things you have to have and they will be documented. In a broad sense, the documents could be Word document, Excel, Power-points, videos, math-lab, or they could be models or simulation models; they are all data*" (APPCOM, interviewee 001).

Knowledge reuse for efficiency

At engineering sites, knowledge reuse started with the processes of knowledge co-development between the central teams and each site. Engineering sites adapted the APPCOM production system into their specific engineering operations. For example, "*We are in the process of rolling out a global quality management system for the whole group, for all [APPCOM] sites. That is a long journey starting this year but it will roll out site by site over the three year period, a big step to introduce standardised quality requirements for over 50 sites in implementing one goal and implementing it on a site by site basis. At the moment, I think there are about 12 sites in the move, in the implementation of which only three have gone online so far. This is still developing knowledge, a three-year program*" (APPCOM, interviewee 003).

Bottom-up knowledge reuse was related to best practice transfer across engineering sites. Chapters 4 and 5 showed that APPCOM engineering sites co-created new knowledge with customers and sub-tier suppliers in engineering programs and clusters. Knowledge co-created with customers and suppliers was then interpreted and transferred to other sites when applicable. The APPCOM production system allowed the company to transfer best practices across different engineering sites. Thus, "*through [APPCOM] production system, we identify things like best practices in a site…, probably the most advanced in manufacturing sites. So people go and share, that site runs this, their accountability approach. We have sites that are doing major project loads, we have help from other sites that come and put things in place. There will be cross learning there*" (APPCOM, interviewee 002).

Knowledge captured for reuse could be anything relating to engineering and manufacturing practices. "*It could be anything from the contract review process […]. It could be in-process manufacturing, it could be inventory management, and it could be stock inspection, anything within that site organization that is applicable to the wider [APPCOM]. We look at those processes to see what works well and what does not work well then we look at incorporating to learn. One [APPCOM] standard flows out across the whole group where considered necessary*" (APPCOM, interviewee 003).

However, bottom-up knowledge reuse was collective rather than being knowledge transfer because APPCOM engineering sites were different in engineering capabilities. Thus, "*you cannot just necessarily pick that process [best practices] up and drop it into all the other [APPCOM] sites […]. Some of the aerospace [sites] have international standards from articles. But it would not apply necessarily to [APPCOM] co-companies like automotive companies. You have to give them standard processes that will meet or best meet most of the [APPCOM] sites […]. It may work the most or it might not work [...]. It might need to be developed slightly differently*" (APPCOM, Interviewee 003).

6.4.3. Intra-Firm Engineering Site Knowledge Boundaries

Interest differences

APPCOM had five key engineering divisions with over 50 sites dispersed across the globe (Appendix 3.2). These might have been different in technological capabilities and engineering operations such as advanced research, development and design, and manufacturing. Additionally, they were dispersed around the world. While the engineering sites focusing on advanced research, technologies and new product development were concentrated within a few sites (around 15 sites) in the UK, the US and Europe, manufacturing engineering and manufacturing sites were distributed in South America and

Asia to reduce production costs. Thus, "*We have split [engineering sites] into a number of different groups […]. Not all have engineering, not all have research and technologies. So there are different phases to making a product […]. Some sites have research and technologies and development of new products, which we call research and development […]. Some sites are manufacturing sites which may not be the same as the engineering sites that develop the products […]. We also have sites which look after the after-market […]. So we have research, we've got development of existing products, manufacturing, and we've got after-market; a lot of locations all over the world*" (APPCOM, interviewee 001).

In addition to business and engineering differences, many engineering sites were originally external companies acquired by APPCOM. Thus, "*[APPCOM] is made up of over 50 sites, some of which come from originally different organizations […] sometimes for many years they [acquired engineering sites] were just stand-alone sites and now [APPCOM] has brought them into the APPCOM organization. It is initially difficult for them to see with bigger world out there, now that [APPCOM] are now involved […]. They are sometime resistant when you are rolling out new initiatives but possibly can decide against rules*" (APPCOM, interviewee 003).

Geographical and culture differences. Geographical and culture differences might intensify the challenges of network learning. Thus, "*it [a new product development team meeting] might be time consuming, cost inefficient, and not be convenient many times. For example, there are people from the USA, from Asia, from Europe. It is difficult to coordinate all the different stakeholders. It might take a lot of time from being please. Sometime you might sit in a brainstorming session that actually does not end up anywhere, you just discuss and you do not conclude anywhere*" (APPCOM, interviewee 004).

Site engineering capability maturity differences. At the time of this study, the APPCOM production system had been developed for five years, but the processes of development across engineering sites was still on-going. These sites were different in terms of technological capabilities, operations and site maturity levels. Such differences required adaptation time and the involvement of the entire group.

Knowledge complexity. In addition to knowledge boundaries across different sites, engineering knowledge was complex and embedded within the engineers and organisational memory. Thus, "*If I have to say it is a loss when people are no longer on a* *project, a lot of learning is in people's head and has not been captured for the future […]. Knowledge is: you've got to turn data into knowledge. But you've got to also make it accessible and have it in 20 hundreds page documents; is that the best way to capture that knowledge and share it? I do not think so. We share that knowledge, we have dissemination sessions, we have forums where people come together and share that knowledge, explain what they have done in the projects, make people aware of it. But in the end, the detailed works are in documents and that is not the easy thing to search for and find*" (APPCOM, interviewee 001).

High volume of organisational information. Further to knowledge complexity, APPCOM faced a high volume of knowledge exchanged across the group. This made knowledge capture more difficult for for the company. "*In a very large organization that needs to be probably managed on a global basis, some of the things that are drawn on the board each day are in a form that it is informatics. Information comes across to it. What can happen is too much of it. And you can run off away with the wrong things*" (APPCOM, interviewee 002).

6.4.4. Boundary Spanning Mechanisms

Boundary spanners

Charismatic centres of excellence. For new technology development, the company recruited a Chief Technology Officer (CTO) who was well-known in both academia and the aerospace industry, with a deep understanding of customer businesses and industrial technologies. The CTO led a board of business directors who were excellent in their narrow areas in directing future technology development for the company. For operational innovation, Chief Operating Officer (COO) were the experts with wide experience in managing global engineering network operations. The COO directed the functionally-focused centres of excellence to develop a new group production system. Thus, "*At the highest level, our most senior engineers are world experts in their fields of fluid flows, heat exchange, and fuel management. And they will have had a wide range of experience, typically 25-30 years, are postgraduates and very clever people. They almost definitely have done a doctoral in something in their fields and they will have strong links to research establishments either universities. That would be the front end. And they will be looking at where our businesses need to go*" (APPCOM, interviewee 002).

Central functional teams. The previous chapters indicated that APPCOM employed central functional teams to collaborate with customers to translate their requirements for engineering site operations. For supplier-focused network learning, the company used decentralised local teams and engineering taskforces to co-create knowledge with sub-tier suppliers and technology partners. In intra-firm network learning, the central functional teams were the boundary spanners to translate and transfer the engineering site knowledge co-created with customers and suppliers to other engineering sites, because the engineering sites had different interests and they may not have been committed to learning. The central teams were a group of experienced engineers in a specific field, such as R&D, quality, risk management or the supply chain. They collaborated with functional peer managers and engineering taskforces at business levels to develop and transfer knowledge across engineering sites for group performance enhancement and technology development. A group quality manager described his routine responsibilities: "*I conduct at all sites for [APPCOM] for benchmarking purpose to make sure that there is no issue from any [APPCOM] sites that could impact on different customers, but also to see any best practices at [APPCOM] sites that we can share across other sites*" (APPCOM, interviewee 003).

Decentralised taskforces and engineering clusters. Engineering taskforces and engineering site functions were the experts in their areas and they captured new knowledge in their operations with customers and suppliers. They might have been the boundary spanners to transfer their knowledge to other sites. For example, engineering sites could set up a team to coach the other sites in similar operations. Engineering taskforces had common conversations in corporate engineering forums to bridge their knowledge gaps and evolve new ideas for future technological innovation (APPCOM, Annual Review, 2015). The aim was to facilitate mutual understanding and knowledge creation between different sites.

Virtual centres of excellence. Virtual centres of excellence assisted engineering taskforces in various projects to develop new products and solve problems. They were experts in a specific technology, dispersed across many sites and connected through a database system. Thus, "*we share a database within [APPCOM] of what engineers are experts at in specific areas. For example, we share the material engineers and there are like 30, 40 material engineers in [APPCOM]. They are experts in this area so whoever might need material* *advice, they will contact one of them as they are the experts. We will share the experts in other areas as well, in polymers, in composites, in sensors, experts in heat exchangers and the mechanics behind it, and control. So that kind of database is available and you can always consult a specific engineer"* (APPCOM, interviewee 004).

Boundary spanning tools

Centralised information systems. APPCOM deployed a set of information systems across the group to support knowledge gathering, interpreting and disseminating across engineering sites, which were parts of the APPCOM group-wide production system. In fact, APPCOM adopted a common (software, applications, products) SAP system for resource scheduling, group quality management, and product design. The CEO gave one example of the benefits of using centralised cross-boundary systems: "*With one world-class system, we can alert the whole group almost at the press of a button to a supplier issue. With it, we can make one investment, rather than many, in updates and upgrades*" (APPCOM, Annual Review 2015).

Common standards. Furthermore, the company created group standards and disseminated them across business units and sites to guide their engineering performance improvement. In fact, APPCOM measured engineering site performance at six levels (red, yellow, green, bronze, silver, and gold). The company wanted all sites to improve their performance to the highest standard level – gold. However, this was challenging because APPCOM engineering sites were at different levels of engineering maturity and thus standard improvement required the involvement of the entire group. The CEO asserted that "*The factories are steaming ahead but to progress through the next three phases of bronze, silver and gold, the entire group must be engaged*" (APPCOM, Annual Review 2015).

Technology platforms. APPCOM used technology roadmaps approved by the central R&D team to guide the technology development at engineering sites. The roadmaps included key platforms and core capabilities that directed discussions and generated ideas across the engineering divisions and sites. Despite being structured, the APPCOM technology roadmaps and platforms still had room for engineers at engineering sites to start up new conversations as necessary (APPCOM, Annual Review 2015).

Learning coordination

Formal program coordination. For the performance improvement of all sites, members of the central teams regularly visited APPCOM sites to help the engineering sites to adapt their operations to the group production system. At the same time, they collected lessons learned for the improvement across sites (APPCOM, interviewee 003). If best practices were complex to transfer, site experts might have been sent to coach and transfer their knowledge to other sites. In the words of a site general manager, "*We sent a planning team over there [group training courses] and shared our findings with other sites as we went on. My team really relish those opportunities across the group which come from having such a tight and well-resourced operations excellence network*" (APPCOM, Annual Review 2015).

Centralised knowledge documentation. Knowledge could be captured by documentation. APPCOM standardised knowledge documentation of engineering sites through common reporting templates. A functional manager noted that APPCOM centralised data reporting: "*We are going to report the data we collect, not collect the data we report*" (APPCOM, Annual Review 2015).

Formal R&D project selection. New technologies were created through a set of formal, hybrid and informal mechanisms. Formal mechanisms included the formulation of a central team including representatives from each business unit. This central team generated APPCOM technology roadmaps and platforms that directed APPCOM engineering sites to propose R&D projects that were selected for funding periodically by the central team.

Periodic informal forums/clusters. Informal mechanisms were adopted to encourage idea generation across engineering sites. For example, APPCOM initiated a program of monthly online seminars where experts (around 1000 engineers) from across the group were invited to discuss key topics. Furthermore, the company set up a digital forum with semi-structured technology roadmaps and platforms to seed discussions, but still gave room for new conversations at engineering sites. Engineers could join in the forum to catch up with regular updates on the latest industry trends and news. They could share their experience and interests with each other. APPCOM engineering sites could establish a team to share their best practices with the other sites in clusters, who shared the same common problems and operations.

Engineering taskforces. Hybrid mechanisms included integrated project teams in which senior engineers and talented graduates collaborated to create new technologies. Graduate engineers were rotated across sites to facilitate innovation. Thus, "*What we like to do in our innovation team is people may come into innovation teams and work on a project for 3-4 years. But I do not want to stay in an innovation team forever. I really want to come in, work on a project and take that project or projects out to the businesses. I think if you work all the time in innovation you become stale and it is quite important that you rotate through. And I do not want the innovation group to ever be in an Ivy League tower where you are with special people, in a special room*" (APPCOM, interviewee 001).

Knowledge governance

Routinized knowledge sharing. To ensure high performance across the group, APPCOM routinized knowledge sharing practices across all sites. Its production system included a common approach that was a structure of interlocking early morning meetings at all sites. Knowledge sharing was conducted on a daily, bottom-up basis, from the shop floor to top management, to ensure engineering operations safety, quality and on time delivery, minimise the inventory and maintain the high productivity of the entire group. Knowledge sharing was supported by lean tools and information systems with standardised reporting templates. The APPCOM production system created a standardised culture of knowledge sharing not only for daily operations, but also for innovation. It enabled APPCOM to move people around the group easily for global service provision (APPCOM, company documents).

Human resource management (HRM). For technology innovation, HRM mechanisms facilitated knowledge sharing and learning for innovation. On the one hand, APPCOM retained world leading experts within their business units. On the other hand, the company attracted and recruited new talent. APPCOM had a graduate programme that identified engineering talents and put their ideas to work. The talents that APPCOM focused on were people around the world who were not just academically talented, but had managerial excellence. As the CTO asserted, "*we assume that [graduate engineers] are all bright engineers because they have got good degrees from good universities but the real thing that is going to set them apart as future leaders is how they conduct themselves and how they can operate in the business*" (APPCOM, Annual Review 2015).

Performance measurement was crucial to encourage engineers to share knowledge and commit to learning. A project manager noted that “*We share the performance measurement every quarter, every three months. There is the one for a manager, which would be a yearly performance measurement*” (APPCOM, interviewee 004). The company also provided different types of training for engineers. Formal training was conducted through both online and offline training courses to improve engineering absorptive capacity for knowledge sharing and learning. Offline training was important for new recruits to grasp basic knowledge about the group production system and standard skills (APPCOM, interviewee 005). Online training was delivered by a group e-library, where engineers could learn 24/7 what they needed. The e-library included over 100 business courses and 250 IT courses for all employees. Training courses were provided in different languages and allowed engineers to learn anywhere and at any time. Furthermore, ad-hoc coaching was necessary to transfer best practices to different sites “*to get them [different sites] to better understand what the group is rolling out, what you are trying to develop and improve*” (APPCOM, interviewee 003).

R&D investment. Investments and budget for R&D encouraged business units to collaborate and share knowledge for innovation. A project manager asserted that “*APPCOM pays great attention to investment for R&D. A major part of revenue is returned to R&D investments to develop future technologies*” (APPCOM, interviewee 005).

Management support. Management support and involvement culture was essential to encourage knowledge sharing; a shop floor engineer noted, “*if the top people got involved like that [group production system training] in workshops on the ground level, it gives your people a chance to really see what you are made of. They will respect you for it*” (APPCOM, Annual Review 2015).

Technological mechanisms

Data mining technologies. APPCOM adopted a centralised approach to capture operations data across sites for timely decision making at the group level. The company developed common SAP applications to manage integrated management reporting across all sites. The applications enabled APPCOM to collect operational performance data automatically on delivery, quality and health and safety across sites. The data collected were analysed to provide real-time operations information for decision-making (APPCOM, Annual Review, 2015).

Intelligent manufacturing technologies. More importantly, APPCOM was developing manufacturing technology adopting wireless technology, such as radio frequency identification (RFID) or near field contact (NFC) tags. These technologies allowed machines to capture the real-time operational actions of operators and thus guided engineering actions, captured information for management and made improvements automatically. At the time of this study, this machine learning application for manufacturing support had been piloted at the factories in the UK before its application on a broader scale. This manufacturing technology with machine learning applications would improve production output, quality, flexibility and traceability in component assembly (APPCOM, Annual Review, 2015).

Simulation software for technology development. For the development of new technologies, specific simulation technologies were used to support knowledge creation. The interviewees highlighted MATLAB - a computing language for technical applications, as current software used to support engineers in their operations.

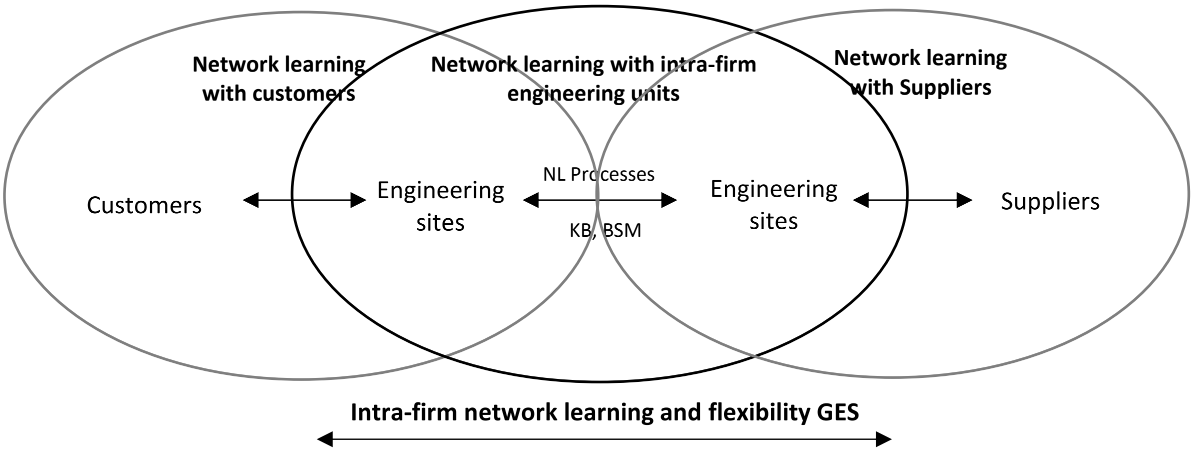
6.4.5. Values

Operational efficiency. Intra-firm network learning with different engineering sites enabled APPCOM to enhance group operation performance. Developing a high-performance common production system enabled all APPCOM sites to deliver on-time, achieve better quality, and earn new levels of trust from customers. The global production system therefore enhanced efficiency for the entire group (APPCOM, Annual Review, 2015).

Technology innovation. Committing to technology leadership enabled APPCOM to develop tomorrow’s technology today and become the first choice in customer systems. Network learning between engineering sites helped APPCOM to harness ideas from across the group, identifying and developing products and technologies that were ready to be offered to a customer.

6.4.6. GES Network Learning with Intra-Firm Engineering Units and GES Flexibility

Intra-firm network learning was driven by the needs to enhance the performance of the entire group in engineering and technology development. This led to knowledge reuse and creation across different engineering sites to bridge their knowledge gaps and thus enhance their performance. Knowledge creation involved both top-down and bottom-up learning. Central excellence teams created new knowledge driven by customers that led to the creation of engineering sites for new technologies and improved operations. For technology innovation, knowledge creation continued to be implemented between different engineering sites, collaborating within technology taskforces and supported by virtual teams. For engineering improvement, engineering co-created knowledge with customers and suppliers and then reused the knowledge created through knowledge reuse. Knowledge reuse was facilitated by central functional teams in order to eliminate the knowledge boundaries between engineering sites. Figure 6-3 highlights the key features of network learning and GES flexibility GES drawn from the case study.



Network learning drivers:
- Operational excellence and technology leadership across the group

Network learning processes:
- Knowledge creation (driven by customers)
- Knowledge reuse for innovation (intra-firm knowledge reuse)
- Knowledge reuse (exploiting engineering site knowledge)

Values:
- Technology innovation
- Improved engineering performance
- Intra-firm relationships and learning culture

Knowledge boundaries (KB):
- Interest, interpretation and operation differences between engineering sites

Boundary spanning mechanisms (KBM):
- Centralised CoE for knowledge creation and knowledge reuse
- Decentralised taskforces and virtual teams for knowledge creation
- Uniform/customised boundary spanning tools and supporting technologies
- Formal/informal coordination and governance

Figure 6-3: Contributions of intra-firm network learning to GES flexibility

Previous research has identified GES network learning practices with intra-firm engineering sites to be independent from those with customers and suppliers (Hoegl and Schulze, 2005; Soderquist, 2006; Zhang et al., 2016). This study clarifies that customer information drives knowledge creation with intra-firm engineering units and suppliers to develop new technologies. Operationally, customers and suppliers can co-create knowledge with engineering sites, which is reused by the other sites through intra-firm network learning and thus enhances firm efficiency. This indicates an all-encompassing inter- and intra-firm network learning process and GES flexibility. To facilitate intra-firm network learning, centralised/formal and decentralised/informal boundary spanning mechanisms are critical to facilitating knowledge creation at both corporate and site levels. For knowledge reuse, centralised/formal boundary spanning mechanisms are superior for bridging the knowledge gaps between different engineering sites and different business interests. In the following section, the RECOM case is examined to explore GES network learning with intra-firm research scientists and GES innovation.

6.5. RECOM Learning with Intra-Firm Research Scientists and GES Innovation

The previous chapters revealed that RECOM research scientists collaborated with customers to capture their problems and were engaged with suppliers to acquire the relevant data and models for new solution development. This section examines how these scientists worked individually and collaborated with each other to create novel solutions verified by supplier data and models that addressed customer problems.

6.5.1. Network Learning Drivers

Knowledge gaps between research scientists

RECOM had different research scientists who were experts in different scientific areas. In the words of one scientist, "*there are others here in this office, 40-50 different scientists. We all come from different backgrounds. They are like chemists, they are biologists, and they are mathematicians who love statistics. Because we have these different groups and all the project teams, gathered by different individuals, you can learn a lot from each other […]. That is what happens quite often here in different projects. You have this variety of people and you can learn from each other*" (RECOM, interviewee 017).

Because the research scientists had different backgrounds, they were motivated to collaborate with each other to facilitate mutual understanding between them so that they could enhance their engineering operations performance as they collaborated closely in projects. One research scientist highlighted, "*It is important for people to know what others* *do and to learn from them*" (RECOM, interviewee 016). Thus, "*It is good to interact with the people you know, not just in our group but also within the whole [RECOM]. Because people come from different backgrounds, there is a lot to learn from people with different expertise. We have seminars and things going on, so you can go to those with people who know things if you know very little*" (RECOM, interviewee 010).

6.5.2. Network Learning Processes

Knowledge creation

The previous chapter revealed that senior RECOM pharmacology scientists collaborated with customers within consortium meetings, consultancy projects and training workshops to understand customer research interests and R&D problems. In chapter 5, all RECOM scientists were shown to search for scientific data and models published by research institutes and to fund doctoral research to develop and verify RECOM models. Research scientists, based on their customer needs, supplier data and models, developed their models for novel bio-simulation solutions in R&D projects approved by project supervisors. Every year, the company had R&D projects driven by their consortium customers to develop the next version of the bio-simulation software. For example, by the time of this study, the consortium had voted to co-develop six projects that RECOM had recommended at the latest consortium meeting. Thus, "*Internal projects include the wish list items decided every year during the consortium meetings; for example transporters and enzyme correlation projects run by five or six scientists. The same person may run multi projects*" (RECOM, interviewee 019).

In these projects, the RECOM research scientists worked in teams and independently. Each scientist collected data and models in the literature to develop his or her own models which contributed to the project team plan. Thus, "*we do research; from models we derive other models, defining them in documents and getting them passed to IT group to program […]. On the other side, we collect data from the literature regarding some aspects of physiology […], we do a metric analysis of the literature and then we come up with the mean of a range for this value from different people. Then they get saved in the software databases*" (RECOM, interviewee 006).

Research scientists might have needed to collaborate with each other in projects and/or between expert groups. However, learning from other scientists was mainly to understand what they did, so that they could collaborate effectively. Additionally, RECOM research scientist conducted bespoke consultancy projects with ad-hoc orders from customers. In consultancy projects, customers merely played the role of information providers for the knowledge creation of the scientists. Knowledge creation processes included both individual research, informal communication and team meetings to address customer problems. Thus, "*In terms of learning, we have our project group. We have learning, in that we organize tele-conferences or meetings where we talk about science. I did this and this and this, work like that and somebody may use this technique in their works, in their projects. So this happens, but this is more, an initial initiative on how to accumulate the knowledge within the team and how to share it with other people*" (RECOM, interviewee 016).

Knowledge reuse for innovation

The models and data created by scientists were stored within company software and a shared information management system. All this knowledge could be reused among RECOM research scientists to generate new models, but they also served as data for the generation of new models. A principal scientist noted that "*we do have a data management system where all the final values are stored and it shows the records of the values and where they came from. There will be hyperlinks to the Excel sheets, the final analysis, so everyone can see where the value came from, which may be a relation database*" (RECOM, interviewee 006).

6.5.3. Intra-Firm Research Scientist Knowledge Boundaries

Different backgrounds

The RECOM research scientists had different backgrounds and responsibilities. These differences created knowledge boundaries between them that required knowledge sharing for mutual understanding. One research scientist noted, "*I have experience in some areas of food companies and I know very few people in this company have knowledge in that area. I do journal clubs [paper seminars] and then I explain to all of them what the paper has done. This kind of thing we always do*" (RECOM, interviewee 015).

Knowledge evolution

In addition to their scientific background differences that required frequent interactions for mutual understanding, the research scientists had to deal with the complex continuous evolution of science, in that they had to update their knowledge constantly to develop new technologies. Thus, "*The complexity of biology is the main problem. It is so complex. Human bodies just are amazing and we still do not know much about them. The more if you ask a specific question, the more you come to a world in which people do not notice there is an ongoing research. Every day I read some papers from this year, or from last ten years, but it is still not clear how biology really works. It is a revolution-driven process. It is not a deterministic system. Humans will find a way to avoid the drug action and it is difficult*" (RECOM, interviewee 016).

6.5.4. Boundary Spanning Mechanisms

Boundary spanners

Project supervisors. The interviewees highlighted the roles of project supervisors as the supporters of the operations of research scientists. Each project teams had two supervisors who were responsible for approving the research plans of the research scientists and helping them to solve any problems arising.

Research scientists. From the field observation and as stressed by interviewees, all the research scientists were involved in learning with each other to understand what the others did so that they could collaborate effectively in solution projects. They were all experts in their areas and responsible for developing an aspect of RECOM software. They conducted their own research and disseminated their knowledge to the other scientists and IT engineers. Their knowledge was captured by the others for project collaboration and knowledge creation.

Boundary spanning tools

Bio-simulation software. The bio-simulation software RECOM developed was the key boundary spanning tool across scientists. All the scientists collaborated to develop the company software, which included scientific models and compounds, and population databases shared among scientists. These models and databases were the platforms from which scientists learned, and enhanced and expanded their knowledge based on the development of science and the requirements of customers over time. Thus, "*we all use [the company software] and it was not made by me. It was made by the others, so I definitely use it*" (RECOM, interviewee 015).

Customer wish list. Another boundary spanning tool was the customer wish list agreed in the annual consortium meetings. This list included the topics and issues that RECOM research scientists needed to focus on for future technology development. They were the technology platforms for them to collaborate and create knowledge.

Common internal database. RECOM had a common SharePoint system for the research scientists to store and share information with each other. In the words of one scientist, "*We have SharePoint, the company SharePoint where people put in data they have collected on the modelling they have done and we all have access to those data*" (RECOM, interviewee 015).

Learning coordination

Research project team coordination. The research scientists were coordinated in research project teams with different scientists (RECOM, interviewee 017). They were coordinated to make plan and do their own research that contributed to projects (RECOM, interviewee 016). One research scientist noted, "*we have a project team, so the project team has two supervisors, so basically via the project teamwork we develop the models. We present the plan to the supervisors, they approve it, there are questions, if there are any problems you have the supervisors*" (RECOM, interviewee 006). In consultancy projects, the frequency and types of coordination were informal, either face to face or by teleconferencing, depending on the agreements of the project team members and clients (RECOM, interviewee 016).

Research documentation for reuse. Individual and project learning were documented and stored within the company software and SharePoint. There was no structured template to document data and models. Data could be stored in Microsoft Word and Excel files in different formats.

Journal paper publication. The results of the company R&D projects were published and used by research scientists. Thus, "*we publish a lot scientifically. Whatever goes into the* *software gets published*" (RECOM, interviewee 016). For consultancy projects, the company could not publish client data and models without their consent or permission.

Informal seminars. Informally, the research scientists organized informal paper seminars or "journal clubs" to share their project works with other scientists who were interested. Thus, "*we chose models to build. We update the whole science team once a year and all people in the science team do journal clubs... everyone is expected to do journal clues every year*" (RECOM, interviewee 015).

Knowledge governance

Intrinsic professional motivation. For the research scientists, most of the interviewees perceived knowledge sharing and learning as essential parts of their work and prerequisites for the research profession. One principal scientist asserted that "*I do not think there is any direct mechanism for encouraging and just expect it as a part of the job role*" (RECOM, interviewee 003).

Another research scientist explained why knowledge sharing was a criterion of the research profession: "*It is not a company, it just starts from your education itself, because when you get your master's degree or PhD, or professors encourage you to do that, so you go to meetings and do that, so you just carry on with that*" (RECOM, interviewee 006).

Talented scientist recruitment. Formally, the company recruited diverse high quality scientists with excellent scientific records. Thus, "*the company always tries to keep the balance of a fresh pool of talents graduating from the universities. The selection criteria for candidates is based on a strict educational background with high impact journal publications and good working knowledge of the practical issues in the field*" (RECOM, interviewee 006).

Flexible open working environment. The knowledge sharing of scientists was encouraged through a set of informal mechanisms. RECOM allowed research scientists to have flexible working hours and locations. They could work from home or be located intheir hometown. Fieldwork observation showed that the company designed their offices as open spaces, where people could easily approach others for discussions. In addition, there were three private meeting rooms for long discussions and meetings.

Budgets for conferences. The company provided a budget for scientists to attend conferences and workshops of academic and industrial communities. In the words of a research scientist, "*the company has the policy of sending us to conferences. They have a budget to use every year to go to conferences and to learn*" (RECOM, interviewee 016).

Technological mechanisms

Specialised predictive software. RECOM scientists adopted varying specific industrial software to analyse complex drug and experimental data for the prediction of drug properties and values for physiological parameters. Company software was the software used by all the scientists for their operations. Moreover, the company used external applications for drug property prediction. A research scientist explained when he had to use an application to predict drug properties: "*You get nothing in the public data, in journals or anything like that. Then you go into prediction. There are many 10% comprise of this program. ACD is to predict something. You do not have reference for it, but it is based on the structure of the drug or something like that. You predict electronically, so that comes in remaining around 10% of the times*" (RECOM, interviewee 006).

Internet search engines. Furthermore, RECOM scientists usually used internet search tools to find new publications. In the words of one research scientist, "*we do not use text mining or other software but only the Google search function within the internet. I put in the information and look at the interaction with something and I get a list of papers cited which I can read*" (RECOM, interviewee 016).

6.5.5. Values

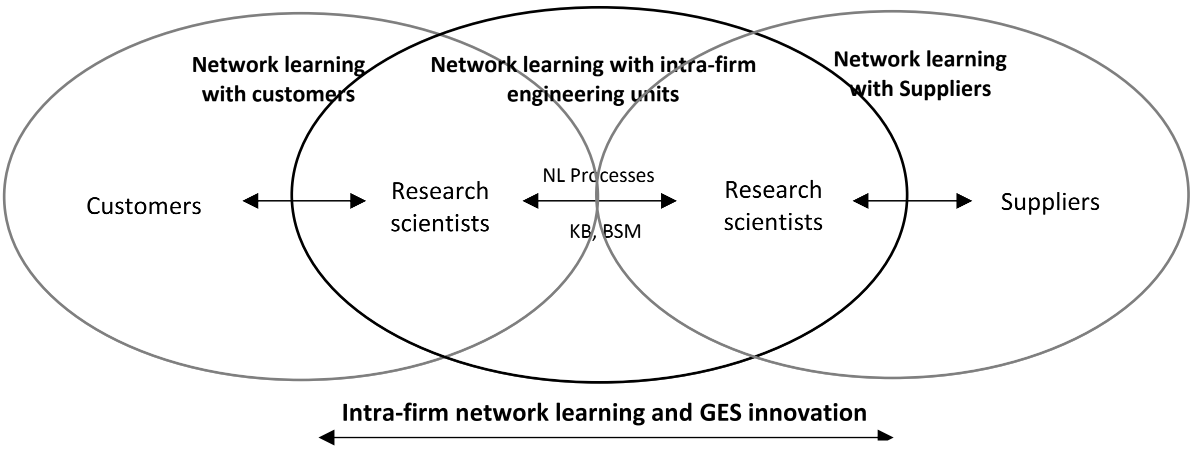
The research scientists collaborated with each other to produce model-based bio-simulation software that helped customers to predict drug behaviour within human bodies accurately and thus design clinical studies efficiently. Annually, RECOM research scientists updated the bio-simulation software with new models, new compound files, and extended features that addressed customer challenges. One research scientist described the success of network learning in this way: "*The project has to be finished and everyone has to be happy. We need to solve the problem, provide good models. That is the measure of success. If we get another request from the clients, we will keep them interested in our software, in* *our works. That is what we need to provide, what we need to prove*" (RECOM, interviewee 016).

Additionally, RECOM had to ensure the quality and accuracy of its technologies in predicting accurately the behaviour of new drugs in the human body. A research scientist asserted that "*One of the biggest drivers for [project learning] is not just people [customers] being satisfied but also when the model is accurate in how it behaves in the clinics*" (RECOM, interviewee 017).

6.5.6. GES Network Learning with Intra-Firm Engineering Units and GES Innovation

Diverse engineers shared the same interests in developing new models, but they had different backgrounds and their knowledge was constantly evolving. The knowledge gaps between diverse engineers were the triggers for intra-firm network learning and GES innovation. The learning processes were informal through project teamwork or informal seminars, and meetings to enhance engineers' mutual understanding and to facilitate solution creation between them. The differences between engineers required informal governance mechanisms to encourage research scientists' knowledge sharing. They had to meet and exchange their works frequently, showing what they had done, and how they had done it, to the others for mutual understanding. Figure 6-4 highlights the key feature of intra-firm network learning and GES innovation.

Prior studies have identified various intra-firm network learning practices and value creation, but they do not offer a clear view of their links between inter-firm network learning and customers and suppliers (Hoegl and Schuler, 2006; Harryson et al., 2008). This study clarifies that central management teams co-create engineering topics of interest with customers to guide knowledge creation with suppliers and between individual engineers in project groups. While intra-firm network learning focuses on generating new solutions, supplier-focused network learning helps to verified them with supplier data and information. GES network learning for innovation is an all-encompassing inter- and intra-firm network learning process. Additionally, individual engineers have different backgrounds and their knowledge has evolved constantly, so they must exchange their knowledge with each other frequently through informal coordination and governance mechanisms for effective learning and innovation. The values created between engineers are new solutions driven by customers.



Network learning drivers:
- Knowledge gaps between diverse engineers

Network learning processes:
- Knowledge creation (driven by customers)
- Knowledge reuse for innovation (intra-firm knowledge exploitation)

Values:
- Novel solutions

Knowledge boundaries (KB):
- Engineer interpretation and language differences

Boundary spanning mechanisms (BSM):
- Centralised and formal boundary spanners (project supervisors)
- Decentralised boundary spanners (research scientists)
- Customised boundary spanning tools and supporting technologies
- Informal coordination and governance mechanisms

Figure 6-4: Contributions of intra-firm network learning to GES innovation

6.6. GES Network Learning with Intra-Firm Engineering Units and Value Creation

The analysis of the three network learning episodes of the three cases is summarised within Table 6.1. The analysis shows the similarity and differences in intra-firm network learning across cases which are discussed as below.

The analysis also enables to draw the key features of GES network learning with not only intra-firm engineering units but also their linkage with inter-firm network learning and the mechanisms used to facilitate them (Table 4.1, 5.1, 6.1). Key features of integrated GES network learning across the three network learning episodes of each case is summarised in chapter 7.

Table 6-1: GES network learning with intra-firm engineering units and value creation

Network learning		**OSCOM** GES Efficiency	**APPCOM** GES Flexibility	**RECOM** GES Innovation
Learning Drivers		Table 4.1: - Changing customer needs for a cost-effective IT solution - Long-term cooperative relationships Table 5.1 - Technology suppliers trusted by customers - Project team emerging knowledge	Table 4.1 - Changing customer demands for better performance - Collaborative relationships Table 5.1 - High-performance sub-tier suppliers - Advanced technology partners (TRL suppliers) - Operational excellence and technology leadership across all engineering sites	Table 4.1 - Changing customer expectations for a novel solution - Consortium relationships Table 5.1 - Suppliers with relevant knowledge for model development - Knowledge gaps between different engineers
Learning process	**Knowledge processes**	Table 4.1 - Knowledge reuse for innovation (knowledge creation with suppliers) - Knowledge creation Table 5.1 - Knowledge creation (supplier knowledge capture, solution verification) - Knowledge reuse	Table 4.1 - Knowledge reuse for innovation - Knowledge creation Table 5.1 - Knowledge creation - Knowledge reuse for innovation (Joint technology development) - Knowledge creation - Knowledge reuse for innovation - Knowledge reuse	Table 4.1 - Knowledge reuse for innovation Table 5.1 - Knowledge reuse for innovation (Literature review; client experiment data capture; granted research) - Knowledge creation - Knowledge reuse for innovation
	Process complexity	Table 4.1 - Customer interest differences - Business domain, technology, process differences - Geographical distance Table 5.1 - Updated supplier technologies - Supplier dispersion - Project team interest differences (e.g. engineer dispersion and resistant for learning) - Project business domain, technical and process differences - Knowledge complexity	Table 4.1 - Customer interest differences - Customer engineering maturity differences - Geographical distance Table 5.1 - Supplier engineering maturity differences - Supplier interest, technology and engineering differences - Engineering site interest differences (e.g. culture differences, organizational inertia - Business and engineering capability differences (e.g. maturity differences) - Knowledge complexity - High volume of information	Table 4.1 - Customer interest differences - Interpretation/ experiment differences - Customer scientific challenges Table 5.1 - Supplier interest, interpretation, experiment differences - Different backgrounds - Knowledge gaps between engineers - Scientific knowledge evolution
Boundary spanning mechanisms	**Boundary spanners**	Table 4.1 - Central excellent management teams (CEO, director, CTO, senior managers) - Central focused functional teams (e.g. onshore/offshore BA, TA) Table 5.1 - Decentralised functional teams (e.g. R&D experts, BA) - Central management teams (searching and approving knowledge for reuse) - Central functional teams	Table 4.1 - Central excellent management teams (CTO, COO, senior Business managers) - Central focused functional teams (e.g. operational teams aligning firm standards with customers) Table 5.1 - Decentralised local functional teams (e.g. supply clusters) - Centralised development taskforces (combined graduate and engineering fellows in project teams) - Central management teams (selecting ideas and approving research proposals)	Table 4.1 - Centralised senior research scientists (co-create customer wish lists) Table 5.1 - All research scientists in four engineering groups - Project supervisors (senior scientists) - All research scientists

			- Centralised functional teams - Decentralised taskforces, clusters - Virtual CoEs	
	Boundary spanning tools	Table 4.1 - Solution frameworks pre-defined with customers - Global project management portals Table 5.1 - Technology targets - Technology online forums/websites - Centralised information systems - Industrial standards - Technological targets	Table 4.1 - Group customer-driven standards/ requirements - Group customer-driven technology platforms - Group integrated information systems (SAP) Table 5.1 - Integrated information system (information sharing) - Common shared standards - Technology requirements - Centralised information systems - Common group standards - Technology platforms	Table 4.1 - Company software (Existing models and databases) - Customer engineering challenges Table 5.1 - RECOM physiological models - Scientific databases - Bio-simulation software - Customer wish list - Common internal database
	Learning coordination	Table 4.1 - Customer survey - Onshore-offshore project coordination - Knowledge documentation/ modularisation Table 5.1 - Supplier periodic training course - Informal forums - Formal project-based coordination - Standardised knowledge documentation - Modularisation - Formal training programs - Periodic knowledge sharing forum	Table 4.1 - Customer negotiation meetings - Formal program coordination - Knowledge documentation - Customer staff grafting Table 5.1 - Supplier clusters, associations - M&A - Joint development projects - Formal program coordination - Centralised/standardised knowledge documentation - Formal R&D project selection - Periodic informal forums/clusters - Engineering taskforces	Table 4.1 - Formal consortium meetings - Periodic informal workshops - Formal consultancy projects Table 5.1 - Reviewed journals - Granted research projects - Informal contacts - Professional conferences - Research project teamwork - Research documentation for reuse - Journal paper publication - Informal seminars
	Knowledge governance	Table 4.1 - Customer contact points - Trust (built by third party certifications, operational transparency, IP protection) Table 5.1 - Partner membership (e.g. number of certificates, customers) - Standardised sharing routines - Customer IP protection - HRM (recruitment, KPI, career development) - Creating common identity (Learning culture, inspiring works, teambuilding)	Table 4.1 - Trust (built by commitments to operation excellence and technology leadership) - Points of contact Table 5.1 - Supplier assessment for learning integration - Talented engineers (capturing technology supplier knowledge) - Routinized knowledge sharing - HRM (talented engineer recruitment and retention, KPI, career development) - R&D investment - Management support for learning	Table 4.1 - Trust (built by scientist publications; third-party affiliation) Table 5.1 - Free of charge licences - Intrinsic professional motivation - HRM (talented scientist recruitment, flexible working hours and environment) - Budgets for conferences

Technology mechanisms	Table 4.1 - Data mining technologies (e.g. cloud and analytics software) - Technology websites Table 5.1 - Internet - Data mining technologies	Table 4.1 - Common integrated virtual assembly (for co-development) Table 5.1 - Virtual assembly - Simulation software - Data mining technologies - Intelligent manufacturing technologies - Simulation software for technology development	Table 4.1 - Internet open sources Table 5.1 - Internet search engines - Predictive software - Specialised predictive software - Internet search engines
Values	Table 4.1 - Cost-effective IT solutions - New frameworks and lessons learned, information on future customer needs - Long-term partnership (e.g. offshore ODC) Table 5.1 - New technological knowledge - Supplier partnership - Efficiency GES (project operation efficiency)	Table 4.1 - High-performance sub-system package solutions - New Standards, technology platforms - Best practices, customer business problems - Supplier of choice Table 5.1 - New knowledge for operational improvement - Complement knowledge for technology development - Supplier relationships - Flexibility GES (operational efficiency & technology innovation)	Table 4.1 - Customer-driven Innovative solutions - Knowledge on customer interests, problems, scope of solutions (e.g. customer wish lists) - Customer affiliation Table 5.1 - Relevant data and models for solution development - Supplier relationships - Innovation GES (new and good models created in teamwork)
Network learning processes and links to network learning with suppliers and intra-firm engineering units	Table 4.1 - Knowledge reuse for innovation (links to knowledge creation with suppliers) - Knowledge creation (links to knowledge reuse with intra-firm project teams) Table 5.1 - Knowledge creation (links to knowledge reuse with project teams, verification of knowledge creation with customer) - Knowledge reuse (Knowledge created with customers and suppliers is reused for efficiency)	Table 4.1 - Knowledge reuse for innovation (links to knowledge creation with intra-firm engineering sites; & knowledge reuse for innovation with suppliers) - Knowledge creation (links to knowledge reuse with intra-firm engineering sites & knowledge creation with suppliers) Table 5.1 - Knowledge creation (links to knowledge reuse with intra-firm engineering sites) - Knowledge reuse for innovation (links to knowledge creation of technology taskforces; customer verification as the end-users) - Knowledge reuse for innovation (between intra-firm engineering sites for data and innovation) - Knowledge creation (transformation of knowledge based on the information captured within knowledge reuse and innovation with customers, intra-firm engineering sites, suppliers) - Knowledge reuse (Knowledge created with customers and suppliers is reuse for efficiency)	Table 4.1 - Knowledge reuse for innovation (links to knowledge creation with intra-firm research scientists & knowledge reuse for innovation with suppliers) Table 5.1 - Knowledge reuse for innovation (links to knowledge creation with intra-firm research scientists, customer verification of knowledge reuse with suppliers) - Knowledge reuse for innovation (between intra-firm research scientists for mutual understanding) - Knowledge creation (transformation of knowledge based on the information captured within knowledge reuse and innovation with customers, intra-firm research scientists, suppliers

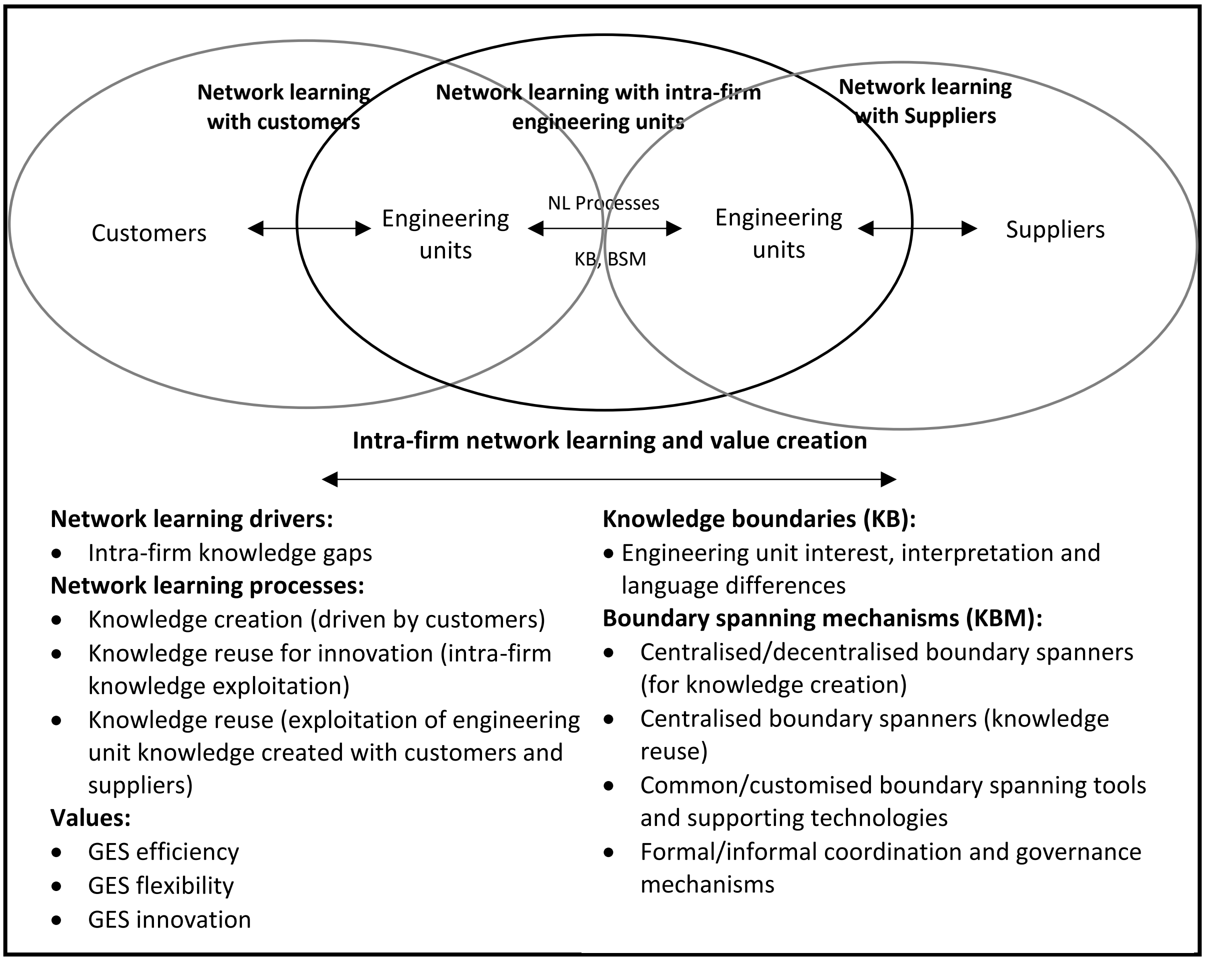
Boundary spanning mechanisms across cases	Table 4.1 - Central management teams - Centralised functional teams - Formal governance mechanisms - Uniform/global information systems, common framework, engineering targets Table 5.1 - Decentralised functional teams - Informal governance mechanisms - Customised engineering targets, platforms - Central management teams - Centralised functional teams - Formal governance mechanisms - Uniform/global information systems, common standards, targets	Table 4.1 - Central management teams - Centralised functional teams - Formal governance mechanisms - Uniform/global information systems, common technology platforms, standards Table 5.1 - Central management teams - Formal governance (joint projects for technology development) - Common technology platforms (e.g. technology requirements) - Decentralised local functional teams (to co-develop operations with sub-tier suppliers) - Informal governance (e.g. supplier clusters) - Customised shared standards - Central management teams (for innovation) - Decentralised technology taskforces, virtual teams, engineering clusters (for innovation) - Informal governance mechanisms (for innovation) - Customised platforms (e.g. development projects) - Centralised functional teams (for efficiency) - Formal governance mechanisms (for efficiency, e.g. formal routines for knowledge sharing) - Uniform information systems and machine learning technologies	Table 4.1 - Central management teams - Formal governance mechanisms - Common technology platforms/ models Table 5.1 - Central management teams - Formal governance (e.g. research grant projects) - Common technology platforms/models (e.g. use of company software) - Central management teams (e.g. project supervisors) - Decentralised research scientists - Informal governance mechanisms (e.g. seminars) - Customised research platforms & predictive technologies

Figure 6-5 presents the common features of intra-firm network learning. Intra-firm network learning is driven by a knowledge gap existing within the firm or between engineering units. In the efficiency case, the company lacked the skills required for future customer needs and at the same time had new knowledge captured by various project teams in their solution co-creation with customers. In the innovation case, the company had diverse engineers with different backgrounds and intra-firm network learning was necessary to bridge their knowledge gaps. Network learning therefore helped to bridge the knowledge gaps and enhance efficiency and innovation between different engineering units. There were three network learning processes that helped to bridge the knowledge gaps between engineering units:

- Knowledge creation: the interactions between engineering units to create new directions, technologies and models for knowledge creation and innovation.
- Knowledge reuse for innovation: the interactions between engineering units to exploit existing knowledge as the input or data for technology innovation.
- Knowledge reuse: the knowledge transfer or selective reuse between engineering units to enhance operational performance for efficiency.

Intra-firm network learning needs to cope with knowledge boundaries between engineering units in terms of different interests, interpretations and languages. In the efficiency case, the project teams had different business domains, technologies and processes and they were dispersed in order to serve different customers globally. In the case of GES flexibility, engineering sites operated in different engineering businesses, having different technological capabilities and engineering maturity levels. In the innovation GES case, diverse engineers, despite sharing common interests in developing novel models, had different backgrounds and knowledge domains. These knowledge boundaries prevented the engineering units from network learning.

To deal with the problems of knowledge boundaries, firms use a set of boundary spanners, boundary spanning tools, and governance and technological mechanisms. Boundary spanners and other mechanisms can be centralised/formal and/or decentralised/informal depending on the differences in the interests of the engineering unit and the network learning purposes, and whether it is knowledge creation or reuse. In knowledge creation, centralised CoEs are employed to facilitate new knowledge creation from different knowledge sources captured from customers. They help to generate technology targets, platforms and directions for the creation of R&D engineering taskforces/ groups, which are decentralised to enhance mutual understanding and knowledge creation between them. Knowledge creation across engineering units is supported by technology platforms and informal governance mechanisms. Knowledge reuse relies on centralised and formal boundary spanning mechanism to align various engineering units with different business interests to share knowledge and learning. Network learning results in a better engineering performance in terms of efficiency, flexibility and GES innovation.



Network learning drivers:
- Intra-firm knowledge gaps

Network learning processes:
- Knowledge creation (driven by customers)
- Knowledge reuse for innovation (intra-firm knowledge exploitation)
- Knowledge reuse (exploitation of engineering unit knowledge created with customers and suppliers)

Values:
- GES efficiency
- GES flexibility
- GES innovation

Knowledge boundaries (KB):
- Engineering unit interest, interpretation and language differences

Boundary spanning mechanisms (KBM):
- Centralised/decentralised boundary spanners (for knowledge creation)
- Centralised boundary spanners (knowledge reuse)
- Common/customised boundary spanning tools and supporting technologies
- Formal/informal coordination and governance mechanisms

Figure 6-5: Contributions of intra-firm network learning to value creation

The analysis reveals some variations. Table 6-1 presents different practices across three cases. It also compare intra-firm network learning with inter-firm network learning within three network learning episodes of a single case, considering the findings in chapters 4 and 5. For cross case analysis, there are two patterns of intra-firm network learning: efficiency and innovation network learning.

Efficient network learning focused on knowledge reuse between different engineering units to reduce the problem of reinventing the wheel. It could be either knowledge transfer or selective reuse depending on the similarity levels of the problems and situations between engineering units. In the case of APPCOM, knowledge reuse was more selective than in the OSCOM case because APPCOM engineering sites had different businesses, technology and engineering capabilities and therefore knowledge had be applied slightly differently. Different engineering units may have had their own interests and also differed from each other in terms of technologies, organisations and geographies. Knowledge reuse should rely on a set of boundary spanning mechanisms as follows:

- Centralised boundary spanners: central management teams are useful for collecting, interpreting and disseminating the right knowledge for transfer and reuse across engineering units which differ in terms of interests, technologies and operations.
- Centralised boundary spanning tools: high volume, dispersed and complex knowledge transfer and reuse are promoted and aligned by centralised information systems, common standards and targets.
- Centralised technologies: data mining and intelligent manufacturing technologies support data collection, interpretation and dissemination for decision making, quality control and on-time delivery.
- Formal learning coordination: standardised project/program-based coordination routines and knowledge documentation/modularisation are necessary for knowledge reuse and transfer and problem solving and thereby enhance operational efficiency.
- Formal knowledge governance: standardised knowledge sharing routines and formal HRM practices are employed to ensure engineers share knowledge and commit to learning.

Innovative network learning bridges the unknown between different engineering units and highlights knowledge creation interaction between them. Knowledge creation processes occur mainly in informal events such as ad-hoc project meetings, seminars and forums based on technology platforms created by the central teams. Different engineers, despite sharing common interests, have different backgrounds and their knowledge is constantly evolving. This creates knowledge boundaries between engineering units in terms of different interpretations and operations and therefore requires firms to adopt a set of boundary spanning mechanisms to bridge their knowledge gaps.

- Decentralised boundary spanners: decentralised taskforces/ clusters/ project groups facilitate knowledge creation between different experts. In the case of APPCOM, virtual centres of excellence are involved in supporting the decentralised teams when they have problems. In the case of RECOM, supervisors are the people who help project teams to solve problems.

- Decentralised boundary spanning tools: technology platforms and customer wish lists loosely guide the knowledge creation of engineers.
- Local technologies: engineers use different specialised simulation and predictive software to support their operations.
- Informal learning coordination: informal mechanisms such as discussion meetings, seminars and forums enable knowledge sharing and learning across different engineers. Teleconferences are used for the meeting of engineers in different locations.
- Informal knowledge governance: most expert engineers share knowledge because of their intrinsic and professional motivations. Flexible working hours and the environment, investments and budgets for learning are among the mechanisms which encourage expert engineers to share knowledge and learning.

6.7. Conclusion

This chapter has clarified the roles of intra-firm network learning in the relationships with inter-firm network learning. The linkage between inter- and intra-firm network learning and the boundary spanning mechanisms adopted to facilitate them is unclear in the literature. Three cases were studied to investigate this linkage and related boundary spanning mechanisms.

The case analysis in the chapter verifies that inter- and intra-firm network learning are inter-related. Inter-firm network learning provides information for intra-firm technology innovation and co-creates knowledge for intra-firm knowledge reuse and efficiency. Intra-firm network learning is driven by a knowledge gap within the firm or between engineering units in addressing a changing customer need or demand. To fill the knowledge gaps, intra-firm network learning involves knowledge creation, knowledge reuse for innovation and knowledge reuse. These processes are based on the information and knowledge of engineering units gained in collaborations with customers and suppliers and thus rely on the knowledge sharing of engineering units.

Engineering units, however, have different interests, interpretations and languages. The firms need to employ boundary spanning mechanisms to facilitate knowledge sharing and learning between them. There are two types of network learning with intra-firm engineering units: efficiency and innovation network learning. Efficiency network learning is motivated by the fact that engineering units cope with similar problems and/or situations and knowledge reuse helps to avoid reinventing the wheel and thus fosters efficiency. Knowledge reuse employs centralised boundary spanning resources and formal governance mechanisms to address the interest differences between different engineering units.

Innovation network learning is driven by the need to bridge the knowledge gaps between diverse engineers with the same interests but different backgrounds. Knowledge creation processes focus on informal knowledge sharing processes that enhance mutual understanding between different engineers whose knowledge is constantly evolving. The knowledge boundaries require decentralised boundary spanning resources and formal, hybrid, and informal governance mechanisms to facilitate knowledge sharing and creation at both corporate and local levels for firm innovation.

The chapter has clarified the relationship between inter- and intra-firm network learning and identified various boundary spanning mechanisms that contribute to value creation in terms of efficiency, flexibility and GES innovation. This indicates that GES network learning is an all-encompassing process including both intra- and inter-firm learning facilitated by various boundary spanning mechanisms. Further discussion is presented in the following chapter.

7. CHAPTER 7: DISCUSSION AND CONCLUSION

7.1. Introduction

The absence of an integrated approach to understanding GES network learning that contributes to value creation was the primary motivation behind this study. It has developed a more holistic conceptual framework for understanding GES network learning, considering the contributions of customers, suppliers and intra-firm engineering units. By integrating and applying existing insights into real GES firm contexts, the study has developed an integrated framework that offers a better understanding for researchers and practitioners to manage GES network learning in an ever-changing global market.

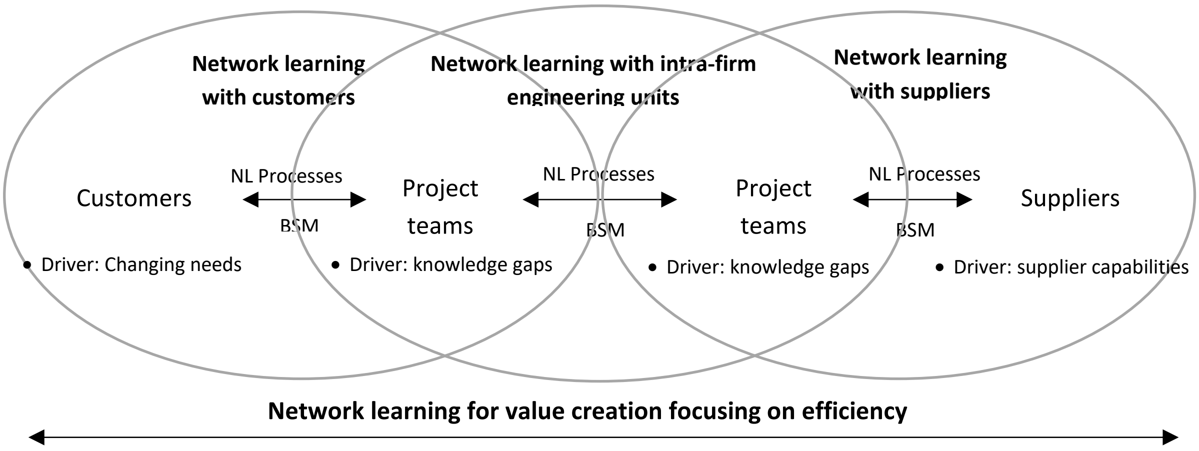
This chapter begins by integrating the research analysis presented in chapters 4, 5 and 6. It then discusses the key features of the integrated framework developed from the three case studies. Finally, theoretical and managerial contributions are considered, followed by research limitations and potential research directions for future studies.

7.2. Overview of the Case Study Analysis

Current literature has developed GES network learning as a set of independent processes, either with customers, suppliers or intra-firm engineering units. This study was designed to examine GES network learning from an integrated approach, considering the interrelation between inter- and intra-firm network learning and value creation. Three cases were studied to explore the contributions of customers (chapter 4), suppliers (chapter 5) and intra-firm engineering units (chapter 6) to network learning, and their linkages. Analysis of each case is presented in the following sections.

7.2.1. Efficiency Case

This case study focused on an analysis of the network learning with customers, suppliers and intra-firm project teams that contributes to GES efficiency. The case studied was a software development service provider, offering bespoke software development services to customers in various industries around the world. It delivered services through two engineering hubs in Asia and 10 engineering offices in Europe, the US, and Asia Pacific. Figure 7-1 highlights the key features of network learning in this case. The red colour highlights the key inter-related network learning processes and boundary spanning mechanisms that contribute to efficiency.



Network learning for value creation focusing on efficiency

Network learning drivers:

- Changing customer needs for cost-effective solutions
- Supplier technologies demanded by customers
- Intra-firm knowledge gaps

Network learning processes

- Knowledge creation (**with customers & suppliers**)
- Knowledge reuse (**with intra-firm project teams**)

Values:

- **Efficiency**

Knowledge boundaries:

- Differences in knowledge interests, interpretations and languages (Customers/project teams)
- Differences in knowledge interpretations and languages (suppliers)

Boundary spanning mechanisms (BSM):

- Central management/ Centralised functional teams, uniform/common information systems and formal governance (**with customers & intra-firm project teams**)
- Decentralised boundary spanners and informal governance (**with suppliers**)

Colours: **Red**: processes and BSM for efficiency

Figure 7-1: Efficiency case: GES network learning and efficiency

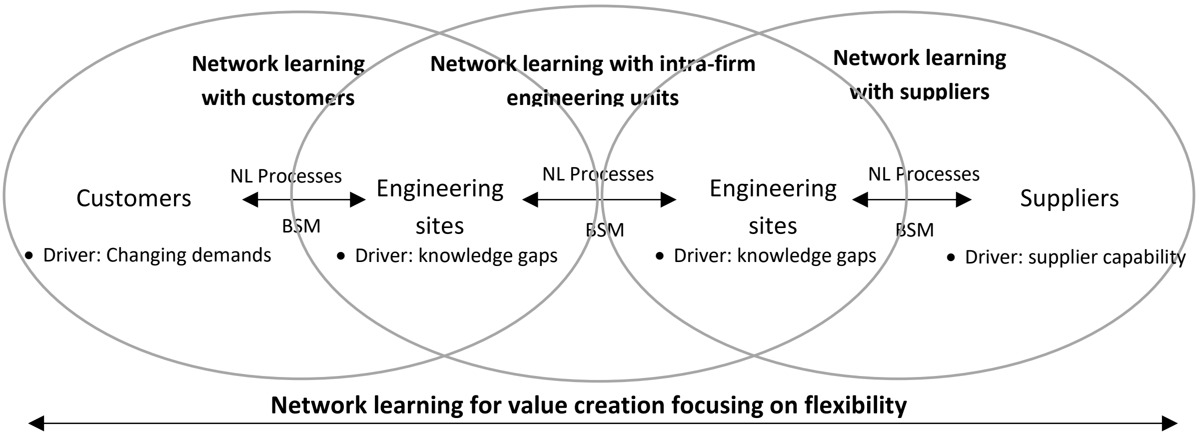
GES efficiency integrated network learning was driven by changing customer needs for cost-effective solutions, intra-firm project team knowledge gaps, and the updated supplier technologies demanded by customers. Customers contributed firstly to GES network learning by co-creating knowledge with intra-firm project teams which was subsequently transferred to other project teams for efficiency. They also provided information on their future needs for firms to identify the directions for technology development with supplies. Suppliers were involved in providing new knowledge to project teams through the transfer and translation of decentralised R&D teams and subsequently used by the project teams to co-create knowledge with customers, which was again used as input for knowledge reuse between project teams. Thus, inter-firm network learning helps to capture information and new knowledge to intra-firm knowledge reuse and efficiency.

GES efficiency network learning, however, was challenging, because customers and project teams had different knowledge interests, interpretations and languages, while suppliers, despite having shared interests with the firm, constantly updated their technologies. Such differences created knowledge boundaries that required the employment of boundary spanners and governance mechanisms.

Central management teams were the boundary spanners who transformed customer need information into new directions for knowledge creation and translated project team codified knowledge for knowledge reuse by other project teams. Centralised functional teams helped to translate and transfer different knowledge across customers and project teams who had different engineering/technological interests and interpretations. Decentralised functional teams were useful in capturing the changing complex knowledge of technology partners who shared common technological interests with the firm. Additionally, network learning with customers and project teams required centralised, common and formal governance mechanisms and tools, while learning with technology partners relied on informal governance and specialised tools. Thus, the efficiency case shows that integrated network learning is an all-encompassing process including inter-related knowledge acquisition processes and knowledge boundary mechanisms across customers, suppliers, and intra-firm engineering units that contribute to GES efficiency.

7.2.2. Flexibility Case

This case study focused on analysing network learning with customers, suppliers and intra-firm engineering sites, which contribute to GES flexibility. The case company was an aerospace engineering service provider, offering engineering service to a few large customers in a several related industries. Services were delivered through over 50 engineering sites located around the globe. Figure 7-2 shows the key features of the integrated network learning process across customers, suppliers and engineering sites in this case. In the figure, the red colour highlight key network learning processes and boundary spanning mechanisms for efficiency, while blue colour indicates the network learning processes and boundary spanning mechanisms that contribute to innovation.



Network learning drivers:

- Changing customer demands for better performance
- Supplier performance & technology maturity levels
- Intra-firm operational excellence and technology leadership

Network learning processes

- Knowledge reuse for innovation **(with customers, intra-firm engineering sites, & suppliers)**
- Knowledge creation (**with customers**, **intra-firm engineering sites**, **& suppliers**)
- Knowledge reuse (**with intra-firm engineering sites**)

Values:

- Flexibility (**operational efficiency** & **technological innovation**)

Knowledge boundaries:

- Differences in knowledge interests, interpretations, and languages (Customers/engineering sites/technology suppliers)
- Differences in knowledge interpretations and language (Intra-firm R&D engineers/ external sub-tier suppliers)

Boundary spanning mechanisms (BSM):

- Central management teams uniform/common information systems and formal governance (**with customers, engineering sites, & technology suppliers**)
- Centralised functional teams, uniform/common information systems and formal governance (**with customers and intra-firm engineering sites**)
- Decentralised taskforces/local functional teams and specialised software & informal governance (**with Intra-firm R&D engineers** & **sub-tier suppliers**)

Colours: **Red**: processes and BSM for efficiency **Blue**: processes and BSM for innovation

Figure 7-2: Flexibility case: GES network learning and flexibility

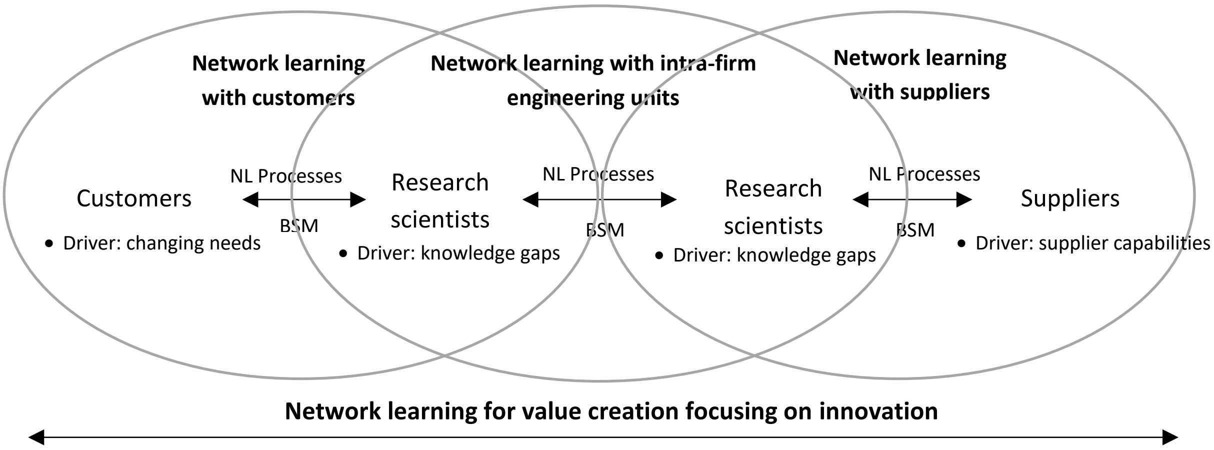
Flexibility network learning across customers, suppliers and the 50 engineering sites was motivated by changing customer demands for better performance, firm strategies for operational excellence and technology leadership across engineering sites, together with operational and technological supplier capabilities. Customers contributed to GES network learning by providing their changing engineering requirements and technology roadmaps. This information was transformed by central management teams into standards and platforms for knowledge co-creation between engineering sites and customers/suppliers. The engineering sites captured the operational knowledge co-created with customers and customers' technological problems. Their knowledge was subsequently applied across sites for group operational improvement and used for knowledge creation and knowledge reuse for innovation across sites. Operational improvement and technological innovation were faciliated by sub-tier and technology suppliers. The company selected high-performance sub-tier suppliers for knowledge co-creation and operational co-development, and technological suppliers for knowledge reuse for technological innovation. The knowledge co-created with sub-tier suppliers could be reused across sites for the improvement of the entire group, while supplier technologies could be reused to transform existing technology for innovation.

The case's network learning needed to deal with different knowledge interests, interpretations, and terminoloties between customers, suppliers and intra-firm engineering sites creating knowledge boundaries. Such differences hindered knowledge sharing and transfer. Management interventions therefore were important in faciliating network learning, involving a set of boundary spanners and governance mechanisms.

The case company employed central management teams to transform customer requirements and technology roadmaps into new standards and platforms that directed network learning with customers, suppliers and intra-firm engineering sites. Centralised functional teams were employed to bridge the knowledge gaps between customers, intra-firm engineering sites and technology suppliers, who had different engineering/ technological interests and interpretations. Decentralised focused taskforces or local functional teams were useful for faciliating technology co-development between intra-firm engineering sites and sub-tier suppliers who shared common interests but having different backgrounds and engineering maturity levels. Centralised boundary spanners were supported by formal governance and uniform tools, while decentralised boundary spanners relied on informal governance and specialised software and tools to facilitate network learning. Thus, GES flexibility network learning comprised a set of inter-related knowledge acquisition processes such as knowledge reuse for innovation, knowledge creation with both customers, suppliers and intra-firm engineering sites for intra-firm knowledge reuse and operational efficiency and intra-firm knowledge creation and technological innovation.

7.2.3. Innovation Case

This case study focused on an analysis of network learning with customers, suppliers and intra-firm research scientists, who contribute to GES innovation. The case company was a bio-simulation technology provider, offering innovative modelling and bio-simulation software that facilitates the drug development processes of pharmaceutical companies. It delivered bio-simulation engineering services through a network of four scientific competence divisions, with over 50 research scientists located in the UK, and 21 offices located worldwide. Figure 7-3 shows the key network learning features of this case drawn from the data analysis. The figure uses blue colour to highlight the key network learning processes and boundary spanning mechanisms that contribute to innovation.



Network learning drivers:
- Changing customer interests and problems
- Research supplier complementary data and models
- Intra-firm diverse research scientists & their knowledge gaps

Network learning processes
- Knowledge reuse for innovation (**with customers, intra-firm research scientists, & suppliers**)
- Knowledge creation (**with intra-firm research scientists**)

Values:
- **Innovation**

Knowledge boundaries:
- Differences in knowledge interests, interpretations, languages (customers/research suppliers)
- Differences in knowledge interpretations and languages (Intra-firm research scientists)

Boundary spanning mechanisms (BSM):
- Central senior researchers, uniform/common platforms/models/databases and formal governance (**with customers & research suppliers**)
- Decentralised research groups/researchers and specialised predictive software & informal governance (**with Intra-firm research scientists**)

Colours: **Blue**: processes and BSM for innovation

Figure 7-3: Innovation case: GES network learning and innovation

Innovation network learning was driven by changing customer needs for novel solutions that addressed their new drug development challenges, intra-firm knowledge gaps between research scientists with diverse backgrounds, and the complementary data and models generated by research institutions. Customers contributed to the network learning by providing their engineering challenges, problems of interest, and ranges of solutions, which were the foundation for knowledge creation and knowledge reuse for innovation between research scientists. The knowledge created by research scientists was subsequently verified and refined by the data and models of the suppliers, who had facilities for experiments and research that the firm did not possess.

Innovative integrated network learning needed to deal with the knowledge boundaries between customers, intra-firm research scientists and research suppliers. While customers and suppliers had different engineering/technological interests and interpretations, intra-firm research scientists had different backgrounds. Network learning thus relied on a set of boundary spanning mechanisms to manage knowledge sharing and transfer across customers, suppliers and intra-firm research scientists.

Central senior research scientists were the boundary spanners who transformed customer interests and the range of solutions into customer wish lists for other research scientists to develop solutions. Network learning with customers was supported by formal governance mechanisms and common platforms. Decentralised research scientists conducted research and informally collaborated with each other in groups and teams to enhance mutual understanding and knowledge creation. Supplier information was collected and managed by formal governance and central senior research scientists to ensure the capture of relevant information for new solution development. Thus, GES innovation integrated network learning include a set of inter-related knowledge acquisition processes supported by a combination of boundary spanners and governance mechanisms. In this process, knowledge reuse for innovation with customers, intra-firm engineering units and suppliers provides information for intra-firm knowledge creation, leading to the creation of novel solutions.

7.3. An Integrated Framework for GES Network Learning and Value Creation

Prior research has developed a distinct view of GES network learning and firm value creation. Operations management scholars emphasise the important roles of intra-firm engineering units in network learning that enhances operations performance, without clarifying the contributions of customers and suppliers (Moore and Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016). The literature on supply chain and industrial marketing management highlights customers and suppliers as the key contributors to GES network learning who foster product and service innovation, without clarifying the roles of intra-firm engineering units and intra-firm network learning (Marra et al., 2012; Coghlan & Coughlan 2014; Jaakkola & Hakanen 2013). These fragmented approaches are problematic, as they have not yet provided a good understanding of GES network learning and value creation, which can be viewed as an all-encompassing process (Grönroos, 2011; Vargo & Lusch, 2008; Lusch et al., 2010). The independent processes developed within the current literature might be parts of the integrated process (Brady & Davies, 2004; Salonen et al., 2018).

The analysis of the three case studies shows that GES network learning is an integrated network learning process across customers, suppliers and intra-firm engineering units, rather than merely being separated in independent processes. The efficiency case highlights an efficiency integrated network learning in which customers and suppliers co-create knowledge with intra-firm engineering units. The knowledge co-created with suppliers and customers is subsequently reused by the other intra-firm engineering units and thus enhance efficiency. It is noted that these inter-related network learning processes are supported by a set of boundary spanning mechanisms. Network learning with customers and engineering units are supported by central functional teams and formal govenance mechanisms, while supplier-focused network learning is supported by decentralised fuctional teams and informal governance mechanisms

The flexibility case shows two parallel integrated network learning processes for efficiency and innovation. The innovation integrated network learning involve knowledge reuse for innovation with customers, intra-firm engineering units, and suppliers to capture information for intra-firm technology and operations transformation or knowledge creation. It is supported by central management teams who transform customer, intra-firm engineering unit, and supplier information into new directions for knowledge creation of decentralised engineering taskforces for technology and process innovation. While central management teams learning is supported by formal govenance mechanisms, intra-firm decentralised engineering taskforces relies more on informal governance to enhance knowledge sharing and learning. Efficiency integrated network learning involve knowledge co-creation with customers and suppliers to enhance operations performance. The knowledge co-created with customers and suppliers is subsequently reused across intra-firm engineering units for enhancing the efficiency of entire group operations. Knowledge creation with customers and knowledge reuse with intra-firm engineering units are supported by centralised functional teams to deal with the differences in knowledge interests between learners. Knowledge creation with suppliers howevers relies on decentralised local functional teams to capture complex knowledge of sub-tier suppliers who share the interest in developing operational knowledge with the firm.

In the innovation case, an innovation integrated network learning is identified. Network learning involves knowledge reuse for innovation with customers and suppliers to capture necessary information for the transformation or knowledge creation and knowledge reuse for innovation of intra-firm engineering units. Knowledge reuse for innovation with customers and suppliers is supported by central management teams and formal governance mechanisms to deal with the differences in knowledge interests of customers and suppliers. Knowledge creation across intra-firm engineering units rely more on decentralised engineering units to encourage mutual understanding between shared interest learners.

Figure 7-4 presents an integrated framework for GES network learning and value creation drawn from the three case studies. The intergrated framework includes three interrelated elements: (i) network learning with customers; (ii) network learning with intra-firm engineering units; and (iii) network learning with suppliers. These elements interact with each other in an integrated process including customers, intra-firm engineering units and suppliers to enhance network operations efficiency, flexibility and service innovation. Intra-firm engineering units plays an integrating role in this process, connecting separated network learning episodes with customers and suppliers. customers can be formally involved in evaluating and/or verifying the network learning with suppliers as the end-users, while supplers can be invited to evaluate and/or verify the solutions co-created with customers. They do not directly contribute to network learning at the same time.

Customers, suppliers, and engineering units interact with each other through a set of knowledge reuse for innovation, knowledge creation and knowledge reuse processes. These processes are supported by boundary spanning mechanisms to facilitate knowledge sharing across knowledge boundaries. The figure uses red and blue colours to highlight two different integrated network learning processes and boundary spanning mechanisms that contribute to either efficiency and/or innovation. The red colour represents to network learning processes and boundary spanning mechanisms that contribute to efficiency. The blue colour emphasises the inter-related network learning processes and boundary spanning mechanisms for innovation. GES network learning for flexibility includes both network learning for efficiency and innovation.

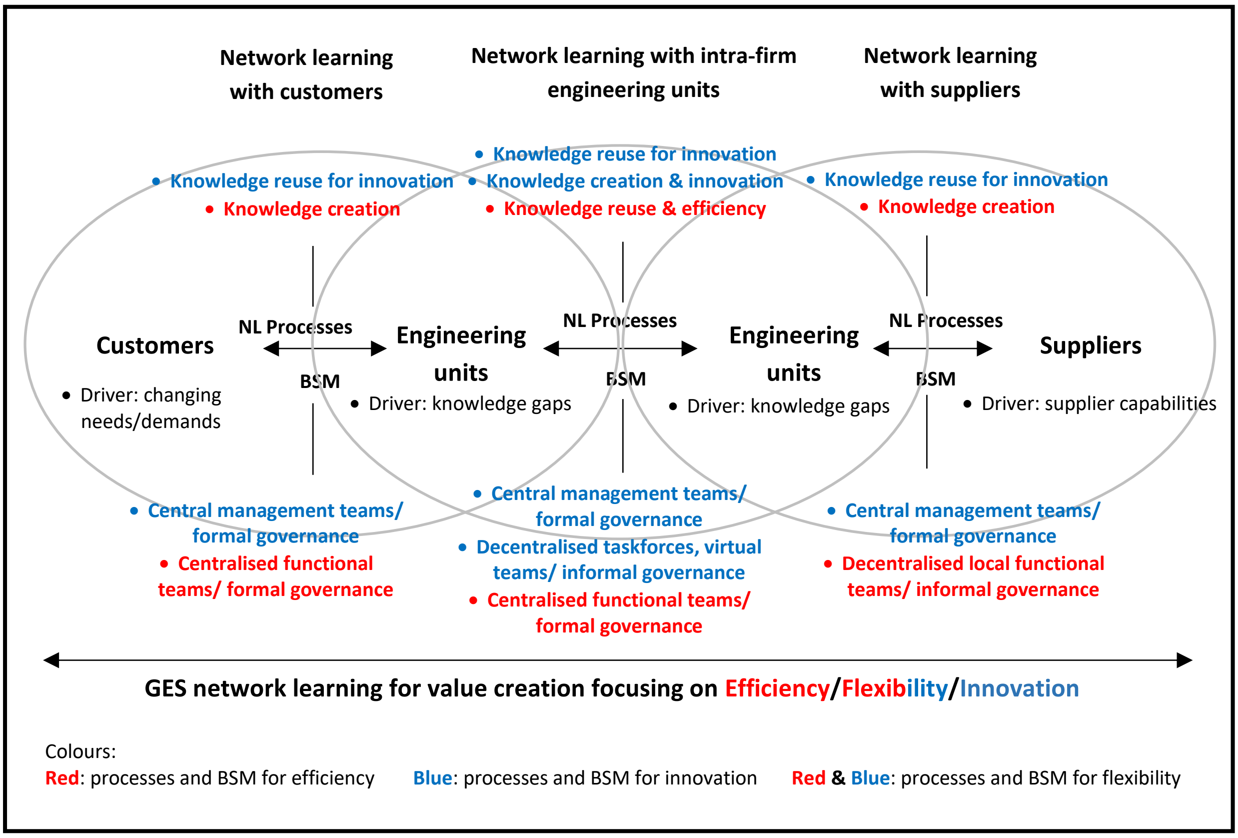


Figure 7-4: GES network learning: an integrated framework

The framework is constructed mainly from the viewpoint of the firm, highlighting GES network learning as a firm process to leverage customers, suppliers and intra-firm engineering units for firm value creation. It did not incorporate customer and supplier viewpoints on its elements that may provide more insights. In the following sections, the characteristics of the integrated framework are described and discussed to understand their key features and linkages in terms of network learning drivers, network learning processes, knowledge boundaries, boundary spanning mechanisms, and created values.

7.3.1. Network Learning Drivers

Past research has identified various drivers that motivate GES firms to adopt network learning either with customers, intra-firm engineering units or suppliers. Operations management researchers have emphasised network learning as a vehicle to bridge the knowledge gaps between dispersed engineering units for knowledge reuse and efficiency (Moore & Birkinshaw, 1998; Kotlarsky et al., 2014) and knowledge creation and innovation (Soderquist, 2006; Zhang et al., 2016). They have also indicated that network learning with suppliers is beneficial for firms to maintain their competitiveness in contexts where industrial knowledge is expanding and markets are changing (Powell et al., 1996; Fine, 1998). It has been recognised that firms are increasingly competing through network learning with suppliers rather than by developing their businesses alone in-house (Teece et al., 1997; Meijboom et al., 2007). Collaborating with suppliers helps firms to enhance operational efficiency and innovation (Todtling et al., 2009; Coghlan & Coughlan, 2014).

In the industrial marketing management research, network learning with customers and suppliers has been highlighted as a means to innovate service and operations performance (Brady & Davies, 2004; Windahl & Lakemoon, 2006; Jaakkola & Hakanen, 2013; Galbraith, 2014). Changing customer demands have been the main drivers for firms to collaborate with them to innovate their service and capture more rents (Wise & Baumgartner, 1999; Daniels & Bryson, 2002; Brady & Davies, 2004). In the context of changing customer demands, firms have been motivated to collaborate with various suppliers to capture their complementary capabilities and be able to produce what customers want (Windahl & Lakemoon, 2006; Davies et al., 2007). The analysis in this study has identified a set of interrelated drivers for network learning with customers, intra-firm engineering units and suppliers. It clarifies that changing customer needs and demands are the main triggers for network learning with them, which subsequently motivates GES firms to collaborate with intra-firm engineering units and suppliers to address these needs/demands.

The three case studies show that GES customers have been under more innovation/competitive pressures from consumers, business customers, competitors and regulatory agencies, along with rapidly changing technologies. They have to alter their needs for engineering solutions and demand more for engineering service efficiency and innovation from their service providers to address their business problems. Network learning with customers is triggered to capture customer needs/demands and/or co-create the solutions that customers want. Under customer pressures for innovation and competition, GES firms have been forced to adopt network learning with intra-firm engineering units to fill the knowledge gaps, enhance performance and/or exploit the capabilities of the entire network. At the same time, GES firms have been motivated to collaborate with various suppliers who are trusted by customers and/or have the capabilities that benefit GES firms' innovation and efficiency. Thus, the drivers for integrated GES network learning include:

- *Changing customer needs/demands* - as a result of customer business and engineering problems caused by changing markets and technologies.
- *Knowledge gaps between engineering units* - a condition in which different engineering units do not know what others are doing, and/or are not performing as well as the others.
- *Supplier capabilities* - supplier abilities that may contribute to firm performance improvement in addressing changing customer demands.

7.3.2. Network Learning Processes

Previous research refers to GES network learning as the processes that are adopted to enhance network operations performance through knowledge reuse and creation (Brady & Davies, 2004; Hoelg & Schulze, 2005; Kotlarsky et al., 2014; Zhang et al., 2016). Knowledge reuse that enhances firm performance can be knowledge transfer (Argote & Ingram, 2000), selective reuse (Markus, 2001) and knowledge reuse for innovation (Majchrzac, 2004; Zhang et al., 2016). Knowledge creation is a process of socialisation, externalisation, combination, and internalisation across customers, suppliers and intra-firm engineering units to generate new knowledge (Nonaka, 1994; Brady and Davies, 2004; Hoegl & Schulze, 2005).

The literature has identified GES network learning as a set of independent knowledge reuse and creation processes with customers, suppliers and intra-firm engineering units (Brady and Davies, 2004; Zhang et al., 2016; Coghlan & Coughlan, 2014). However, the linkage and sequence of these processes have not yet been clarified (Brady & Davies, 2004; Jaakkola & Hakanen, 2013; Kotlarsky et al., 2014; Zhang et al., 2016; Coghlan & Coughlan, 2014). The three case studies show that GES network learning includes a set of inter-related knowledge reuse for innovation, knowledge creation and knowledge reuse across customers, intra-firm engineering units and suppliers.

GES network learning always starts with knowledge reuse for innovation with customers and subsequently knowledge creation, knowledge reuse for innovation, and knowledge reuse with intra-firm engineering units, suppliers and customers. In the efficiency and flexibility cases, GES network learning for operational efficiency involves knowledge reuse for innovation with customers to capture customer requirements/needs; knowledge creation subsequently occurs with intra-firm engineering units, supplier, and customers. In the efficiency case, the company did not create knowledge in-house. Instead, knowledge is co-created with suppliers and subsequenly with customers. In the flexible case, customer information was used for intra-firm knowledge creation before the knowledge is co-created further with customers and suppliers. The knowledge co-created with suppliers and customers then is reused by intra-firm engineering units to enhance their efficiency. GES network learning for service innovation starts with knowledge reuse for innovation with customers to capture their interests and expectations. This process is followed by knowledge creation with intra-firm engineering units and knowledge reuse for innovation with suppliers and other intra-firm engineering units to generate innovative service. Thus, rather than being isolated within independent processes, the integrated GES network learning process comprises of a set of interrelated knowledge creation and reuse processes that contribute to the acquisition and application of information and knowledge across customers, intra-firm engineering units and suppliers for operational efficiency and innovation.

- *Knowledge creation* - the interactions between intra-firm engineering units with customers and/or suppliers and between intra-firm engineering units themselves which lead to new knowledge for the firms.

- *Knowledge reuse for innovation* - the interactions between intra-firm engineering units and customers, suppliers and between themselves which lead to new understanding, facilitating the transformation of firms' existing knowledge residing within diverse intra-firm engineering units into something innovative.
- *Knowledge reuse* - the knowledge transfer and/or selective reuse processes between intra-firm engineering units which lead to performance enhancement.

7.3.3. Knowledge Boundaries

The literature highlights the knowledge boundaries between customers, intra-firm engineering units and suppliers as challenges to network learning (Hakanen & Jaakkola, 2012; Kotlarsky et al., 2014; Ayala et a., 2017). Different knowledge interests, interpretations and languages (terminologies) are barriers to network learning with customers, suppliers and intra-firm engineering units (Carlile, 2004). Research has shown that customer collaboration in co-creating solutions with GES firms is key to network learning and innovation (Brady &Davies, 2004). Solutions should be created through the eyes of the customers and thus requires customer adaptation, and political and operational counselling to be successful (Tuli et al, 2007; Hakanen & Jaakkola 2012). Supplier knowledge boundaries have been acknowledged within supply network learning (Matthyssens & Vandenbempt, 2008; Ayala et al., 2017). Issues pertaining to supplier openness to learning, free-riding, and tacit knowledge transfer are among the knowledge sharing barriers that require management to faciliate network learning with suppliers (Dyer & Nobeoka, 2000; Todtling et al., 2009; Coghlan & Coughlan, 2014). Network learning with intra-firm engineering units faces knowledge boundaries between globally dispersed independent engineering centres with technological, organisational and geographical distances, which create conflicts of interest and organisational inertia, hindering network learning (Criscuolo & Narula, 2007). Diverse project teams are also a challenge to network learning (Kotlarsky et al., 2014).

The case analysis shows that GES network learning can cope with different knowledge interests, interpretations and languages between customers, intra-firm engineering units and suppliers. In the GES efficiency case, customers came from different industries and had their own businesses, technologies and processes that the firm had to follow. Customers might also have different knowledge interpretations and languages in the knowledge sharing and learning process. Serving different customers in different industries led to the fact that intra-firm project teams had different knowledge domains, technologies and processes, while they were highly dispersed and engaged in many projects. Although sub-tier technology suppliers shared the same interests in developing firm technologies, their technological maturity was superior and more complex for the firm to capture. In the GES innovation case, both customers and suppliers had different businesses and they might not be interested in developing the technologies that the firm was concerned with. Such knowledge interest differences prevented customers and suppliers from sharing knowledge with the firm. Intra-firm engineers, despite sharing similar interests in developing firm technologies, had different backgrounds that created knowledge gaps between them. Additionally, a key issue in knowledge sharing and network learning was intellectual properties. Informants highlighted the importance of not sharing information relating to these. They only shared or published customer information when they had customer consent. Therefore, boundary spanning mechanisms were employed by the case companies to address the following barriers and thus facilitate GES network learning:

- *Customer knowledge boundaries* - differences in knowledge interests, interpretations, and languages that hinder customer knowledge transfer to firms.
- *Supplier knowledge boundaries* - differences in knowledge interests, interpretations, and languages that hinder supplier knowledge transfer to firms.
- *Engineering unit knowledge boundaries* - differences in knowledge interests, interpretations and languages that hinder engineering unit knowledge transfer to firms.

7.3.4. Boundary Spanning Mechanisms

Many boundary spanning mechanisms have been identified within the industrial marketing and operations management literature (Moore and Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016; Breidbach and Maglio, 2016; Salonen et al., 2018). However, existing mechanisms are fragmented, facilitating either intra-firm network learning (Kotlarsky et al., 2014; Zhang et al., 2016) or inter-firm network learning (Brady and Davies, 2004; Breidbach and Maglio, 2016), and focusing on either efficiency (Moore and Birkinshaw, 1998; Brady and Davies, 2004) or innovation (Hoegl and Schulze, 2005; Todtling et al., 2009; Galbraith, 2014). It is argued that effective GES network learning relies on the application of a set of boundary spanning mechanisms, rather than adopting a separate single one (Kotlarsky et al., 2014). It is difficult to establish from the literature what, when and why a boundary spanning mechanism should be used to enhance GES network learning with customers, suppliers and intra-firm engineering units.

The three case studies approached GES network learning as an integrated process, incorporating customers, suppliers and intra-firm engineering units. This enabled the drawing up of a set of consistent boundary spanning mechanisms that can be employed to address the knowledge boundaries across customers, suppliers and intra-firm engineering units. The analysis of the three cases identified a set of boundary spanning mechanisms, including:

- *Boundary spanners* - e.g. individuals, teams and groups that help to transform, translate and transfer different knowledge across organisational and geographical boundaries.
- *Boundary spanning tools* - e.g. engineering information systems, standards, solution frameworks and technology platforms that guide the interactions and learning between different learning actors.
- *Technological mechanisms* - e.g. data mining software, the internet, and machine learning technologies that assist in capturing, interpreting, and disseminating information for decision making, knowledge creation and reuse.
- *Learning coordination* - e.g. methods, procedures and processes to integrate different dispersed actors for knowledge creation and reuse.
- *Knowledge governance* - e.g. methods, procedures and processes to encourage different dispersed actors to share their knowledge for learning.

There are variations in adopting boundary spanning mechanisms across customers, suppliers and intra-firm engineering units. The employed boundary spanning mechanisms differ in terms of the levels of (1) centralisation (or decentralisation), referring to the degree of central control to boundary spanners; (2) dispersion (or colocation), referring to the degree of geographical dispersion/ co-location of boundary spanners; (3) standardisation (or flexibility), referring to the degree of governance formality/ informality, such as learning coordination mechanisms, knowledge sharing procedures, routine, and learning incentive policies; and (4) unification (or customisation), referring to the degree of uniform/ localisation of supporting boundary spanning tools and technologies for network learning.

The analysis of the three cases shows that central/dispersed management teams are the boundary spanners who translate and transform customer information into engineering targets, standards and technology platforms. These types of knowledge guide the service innovation and improvement of intra-firm engineering units as they interact with customers, suppliers and other intra-firm engineering units. Central management teams subsequently play the roles of the supervisors and evaluators to ensure that the learning of engineering units and supplier-focused network learning aligns with the engineering and technology targets and platforms set by them.

Centralised/dispersed functional teams and technology taskforces are the boundary spanners who translate and transfer the knowledge of customers, intra-firm engineering units to the other engineering units and enable the knowledge creation and reuse of intra-firm engineering units. The employment of centralised boundary spanners aligns different knowledge interests and interpretations into common directions and platforms, facilitating knowledge sharing and learning between different organisational and geographical boundaries. Centralised boundary spanners are supported and combined with formal governance mechanisms and uniform boundary spanning tools and technologies to facilitate knowledge sharing and learning across globally dispersed actors who have different knowledge interests and interpretations.

Decentralised and co-located expert engineers within technology taskforces, research groups and engineering units are employed as boundary spanners to collaborate with each other (technology taskforces/virtual teams) and with sub-tier suppliers (local functional teams) who share the same knowledge interests but need to bridge the knowledge gaps between them. These boundary spanners are useful in facilitating knowledge creation and innovation. They are supported by informal governance mechanisms to facilitate mutual understanding and adopt customised software and technologies for their specialised operations.

7.3.5. Values

The literature on the value creation of the firm highlights the importance of network learning for it (Powell et al., 1996; Kogut, 2000). Firms can create value through intra- and/or inter-firm network learning (Chai et al., 2003; Dyer & Nobeoka, 2000; Westerlund, 2010). These types of learning create value through enhanced network efficiency (Chai et al., 2003; Dyer & Nobeoka, 2000) and innovation (Criscuolo & Narula, 2007; Moller and Rajala, 2007). Although network learning is essential for firm value creation, past research mainly emphasises the network learning that creates use value and captures exchange value inside firms for the consumption of customers (Dyer & Nobeoka, 2000; Harryson et al., 2008). Recent research on GES network learning highlights that GES firms can create value by using intra-firm or inter-firm GES network learning with customers and suppliers (Kotlarsky et al, 2014; Zhang et al, 2016; Moller and Rajala, 2007; Jaakkoola and Hakanen, 2013). However, the literature on GES value creation has viewed these processes independently and there is little connection between inter- and intra-firm network learning processes in creating value for firms (Salonen et al., 2018). The analysis in this study shows that GES network learning creates value through an integrated inter- and intra-firm network learning process (Figure 7-5).

Inter- and intra-firm network learning contributes to the creation of value through a combination of inter-related knowledge reuse for innovation, and knowledge creation and reuse across customers, suppliers and intra-firm engineering units. The knowledge captured within inter-firm network learning can be used for intra-firm network learning to enhance GES performance in terms of:

- *Efficiency* - GES operations implement their engineering tasks with fewer resources.
- *Innovation* - GES operations create novel solutions driven by customers more effectively.
- *Flexibility* - GES operations respond quickly to changing customer demands for efficiency and innovation.

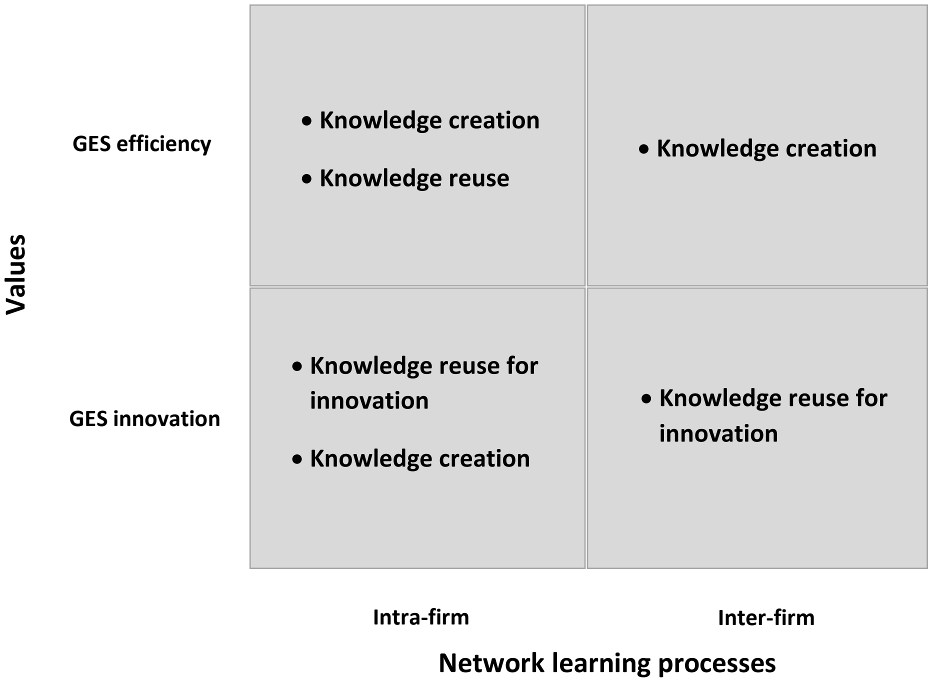


Figure 7-5: GES network learning and value creation

Other values. The analysis of the three cases reveals that besides efficiency, flexibility and innovation, GES network learning with customers, suppliers and intra-firm engineering units can generate other non-monetary value, such as knowledge and relationships. GES network learning enables the enhancement of customer and supplier relationships, while long-term relationships with customers ensure future business awards (e.g. ODCs) and customer support (e.g. R&D investment, support, consulting), and partnerships with suppliers provide many benefits such as membership operational support, shared ideas and benefits and learning. Customers and suppliers are also sources of information for knowledge co-creation and information for future opportunities, which are valuable for firms' future development. However, learning with customers and suppliers leads to risks such as high staff turnover, knowledge leakage and inappropriate learning. Intra-firm network learning enables different engineering units to share knowledge and enhance collaboration, creating a learning culture and common identity among diverse engineering units.

Value capture. Value created in in the relationship learning with customers and suppliers can be captured by firms, customers or suppliers (Jaakkola and Hakanen, 2013). Although value capture is not within the scope of this study, the analysis implies that firms may or may not benefit from the learning with customers or suppliers. For example, in the efficiency case, the company had two fixed-price CoEs set up for learning with new customers or difficult projects. Profit might not be the priority in these projects, but their learning might be commercialised in other projects with other customers. In the innovation case, the company granted updated licences free-of-charge to consortia and non-profit customers to gain access to customers' data and consultancy. Its learning was integrated within the company software and could be used for other commercial purposes. In the flexibility case, the companies shared ideas and benefits with partner suppliers but might expose themselves to knowledge leakage. These factors may prevent customers and suppliers from engaging in GES network learning. Future research is required for further understanding of GES network learning from the viewpoints of customers and suppliers in order to develop the framework further.

7.4. Theoretical Contributions

7.4.1. Operations Management

The integrated framework contributes conceptually to the literature on GES operations management. Past research has highlighted GES network learning for value creation as a set of knowledge reuse and creation and supporting knowledge management mechanisms between engineering units such as individual, project teams, and engineering centres (Moore and Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016). However, prior research has mainly focused on network learning and knowledge management with intra-firm engineering units while there has been less exploration of network learning practices with customers, suppliers, and intra-firm engineering units. The integrated framework in this study extends the literature by clarifying the roles of customers and suppliers in GES network learning and value creation. It offers an integrated approach to network learning and value creation by highlighting a set of interrelated knowledge acquisition processes across customers, suppliers, and intra-firm engineering units, rather than independent processes as having been developed within the existing literature. It also elaborates the knowledge management mechanisms that support the integrated network learning process which is not clear in the literature.

7.4.2. Innovation Management

The literature on GES innovation management has shown that GES firms can adopt an integrated GES network learning with customers, suppliers and intra-firm engineering units to facilitate GES innovation and performance (Brady and Davies, 2004; Salonen et al., 2018). However, prior research has mainly focused on organizational and business innovation, while GES network learning and innovation has been less explored (Brady and Davies, 2004). A few studies have attempted to examine GES network learning and performance enhancement (Salonen et al., 2018). However, their focuses are on a specific knowledge management mechanisms that facilitate GES network learning such as modularity and platforms rather than an integrated process. This study thus provides a comprehensive understanding of GES network learning and performance enhancement.

The framework suggests a set of knowledge acquisition processes and boundary spanning mechanisms across customers, suppliers and intra-firm engineering units that contribute to GES performance. This integrated approach to GES innovation supports the innovation value chain framework in knowledge-based services, in which external relationships contribute to idea generation, firm knowledge transformation and exploitation (Hansen and Birkinshaw, 2007; Love et al., 2011). It adds to this literature by providing empirical evidences within GES firm contexts which is sparse in the literature.

7.5. Managerial Implications

In addition to its theoretical contribution, the study has been motivated by managerial considerations. Network learning has been recognised as an important process for GES firms in maintaining their competitiveness in the dynamic global context (Moore and Birkinshaw, 1998; Zhang et al., 2016). However, the network learning literature has not yet provided good guidance for firms on leveraging network learning in an integrated approach for their GES operations. The integrated framework in this study should be useful for managers who wish to understand and implement integrated network learning for enhancing GES network performance.

It suggests that managers can approach GES network learning and value creation by adopting a set of interrelated knowledge acquisition processes across customers, suppliers, and intra-firm engineering units. By applying these processes, GES firms should focus on combining a set of boundary spanners and governance mechanisms to facilitate knowledge sharing and learning between customers, suppliers, and intra-firm engineering units. There are three important factors that managers should pay attention in applying integrated network learning.

7.5.1. Promoting Customer Knowledge Sharing

GES network learning is promoted when customers cooperate and share knowledge. This study suggests that customers are willing to cooperate with GES firms for knowledge sharing and learning when they trust the firm's performance and can gain benefits from the collaboration. Trust can be built through formal mechanisms. The formal affiliation of third parties who customers trust is important to demonstrate firm abilities. In the efficiency case, the company partnered with technology suppliers trusted by customers to gain trust and be awarded businesses. The innovation case company affiliated itself with regulatory agencies, research institutions and scientific publications to demonstrate its abilities and to obtain support from customers. Customers can benefit from firms' third party affiliations through the opportunities to access these third parties. GES firms can create strategic alliances and partnership relationships with third parties. Customers are thus motivated to learn with the firms in order to have access to their partners, for example in firm strategic alliances or joint development projects.

Investment and commitment with operational excellence and technology innovation are important for building customer trust. In the flexibility case, the firm committed to formal operational improvement programs and invested in new technologies to gain customer trust. IP protection facilitates customer knowledge sharing, as customers do not want to share their confidential information with other parties. The three cases show that they did not share customer information without customer consent. Operational openness and transparency are critical, as customers want to know what GES firms are doing benefit them. In many situations, incentives can be useful to foster customer cooperation in learning. The case studies showed that GES firms provided incentives in order to have learning opportunities with customers, such as low fixed-prices that customers wanted to pay, a free-of-charge software licence, or risk/benefit sharing in operational and technological co-development.

7.5.2. Promoting Supplier Knowledge Sharing

GES network learning can be enhanced by integrating supplier knowledge. Supplier capabilities can help GES firms to improve their operations and develop new technologies. The results of this study suggest that supplier cooperation can be built through formal and informal mechanisms. GES firms can sign contracts with technology suppliers to co-develop technologies within joint development projects. Through this formal coordination, technology suppliers with different interests are motivated to share their relevant knowledge with GES firms.

Informal mechanisms can be adopted to motivate sub-tier suppliers to cooperate in GES network learning, sharing their ideas and benefits with the firm. There are many informal ways firms can use to promote supplier cooperation; for example, they can follow supplier requirements. In the efficiency case, the firm obtained supplier certifications and served a number of customers in order to establish supplier partnerships. Partner membership helped the firm to gain supplier support in GES operations. The flexibility case selected suppliers who were willing to learn, and established supplier clusters as platforms to share ideas and benefits with suppliers. Collaborative relationships are based on trust, shared benefits and informal governance mechanisms. Suppliers and GES firms collaborate to co-develop and compete effectively in changing global contexts.

7.5.3. Employing Boundary Spanners and Governance Mechanisms

Inter- and intra-firm network learning needs to cope with many challenges relating to knowledge boundaries between diverse customers, suppliers and intra-firm engineering units. This study suggests that firms should employ a set of boundary spanners and governance mechanisms to cope with knowledge boundaries and thus facilitate GES network learning.

Boundary spanners. Firms can use three types of boundary spanners to bridge the knowledge gaps between customers, suppliers and engineering units. To facilitate knowledge creation, centralised charismatic CoEs are essential to create technology platforms, targets and topics that create shared interests and enhance knowledge sharing between customers, suppliers and intra-firm engineering units who have different knowledge interests. Centralised functionally-focused CoEs then help to economise knowledge transfer and sharing between learning actors. In the context in which customers, suppliers and intra-firm engineering units have common interests, decentralised local functional teams, engineering taskforces and virtual CoEs are more relevant in facilitating mutual understanding and knowledge creation.

Boundary spanning tools and technologies. As customers, suppliers and intra-firm engineering units are globally dispersed and generate a high volume of information, GES network learning relies on boundary spanning tools and technologies to support its knowledge sharing, interpreting and distributing. In the context of high dispersion and knowledge interest differences between customers, suppliers and intra-firm engineering units, centralised and uniform information systems, technology platforms and learning technologies should be employed to align the dispersed, diverse and high volume information of learning actors in the GES network learning process. For network learners who share common interests, decentralised and localised information systems, engineering topics and learning technologies are preferred to facilitate creativity and innovation between learning actors.

Governance mechanisms. Different customers, suppliers and intra-firm engineering units should be governed economically in GES network learning. When these have different interests and are highly dispersed, standardised procedures, routines and policies for learning coordination and knowledge sharing are important to align their different interests and reduce the cost of communication caused by organisational dispersion and complexity. For those who have common interests, flexible governance is more relevant to encourage mutual understanding, creativity and innovation.

7.6. Research Limitations and Directions for Future Studies

This study has a number of limitations that offer opportunities for future research. First, the research has focused on GES network learning and value creation from the perspective of the firm, highlighting the network learning practices that contribute to firm value creation. The integrated framework developed does not consider the views of customers or suppliers of this process. Future studies can develop this framework by examining customer and supplier views on firm network learning processes, which may help to reveal other influencing factors, such as competitors, knowledge leakage, inappropriate learning and value capture, which may affect firms' GES network learning.

Second, the study has examined product development services for the benefit of customer processes. These are largely related to customer process support services, involving the development of a new product. There are other solution services, such as basic installed base, product maintenance and operations, and professional services in which customers and suppliers have different demands, expectations and perhaps interactions with GES firms (Kujala et al., 2010; Oliva & Kallenberg, 2003). In fact, these services are additional value-added services to GES and may require different GES network learning practices to create value. Additionally, the study only investigated GES in which the integrating role of the firm is important. Future studies cpould expand or test the framework by applying it to other service industries, such as finance, marketing or entertainment, in which customers and suppliers might also be the key players in network learning. For example, a key account management team (KAM) between customers, suppliers and firms should be established for network learning (Hakanen, 2014).

Third, the integrated framework is developed for network firms with consideration into the wider context with its customers and suppliers. An increasing number of studies have focused on inter-firm network learning processes, identifying a variety of inter-firm network learning mechanisms (Gibb, Sune, & Albers, 2017; Morris et al., 2006; Peters et al., 2016). Despite being contextually different, many network learning mechanisms developed in this research are similar to those developed in previous studies, but the validity of the proposed framework within the inter-firm network context remains to be proven.

This research is based on an intensive three-case study research design rather than adopting an extensive research design. Because integrated GES network learning is complex, involving customers, suppliers and intra-firm global engineering units, the thesis has proposed three different cases to develop a research sample for theory building, rather than theory testing. This sampling strategy offered the opportunity to capture GES network learning fully in different contexts, enabling theoretical replication to be achieved. The three cases enabled an in-depth investigation of theoretical and empirical understanding, which would not have been possible if the researcher had adopted an extensive approach.

In fact, the analysis of the three case studies has identified commonalities and differences in GES network learning patterns, highlighting that the proposed GES network learning framework is likely to be valid in other contexts. Future research could test the framework with larger samples to enhance its validity.

7.7. Conclusion

The study was designed to examine how GES firms manage network learning for value creation. It has shown that they can use integrated GES network learning, including a set of interrelated knowledge acquisition processes and knowledge management mechanisms across customers, suppliers and intra-firm engineering units to enhance GES efficiency and innovation.

The research has resulted in an integrated framework that offers a more holistic insight into GES network learning and value creation. Additionally, the framework enriches the literature on innovation management by providing evidence of an integrated inter- and intra-firm network learning process that facilitates GES innovation. The framework suggests a set of boundary spanning mechanisms for firms to promote GES network learning and value creation in changing global market.

Future research could develop the framework by examining the views of customers and suppliers on firms’ integrated network learning processes, which may help to reveal more insights. It is also suggested that future studies could enhance the framework validity by applying it to other GES services, business service industries and inter-organizational networks, and with larger samples.

REFERENCES

Abdelzaher, D. M. (2012). The impact of professional service firms' expansion challenges on internationalization processes and performance. *The Service Industries Journal, 32*(10), 1721-1738. doi:10.1080/02642069.2012.665901

Adenfelt, M., & Lagerström, K. (2006). Knowledge development and sharing in multinational corporations: The case of a centre of excellence and a transnational team. *International Business Review, 15*(4), 381-400.

Afify, A. A., & Pham, D. T. (2005). Machine-learning techniques and their applications in manufacturing. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 219*(5), 395-412. doi:10.1243/095440505x32274

Alavi, M., & Leidner, D. E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS quarterly*, 107-136.

Alvesson, M., & Kärreman, D. (2001). Odd couple: making sense of the curious concept of knowledge management. *Journal of management studies, 38*(7), 995-1018.

Anderson, J. C., & Narus, J. A. (1998). Business marketing: understand what customers value. *Harvard business review, 76*, 53-67.

Araujo, L., Dubois, A., & Gadde, L. E. (2003). The multiple boundaries of the firm. *Journal of management studies, 40*(5), 1255-1277.

Argote, L. (1999). Organizational Learning: Creating. *Retaining and Transferring*.

Argote, L., & Ingram, P. (2000). Knowledge transfer: A basis for competitive advantage in firms. *Organizational behavior and human decision processes, 82*(1), 150-169.

Argote, L., & Kane, A. A. (2009). Superordinate identity and knowledge creation and transfer in organizations. *Knowledge governance*, 166-190.

Argote, L., & Miron-Spektor, E. (2011). Organizational learning: From experience to knowledge. *Organization science, 22*(5), 1123-1137.

Argyris, C., & Schön, D. (1978). Organizational Learning, Readings. *MA: Addison*.

Ayala, N. F., Paslauski, C. A., Ghezzi, A., & Frank, A. G. (2017). Knowledge sharing dynamics in service suppliers' involvement for servitization of manufacturing companies. *International Journal of Production Economics, 193*, 538-553.

Bagchi, P. K., & Skjoett-Larsen, T. (2003). Integration of information technology and organizations in a supply chain. *The International Journal of Logistics Management, 14*(1), 89-108.

Baines, T., Lightfoot, H., Benedettini, O., & Kay, J. (2009). The servitization of manufacturing: A review of literature and reflection on future challenges. *Journal of Manufacturing Technology Management, 20*(5), 547-567.

Baines, T., & W. Lightfoot, H. (2013). Servitization of the manufacturing firm. *International Journal of Operations & Production Management, 34*(1), 2-35. doi:10.1108/ijopm-02-2012-0086

Barratt, M. (2004). Understanding the meaning of collaboration in the supply chain. *Supply Chain Management: An International Journal, 9*(1), 30-42.

Barratt, M., Choi, T. Y., & Li, M. (2011). Qualitative case studies in operations management: Trends, research outcomes, and future research implications. *Journal of Operations management, 29*(4), 329-342.

Bazeley, P. and Jackson, K. eds., 2013. Qualitative data analysis with NVivo. Sage Publications Limited.

Bhaskar, R. (2013). *A realist theory of science*: Routledge.

Birkinshaw, J. (2002). Managing internal R&D networks in global firms: what sort of knowledge is involved? *Long Range Planning, 35*(3), 245-267.

Birkinshaw, J., & Hansen, M. T. (2007). The innovation value chain. *Harvard business review, 85*(6), 121-130.

Blaikie, N. (2007). *Approaches to social enquiry: Advancing knowledge*: Polity.

Bose, I., & Mahapatra, R. K. (2001). Business data mining—a machine learning perspective. *Information & management, 39*(3), 211-225.

Bowman, C., & Ambrosini, V. (2000). Value creation versus value capture: towards a coherent definition of value in strategy. *British Journal of Management, 11*(1), 1-15.

Bowman, C., & Ambrosini, V. (2007). Firm value creation and levels of strategy. *Management Decision, 45*(3), 360-371.

Brady, T., & Davies, A. (2004). Building project capabilities: from exploratory to exploitative learning. *Organization studies, 25*(9), 1601-1621.

Breidbach, C. F., & Maglio, P. P. (2016). Technology-enabled value co-creation: An empirical analysis of actors, resources, and practices. *Industrial marketing management, 56*, 73-85.

Brown, J. S., & Duguid, P. (1998). Organizing knowledge. *California management review, 40*(3), 90-111.

Brown, J. S., & Duguid, P. (2001). Knowledge and organization: A social-practice perspective. *Organization science, 12*(2), 198-213.

Bryman, A. (2015). *Social research methods*: Oxford university press.

Cagliano, R., Caniato, F., & Spina, G. (2006). The linkage between supply chain integration and manufacturing improvement programmes. *International Journal of Operations & Production Management, 26*(3), 282-299.

Capaldo, A. (2014). Network governance: A cross-level study of social mechanisms, knowledge benefits, and strategic outcomes in joint-design alliances. *Industrial marketing management, 43*(4), 685-703. doi:10.1016/j.indmarman.2014.02.002

Carlile, P. R. (2002). A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organization science, 13*(4), 442-455.

Carlile, P. R. (2004). Transferring, translating, and transforming: An integrative framework for managing knowledge across boundaries. *Organization science, 15*(5), 555-568.

CAS. (2014). Annual report. *Cambridge Service Alliance, University of Cambridge*.

Cenamor, J., Rönnberg Sjödin, D., & Parida, V. (2017). Adopting a platform approach in servitization: Leveraging the value of digitalization. *International Journal of Production Economics, 192*, 54-65. doi:10.1016/j.ijpe.2016.12.033

Cenamor, J., Sjödin, D. R., & Parida, V. (2017). Adopting a platform approach in servitization: Leveraging the value of digitalization. *International Journal of Production Economics, 192*, 54-65.

Chai, K.-H., Gregory, M., & Shi, Y. (2003). Bridging islands of knowledge: a framework of knowledge sharing mechanisms. *International journal of technology management, 25*(8), 703-727.

Chase, R. B. (1981). The customer contact approach to services: theoretical bases and practical extensions. *Operations research, 29*(4), 698-706.

Cheung, P.-K., Chau, P. Y., & Au, A. K. (2008). Does knowledge reuse make a creative person more creative? *Decision Support Systems, 45*(2), 219-227.

Childerhouse, P., & Towill, D. R. (2011). Arcs of supply chain integration. *International journal of production research, 49*(24), 7441-7468.

Christensen, C. M., Carlile, P., & Sundahl, D. (2002). The process of theory building. *Harvard Business School, Cambridge, MA, Harvard University, 17*.

Coghlan, D., & Coughlan, P. (2014). Effecting Change and Learning in Networks Through Network Action Learning. *The Journal of Applied Behavioral Science, 51*(3), 375-400. doi:10.1177/0021886314540210

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative science quarterly*, 128-152.

Coopey, J. (1995). The learning organization, power, politics and ideology introduction. *Management learning, 26*(2), 193-213.

Cornet, E., Katz, R., Molloy, R., Schädler, J., Sharma, D., & Tipping, A. (2000). Customer solutions: From pilots to profits. *Booz Allen & Hamilton, New York*.

Criscuolo, P., & Narula, R. (2007). Using multi-hub structures for international R&D: organisational inertia and the challenges of implementation. *Management International Review, 47*(5), 639-660.

Crossan, M. M., Lane, H. W., White, R. E., & Djurfeldt, L. (1995). Organizational learning: Dimensions for a theory. *The International Journal of Organizational Analysis, 3*(4), 337-360.

Cyert, R. M., & March, J. G. (1963). A behavioral theory of the firm. *Englewood Cliffs, NJ, 2*.

Daft, R. L., & Weick, K. E. (1984). Toward a model of organizations as interpretation systems. *Academy of management review, 9*(2), 284-295.

Daniels, P., & Bryson, J. (2002). Manufacturing services and servicing manufacturing: knowledge-based cities and changing forms of production. *Urban Studies, 39*(5-6), 977-991.

Davenport, T. H., & Prusak, L. (1998). *Working knowledge: How organizations manage what they know*: Harvard Business Press.

Davies, A., Brady, T., & Hobday, M. (2007). Organizing for solutions: Systems seller vs. systems integrator. *Industrial marketing management, 36*(2), 183-193.

Denzin, N. K. (1978). Triangulation: A case for methodological evaluation and combination. *Sociological methods*, 339-357.

Dias, W. (2007). Philosophical grounding and computational formalization for practice based engineering knowledge. *Knowledge-Based Systems, 20*(4), 382-387.

Dittrich, K., & Duysters, G. (2007). Networking as a means to strategy change: the case of open innovation in mobile telephony. *Journal of Product Innovation Management, 24*(6), 510-521.

Doz, Y., & Santos, J. F. (1997). On the management of knowledge: From the transparency of collocation and co-setting to the quandary of dispersion and differentiation.

Durbin, P. T. (1991). *Critical perspectives on nonacademic science and engineering* (Vol. 4): Lehigh University Press.

Durcikova, A., Fadel, K. J., Butler, B. S., & Galletta, D. F. (2011). Research note—knowledge exploration and exploitation: the impacts of psychological climate and knowledge management system access. *Information Systems Research, 22*(4), 855-866.

Dyer, J. H., & Nobeoka, K. (2000). Creating and managing a high-performance knowledge-sharing network: the Toyota case. *Strategic management journal*, 345-367.

Earl, M. (2001). Knowledge management strategies: Toward a taxonomy. *Journal of management information systems, 18*(1), 215-233.

Easterby-Smith, M., Thorpe, R., & Jackson, P. R. (2012). *Management research*: Sage.

Easterby-Smith, M., Lyles, M. A., & Tsang, E. W. (2008). Inter-organizational knowledge transfer: Current themes and future prospects. *Journal of management studies, 45*(4), 677-690.

Edmondson, A. C., & McManus, S. E. (2007). Methodological fit in management field research. *Academy of management review, 32*(4), 1246-1264.

Edwards, T., Battisti, G., & Neely, A. (2004). Value creation and the UK economy: a review of strategic options. *International Journal of Management Reviews, 5*(3-4), 191-213.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of management review, 14*(4), 532-550.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *The Academy of Management Journal, 50*(1), 25-32.

Eloranta, V., & Turunen, T. (2016). Platforms in service-driven manufacturing: Leveraging complexity by connecting, sharing, and integrating. *Industrial marketing management, 55*, 178-186. doi:10.1016/j.indmarman.2015.10.003

Ernst & Young Survey Report (2018). How are engineering and construction companies adapting digital to their businesses? https://www.ey.com/Publication/vwLUAssets/EY-Digital-survey/$File/EY-Digital-survey.pdf

Ettlie, J. E., & Kubarek, M. (2008). Design reuse in manufacturing and services. *Journal of Product Innovation Management, 25*(5), 457-472.

Fernandez-Stark, K., Bamber, P., & Gereffi, G. (2010). Engineering services in the Americas. *Center on globalization, governance & competitiveness*, 1-99.

Filieri, R., & Alguezaui, S. (2015). Knowledge sourcing and knowledge reuse in the virtual product prototyping: an exploratory study in a large automotive supplier of R&D. *Expert Systems, 32*(6), 637-651.

Fine, C. H. (1998). *Clockspeed: Winning industry control in the age of temporary advantage*: Basic Books.

Fiol, C. M., & Lyles, M. A. (1985). Organizational learning. *Academy of management review, 10*(4), 803-813.

Fleck, J. (1997). Contingent knowledge and technology development. *Technology analysis & strategic management, 9*(4), 383-398.

Flynn, B. B., Sakakibara, S., Schroeder, R. G., Bates, K. A., & Flynn, E. J. (1990). Empirical research methods in operations management. *Journal of Operations management, 9*(2), 250-284.

Forsgren, M., Pedersen, T., & Foss, N. J. (1999). Accounting for the strengths of MNC subsidiaries: the case of foreign-owned firms in Denmark. *International Business Review, 8*(2), 181-196.

Foss, N. J. (2007). The emerging knowledge governance approach: Challenges and characteristics. *Organization, 14*(1), 29-52.

Foss, N. J., & Michailova, S. (2009). *Knowledge governance: Processes and perspectives*: Oxford University Press.

Frohlich, M. T., & Westbrook, R. (2001). Arcs of integration: an international study of supply chain strategies. *Journal of Operations management, 19*(2), 185-200.

Fruchter, R., & Demian, P. (2002). CoMem: Designing an interaction experience for reuse of rich contextual knowledge from a corporate memory. *Ai Edam, 16*(03), 127-147.

Galbraith, J. R. (2002). Organizing to deliver solutions. *Organizational dynamics, 31*(2), 194-207.

Galbraith, J. R. (2014). *Designing organizations: Strategy, structure, and process at the business unit and enterprise levels*: John Wiley & Sons.

Garvin, D. A., Edmondson, A. C., & Gino, F. (2008). Is yours a learning organization? *Harvard business review, 86*(3), 109.

Gassmann, O., & Von Zedtwitz, M. (1999). New concepts and trends in international R&D organization. *Research Policy, 28*(2), 231-250.

Gibb, J., Sune, A., & Albers, S. (2017). Network learning: Episodes of interorganizational learning towards a collective performance goal. *European Management Journal, 35*(1), 15-25. doi:10.1016/j.emj.2016.09.001

Gilbert, M., & Cordey-Hayes, M. (1996). Understanding the process of knowledge transfer to achieve successful technological innovation. *Technovation, 16*(6), 301-312.

Goffin, K., Koners, U., Baxter, D., & Van der Hoven, C. (2010). Managing lessons learned and tacit knowledge in new product development. *Research-Technology Management, 53*(4), 39-51.

Goldstein, S. M., Johnston, R., Duffy, J., & Rao, J. (2002). The service concept: the missing link in service design research? *Journal of Operations management, 20*(2), 121-134.

Gond, J.-P., & Herrbach, O. (2006). Social reporting as an organisational learning tool? A theoretical framework. *Journal of Business Ethics, 65*(4), 359-371.

Granovetter, M. (1985). Economic action and social structure: The problem of embeddedness. *American journal of sociology, 91*(3), 481-510.

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic management journal, 17*(S2), 109-122.

Gray, P. H., & Meister, D. B. (2006). Knowledge sourcing methods. *Information & management, 43*(2), 142-156.

Grix, J. (2002). Introducing students to the generic terminology of social research. *Politics, 22*(3), 175-186.

Gronroos, C. (1990). Service management and marketing. In: Lexington Books, Lexington, MA.

Grönroos, C. (2011). Value co-creation in service logic: A critical analysis. *Marketing theory, 11*(3), 279-301.

Grönroos, C., & Helle, P. (2010). Adopting a service logic in manufacturing: Conceptual foundation and metrics for mutual value creation. *Journal of Service Management, 21*(5), 564-590.

Gupta, A. K., Smith, K. G., & Shalley, C. E. (2006). The interplay between exploration and exploitation. *Academy of management journal, 49*(4), 693-706.

GVR, (2017). Engineering Services Outsourcing (ESO) Market Analysis By Application (Aerospace, Automotive, Construction, Semiconductor, Pharmaceutical, Telecom), By Location, By Region, And Segment Forecasts, 2014 - 2025.

http://www.grandviewresearch.com/industry-analysis/engineering-services-outsourcing-market.

Hakanen, T. (2014). Co-creating integrated solutions within business networks: The KAM team as knowledge integrator. *Industrial marketing management, 43*(7), 1195-1203. doi:10.1016/j.indmarman.2014.08.002

Hakanen, T., & Jaakkola, E. (2012). Co-creating customer-focused solutions within business networks: a service perspective. *Journal of Service Management, 23*(4), 593-611.

Hansen, M. T. (1999). The search-transfer problem: The role of weak ties in sharing knowledge across organization subunits. *Administrative science quarterly, 44*(1), 82-111.

Hansen, M. T. (2002). Knowledge networks: Explaining effective knowledge sharing in multiunit companies. *Organization science, 13*(3), 232-248.

Hansen, M. T., Nohria, N., & Tierney, T. (1999). What's your strategy for managing knowledge? *The knowledge management yearbook 2000–2001*, 1-10.

Harryson, S. J., Dudkowski, R., & Stern, A. (2008). Transformation networks in innovation alliances–the development of Volvo C70. *Journal of management studies, 45*(4), 745-773.

Helander, A., & Möller, K. (2007). System supplier's customer strategy. *Industrial marketing management, 36*(6), 719-730.

Hill, T. P. (1977). On goods and services. *Review of income and wealth, 23*(4), 315-338.

Hislop, D. (2009). *Knowledge management in organizations: A critical introduction*: Oxford University Press.

Hoegl, M., & Schulze, A. (2005). How to Support Knowledge Creation in New Product Development:: An Investigation of Knowledge Management Methods. *European Management Journal, 23*(3), 263-273.

Huber, G. P. (1991). Organizational learning: The contributing processes and the literatures. *Organization science, 2*(1), 88-115.

Husted, K., & Michailova, S. (2009). Socialization tactics as a governance mechanism in R&D collaborations. *Knowledge Governance: Processes and Perspectives*, 191-219.

Inkpen, A. C., & Pien, W. (2006). An examination of collaboration and knowledge transfer: China–Singapore Suzhou Industrial Park. *Journal of management studies, 43*(4), 779-811.

Inkpen, A. C., & Tsang, E. W. (2005). Social capital, networks, and knowledge transfer. *Academy of management review, 30*(1), 146-165.

ISG. (2013). Robust growth for engineering services outsourcing: spend shifts to emerging markets; captives reassessed. https://www.isg-one.com/docs/default-source/default-document-library/94-eso-market-trends_interactive.pdf?sfvrsn=0.

ISG. (2016). The Three Waves in the Evolution of the Engineering Services Outsourcing Industry. *at* https://www.isg-one.com/docs/default-source/default-document-library/evolving-engineering-services.pdf?sfvrsn=0.

Jaakkola, E., & Hakanen, T. (2013). Value co-creation in solution networks. *Industrial marketing management, 42*(1), 47-58. doi:10.1016/j.indmarman.2012.11.005

Johnstone, S., Dainty, A., & Wilkinson, A. (2009). Integrating products and services through life: an aerospace experience. *International Journal of Operations & Production Management, 29*(5), 520-538.

Kaiser, S., & Ringlstetter, M. J. (2010). *Strategic management of professional service firms: theory and practice*: Springer Science & Business Media.

Kaplinsky, R., & Morris, M. (2000). *A handbook for value chain research* (Vol. 113): University of Sussex, Institute of Development Studies.

Kellogg, D. L., & Nie, W. (1995). A framework for strategic service management. *Journal of Operations management, 13*(4), 323-337.

Ketokivi, M., & Choi, T. (2014). Renaissance of case research as a scientific method. *Journal of Operations management, 32*(5), 232-240.

Kirby, R. S. (1990). *Engineering in history*: Courier Corporation.

Knight, L. (2002). Network learning: Exploring learning by interorganizational networks. *Human relations, 55*(4), 427-454.

Knight, L., & Pye, A. (2004). Exploring the relationships between network change and network learning. *Management learning, 35*(4), 473-490.

Knight, L., & Pye, A. (2005). Network learning: An empirically derived model of learning by groups of organizations. *Human relations, 58*(3), 369-392.

Koen, B. V. (2003). *Discussion of the method: Conducting the engineer's approach to problem solving*: Oxford University Press on Demand.

Kogut, B. (2000). The network as knowledge: Generative rules and the emergence of structure. *Strategic management journal*, 405-425.

Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization science, 3*(3), 383-397.

Kotlarsky, J., Scarbrough, H., & Oshri, I. (2014). Coordinating expertise across knowledge boundaries in offshore-outsourcing projects: The role of codification. *Management Information Systems Quarterly, 38*(2), 607-627.

Kristjánsson, B., Helms, R., & Brinkkemper, S. (2012). Integration by communication: knowledge exchange in global outsourcing of product software development. *Expert Systems*.

Kujala, S., Artto, K., Aaltonen, P., & Turkulainen, V. (2010). Business models in project-based firms–Towards a typology of solution-specific business models. *International journal of project management, 28*(2), 96-106.

Lam, A. (1997). Embedded firms, embedded knowledge: Problems of collaboration and knowledge transfer in global cooperative ventures. *Organization studies, 18*(6), 973-996.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*: Cambridge university press.

Leca, B., & Naccache, P. (2006). A critical realist approach to institutional entrepreneurship. *Organization, 13*(5), 627-651.

Leonard, D., & Sensiper, S. (1998). The role of tacit knowledge in group innovation. *California Management Review, 40*(3), 112-132.

Lepak, D. P., Smith, K. G., & Taylor, M. S. (2007). Value creation and value capture: a multilevel perspective. *Academy of management review, 32*(1), 180-194.

Levitt, B., & March, J. G. (1988). Organizational learning. *Annual review of sociology, 14*(1), 319-338.

Liao, S.-H., Chu, P.-H., & Hsiao, P.-Y. (2012). Data mining techniques and applications – A decade review from 2000 to 2011. *Expert Systems with Applications, 39*(12), 11303-11311. doi:10.1016/j.eswa.2012.02.063

Love, J. H., Roper, S., & Bryson, J. R. (2011). Openness, knowledge, innovation and growth in UK business services. *Research Policy, 40*(10), 1438-1452.

Lovelock, C., & Gummesson, E. (2004). Whither services marketing? In search of a new paradigm and fresh perspectives. *Journal of service research, 7*(1), 20-41.

Lusch, R. F., Vargo, S. L., & Tanniru, M. (2010). Service, value networks and learning. *Journal of the academy of marketing science, 38*(1), 19-31.

Majchrzak, A., Cooper, L. P., & Neece, O. E. (2004). Knowledge reuse for innovation. *Management Science, 50*(2), 174-188.

Malhotra, A., Gosain, S., & Sawy, O. A. E. (2005). Absorptive capacity configurations in supply chains: gearing for partner-enabled market knowledge creation. *MIS quarterly*, 145-187.

Malhotra, N., & Morris, T. (2009). Heterogeneity in professional service firms. *Journal of management studies, 46*(6), 895-922.

March, J. G. (1991). Exploration and exploitation in organizational learning. *Organization science, 2*(1), 71-87.

Markus, L. M. (2001). Toward a theory of knowledge reuse: Types of knowledge reuse situations and factors in reuse success. *Journal of management information systems, 18*(1), 57-93.

Mathieu, V. (2001). Product services: from a service supporting the product to a service supporting the client. *Journal of Business & Industrial Marketing, 16*(1), 39-61.

Matthyssens, P., & Vandenbempt, K. (2008). Moving from basic offerings to value-added solutions: Strategies, barriers and alignment. *Industrial marketing management, 37*(3), 316-328.

McCutcheon, D. M., & Meredith, J. R. (1993). Conducting case study research in operations management. *Journal of Operations management, 11*(3), 239-256.

McDermott, R. (1999). Why information technology inspired but cannot deliver knowledge management. *California management review, 41*(4), 103-117.

Meijboom, B., Voordijk, H., & Akkermans, H. (2007). The effect of industry clockspeed on supply chain co-ordination: Classical theory to sharpen an emerging concept. *Business Process Management Journal, 13*(4), 553-571.

Metters, R., & Marucheck, A. (2007). Service management—academic issues and scholarly reflections from operations management researchers. *Decision Sciences, 38*(2), 195-214.

Mikkola, J. H. (2003). Modularity, component outsourcing, and inter-firm learning. *R&D Management, 33*(4), 439-454.

Miles, L. (1985). Techniques of value analysis and engineering. 1961. In: McGraw-Hill, New York.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*: sage.

Miller, D., Hope, Q., Eisenstat, R., Foote, N., & Galbraith, J. (2002). The problem of solutions: balancing clients and capabilities. *Business horizons, 45*(2), 3-12.

Miller, K. D., & Tsang, E. W. (2010). Testing management theories: critical realist philosophy and research methods. *Strategic Management Journal, 32*(2), 139-158.

Miner, A. S., & Mezias, S. J. (1996). Ugly duckling no more: Pasts and futures of organizational learning research. *Organization science, 7*(1), 88-99.

Mohan Reddy, N. (1991). Defining product value in industrial markets. *Management Decision, 29*(1).

Möller, K., & Rajala, A. (2007). Rise of strategic nets—New modes of value creation. *Industrial marketing management, 36*(7), 895-908.

Möller, K., & Svahn, S. (2003). *Role of knowledge in the value creation in business nets*: Citeseer.

Montavon, G., Rupp, M., Gobre, V., Vazquez-Mayagoitia, A., Hansen, K., Tkatchenko, A., . . . Von Lilienfeld, O. A. (2013). Machine learning of molecular electronic properties in chemical compound space. *New Journal of Physics, 15*(9), 095003.

Moore, K., & Birkinshaw, J. (1998). Managing knowledge in global service firms: centers of excellence. *The academy of Management executive, 12*(4), 81-92.

Morris, M., Bessant, J., & Barnes, J. (2006). Using learning networks to enable industrial development: Case studies from South Africa. *International Journal of Operations & Production Management, 26*(5), 532-557.

Myers, M. B., & Cheung, M.-S. (2008). Sharing global supply chain knowledge. *MIT Sloan Management Review, 49*(4), 67.

Neely, A., Benedettini, O. and Visnjic, I., 2011, July. The servitization of manufacturing: Further evidence. *In 18th European operations management association conference* (Vol. 1).

Newell, A., & Simon, H. A. (1972). *Human problem solving* (Vol. 104): Prentice-Hall Englewood Cliffs, NJ.

Nickerson, J. A., & Zenger, T. R. (2004). A knowledge-based theory of the firm—The problem-solving perspective. *Organization science, 15*(6), 617-632.

Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. *Organization science, 5*(1), 14-37.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*: Oxford university press.

Nonaka, I., Toyama, R., & Konno, N. (2000). SECI, Ba and leadership: a unified model of dynamic knowledge creation. *Long Range Planning, 33*(1), 5-34.

Normann, R., & Ramirez, R. (1993). From value chain to value constellation: Designing interactive strategy. *Harvard business review, 71*(4), 65-77.

O'Cass, A., & Ngo, L. V. (2011). Examining the firm's value creation process: a managerial perspective of the firm's value offering strategy and performance. *British Journal of Management, 22*(4), 646-671.

Oliva, R., & Kallenberg, R. (2003). Managing the transition from products to services. *International journal of service industry management, 14*(2), 160-172.

Osterloh, M., & Weibel, A. (2009). The governance of explorative knowledge production. *Knowledge governance-processes and perspectives*, 138-165.

Palo, T., & Tähtinen, J. (2011). A network perspective on business models for emerging technology-based services. *Journal of Business & Industrial Marketing, 26*(5), 377-388.

Payne, A. C., Chelsom, J. V., & Reavill, L. R. (1996). *Management for engineers*: Wiley Chichester.

Pedler, M., Boydell, T., & Burgoyne, J. (1991). The learning company: a strategy for sustainable development (Maidenhead, McGraw Hill).

Pekkarinen, S., & Ulkuniemi, P. (2008). Modularity in developing business services by platform approach. *The International Journal of Logistics Management, 19*(1), 84-103. doi:10.1108/09574090810872613

Peters, L. D., Pressey, A. D., & Johnston, W. J. (2016). Contingent factors affecting network learning. *Journal of Business Research, 69*(7), 2507-2515.

Petroski, H. (1992). Engineering: History and failure. *American Scientist, 80*(6), 523-526.

Pitelis, C. N. (2009). The co-evolution of organizational value capture, value creation and sustainable advantage. *Organization studies, 30*(10), 1115-1139.

Polanyi, M. (1967). The Tacit Dimension New York. *Garden City, 4*.

Porter, M. E., & Advantage, C. (1985). Creating and sustaining superior performance. *Competitive advantage*, 167.

Powell, W., & Grodal, S. (2005). Networks of innovators. *The Oxford handbook of innovation*, 56-85.

Powell, W. W., Koput, K. W., & Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative science quarterly*, 116-145.

Ravald, A., & Grönroos, C. (1996). The value concept and relationship marketing. *European journal of marketing, 30*(2), 19-30.

Reed, M. (2005). Reflections on the ‘realist turn’in organization and management studies. *Journal of Management Studies, 42*(8), 1621-1644.

Reger, G. (2004). Coordinating globally dispersed research centres of excellence—the case of Philips Electronics. *Journal of International Management, 10*(1), 51-76.

Rogers, G. F. C. (1983). The Nature of Engineering a Philosophy of Technology.

Salonen, A., Rajala, R., & Virtanen, A. (2018). Leveraging the benefits of modularity in the provision of integrated solutions: A strategic learning perspective. *Industrial marketing management, 68*, 13-24.

Sampson, S. E., & Froehle, C. M. (2006). Foundations and implications of a proposed unified services theory. *Production and operations management, 15*(2), 329-343.

Sasser, W. E., Olsen, R. P., & Wyckoff, D. D. (1978). *Management of service operations: Text, cases, and readings*: Allyn & Bacon.

Sayer, A. (2000). *Realism and social science*: Sage.

Scarbrough, H., & Amaeshi, K. (2009). Knowledge governance for open innovation: evidence from an EU R&D collaboration. *Knowledge governance: perspectives, processes and problems. Oxford University Press, Oxford*, 220-246.

Schuman, H., & Scott, J. (1989). Generations and collective memories. *American sociological review*, 359-381.

Shi, Y., & Gregory, M. (1998). International manufacturing networks—to develop global competitive capabilities. *Journal of Operations management, 16*(2), 195-214.

Sicilia, M.-a., García-Barriocanal, E., Sánchez-Alonso, S., & Rodríguez-García, D. (2009). Ontologies of engineering knowledge: General structure and the case of software engineering. *The Knowledge Engineering Review, 24*(03), 309-326.

Siggelkow, N. (2007). Persuasion with case studies. *Academy of management journal, 50*(1), 20-24.

Simpson, T. W., Siddique, Z., & Jiao, J. R. (2006). Platform-based product family development. In *Product platform and product family design* (pp. 1-15): Springer.

Sirmon, D. G., Hitt, M. A., & Ireland, R. D. (2007). Managing firm resources in dynamic environments to create value: Looking inside the black box. *Academy of management review, 32*(1), 273-292.

Sirmon, D. G., & Lane, P. J. (2004). A model of cultural differences and international alliance performance. *Journal of International Business Studies, 35*(4), 306-319.

Smith, K. A. (1988). The nature and development of engineering expertise. *European Journal of Engineering Education, 13*(3), 317-330.

Söderquist, K. E. (2006). Organising knowledge management and dissemination in new product development: lessons from 12 global corporations. *Long Range Planning, 39*(5), 497-523.

Soosay, C. A., Hyland, P. W., & Ferrer, M. (2008). Supply chain collaboration: capabilities for continuous innovation. *Supply Chain Management: An International Journal, 13*(2), 160-169.

Spender, J.-C. (1996). Organizational knowledge, learning and memory: three concepts in search of a theory. *Journal of organizational change management, 9*(1), 63-78.

Spohrer, J., & Maglio, P. P. (2008). The emergence of service science: Toward systematic service innovations to accelerate co-creation of value. *Production and Operations management, 17*(3), 238-246.

Storbacka, K. (2011). A solution business model: Capabilities and management practices for integrated solutions. *Industrial marketing management, 40*(5), 699-711. doi:10.1016/j.indmarman.2011.05.003

Strauss, A., & Corbin, J. (1998). Basics of qualitative research: Procedures and techniques for developing grounded theory. In: Thousand Oaks, CA: Sage.

Subrahmanian, E., Rachuri, S., Fenves, S. J., Foufou, S., & Sriram, R. D. (2005). Product lifecycle management support: a challenge in supporting product design and manufacturing in a networked economy. *International Journal of Product Lifecycle Management, 1*(1), 4-25.

Szulanski, G. (1996). Exploring internal stickiness: Impediments to the transfer of best practice within the firm. *Strategic management journal, 17*(S2), 27-43.

Szulanski, G. (2000). The process of knowledge transfer: A diachronic analysis of stickiness. *Organizational behavior and human decision processes, 82*(1), 9-27.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic management journal*, 509-533.

Thomas, L. D., Autio, E., & Gann, D. M. (2014). Architectural leverage: putting platforms in context. *The Academy of Management Perspectives, 28*(2), 198-219.

Tidd, J. (2006). A review of innovation models. *Imperial College London, 16*.

Tidd, J., Bessant, J., & Pavitt, K. (2005). *Managing innovation integrating technological, market and organizational change*: John Wiley and Sons Ltd.

Tidd, J., & Hull, F. M. (2006). Managing service innovation: the need for selectivity rather than 'best practice'. *New Technology, Work and Employment, 21*(2), 139-161.

Tödtling, F., Lehner, P., & Kaufmann, A. (2009). Do different types of innovation rely on specific kinds of knowledge interactions? *Technovation, 29*(1), 59-71.

Trent, R. J., & Monczka, R. M. (1998). Purchasing and supply management: trends and changes throughout the 1990s. *Journal of Supply Chain Management, 34*(3), 2-11.

Tuli, K. R., Kohli, A. K., & Bharadwaj, S. G. (2007). Rethinking customer solutions: From product bundles to relational processes. *Journal of marketing, 71*(3), 1-17.

Turner, J. R., & Keegan, A. (2001). Mechanisms of governance in the project-based organization:: Roles of the broker and steward. *European Management Journal, 19*(3), 254-267.

Valtakoski, A. (2017). Explaining servitization failure and deservitization: A knowledge-based perspective. *Industrial marketing management, 60*, 138-150. doi:10.1016/j.indmarman.2016.04.009

Vargo, S. L., & Lusch, R. F. (2004). Evolving to a new dominant logic for marketing. *Journal of marketing, 68*(1), 1-17.

Vargo, S. L., & Lusch, R. F. (2008). Service-dominant logic: continuing the evolution. *Journal of the academy of marketing science, 36*(1), 1-10.

Vargo, S. L., Maglio, P. P., & Akaka, M. A. (2008). On value and value co-creation: A service systems and service logic perspective. *European Management Journal, 26*(3), 145-152.

Vereecke, A., Van Dierdonck, R., & De Meyer, A. (2006). A typology of plants in global manufacturing networks. *Management Science, 52*(11), 1737-1750.

Von Nordenflycht, A. (2010). What is a professional service firm? Toward a theory and taxonomy of knowledge-intensive firms. *Academy of management review, 35*(1), 155-174.

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management, 22*(2), 195-219.

Weick, K. E., & Roberts, K. H. (1993). Collective mind in organizations: Heedful interrelating on flight decks. *Administrative science quarterly*, 357-381.

Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems thinker, 9*(5), 2-3.

Westerlund, M., & Rajala, R. (2010). Learning and innovation in inter-organizational network collaboration. *Journal of Business & Industrial Marketing, 25*(6), 435-442.

Whitaker, J., Mithas, S., & Krishnan, M. S. (2010). Organizational learning and capabilities for onshore and offshore business process outsourcing. *Journal of management information systems, 27*(3), 11-42.

Wiengarten, F., Humphreys, P., Cao, G., Fynes, B., & McKittrick, A. (2010). Collaborative supply chain practices and performance: exploring the key role of information quality. *Supply Chain Management: An International Journal, 15*(6), 463-473.

Wilson, D. T., & Jantrania, S. (1994). Understanding the value of a relationship. *Asia-Australia marketing journal, 2*(1), 55-66.

Windahl, C., & Lakemond, N. (2006). Developing integrated solutions: The importance of relationships within the network. *Industrial marketing management, 35*(7), 806-818.

Winter, S. G., & Nelson, R. R. (1982). An evolutionary theory of economic change.

Wise, R., & Baumgartner, P. (1999). Go downstream, the new profit imperative in manufacturing. *Harvard Business Rev., Sept.–Oct*, 133–141.

Wise, R., & Baumgartner, P. (1999). Go downstream. The new profit imperative in manufacturing. *Harvard business review, 77*(5).

Womack, J. P., & Jones, D. T. (1996). Lean thinking: Banish waste and create wealth in your organisation. *Simon and Shuster, New York, NY, 397*.

Wuest, T., Weimer, D., Irgens, C., & Thoben, K.-D. (2016). Machine learning in manufacturing: advantages, challenges, and applications. *Production & Manufacturing Research, 4*(1), 23-45. doi:10.1080/21693277.2016.1192517

Yin, R. K. (2003). Case Study Research: Design and Methods. edition. In: Thousand Oaks, CA: Sage.

Zack, M. H. (1999). Managing codified knowledge. *Sloan management review, 40*(4), 45.

Zander, U., & Kogut, B. (1995). Knowledge and the speed of the transfer and imitation of organizational capabilities: An empirical test. *Organization science, 6*(1), 76-92.

Zeithaml, V. A. (1988). Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence. *The Journal of marketing*, 2-22.

Zeithaml, V. A., Parasuraman, A., & Berry, L. L. (1985). Problems and strategies in services marketing. *The Journal of Marketing*, 33-46.

Zhang, Y., & Gregory, M. (2011). Managing global network operations along the engineering value chain. *International Journal of Operations & Production Management, 31*(7), 736-764.

Zhang, Y., Gregory, M., & Neely, A. (2016). Global engineering services: Shedding light on network capabilities. *Journal of Operations management, 42*, 80-94.

Zhang, Y., Gregory, M., & Shi, Y. (2007). Global engineering networks: the integrating framework and key patterns. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 221*(8), 1269-1283.

Zhang, Y., Gregory, M., & Shi, Y. (2008). Global engineering networks (GEN) Drivers, evolution, configuration, performance and key patterns. *Journal of Manufacturing Technology Management, 19*(3), 299-314.

Zhang, Y., Gregory, M., & Shi, Y. (2014a). Managing global engineering networks part I: Theoretical foundations and the unique nature of engineering. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 228*(2), 163-171.

Zhang, Y., Gregory, M., & Shi, Y. (2014b). Managing global engineering networks part II: Case studies and directions for the future research. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 228*(2), 172-180.

Zhang, Y., & Zhang, L. (2014). Organizing complex engineering operations throughout the lifecycle: A service-centred view and case studies. *Journal of Service Management, 25*(5), 580-602.

APPENDIX 1: KEY PAPERS ON NETWORK LEARNING OF THE FIRM

Authors	**Network learning**				
	Nature	**role**	**context**	**practices**	**outcome**
Moore and Birkinshaw (1998)	Knowledge leverage across dispersed divisions	Leverage dispersed intangible knowledge across countries	Global Service operations network of a firm; intangible knowledge dispersion	Centres of excellence as the vehicles to capture, interpret and disseminate knowledge across network members	Network performance enhancement
Dyer and Nobeoka (2000)	Knowledge development and capture processes, network-specific mechanisms	Create network identity; prevent knowledge hiding and free rider	Vertical supply network (internal and external suppliers of a manufacturing firm)	Multilateral and bilateral routines, centralised supporting division, supporting teams, rules/ standards	Network performance enhancement, network changes
Knight (2002)	The fourth level of organizational learning	Shared cognitive and behaviour change across network	Inter-organizational networks (strategic and wider networks)	Network learning practices are embedded within a network learning episode	Network changes
Chai et al. (2003)	Knowledge transfer process (awareness and transfer)	Facilitate the “reach” of explicit knowledge transfer and the “rich” of tacit knowledge transfer	International manufacturing operations network of firms	Variety of social and information technology mechanisms for knowledge transfer	Network performance enhancement
Knight and Pie (2004)	Organizational processes and changes	Facilitate network changes	A national network of independent health service centres (horizontal network)	Processes and mechanisms developing method, commitment, meaning of network	Changes to network practices, structures, and interpretation
Brady and Davies (2004)	Exploratory and exploitative learning processes	Explore new knowledge and exploit existing dispersed knowledge for turnkey services development	Global manufacturing operations network of firms	Project-led and business-led learning processes	Network innovation, business innovation, new service development
Hoegl (2005)	Processes and mechanisms for knowledge creation	Facilitate new product development of the firms	Global R&D networks of firms	Informal events (socialisation); experience workshops, expert interviews, experience reports	Network performance enhancement

				(externalisation); communities of practice, project briefings, best practice cases, knowledge broker, databases (combination); research services (internalisation)	
Morris et al. (2006)	Knowledge acquisition, interpretation and application processes	Recognize best practices and disseminate to network members	Supplier association, supplier development programmes (horizontal network); tacit knowledge transfer	Workshops facilitated by a local university, technical task teams, inter-firm visits, newsletter, facilitators	Network operational performance
Criscuolo and Narula (2007)	Network Structural and social mechanisms	Overcome levels of inter-unit geographical, organisational and technological distance	Global R&D networks of firms	Global functions, specific task forces in particular target families (CoEs), cross-disciplinary boards, socialisation mechanisms, job rotations	Network performance enhancement
Scarbrough and Amaeshi (2009)	Knowledge sharing and creation	Facilitate knowledge creation and prevent knowledge spin-over (cause by opportunism and appropriate risk)	International R&D strategic network (A regional programme containing 63 companies and institutions coordinated by a lead firm)	Relational mechanisms, work packages (modularisation of knowledge), information technology	New engine/ airframe design & development for aerospace industry
Mason et al. (2012)	Knowledge processes of lead firm	Enhance supply network success	Supply network of a manufacturer and its business service providers (business network)	Supplier conference, tendering process	Network perception changes in terms of relationship, performance, resource boundaries, and structure
Kristjansson (2012)	Network knowledge transfer	Facilitate explicit and tacit knowledge transfer across network	Onshore-offshore engineering service operations network (client, vendor, and	Global knowledge systems with communication tools and codification templates	Network performance enhancement

			service providers) – business network		
Kotlarsky et al. (2014)	Network Knowledge sharing and reuse	Facilitate coordination of dispersed expertise and knowledge creation across network operations	Onshore-offshore engineering service operations network (client, vendor, and service providers) – business network	Knowledge codification and codification of knower in knowledge management system, Centres of excellence (Virtual CoEs)	Network performance enhancement (problem solving effectiveness)
Coghlan and Coughlan (2015)	Action learning processes (Collaborative problem-solving processes)	Network problems solving	Strategic supply network for productive service delivery – business network	Network monthly workshops, actions and reflection	Network operations enhancement
Peters et al. (2016)	Absorptive capacity process	Facilitate knowledge cognition and knowledge sharing in project network	Business network established to deliver construction projects	Social integration and power relations mechanisms	Network changes and performance enhancement
Gibb et al. (2016)	Knowledge creation and knowledge transfer and adoption processes	Deal with common problems of the whole industry	Horizontal Industrial network, network learning episodes (how to compete & how to perform)	Associations, Neutral body as central hub firm and firms' representatives, research project with international leaders (solution partnership), adoption partners	Network cognition and behaviour changes, network performance enhancement
Zhang et al. (2016)	Collective learning processes and knowledge management	Value creation	Global engineering service operations networks of GES firms	Knowledge reuse, creation and digital learning mechanisms	Network performance enhancement in terms of efficiency, flexibility, and innovation

APPENDIX 2: PRELIMINARY FRAMEWORK: CATEGORIES AND KEY ISSUES

Network learning	Operational factor	Key issues/ literature
GES network learning with customers and value creation		
Drivers	Changing customer demands	**A new demand for a new service** *(*Brady & Davies, 2004; Cenamor et al., 2017) **New demands for a new product** *(*Galbraith, 2014) **Changing expectations for operational and technological enhancements** (Johnstone et al., 2009)
Processes	Knowledge creation	**Project teams – customers co-creation** (Brady & Davies, 2004; Windahl and Lakemond, 2006) **Customer-focused relational learning process** (Tuli et al., 2007; Hakanen & Jaakkola, 2012)
	Knowledge reuse for innovation	**New product co-development between research groups – customers** (Majchrzak et al., 2004; Galbraith, 2014; Tidd, 2005) **Integrated product-service co-development with customers** (Mathieu, 2001; Breidbach & Maglio, 2016; Johnstone et al., 2009)
Customer knowledge boundaries	Interest differences	**Diverse customers in different industries and businesses** (e.g. horizontal and vertical customers) *(*Galbraith, 2002; Johnstone et al., 2009)
	Interpretation, language differences	**Diverse business domains, technologies and processes** (Brady & Davies, 2004; Kotlarsky et al., 2014)
Boundary spanning mechanisms	Boundary spanners	**Research groups** (Galbraith, 2014) **Central project taskforces** (Brady & Davies, 2004, Kotlarsky et al., 2014; Windahl & Lakemond, 2006) **Facilitators/conductors** (Breidbach & Maglio, 2016) **Engineering functions** (Soderquist, 2006; Johnstone et al., 2009)
	Spanning tools	**Global portal/ information systems** (Kristjánsson, Helms, & Brinkkemper, 2012; Breidbach & Maglio, 2016; Cinamor el.al., 2017) **Engineering platforms** (e.g. customer engineering requirements, new technologies, products, service concepts) (Tuli et al., 2007; Tidd, 2005; Galbraith, 2014; Johnstone et al., 2009)
	Learning coordination	**Formal project interactions** (e.g. onsite/offshore meetings, workshops) (Brady & Davies, 2004; Helander & Möller, 2007) **Informal consortium interactions** (Galbraith, 2014; Scarbrough & Amaeshi, 2009) **Solution documentation/ modularisation** (Cenamor et al., 2017, Kotlarsky et al., 2014)
	Knowledge governance	**Customer selection** (Cornet et al., 2001; Brady & Davies, 2004; Storbarka, 2011) **Trust and reputation** (Capaldo, 2014; Scarbrough & Amaeshi, 2009) **Agreed routines** (Mathieu, 2001; Windahl & Lakemond, 2006)
	Learning technologies	**Digital technologies** (e.g. cloud and analytic technologies for management) (Cenamor, Sjödin, & Parida, 2017; Zhang et al., 2016; Eloranta & Turunen, 2016)
Value creation	Monetary value	**Process-oriented and output-oriented solutions (**Breidbach & Maglio, 2016; Windahl & Lakemoon, 2006)
	Non-monetary value	**Relationships, knowledge, new services** (Brady & Davies, 2004; Windahl & Lakemoon, 2006; Hakanen & Jaakkola, 2012)

GES network learning with suppliers and value creation		
Drivers	Supplier capabilities	**Supplier operations** (Myer & Cheung, 2008; Coghlan & Coughlan, 2014, Salonen et al., 2017) **Supplier complementary technologies/services** (Windahl & Lakemond, 2006; Jaakkola & Hakanen, 2013; Tidtling et al, 2009, Tidd, 2005; Galbraith, 2014)
Processes	Knowledge creation	**e.g. Operational co-development; solution co-creation** (Coghlan & Coughlan, 2014; Salonen et al., 2017)
	Knowledge reuse for innovation	**e.g. New technology/service co-creation** (Chiesa & Manzini, 1998; Powell & Ghodal, 2005; Galbraith, 2014; Jaakkola & Hakanen, 2013; Windahl & Lakemond, 2006)
Supplier knowledge boundaries	Interest differences	**Diverse technology partners in different industries and areas** (Ayala et al., 2017; Myer & Cheung, 2008)
	Interpretation, language differences	**Sub-tier supplier operation differences** *(*Dyer & Nobeoka, 2000; Coghlan & Coughlan, 2014)
Boundary spanning mechanisms	Boundary spanners	**Decentralised voluntary teams** (Coghlan & Coughlan, 2014; Dyer & Nobeoka, 2000) **Technological researchers** (Todtling et al., 2009; Galbraith, 2014)
	Spanning tools	**Common operational topics** (Coghlan & Coughlan, 2014) **Common frameworks** (Peters et al., 2016) **Integrated information platforms** (Eloranta & Turunen, 2016; Salonen et al., 2017) **Solution platforms** (Salonen et al., 2018)
	Learning Coordination	**Formal coordination** (e.g. solution contracted projects) (Windahl & Lakemond, 2006; Jaakkola & Hakanen, 2013) **Hybrid coordination** (e.g. technology joint development) (Tidd, 2005; Todtling et al., 2009) **Informal coordination** (e.g. vertical supplier association meetings, action learning workshops, etc) (Coghlan & Coughlan, 2014; Dyer & Nobeoka, 2000) **Standardised modularisation** (Eloranta & Turunen, 2016; Salonen et al., 2017)
	Knowledge governance	**Informal mechanisms** (e.g. trust, rules, incentive and penalties for knowledge sharing with suppliers) (Capaldo, 2014; Dyer & Nobeoka, 2000, Marra et al., 2012) **Formal mechanisms** (e.g. project-based contracts, IP protection, agreed practices) (Windahl & Lakemond, 2006; Peters et al., 2016; Salonen et al., 2017)
	Learning technologies	**Digital internet technologies** (Salonen et al., 2017; Zhang et al., 2016)
Value creation	Monetary value	**New customer-driven solutions (**Windahl & Lakemoon, 2006**;** Jaakkola & Hakanen, 2013)
	Non-monetary value	**Stronger relationships, new knowledge and service** (Brady & Davies, 2004; Coghlan & Coughlan, 2014; Jaakkola & Hakanen, 2013)
GES network learning with intra-firm engineering units and value creation		
Drivers	Knowledge gaps between engineering units	**Network coordination for new product development** *(*Criscuolo & Narula, 2007; Reger 2004) **Knowledge transfer across countries for efficiency** (Moore & Birkinshaw, 1998; Kotlarsky et al., 2014)
Processes	Knowledge creation	**Knowledge creation** (Hoegl & Schulze, 2005; Criscuolo & Narula, 2007, Zhang et al., 2016)

	Knowledge reuse	**Knowledge transfer** (Argote & Ingram, 2000; Chai et al., 2003) **Knowledge reuse** (Moore & Birkinshaw, 1998; Markus, 2001; Kotlarsky et al., 2014)
Engineering unit knowledge boundaries	Interest differences	**Diverse engineering centres and project teams** (Kotlarsky et al., 2014; Criscuolo & Narula, 2007; Reger, 2004)
	Interpretation, language differences	**Engineering knowledge complexity** (Moore & Birkinshaw, 1998; Malhotra & Morris, 2009; Zhang et. al., 2014)
Boundary spanning mechanisms	Boundary spanners	**Charismatic centres of excellence** (Moore & Birkinshaw, 1998; Criscuolo & Narula, 2007; Reger, 2004, Adenfelt & Lagerström, 2006) **Focused centres of excellence** (Moore & Birkinshaw, 1998; Kotlarsky et al., 2014) **Virtual centres of excellence** (Moore & Birkinshaw, 1998; Zhang et al., 2016)
	Spanning tools	**Shared databases, standards, modules** (Kotlarsky et al., 2014; Zhang et al., 2016; Cenamor et al., 2017) **Common technology platforms** (Reger 2004; Criscuolo & Narula, 2007)
	Learning coordination	**Formal coordination** (Reger, 2004; Adenfelt & Lagerström, 2006) **Hybrid coordination** (e.g. taskforces, strategic projects) (Reger, 2004; Criscuolo & Narula, 2007, Todtling et al., 2009) **Informal coordination** (e.g. socialisation, rotations) (Reger, 2004; Criscuolo & Narula, 2007; Hoegl & Schulze (2005) **Internal market** (Reger, 2004) **Modularisation** (Eloranta & Turunen, 2016; Palo & Tähtinen, 2011; Storbacka, 2011) **Project knowledge codification** (Kotlarsky et al., 2014; Goffin et al., 2010)
	Knowledge governance	**Formal mechanisms** (e.g. standardised processes, Human Resource Management, incentives and rewards, budgeting for learning) (Hansen et al., 1999; Argote & Kane, 2009; Garvin, Edmondson, & Gino, 2008) **Informal mechanisms** (e.g. creativity encouragement, intrinsic motivation, favourable environment for innovation) (Pedler, Boydell, & Burgoyne, 1991; Hansen et al., 1999; Osterloh & Weibel, 2009)
	Learning technologies	**Digital technologies** (e.g. big data, internet of things and machine learning technologies) (Montavon et al., 2013; Wuest et al., 2016; Zhang et al., 2016)
Value creation	Monetary value	**Efficiency** (Moore & Birkinshaw, 1998; Kotlarsky et al., 2014); **flexibility** (Johnstone et al., 2009; Zhang et al., 2016); **Innovation** (Reger, 2004; Hoegl & Schulze, 2005).
	Non-monetary value	**Relationships and knowledge** (Criscuolo & Narula, 2007; Hoegl & Schulze, 2005)

APPENDIX 3: BACKGROUND OF OSCOM SERVICE OPERATIONS NETWORK

Company profile

At the time of this study, OSCOM was a global professional recruitment consultancy and Information Technology (IT) engineering service provider. OSCOM was founded in 1988 in the UK as a professional recruitment consultancy. The company run its information technology service business since 2000. OSCOM established two captive engineering centres in Asia and leverage the global network of 43 offices with over 7000 professionals in 26 countries to provide IT advisory, bespoke software development, outsourcing solutions and business process services to a wide range of customers worldwide. OSCOM was well-known as a leading global information technology (IT) service provider in South East Asia. Since OSCOM run its IT engineering service business, the company had a steady growth in revenue. It employed over 1500 engineers. In 2016, it witnessed a 48.2% growth in gross profits compared with the previous year. With a customer-focused and cost-saving strategy, OSCOM conducted an onshore-offshore business model in which offshore captive engineering centres worked closely with onshore offices as a network to ensure cost-effective and responsive solutions for a wide range of customers worldwide. Figure 1 presents OSCOM service business structure.

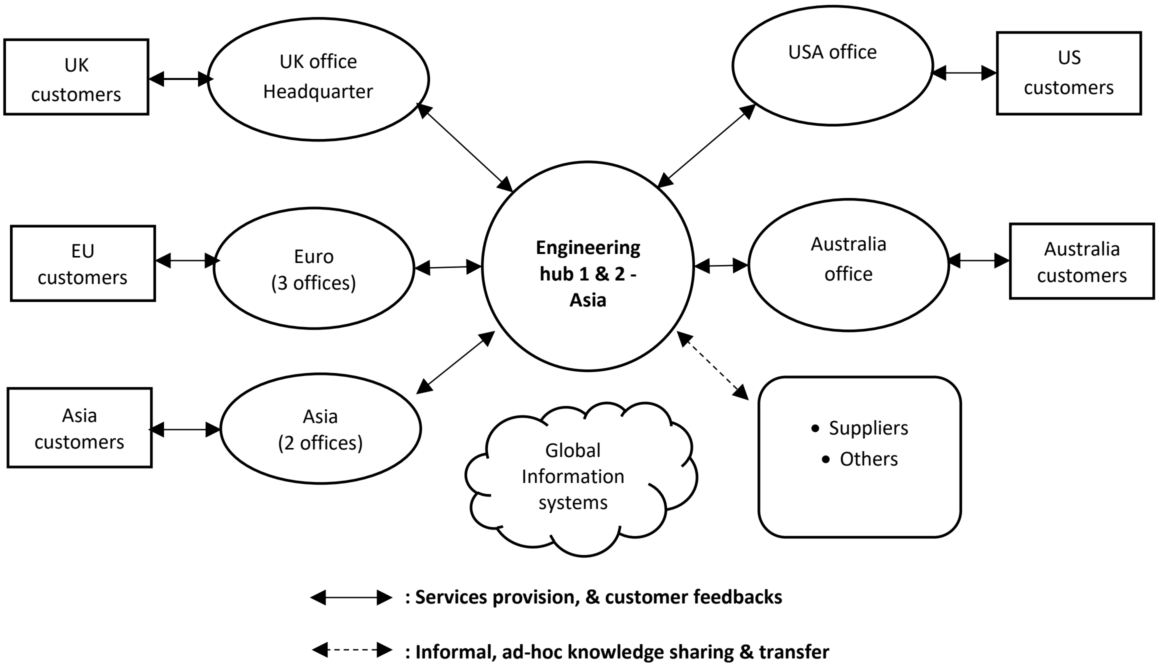


Figure A3- 1: OSCOM engineering service network structure

Source: Adapted from company website, documents, and interviews

OSCOM customers

OSCOM customers were global dispersed. They situated across many countries in four continents - Europe, the USA, Asia, and Australia. OSCOM customers operated in many industries, ranging from services to manufacturing. They could be very large customers such as Google, Ford, the NHS and Honda, to small ones. They could be the end-users or service vendors. Despite being diverse, OSCOM customers shared a common demand for cost-effective solutions as the managing director stressed: “Customers know what they want, and they want to have cost effective solutions to address their needs.”

OSCOM engineering units

OSCOM engineering units included the different IT engineers, expert groups (e.g. project teams and functions), and engineering centres/offices. They were organized in a complex network structure (Figure 2). In fact, OSCOM had over 1500 engineers who permanently and temporally worked at the two engineering centres and offices across the globe. Generally, engineers were business analysts, system architects, information technology developers, testers. They had different engineering backgrounds and skills such as Java, LAMP (Linux-Apache-MySQL-PHP), Mobile, DBA (Database administration), FE (Fundamental IT Engineer Examination), “.Net”, and so on. Engineers were integrated in projects, taskforces and functions within engineering centres and offices to deliver services to clients.

OSCOM suppliers

There were a few suppliers OSCOM collaborated to generate solutions effectively. Suppliers were mainly technology suppliers providing OSCOM knowledge on software development processes and leading-edge information technologies for its operations. For many years, OSCOM was a Microsoft Gold Certified partner for multiple disciplines. OSCOM was also the partner of Amazon Web Services (AWS) providing cloud computing technology for individuals, groups and organizations. Also, the company partnered with a few non-profit standard development organizations to capture global standards for IT operations and management. OSCOM was the members of international standard organizations such as ISO and CMMI.

Other suppliers were skills and capabilities providers. A few suppliers were integrated to fill the skill and business model gaps. They helped to increase OSCOM capability in conducting onshore-nearshore-offshore business model. Additionally, OSCOM partnered with some key clients to develop new IT engineering services. The company also actively engaged in local and international professional groups such as national outsourcing associations (UK), global sourcing associations, and online professional forums to update and develop new technological trends.

IT engineering services

OSCOM services improved its customer business processes through IT advisory, bespoke software development, business process outsourcing solutions. IT advisory services facilitated client digital transformations and addressed today client business challenges. These services involved customer business research, analysis and solution recommendations. The extensive understanding of business challenges enabled OSCOM to leverage experiences and expertise across industries to ask questions, to seek the right answers, and to provide advices as well as IT solutions for client business challenges.

Bespoke software development services were customer-focused solution services. These services were undertaken by a pool of talented engineers who applied their technological knowledge and engineering techniques to bring in the best innovative and practical solutions according to client needs and requirements in various sectors. Software development services covered all information technology languages such as Java, .Net, and HTML and emerging technologies such as mobile, cloud, system integration, digital platform development, progress solutions and analytics. Additionally, OSCOM offered business process outsourcing solutions which were tailored for specific process requirements of customers from process design, governance, and administration to delivery.

Operations – Matrix organization for service delivery

Engineering capabilities were classified into 14 competency divisions embedded within the two engineering centres in Asia. Service operations were based on a matrix organization of competence divisions in which engineers were distributed to form cross functional teams in projects to deliver services to clients across countries. Operations were customer-focused and combined local expertise with offshore teams in a collaborative manner. Customers, onshore, and offshore teams worked in tandem to enable the engagement and monitor of all parties during the service production.

Figure 2 provides a general view of OSCOM complex operational structure. The organizational chart and activity flows illustrates the collaboration between the onshore offices, offshore engineering centres and customers. In fact, OSCOM grouped project teams according to five regions: the UK (Euro), the US, Japan, Asian Pacific (APAC), and Fixed price groups. Furthermore, engineers were grouped into specialised taskforces to support project operations. They were also temporally or permanently sent to 8 offices to work with customers worldwide.

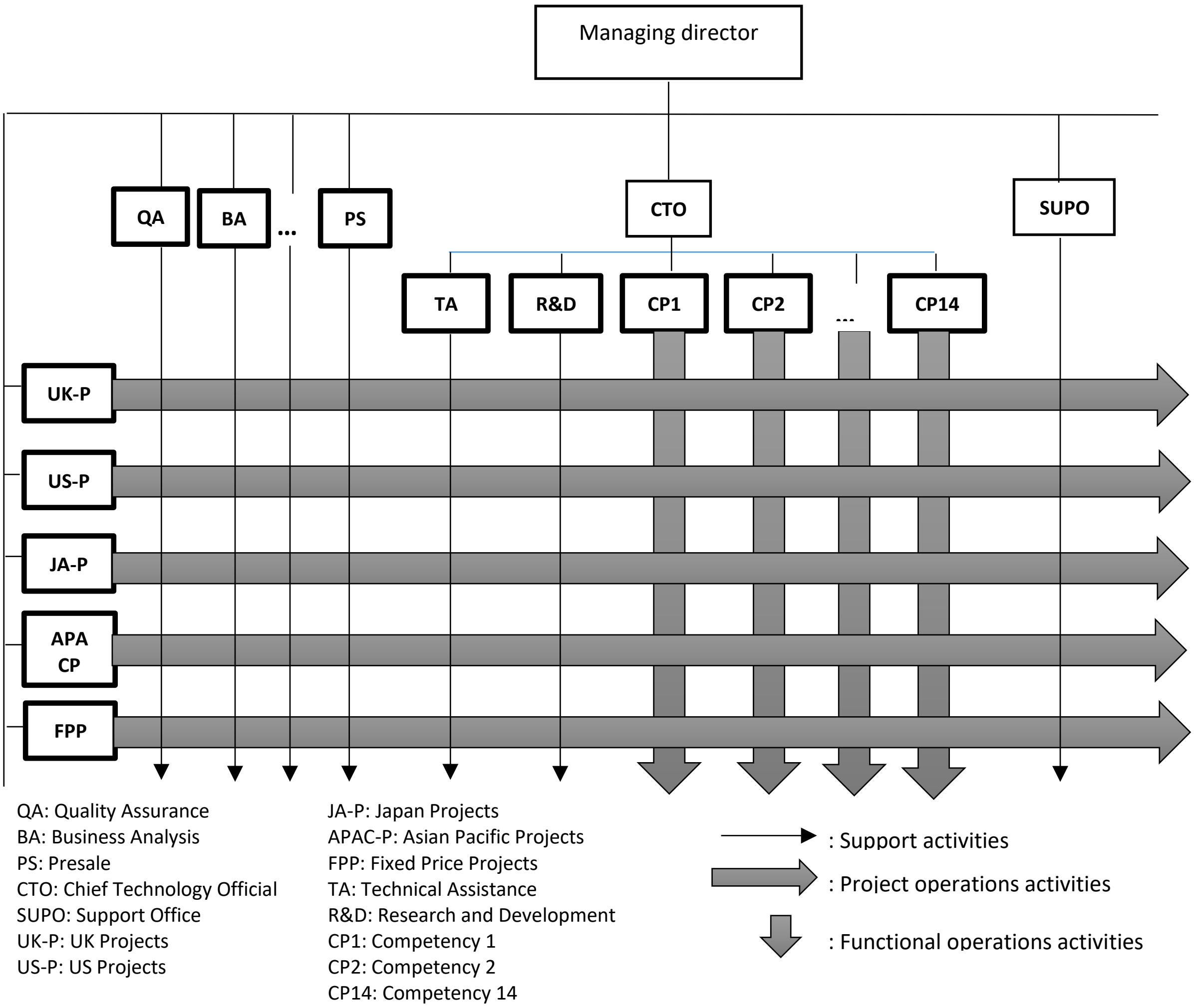


Figure A3- 2: OSCOM onshore-offshore operations organization chart

Source: Adapted from company internal documents and interviews

GES network learning purposes

In order to create cost-effective services for customers worldwide, OSCOM focused on:

- Excellent standardised operations: OSCOM continuously maintained CMMI level 5, the highest level for operational continuous improvement in the IT industry. The company followed international standard such as ISO 27001 and global standards for IT management.
- Customer-focused: building relationships through innovative solutions with cost-effective operations.
- Technology innovation: continuously updating technology trends and selectively developing technologies to meet customer changing demands.

GES network learning was conducted to facilitate the above strategic priorities. The main strategic approach of GES network learning at OSCOM was cost-effective solutions.

APPENDIX 4: BACKGROUND OF APPCOM SERVICE OPERATIONS NETWORK

Company profile

By the time this study conducted in 2016, APPCOM was a global components and sub-systems producer which provided engineering solutions for the aerospace, defence and energy industries. The company had a long tradition rooting back in 1850s. After more than 150 year history of development in aerospace and energy industries, the company had five engineering divisions with over 52 sites around the world and employed around 11,000 engineers. Engineering sites were located in North America, the UK and Europe, and Asia Pacific. Services included engineering solutions for aircraft braking systems, control systems, polymers and composites, sensing systems and customised equipment. As a pioneer in technologies with a clear technology leadership strategy, the company was a global leading tier 1 and 2 supplier in aerospace industry, providing solutions to many large global companies in the aerospace and energy sectors and generating approximately £2 billion in revenue in 2016. Figure 1 exhibits the key characteristics of APPCOM engineering service business structure.

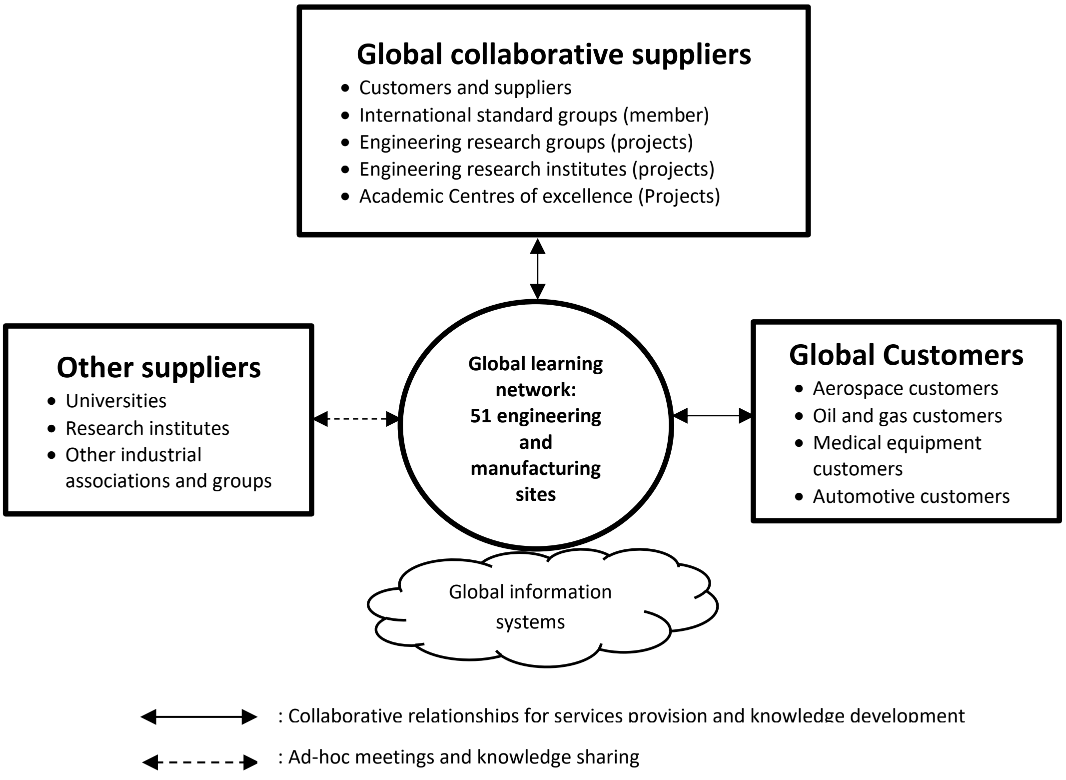


Figure A4- 1: APPCOM engineering service network structure

Source: Adapted from company website, documents and interviews

APPCOM customers

APPCOM provided engineering services to a few large customers. Airbus, BAE Systems, Boeing, Bombardier, General Electric, Honeywell, Lockheed Martin, Raytheon, Rolls-Royce, and United Technologies Corporation were mong leading aerospace customers of APPCOM. The company also provided engineering solutions to large companies in the energy sector, such as Petrobras, Shell, and Siemens (10% revenue). A small amount of revenue came from customers in medical device and automotive industries (2%).

APPCOM engineering units

APPCOM employed approximately 11,000 engineers around the world. Most of them (92%) were based in the USA, the UK and Europe. They had diverse education backgrounds in engineering and operations. The disciplines varied widely, ranging from systems engineering, mechanical engineering, electrical engineering, material sciences, design engineering, production engineering, and operations management and so on. Additionally, engineers were international and had diverse cultures.

APPCOM had the following five key engineering divisions:

(1) Aircraft braking systems: this division specialised in providing aircraft braking systems to a diverse group of customers in the aerospace industry. The division held the leading position in aircraft wheels, brakes and brake control systems and its products were used on thousands of civil aircrafts. The division had six sites which are located in the USA (3 sites), Mexico (2 sites), and the UK.

(2) Control systems: this division specialised in supplying fire protection and control, pneumatics, fluid control, thermal management and electro-mechanical equipment and sub-systems. The division had nine sites which are located in the USA (6 sites) and the UK (3 sites).

(3) Equipment Division: this division specialised in applying company competencies to specialist customers. The division had eight sites in the following countries: the USA (3 sites), the UK (3 sites), Spain (1 site), and China (1 site).

(4) Polymers and Composites Division: this division specialised in solving problems relating to fuel containment and systems, sealing and advanced composites. The division was located mainly in the USA (6 sites), the UK (3 sites) and Mexico (2 sites).

(5) Sensing Systems: this division specialised in designing products to operate under harsh and demanding conditions. The division had 17 sites worldwide, including 5 sites in the USA, 6 sites in Europe, 3 sites in the UK, 1 site in China, 1 site in India and 1 site in Vietnam.

APPCOM also had a services and support division located in Singapore, which linked maintenance services from all other divisions with global customers' needs. All of the divisions operated separately. They were integrated with each other through projects and programmes to fulfil the customer requirement packages.

At the Group level, APPCOM had five central functions:

(1) Applied research and technology was a centralised team who coordinated experts across group divisions to generate new technologies for the group
(2) Operations was the division responsible for developing best practices for engineering and manufacturing operations across the group.
(3) Programme management was the team who manage programmes across business.
(4) Sales and marketing was the team responsible to sell systems, to manage channel and distribution partners.
(5) Supply chain was the team managing suppliers and purchasing across the group.
(6) Strategy was the team responsible for finding strategies to understand customer need, to enhance operation efficiency and competitiveness.

APPCOM suppliers

APPCOM had approximately 6000 direct suppliers globally. Suppliers range from 3 people in a small workshop to large multinational corporations. Suppliers varied from physical components providers to engineering research institutes, universities and technological partners. The relationships with suppliers could be arm's length or collaborative.

APPCOM collaborated with a variety of suppliers to develop not only new technologies but also new standards, and new ways of doing things. The collaboration forms were diverse, ranging from joint venture and/or development to collaborative networks. In addition, APPCOM actively participated in international standard groups and associations where key suppliers and customers were involved in developing standards and best practices for the aerospace industry.

APPCOM engineering services

At the time of this study, APPCOM was the global leading provider of over 25 capabilities. Table 1 presents some examples of key capabilities. These capabilities were applied to customer requirements in several industries, including aerospace, defence, energy, automotive and medical. But most of the applications were concentrated in civil aerospace industries, which account for over 50% of APPCOM revenue.

Table A4- 2: APPCOM engineering divisions and capabilities

Aircraft braking systems	Control systems	Equipment group	Polymers and composites	Sensing systems
• Aircraft brakes & wheels • Braking control systems • Braking monitoring systems	• Aerospace valve systems • Thermal management systems • High pressure ducting systems • Electro-mechanical products • Industrial controls and ground fuelling systems • Safety systems	• Defence systems • Training systems • Position sensors and controls • Heat exchange services • Other services	• Fuel containment and systems • Sealing solutions • Advanced composites	• Avionics, inertial sensing and ignition • Power and motion • Performance sensing • Sensing and monitoring

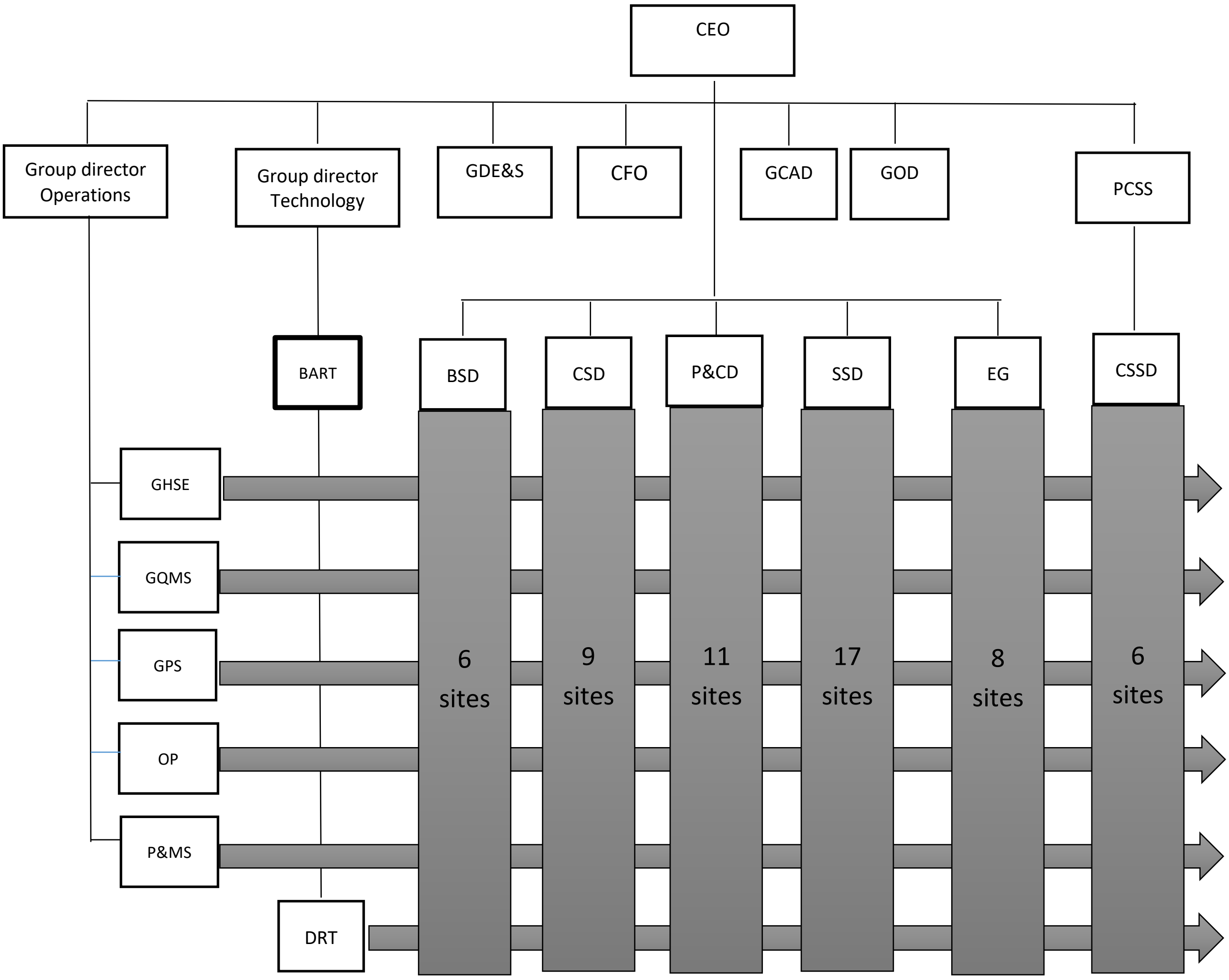
Sources: adapted from company website

In fact, APPCOM physical components and sub-systems were tailored according to customer requirements. Engineering services involved technology development, system design and manufacturing engineering. APPCOM had around 15 sites conducting advanced research and 30 sites had strong design capabilities, the other sites were specialised in manufacturing engineering and production. They were combined in programmes in an integrated manner.

APPCOM service operations

Engineering resources were often organized within modular projects and programmes to deliver a package of solutions to customers. Modular engineering divisions were combined in programmes. They operated in various projects to serve customers on a global scale.

Figure 2 presents operational structure of APPCOM. Projects within five engineering divisions were incorporated in complex programmes under the management of group functions. These functions had processes and provide supports to divisions and projects in terms of operations, supply chain, technologies, and so on.



CEO: Chief Executive Official
GDE&S: Group Director Engineering and Strategy
CFO: Chief Financial official
GCAD: Group Corporate Affair Director
GOD: Group Organization Director
PCSS: President Customer Services and Support
BART: Board of Advanced Research and Technology
BSD: Braking Systems Division
CSD: Control Systems Division
P&CD: Polymers and Composites Division
SSD: Sensor Systems Division
EG: Equipment Group
CSSD: Customer Service and Support Division
GHSE: Group Health and Safety Environment
GQMS: Group Quality and Management System
GPS: Global Production System
OP: Operations Planning
P&MS: Procurement and Manufacturing Strategy
DRT: Divisional Research and Technology

➡ : Processes & Support

Figure A4- 3: APPCOM operations organization chart

Source: Adapted from company documents

GES network learning purposes

APPCOM operations strategy focused on following priorities:

(1) Customer-focused operations with dedicated leadership, one aftermarket, different relationships and strong programme management.

(2) Achieving operations excellence by transforming the whole organization through a new global production system.

(3) Use of technology by investing selectively in manufacturing and product technology and reasserting authority.

These strategic priorities reflected a flexible value creation intention towards both leading technologies and operational excellence. As such, APPCOM committed with both new technology development and continuous operation improvement.

APPENDIX 5: BACKGROUND OF RECOM SERVICE OPERATIONS NETWORK

Company profile

By the time of this research, RECOM was a global corporation providing drug development consulting, modelling and simulation services to pharmaceutical industry on a global scale. Although RECOM was found in 2008, the modelling and simulation (bio-simulation) service business was established in 2001 in the UK as a university spin-out company. The spin-out company was acquired by RECOM in 2012 and becomes the key engineering division of the group. By the time of this research in 2016, RECOM comprised of nine companies operating in different businesses, employing 400 employees, including approximately 150 research scientists who held a PhD degree. Most of the research scientists were located in the UK producing bio-simulation solutions to more than a thousand pharmaceutical companies, including the top 40, hundreds of academic institutes and numerous regulatory agencies around the world. The company was well-known in the industry because of its technological discoveries and increased regulatory acceptance. Figure 1 presents the structure of RECOM engineering service business structure.

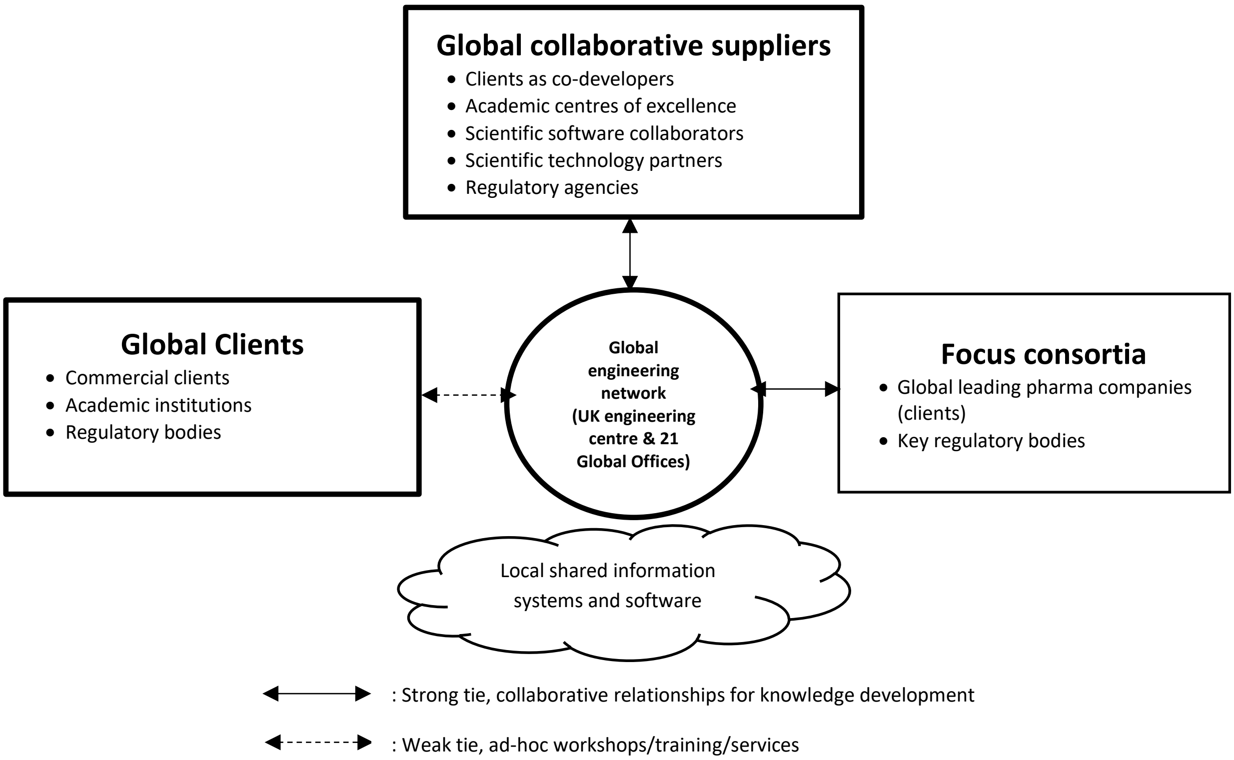


Figure A5-1: RECOM engineering service network structure

Source: Adapted from company website, documents, and interview

RECOM Customers

RECOM engineering services served more than 1200 commercial companies in pharmaceutical industry, 250 academic institutions and almost key regulatory agencies around the world. Most of the largest pharmaceutical companies were RECOM customers and partners who co-developed and used RECOM bio-simulation platforms and consulting services for their new drug development decision making. Academic institutions and regulatory agencies used RECOM platform as a learning tool in their programmes and projects.

RECOM engineering units

RECOM engineering units included around 150 research scientists who were the experts in different areas. Their responsibilities were to develop Physiologically-based pharmacokinetic (PBPK) and Pharmacokenetic/ Pharmacodynamic (PK/PD) models and integrated them into a bio-simulation platform. They were grouped within four engineering divisions: R&D, qualitative system pharmacology, modelling and simulation, and translational science. From these divisions, research scientists were combined into projects. Most of engineers who possess PhD degrees were located in the UK and many of them were recognized as world-class scientists. Some were dispersed in Europe and the USA. In addition to various expertise backgrounds, the scientists were also diverse in cultures, coming from different countries around the world.

At the group level, RECOM encompassed nine independent member companies with 21 offices dispersed across the globe. They operated in different functions that support the drug development process. The functions of the nine companies were:

(1) Company 1: Drug discovery informatics, products and services.
(2) Company 2: Software, strategic and regulatory services for clinical drug development.
(3) Company 3: Pharma modelling and simulation for all stages of drug development.
(4) Company 4: Drug development consultancy, programme management and model-based drug management.
(5) Company 5: Regulatory writing and document-focused services
(6) Company 6: Disclosure and transparency-focused services, medical writing.
(7) Company 7: Model-based meta-analysis, clinical databases, pharmacometric services.

(8) Company 8: Quantitative system pharmacology.
(9) Company 9: Strategic planning and stewardship of complex drug development programs.

Most of engineering service resources were concentrated at company 3 located in the UK, while other companies and their offices were dispersed around the world, offering other supporting functions for the drug development process.

RECOM suppliers

RECOM had a wide range of suppliers collaborating to develop the bio-simulation platform. As engineering research operations required a large amount of scientific data and information, RECCOM partnered with many universities and academic centres of excellence and large pharmaceutical companies. For academic institutions, the company provided free-of-charge licence of the bio-simulation platform for the purpose of training, learning and co-development. Furthermore, RECOM funded doctoral research at many research centres of excellence across the world for innovation. The company also cooperated with scientific software developers, scientific technology partners, and regulatory agencies to effectively build its software platform.

Notably, RECOM established consortiums for technology co-development. The most successful consortium operated since 2001 as a collaborative research centre for physiologically-based pharmacokinetics and mechanistic modelling. The consortium was a successful community with a steadily increasing number of members, and it helped to develop a number of discoveries which have been presented by the increasing number of new, enhanced models and publications in various areas. At the time of this research, the consortium had more than 36 members, including most of the top 40 pharmaceutical companies in the world. Also, many leading global academic institutions and key regulatory agencies were RECCOM’s affiliates. Continuing this success, the company launched the second global consortium early in 2017, collaborating in quantitative systems pharmacology for predicting the immune response of biologics and its impact on drug development.

Engineering services

RECOM provided bio-simulation customised solutions at all stages of drug development, from discovery, pre-clinical trials, early state development, late stage development, approval and patient care (Table 1). Engineering research services included quantitative system pharmacology, physiologically-based pharmacokinetic software and services, and pharmacokinetic/ pharmacodynamics software and services. Research scientists generated services through data analysis and modelling. Discoveries and solutions were integrated into a software platform which enabled customers to virtually experiment the interaction between drug and bodies and thus supported their decision making in drug development processes.

Table A5-1: RECOM end to end solutions to improve drug development productivity

Discovery	Pre-clinical	Early stage development	Late stage development	Approval	Patient care
Scientific informatics and decision-support software					
Quantitative Systems Pharmacology					
	Physiologically-based pharmacokinetic (PBPK) software and services				
	Pharmacokenetic/ Pharmacodynamic (PKPD) software and services				
		Model-based meta-analysis services			
		Clinical trial outcome databases			
	Regulatory/ medical strategy and Writing				

Source: company document

Annually, RECOM updated their discoveries into their software platform. Key engineering discoveries could be, for example, new, enhanced PBPK, PKPD models, updated compound libraries, matching of real clinical trials, new report templates and monitoring multiple metabolites. The solutions were actively generated based on the problems customers might find challenging to solve. The scientists actively conducted research and development on the bio-simulation platform to add value for the customers.

Operations – Network of collocated engineering divisions

RECOM had nine companies working separately. The main engineering function was decentralised in a company where research scientists were clustered in a few centres located in the UK. Engineering research functions were grouped in four divisions: research and development, quantitative systems pharmacology, translational science, and modelling and simulation. The four divisions covered a wide range of scientific areas (Figure 2) that contribute to R&D, PBPK, PKPD, and QSP (quantitative systems pharmacology) services.

The four divisions collaborated closely with each other in projects to generate solutions for customers worldwide. Most of scientists were co-located in the UK. They travelled around the world through their offices network to provide support and services to customers.

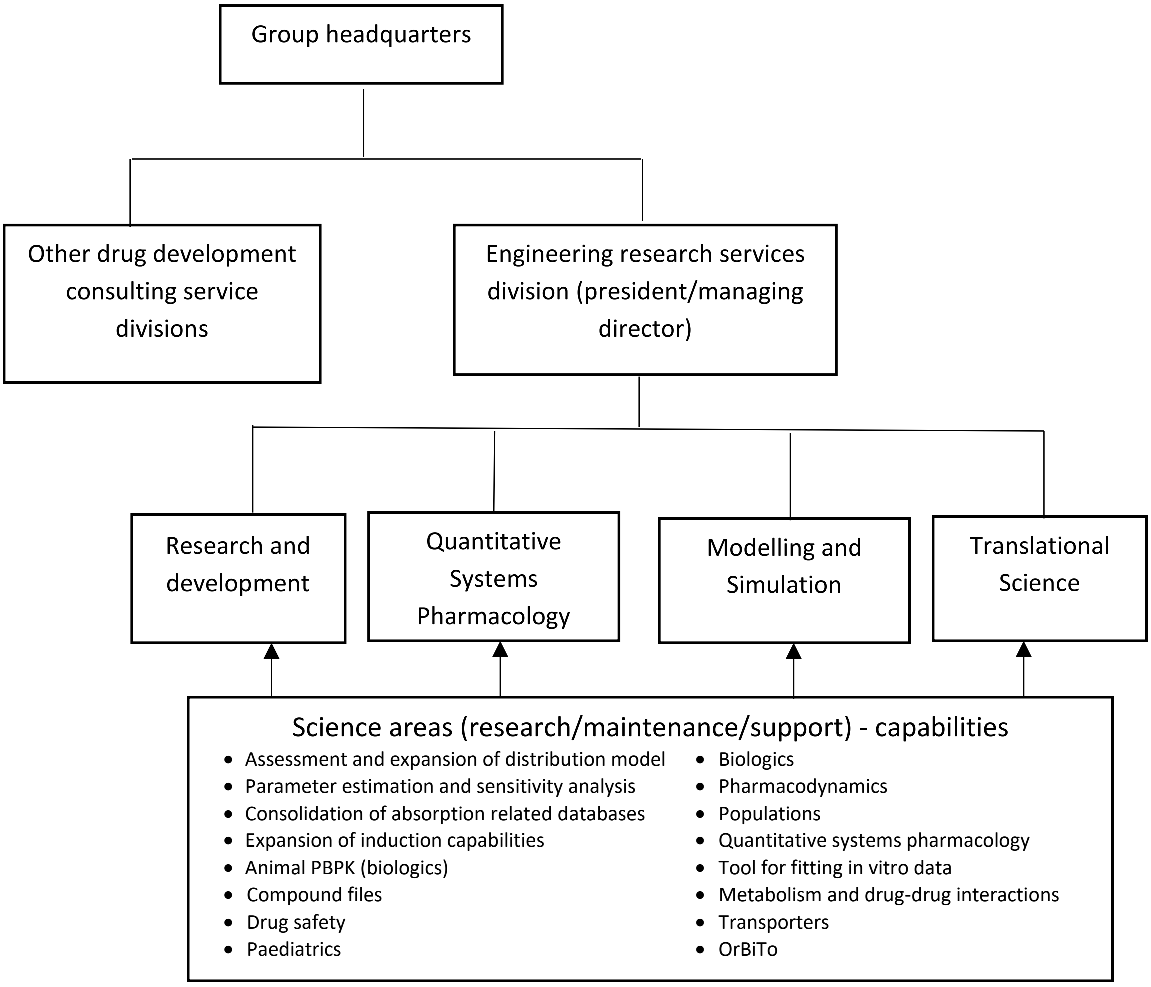


Figure A5-2: RECOM matrix operations organization chart

Source: Adapted from company website and document

Figure 2 presents the matrix structure of RECOM engineering operations. Four divisions were co-located in the UK. They were combined in projects to deliver services in various science areas in which they were competent. Key competences are exhibited in Figure 2.

GES network learning purposes

The mission of RECOM engineering operations was to optimize drug development processes through modelling and simulation engineering. Technology advancement and the increasing understanding of biological sciences gave rise to the demands for excellent bio-simulation platform. Model-informed drug development enabled clients to optimize their decision making relating to drug safety, efficacy, dosing, special populations and others.

RECOM operation strategy focused on customers and innovation. Engineering operations were to develop effective bio-simulation platform that addressed customer needs in drug development. As such, the mission of GES network learning was to innovate the software platform through constant research and development, creating a new effective way for drug development and fulfilling the growing needs of customers around the world.

APPENDIX 6: RESEARCH PROTOCOL

Network learning in global engineering services

Cover letter to recruit potential participants

Dear Mr/ Miss…... ,

My name is Thanh Tran. I am a doctoral researcher at the Department of Management, Birmingham Business School, University of Birmingham, UK. I am conducting a study on "network learning in global engineering services". Engineering network learning is the collective learning and management of knowledge across networked internal divisions, external partners and customers. The study aims to explore key network learning mechanisms and their coordination for effective value creation in global engineering services.

I obtained your contact by … I understand that ……. is a global leading engineering company, which offers a good case of network learning. I wish to carry out research to further develop the understanding of how network learning helps with service operations of the company.

I am writing to invite you to participate in a short interview (60 minutes), to be arranged at your convenience. For more details about the research, I attach the research introduction, participant information, my CV and a letter from my supervisor.

If you have any questions, please do not hesitate to contact me. I will call you in a few days to address any questions you may have.

Thank you for your attention and I am looking forward to meeting with you soon.

Best regards,

Thanh Tran,

Doctoral researcher
Department of Management
Birmingham Business School
University of Birmingham
Edgbaston
Birmingham B15 2TT
United Kingdom
[redacted]

Network learning in global engineering services

Brief introduction to the research

Background

Engineering services companies have organised their global engineering resources in network forms to create favourable settings for organizational learning and in turn be more competitive globally. Indeed, network learning of engineering services firms is the collective learning and management of knowledge across dispersed networked internal divisions, external partners and customers. However, these companies have coped with many challenges in network learning concerning the locating, capturing, sharing and creating knowledge across networked internal and external engineering units due to the complex, dynamic and dispersed nature of global engineering services. Recent research has pointed to the need for a conceptual framework of engineering network learning so as to better understand how to coordinate learning mechanisms in order to effectively create value in global engineering services. This study aims to develop a research agenda to address this need.

Research objectives

- To explore key network learning mechanisms for effective engineering service operations

Key issues investigated in this study

- How to facilitate innovation and efficiency in engineering service operations
- Trends of network learning management in global engineering services
- How to effectively exploit dispersed engineering resources

Benefits to companies

- Evaluating current practices of network learning
- Identifying best management practices
- Providing insight into the design of a network learning organization
- Improved performance of engineering services

Expected outcomes

- A conceptual framework of network learning
- Effective strategies for network learning
- Processes to design and operate network learning

Network learning in global engineering services

Participant information statement

What is the study about?

You are invited to take part in the study “Network learning in global engineering services”. Engineering network learning is the collective learning and management of knowledge across engineering firms’ networked internal divisions, external partners and customers. The study aims to explore key network learning mechanisms and their coordination for effective value creation in global engineering services. In order to achieve the research objectives, the study will involve a number of interviews with managers and practitioners who have an in-depth view of global engineering service operations.

Who is associated with the study?

Thanh Tran, MBA	Doctoral researcher	Email: CTT373@bham.ac.uk
YuFeng Zhang, PhD	Chief supervisor	Email: zhangys@bham.ac.uk
Pamela Robinson, PhD	Supervisor	Email: p.k.robinson@bham.ac.uk

What does the study involve?

If you agree to participate in the study, you will engage in an interview lasting around 45-60 minutes. The interview will be arranged at a time, date and location of your convenience. I would like to conduct the interview at the earliest possible time. You will be asked several open-ended questions relating to collective learning and knowledge management within engineering networks of your company to enable effective global service operations. If there are any questions you are not comfortable with or don’t wish to answer, that’s fine. Also, you may stop at any stage of the interview. With your consent, I may record the audio content of the interview for the purpose of enhancing the accuracy of the qualitative analysis.

Can I withdraw from the study?

The participation in this study is completely voluntary. As a participant, you have the right to withdraw from the project any time prior to 31st March 2017. If you decide you would rather not participate, there is a form below to complete and your data will be destroyed as per research best practice.

Will anyone know the results?

Once the interviews have been completed, they will be transcribed for analysis. Only the researchers will have access to the participants’ information. Your name will not be on the tape and interview transcripts so as to keep your identity confidential. Direct quotes may be used in publications but these will be anonymised and anything which could identify you or your company will be removed.

Data Protection Act 1998

The information you give in the interview will be used for the purposes of the study only. The information will be kept securely for a period of 10 years after the study ends and then will be destroyed.

What are the possible risks and benefits of taking part?

Please note that the intent of the research is analysing general learning strategies without accessing any trade secrets and/or intellectual property. Any concern about intellectual property rights or trade secrets should be openly expressed in the interview. A summary of key research findings will be provided to you upon request.

What if I require further information about the study or my involvement in it?

If you would like to know more at any stage, please feel free to contact the primary researcher, Thanh Tran at [redacted]

Network learning in global engineering services

Withdrawal Form

To be emailed back to the primary researcher, Thanh Tran, if you, the interviewee, no longer wishes to participate in the research being conducted. In accordance with the University's Research Guidelines all commentary given thus far will be destroyed.

(For reference purposes only, this form will be kept confidential)

I confirm that I wish to cease my participation in the above project.

Print name (BLOCK CAPITALS): …………………………………………………………..

Signature: ………………………………   Date: ……………………………..

Network learning in global engineering services

Consent form

Please tick the boxes below if you agree with the following statements:

I confirm that I have read and understand the participant information statement for the above study and have had the opportunity to ask questions. ☐

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason before 31/3/2017. ☐

I agree to this interview being recorded. ☐

I agree to take part in the above study. ☐

(For reference purposes only, this form will be kept confidential)

……………………………..	…………………….....	…..……………………….
Name of participant	Date	Signature
…………………………..	…………………….....	…..……………………….
Name of researcher	Date	Signature

Two copies: 1 - Participant; 1 - Researcher

Network learning in global engineering services

Interview protocol

About interviewee experience:

1. What is your position in your company?____________________________
2. How long have you been in this position (and also at the company generally)?__
3. What is your area of specialisation and qualification?____________________
4. Do you work in a functional division or projects?_______________________
5. If you work for projects, what types of project do you often engage in?______
6. What are your roles in projects?_____________________________________

About the company: Could you tell me about your company:

1. Types of company (private/corporate, state-own companies):_______________
2. Revenue (& profits) of the previous financial year (in million £):____________
3. Number of employees:____
4. Number of engineers:____
5. Number of subsidiaries/ facilities and their locations:______________________

About the global engineering service operations:

1. What engineering services do your company offer?_____
2. What is the main strategic objective(s) of your service operations?__

About managing engineering network learning in engineering service operations:

Network learning: the processes of capturing, creating, disseminating knowledge across boundary/ border [global dispersed internal engineering units and external customers & partners] for better operations performance

Context of network learning:

What are the drivers of network learning? (*External drivers: changing customers' demands and technologies, scared resources, global competition; Internal drivers: global efficiency, effectiveness, flexibility)*

Customers. Who are your customers? What are the challenges customers faces? And how do your services help them?

Suppliers. Who are your suppliers? What are their contribution to service operations? How does your company collaborate with them to create solutions?

Network organization. How do your firms organize resources for global service operations? (*Prompt: e.g. R&D centres of excellence; competence divisions; business divisions; functional divisions etc.*); Why is network learning conducted between them? What are the challenges of network organization on network learning?

Network learning:

What is your view about learning across internal and external boundaries and borders? Could you tell me about your company's network learning practices? (E.g. knowledge reuse, knowledge creation practices) And how learning practices contribute to service operations? Who are the main actors in network learning processes? What are the challenges (barriers) to the network learning of your company?

Boundary spanning mechanisms of network learning:

How does your firm organise resources for network learning across boundaries/ borders?

Prompts:

- Structure: Centralised independence divisions/ decentralised embedded knowledge management teams within projects or functional divisions.
- Information systems (gathering, storing and transferring data): internal top-down and peer communication; external communication
- Coordination mechanisms: Formal/ informal coordinating procedures, methods (common/ customised knowledge processes, templates, job rotation, people to people/ people to machine to people/ people to machine learning to people mechanisms)
- Governance mechanisms: Formal policies/ Informal culture (trust, identity, informal rules of knowledge sharing); Formal rewards/ informal rewards (incentives)
- Intelligent data mining software programs (interpreting data)

How do other functions [e.g. HR, Leadership] contribute to network learning?
Prompt:

- Managing talents and their learning behaviours (e.g. incentive policies, leadership style)
- Recruitment strategies (diversity, creativity)
- Management style: supportive control (autonomy)/ hierarchy

How does your firm measure the learning outcome of the organization?
Prompt: In terms of individual, organizational, and professional learning outcomes

Is there anything do you think I should know about network learning?
Do you have any questions for me?

Thank you for your cooperation!

APPENDIX 7: BACKGROUND INFORMATION OF INTERVIEWEES

Case Company	Interviewee code	Roles	No. of years in the company	No. of interviews taken
OSCOM	001	CEO	11	1
OSCOM	002	General Director	11	3
OSCOM	003	CTO	4	1
OSCOM	004	Quality Manager	7	2
OSCOM	005	Delivery Manager	4	2
OSCOM	006	Pre-Sale manager	7	1
OSCOM	007	Business Analyst	6	2
APPCOM	001	CTO - VP	6	1
APPCOM	002	Global Supply Chain Manager	4	1
APPCOM	003	Global Quality Manager	22	1
APPCOM	004	New Product Development Manager	3	2
APPCOM	005	Manufacturing engineering project director	12	1
RECOM	001	VP of Research & Development	15	1
RECOM	002	Head of Transnational Science	5	1
RECOM	003	Deputy Head of Translational Science	10	1
RECOM	004	Head of System Modelling	1.5	1
RECOM	005	Deputy Head of IT	12	1
RECOM	006	Principal Scientist	7	1
RECOM	007	Librarian	2.5	1
RECOM	008	Research Scientist	0.6	1
RECOM	009	Consultant and Scientific Advisor	6	1
RECOM	010	Senior Research Scientist	3	1
RECOM	011	Senior Research Scientist	6	1
RECOM	012	HR Officer	5.5	1
RECOM	013	Senior Research Scientist	7	1
RECOM	014	Principal Scientist	6	1
RECOM	015	Research Scientist	2	1
RECOM	016	Research Scientist	1.5	1
RECOM	017	Research Associate	0.6	1
RECOM	018	Research Scientist	1	1
RECOM	019	Research Associate	1	2