Architectural Innovation Capability and Performance: The Moderating Role of Absorptive Capacity

AZZAM, ALA'A,MAHMOUD,MOHAMMAD

Durham University
Business School

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Ala'a Mahmoud Azzam

Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

Durham University Business School

Durham University

May 2016

ABSTRACT

Knowledge processing capabilities including knowledge creation and absorptive capacity are required to renew a firm's knowledge stock. These capabilities keep firms abreast of technological and market changes as they enable a proactive approach in responding to these changes. An outdated knowledge stock and the overlooking of changes in external knowledge are destructive in today's competitive environment; firms in these circumstances risk being caught in competency traps and rigidities. Hence, knowledge exploitation has an indispensable role in enhancing innovation. This thesis focuses on architectural innovation which is the capability to reconfigure products' components and so create novel products. It requires the creation of new architectural knowledge while reserving the component knowledge. Although this innovation capability relies profoundly on creating new architectural knowledge, it is also important that firms are competent in absorbing external knowledge. Although the literature on new product development performance captures innovation as a prerequisite of performance, it is yet unclear how architectural innovation capability affects performance. Therefore, this thesis explores the interaction effect of architectural innovation capability and absorptive capacity on firms' performance.

Although knowledge creation coined with organisation's absorptive capacity drive innovation, the innovation literature over the last two decades emphasises integrating knowledge from external sources, particularly from lead users. Lead users' contribution to product quality is one of the under-researched areas. In addition to the dearth of empirical research, quality was measured by experts' judgment; it is possible that this judgment may be a biased evaluation of quality compared with a quantitative scale devoted to measure quality. To overcome the previous research's limitation in measuring quality, this research examines how lead users' integration promotes product quality as measured using a validated scale.

The developed theoretical framework links knowledge creation with architectural innovation capability; at the same time it explores the interaction effect of architectural innovation capability and absorptive capacity on new product development performance. Furthermore, the theoretical model captures the effect of lead users' integration on development time and product quality. Empirical findings, based on primary data collected from 196 UK manufacturing companies show that, knowledge creation modes (socialisation and internalisation) have a positive effect on enhancing architectural innovation capability. Also, absorptive capacity interaction with architectural innovation capability affects financial performance. Assimilation and transformation strengthen innovation's impact on performance, while exploitation

weakens this effect. Finally, the analysis shows that the integration of lead users positively affects development speed and product quality.

Overall, this study contributes to the literature on knowledge processing capabilities by suggesting that knowledge creation is one of the underlying capabilities needed for innovation. In addition, this research contributes to the sheer amount of literature on absorptive capacity, by suggesting that different capacities have different effects on innovation and performance. The major value added by this research relates to architectural innovation capability; the findings suggest that both knowledge processing capabilities and absorptive capacity affect the capability to create new linkages between product components and technologies.

STATEMENT OF ORIGINALITY

The author hereby confirms that this piece of work is the result of his own work. Material from work of others has been acknowledged, and quotations and Paraphrases suitably indicated.

DECLARATION OF RIGHTS

ACKNOWLEDGMENT

The greatest praise is for Almighty Allah who blessed me with great patience, strength, and endurance during this journey.

I express my deepest gratitude to my supervisors Dr Christos Tsinopoulos, Dr Paul Hughes, and Dr Carlos Sousa for their support, guidance, and for stimulating my intellectual thinking. Through their supervision, they challenged my thinking and helped me to explore the researcher who I am today.

I express my appreciation to my examiners Dr Christopher Williams and Professor Emmanuel Adamides for their constructive feedback and comments that have enriched my intellectual thinking and my thesis.

I extend my deepest appreciation for my parents for their unconditional love, care, and support from day one. Sincere appreciation goes to my husband, who never stopped believing in my capabilities and offered me nothing but love and support. I appreciate my mother-in-law (my second mother) for her prayers and care throughout the years. I hope my son will grow strong and intelligent to read these words to realise how he brought joy and love to my life every single day. May God bless all my beloved family.

Last but not least, I would like to thank my Ph.D. colleagues at Durham University Business School, and the Doctoral office staff for their professional services.

DEDICATION

This effort is dedicated to my parents who instilled the love of knowledge and learning from a young age, whom without I would not be able to pursue my dreams to the fullest. Thanks you for teaching me to believe in myself. And it is dedicated to my beloved husband and my little boy who were always by my side and filled my life with love and joy.

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CHAPTER ONE: INTRODUCTION

1.1 Research background

In today's ever-changing environment, there is a need to respond to external technological and market changes. This is particularly the case in the manufacturing industry, where competition is very fierce and customers' needs are changing (Teece, 1996). The proliferation of research that investigate how organisations can survive in this environment was the motivation behind this research, This research endeavours to answer some intriguing questions about the main drivers of success from a knowledge-based view and innovation perspectives.

Knowledge processing capabilities aim to renew firms' knowledge stock and allow firms to keep up to date on technological and market changes. The ability to create and manage knowledge is a prerequisite of innovation, as the process of creating knowledge can leverage firms' resources and efforts into creative and novel outcomes (Schulze and Hoegl 2008). Although innovation has various prerequisites, the focus of this research is on knowledge creation. Knowledge processing capabilities such as knowledge creation is essential to create value and produce innovative outcomes (Nonaka and Von Krogh, 2009, Grant, 1996).

Product innovations can be of various types: incremental, radical, modular, and architectural (Henderson and Clark, 1990). Architectural innovation (AI), which is the interest of this research, is concerned with reconfiguring product's components to create better and enhanced products. Having architectural innovation capability arguably enhances firms' ability to respond to new technological and market changes through the ability to develop new products that fit such changes. In which, further

exploitation of existing technology enables changes in product architecture (e.g. portable copiers, front wheel drive cars, and proximity aligner in semiconductor manufacturing) (Bozdogan, *et al.*, 1998). In this research architectural innovation is placed at the centre of attention in terms of linking knowledge creation with performance. In other words, how organisations can benefit from their architectural innovation capability to enhance performance.

Absorptive capacity (APCA) received attention in this research as a vital tool to acquire, assimilate, transform, and exploit relevant external knowledge (Zahra and George, 2002). Having the capability to scan and filter the environment for relevant knowledge enhances innovation as well as performance (Kostopoulos *et al.*, 2011). Knowledge from external sources is important and lead users' integration can serve as a need forecasting laboratory (Von Hippel, 1986a). Hence, collaborating with lead users can yield benefits in terms of accelerated development time and enhanced product quality.

To conclude, this study aims to investigate knowledge creation modes effects on architectural innovation capability. In addition, this study aims to investigate the interaction effect of absorptive capacity and architectural innovation capability on development cost and financial performance. Finally, lead users' integration effect on development time and product quality will be examined.

1.2 Research motivation

This research contributes to developing a framework of architectural innovation capability to optimise performance in a rapidly changing environment. The pressure to innovate has become pervasive in today's markets. Technological changes,

customer demands, and revolutionary technologies combine to place pressure on firms to constantly innovate and provide cutting-edge outcomes. Developing innovative capabilities (such as architectural innovation capability) enhances firms' ability to respond to market demands by producing innovative products and services and can has a profound impact on their performance (Henderson and Clark, 1990, Wang and Ahmed, 2004).

In this vein, Rolls-Royce turbofan engines are examples of investing in revolutionary technology, and this is the reason they are now competing in global markets (Pugh, 2015). Based on their revolutionary three-shaft architecture and lower prices, Rolls-Royce outperformed General Electric Transportation (GE) and Pratt-Whitney in 2004 (Lazonick and Prencipe, 2005). Rolls-Royce was not always among the top three in the high-thrust aircraft engine industry, they spent years innovating and developing the Trent technology, and even at one point went bankrupt. However, the modularity embedded in their Trent design enabled them to develop and reconfigure their design to be deployed in different market niches, and was described by aviation experts as "hard to beat" (Williams, 1995). So it can be concluded that Rolls-Royce's architectural innovation capability enabled it to deploy its underpinning revolutionary technology across different markets (e.g. the big-engine and civil engine markets).

At the same time, there has been an increasing realisation that different modes of knowledge creation, i.e. socialisation, externalisation, combination, and internalisation, can affect how innovation is configured and delivered (Schulze and Hoegl, 2006, Schulze and Hoegl, 2008, Nonaka, 1994). Knowledge creation capability is acknowledged to enhance innovation and performance respectively, but

the lack of empirical research has yielded divergent and contradictory results (Forés and Camisón, 2016). On the one hand, Schulze and Hoegl (2006) found that some knowledge creation modes enhance product success while other modes negatively affect it. On the other hand, creativity and novelty were linked to knowledge creation modes in two other studies, however, the results were contradictory (Schulze and Hoegl 2008, Lee and Choi 2003). There is, therefore, a need to understand in more detail how knowledge creation modes contribute to innovation capability.

While knowledge creation is regarded as an important prerequisite to innovation, it only focuses on internally creating knowledge and ignores the importance of acquiring external technological and market knowledge. Firms which are competent in scanning the environment to acquire, assimilate, transform, and exploit knowledge, are said to have an absorptive capacity (Zahra and George, 2002). Increasingly, research emphasises the importance of absorptive capacity in leveraging firms' knowledge by effectively assimilating external sources of knowledge to facilitate innovation (Tsai, 2001, Zahra and George, 2002). However, few researchers investigated the combination of knowledge absorption and knowledge creation to drive innovation as well as performance (Forés and Camisón, 2016). Evidence shows that even if firms are exposed to the same external knowledge, they will have different innovation performance (Camisón and Forés, 2011, Escribano *et al.*, 2009). Therefore, there is a need to know how each absorptive capacity process (acquisition, assimilation, transformation, and exploitation) can enhance innovation and performance.

Firms have limited resources and capability that can be deployed to create innovative products fitting customer needs. In addition, product market research has a risk of failure, which can be avoided by integrating a unique type of customers called lead users (Von Hippel 1986). Lead users have certain characteristics which make them very competent in adding value to new product development (NPD) processes. Big companies such as 3M, HILTI, and Johnson & Johnson, frequently work with lead users (Lüthje and Herstatt, 2004), and they realise the importance of systematically integrating lead users into the fuzzy-front-end of generating product concepts and the key attributes of products (Bilgram *et al.*, 2008, Von Hippel, 1986a). Lead users are competent in adding value to the NPD process because they are well qualified and motivated, and they perceive a great benefit from having a solution to their latent need. An important question that is raised here is how can lead users enhance product quality and accelerate the NPD process based on their unique characteristics.

In conclusion, this research is interested in architectural innovation capability and what can enhance it, and at the same time how it can improve organisational performance. In addition, this research was needed to clarify the link between each knowledge creation mode and architectural innovation capability. Finally, this study will clarify the moderation effect of each absorptive capacity on the indirect effect of architectural innovation capability and performance (these research interests are explained in more detail in the following section).

1.3 Research questions

This research aims to examine factors which affect innovation and performance, while taking into consideration the importance of knowledge creation as well as knowledge

absorption. Moreover, this research will examine whether integrating lead users in new product development (NPD) process can enhance performance. The motivation behind this study is to take a holistic view of the way firms can deal with knowledge to elicit value in the shape of a novel outcome or a better performance, in addition to investigate external knowledge internalisation and combination and their benefits at an organisational level. Firms that are competent in acquiring external technological or market knowledge have better survival chances (Cohen and Levinthal 1990, Zahra and George 2002); "in an economy where the only certainty is uncertainty, the one sure source of lasting competitive advantage is knowledge" Nonaka 1991: 175.

Conceptual as well as empirical literature in the last two decades on knowledge creation (Nonaka, 1994, Schulze and Hoegl, 2006, Schulze and Hoegl, 2008, Lee and Choi, 2003, Nonaka, 1991, Nonaka and Takeuchi, 1995) demonstrated that firms' financial performance and survival depends on their capability to create and exploit knowledge. Moreover, the current literature on absorptive capacity achieved similar outcomes through investigating external knowledge acquisition and exploitation (Cohen and Levinthal, 1990, Zahra and George, 2002, Kostopoulos *et al.*, 2011). The previous researches suggest that, knowledge creation capability and knowledge absorptive capacity achieve similar output from two different sources of knowledge and through different sets of processes or modes.

Despite the proliferation of research that captures knowledge creation and absorption, there is not enough empirical evidence on the combination of creating as well as absorbing knowledge on performance. A few researchers have advocated a knowledge accumulation model from different processes. For example, Forés and

Camisón (2016) investigated the effect of knowledge creation and absorptive capacity on radical as well as incremental innovation, however they did not examine other types of innovation. Caloghirou *et al.* (2004) investigated the effect of internal and external knowledge processing capabilities and their effect on innovative performance. Although their research offers insights into the importance of internal and external knowledge processing, it has a limitation having used absolute measures for knowledge creation and absorptive capacity, rather than taking the process perspective of each into consideration.

Although incremental innovation enhances firms' efficiency, and radical innovation is needed to avoid competency traps and inertia (Levinthal and March, 1993), architectural innovation is equally important especially in a period of rapid technological and market changes (Henderson and Clark, 1990). Product architectural innovation (AI) is the reconfiguration of product components and challenging the whole architectural knowledge of existing products: it creates new interfaces between components without the introduction of fundamentally new component technology or subsystems (Magnusson *et al.*, 2003, Henderson and Clark, 1990, Gatignon *et al.*, 2002b).

Architectural innovation has many benefits over other types of innovation which can be explained by the following example. On the one hand, a firm that focuses on incrementally innovating its existing products, will produce mainly line extensions and incremental improvement. Under the fast pace of changing customer preferences, demand, and environmental uncertainty, focusing on "incremental innovation [will be] a recipe for decline, not growth" (Von Hippel *et al.*, 1999: 3). As incremental

innovations are usually motivated by imitation (Schewe, 1996) and they are reactive in nature to "market pull". While on the other hand, radical innovation which is considered a risky departure from existing practice, (Raisch and Birkinshaw, 2008) leads to a complete change of products. While radical innovation is a proactive and revolutionary method (Tushman and O'Reilly), relying extensively on it and ignoring product continuity can create organisational chaos (Levinthal and March, 1993). In the middle of the two major poles of innovation, fall modular and architectural innovations. Modular innovation produces new component technologies and requires a balance between the long-time requirements of technology development and the demands of short time-to-market. This will make firms' job even harder under the technological uncertainty (Magnusson *et al.*, 2003, Clark and Fujimoto, 1991) especially when modular innovation overturns the core design of subsystems. However, architectural innovation has the advantage of retaining the component knowledge and does not require the creation of new component technologies (Henderson, 1991), hence, it retains the product system knowledge gained from previous product development.

Acquiring knowledge of changes in the external environment combined with the capability to internalise and exploit this knowledge in order to create architectural innovation is one way to overcome organisational inertia (Cohen and Levinthal, 1990, Magnusson *et al.*, 2003). Architectural innovation capability enables firms to process existing knowledge stock and generate novel architectural knowledge (Henderson and Clark 1990). Consequently, this innovation capability enables the departure from outdated product designs that do not fit with new technological or market changes (Section 2.6.4).

Knowledge creation consists of four modes (socialisation, externalisation, combination, and internalisation) which aim to amplify knowledge through spirals of tacit and explicit knowledge conversions (Nonaka, 1994). Previous conceptual and empirical research investigated knowledge creation's link to innovation based on Nonaka's model (Kogut and Zander, 1992a, Leiponen, 2006, Madhavan and Grover, 1998, Nonaka and Takeuchi, 1995, Daniel Sherman *et al.*, 2005, Song *et al.*, 2005, Jiang and Li, 2009, Smith *et al.*, 2005, Tödtling *et al.*, 2009). However, the extant empirical research lacks consistency in terms of the effect of each knowledge creation mode on innovation. For example socialisation, the first mode of knowledge creation, was examined as a prerequisite for product success (Schulze and Hoegl, 2006), for the novelty of product ideas (Schulze and Hoegl, 2008), and for organisational creativity (Lee and Choi, 2003). However, outcomes of these three studies were not consistent. Since research proved that socialisation enhances the novelty of product ideas and creativity while in the development phase it negatively affects product success. Due to the lack of consistency of research outcomes, knowledge creation merits further research and examination.

Knowledge creation conversion processes create an environment to share knowledge, what is referred to as "*Ba*" (Nonaka and Konno, 2005), through different iteration and levels of tacit-explicit knowledge conversion. This environment motivates an ongoing dialogue between tacit and explicit knowledge which is essential for innovation. Arguably tacit knowledge is internalised at the end of each spiral of knowledge creation (Nonaka, 1994). Internalisation aims to integrate tacit knowledge into individuals' mental models and leverage this knowledge to stimulate creativity (Tiwana and Mclean, 2005).

Consequently based on the previous discussion and given the fact that the field of architectural innovation is still evolving, the researcher is interested in knowledge processes capabilities as pre-requisites for architectural innovation capability. This has created the motivation to examine knowledge creation modes (socialisation, externalisation, combination, and internalisation) effects on architectural innovation capability. Thence, the first question of interest is as follow:

Q1. How does knowledge creation affect architectural innovation capability?

Firms which have competence in utilising and incorporating external knowledge into novel outcomes (i.e. absorptive capacity) are more likely to enhance their performance (Forés and Camisón, 2016). Therefore, recent research focuses on knowledge accumulation as well as knowledge creation as drivers of performance (Forés and Camisón, 2016). However, is knowledge accumulation, from internal or external sources, adequate to enhance performance?

Enhancing performance (efficiency and effectiveness) is an important goal for firms (Tsai, 2001, Darroch, 2005, López-Nicolás and Meroño-Cerdán, 2011), and in particular doing so by capitalising on external knowledge through their absorptive capacity, in addition to leveraging internal knowledge (Von Krogh *et al.*, 2001). There are burgeoning, yet mixed, findings related to innovation, absorptive capacity and organisational performance. Innovation, although beneficial for performance (Damanpour, 1991, Jiménez-Jiménez and Sanz-Valle, 2011, Damanpour *et al.*, 1989, Roberts, 1999, Wheelwright and Clark, 1992), has been regarded as an expensive and risky activity with negative outcomes including increased cost as well as unwarranted

changes (Simpson *et al.*, 2006). Moreover, innovation can act differently depending on the external environment, and it does not always enhance performance, especially in stable environments (Wright *et al.*, 2004). Therefore, this research is interested to study how innovation benefits can be enhanced, while minimising its negative outcomes through incorporating absorptive capacity.

Furthermore, different types of innovation (radical, incremental, or modular) have been linked to performance (Dewar and Dutton, 1986, Subramanian and Nilakanta, 1996, Slater *et al.*, 2014). Despite architectural innovation's acknowledged importance (Henderson, 1991, Bozdogan *et al.*, 1998, Popadiuk and Choo, 2006), it has never been empirically linked with organisational performance (to the best of our knowledge). This research will empirically investigate the potential interaction effects of architectural innovation capability and absorptive capacity on firms' performance. The previous discussion motivates the second research question:

> *Q2. How does the interaction between architectural innovation capability and absorptive capacity affect firms' performance?*

In addition to absorptive capacity and architectural innovation capability's potential effect on performance, this research is interested in examining the role of lead users' integration in enhancing firms' performance. Lead users' integration has received much attention recently due to its positive effect, on new product development performance, including cost reduction (Von Hippel, 1998), accelerating new product development (Tsinopoulos and Al-Zu'bi, 2012), and idea generation (Lilien *et al.*, 2002). Although quality is a well-established performance indicator (Phillips *et al.*,

1983), its link with lead users' integration has not received much empirical attention (Schuhmacher and Kuester, 2012). Lead users have characteristics such as, use experience and intrinsic motivation which motivates them to generate ideas for superior products which provide solutions to latent needs. Therefore, creating a link with lead users has a potential in speeding the NPD process as well as enhancing product quality. Hence, this research will endeavour to investigate the following research question:

> *Q3. How does lead users' integration affect product quality and new product development time?*

By answering these research questions (using primary data through a questionnaire survey) this study may benefit decision makers in adopting methods that can boost the performance of their organisations. In addition, this study will make a valuable contribution to the literature and empirically inform the subject of knowledge creation and absorptive capacity effect on innovation capability and subsequently on organisations performance.

1.4 Methodology

Based on an extensive research and understanding of the best fit between available research design choices and the current research questions; this study will answer the research questions proposed by following the positivism research philosophy and deductive research approach. Further justification is presented in the Methodology chapter (Section 4.2, 4.3). In addition, a rigorous and systematic approach is

employed in collecting primary data. Survey research tool was used to collect data, and the total design method (TDM) was employed to design the research instrument.

The questionnaire targeted managing directors and executive managers in the UK manufacturing industry. Questionnaire administration was carried out following recommendation in previous similar research and from Dillman *et al.* (2014) infamous book. Prior to commencing data collection, a pilot study was conducted to identify any unforeseeable and unwarranted errors. Recommendations from the pilot test were taken into consideration.

Subsequently, after data collection, the data set has been screened to exclude any noise and make sure that data is ready for subsequent, validity, reliability, and factor analysis. Chapter 5 presents the research analysis conducted using structural equation modelling (SEM) in order to test the research hypotheses.

1.5 Thesis overview

In order to meet the research objectives, this research implemented a sequential model which is outlined in the following section:

Chapter 2: Literature review

This chapter provides an extensive review of the extant relevant published academic literature and theories in the field of knowledge management, innovation, absorptive capacity, and lead user. The chapter provides a summary of the current literature and key issues identified.

Chapter 3: Hypotheses development

This chapter presents research hypotheses development and the conceptual model which captures the interplay between study variables.

Chapter 4: Research design and methodology

This chapter provides a detailed discussion of the adopted research philosophy, approach, and design and data collection. In addition, questionnaire development, as well as administration, are reported.

Chapter 5: Data Analysis

This chapter presents descriptive statistics of the sample, data analysis, and reliability and validity. It reports the measurement models (exploratory and confirmatory factor analysis results; EFA & CFA), and structural equation model testing (hypotheses testing) using LISREL.

Chapter 6: Discussion

This chapter reports detailed discussion of the findings in light of the theoretical underpinning presented in Chapter 2. In addition, a reflection is made whenever relevant to explain and investigate supported as well as unsupported research hypotheses.

Chapter 7: Conclusion and recommendation

This chapter includes the main findings of the research, the contribution, the theoretical and managerial implications, research limitations, and suggestion for

future research for scholars who seek to further enhance the state of knowledge in this field.

1.6 Summary

This chapter has outlined the research background, motivation, justification of research questions, and methodology. In summary, the main objectives of this research are to investigate knowledge creation modes effects on innovation, as well as the interaction effect between absorptive capacity and architectural innovation capability on development cost and financial performance. Moreover, the last objective is to identify lead users' integration effect on product development time acceleration, and product quality. This research follows logical sequential steps to carry out each step and it employs a survey to collect data, Structural equation modelling (SEM) is used to analyse the structural model. The following chapters will unfold the process followed in detail.

CHAPTER TWO: LITERATURE REVIEW

2.1 Research summary and contribution

This study contributes to new product development research by providing insights into the variables that can affect product innovativeness, in particular architectural innovation capability. Due to the importance of architectural innovation (Henderson and Clark, 1990), its antecedents represents an important research issue. this research systematically investigated the effect of knowledge creation on architectural innoavtion capability.

Producing novel products will create new markets or reform existing markets (Abernathy and Clark 1985) which will provide an opportunity for existing firms to enhance their performance. As mentioned earlier (in Chapter 1), there are four main types of technological innovations which are; continuous (incremental), discontinuous (radical), innovations that introduce new component technologies (modular), and innovations that create new interfaces between components (architectural innovation) (Henderson and Clark, 1990).

This research investigates architectural innovation for the following reason; established firms face a challenge when developing architectural innovations (Henderson and Clark 1990, Wade 1995, Dean and Meyer 1996, Wade 1996). This challenge is of two folds; first, established firms have architectural knowledge embedded in their existing routines, which makes it hard to incorporate the new architectural knowledge into their product development process and their old

frameworks, therefore, they may face inertia in responding to external market changes if they are unable to recognise architectural innovations and change accordingly.

Second, new entrants have a superior advantage that enables them to absorb new architectural knowledge and copy new products, as they do not have previous embedded frameworks, or routines. Hence, new entrants may outperform established firms (Wade 1995). Therefore, this type of innovation proves to be of great importance for all players in any industry, *i.e.* established firms have to overcome the challenge associated with architectural innovation, while at the same time, new entrants have to seize the opportunity of copying this type of innovation. Bozdogan *et al.* (1998) focused on architectural innovation and supplier integration in order to build enduring competitive strength; this was achieved by leveraging the specialised knowledge bases of supplier networks, especially in the early stages of product development. Although their work extended the concept of architectural innovation to the inter-enterprise context by investigating suppliers' integration, their work however was preliminary in nature and their case study results may not be replicated in other settings due to generalizability concerns. This thesis aims to analyse architectural innovation capability and investigate knowledge processing capabilities in product development using quantitative data collected from the UK manufacturing industry.

The underlying proposition in the literature is that firms which can create knowledge, are better at delivering value by generating superior products (Kogut and Zander, 1992a, Nonaka and Takeuchi, 1995, Madhavan and Grover, 1998). In this research knowledge creation is considered a process rather than the level or the amount of knowledge created, perceiving knowledge as a stock limits the amplification effect of

knowledge conversion, and ignores that fact that the sum of knowledge is greater than the sum of individual participant knowledge (Hayek, 1945). Hence this research adopts Nonaka's (1994) knowledge creation model (Section 2.5). This model captured knowledge creation as process of tacit and explicit knowledge interaction. Few scholars have empirically studied the relationship between knowledge creation and innovation (Schulze and Hoegl, 2006, Smith *et al.*, 2005, Su *et al.*, 2013). Schulze and Hoegl (2006, 2008) produced the only research (to the best of our knowledge) that studied the relationship of each type of knowledge creation (socialisation, externalisation, combination, and internalisation) and new product success as well as the novelty of product ideas. On the other hand, other researchers investigated knowledge creation capability, including Smith *et al.* (2005) who studied its effect on the rate of new product introduction. Su *et al.* (2013) found that knowledge creation capability affects product innovativeness. However, a more in-depth research of each process was highly recommended in previous research.

Nonaka's (1994) knowledge creation models includes four modes of knowlede conversion (socilasation, externalisation, combination, and internalisation). First, socialisation is a process of sharing tacit knowledge, interaction, and sharing experience among individuals. Sharing tacit knowledge includes sharing architectural knowledge which "tends to be embedded in the tacit knowledge of the organisation" (Henderson, 1991: 44). Because architectural innovation depends on components' configuration and integration, sharing architectural knowledge is vital for developing architectural innovation. This research proposes that socialisation acts as a tool to facilitate architectural innovation development.

The second mode is externalisation which includes articulating tacit knowledge into explicit concepts that "helps promote reflection and interaction between individuals" (Nonaka and Takeuchi, 1995: 64). Externalisation is triggered by dialogue or collective reflection and is valuable in the concept phase to articulate tacit knowledge. As Peltokorpi *et al.* (2007) point out "exposure to diverse ideas during the externalisation phase is important as every step in the innovation process is proposed to be about someone asking about imaginary possibilities, speculating about what would happen if, and reflecting on yet unrealised and perhaps unrealisable solutions" (Peltokorpi *et al.*, 2007: 56). Hence, acquired tacit knowledge from the socialisation process is of little use unless externalised and developed into a concept or a prototype. Thus, externalisation is an important mode of knowledge creation, as this is where new explicit concepts are created through using sequential serials of metaphor, analogy, and modelling (Nonaka, 1994, Nonaka and Takeuchi, 1995, Peltokorpi *et al.*, 2007). This research proposed that externalisation enhances the production of architectural innovation products, because it leads to exposure to diverse ideas which enables individuals to capture new architectural knowledge and articulate it into explicit knowledge to start the dialogue and reflection among individuals. This exposure can lead to creating new ideas about possible new links between existing components, hence, creating new architectural knowledge that adds value in the NPD process.

The third mode is combination which adds the least value among the four modes, as it exchanges explicit knowledge to be integrated into the knowledge system (Nonaka and Takeuchi, 1995). Yet, knowledge combined from different domains can help in realising new innovative solutions based on looking at challenges from different

perspectives. Among the challenges faced by firms is to realise the change in the external environment (for example, as technological change) that triggers the need to create new innovative solutions by reconfiguring products components to incorporate the new technologies. Therefore, combination acts as a knowledge audit which adds value in terms of informing individuals of what knowledge is available and where, especially when knowledge is spatially separated.

Finally, the last mode is knowledge internalisation which includes individual efforts to absorb accumulated organisational know-how in which individuals strive to learn the recipe of 'how to do it' (Kale and Singh, 2007). Knowledge internalisation requires team members to be familiar with each other's expertise and skills which helps them to comprehend the pool of available knowledge. This potential to identify and recognise peer's knowledge, understanding the available pool of knowledge, and how each other's unique knowledge fits together, will enable individuals to efficiently use it collectively to create innovative products (Kale and Singh, 2007). This process of recognising, assimilating, and exploiting peers' specialised knowledge is essential to facilitate the capability of reconfiguring architectural knowledge. Locating and leveraging knowledge possessed by different team members and the "the constant interaction of a multidisciplinary team whose members work together from start to finish" (Nonaka and Takeuchi, 1995: 242) allow firms to create new products or modify existing ones (Rothaermel and Hess, 2007).

Organisations need to create, utilise, and exploit knowledge to generate innovations (Kogut and Zander, 1992a, Teece, 1996). Firms that possess prior knowledge can evaluate the value of new knowledge in order to absorb it (Cohen and Levinthal,

1990). Firms failing to evaluate the importance of new knowledge might overlook changes in the environment and may fail to retain high performance. For example, previous research by Henderson and Clark (1990) shows the importance of recognising the value of new information, and their empirical study shows how failing to recognise the change in architectural knowledge actually affects the survival of firms in the semiconductor photolithographic alignment equipment industry; firms fail to appreciate new knowledge which was filtered out. In this case, old architectural knowledge was emphasised at the expense of losing new knowledge which may lead firms to develop core rigidities.

Absorptive Capacity (APCA) is proven to mediate the relationship between external knowledge and financial performance (Kostopoulos *et al.*, 2011). However, other resources are also required to advance financial performance. Therefore, knowledge creation and APCA interact to influence innovation capability (Caloghirou *et al.*, 2004, Camisón and Forés, 2010). As a result, innovation capability affects innovation performance, while absorptive capacity plays a mediator role affecting innovation performance (Kostopoulos *et al.*, 2011). However, (Kostopoulos *et al.*, 2011) research overlooked the fact that absorptive capacity has four types which have different moderation effects on the relationship between innovation and performance. Potential and realised absorptive capacity have a distinct effect on upgrading innovative performance which will be investigated in more detail in this research.

Yet another area that might strengthen and upgrade performance (especially quality and cycle time) is lead users integration. Ideas generated through traditional market research are less likely to produce breakthrough innovations and rather tend to

contribute marginally to the firm's products portfolios through incremental innovations (Eliashberg *et al.*, 1997). However, integrating lead users can add more value as they are ahead of the trend and expect high benefits from innovated products (Von Hippel 1986). Furthermore, lead users have proved to have the ability to produce novel products with high commercial attractiveness across many industries; such as sport, gaming, and software industries (Franke *et al.*, 2006). Hence lead users' integration received high attention and many firms nowadays proactively integrate lead users in the new product development process. Firms collaborating with lead users report an increased rate of new product success (Gruner and Homburg, 2000) greater product variety (Al-Zu'bi and Tsinopoulos, 2012) and sales potential (Lilien *et al.*, 2002). In comparison to in-house product development, lead users are likely to produce less risky products which are less prone to market failure (Gruner and Homburg, 2000). In addition, lead users' integration can reduce product development cost (Tsinopoulos and Al-Zu'bi, 2012).

This current research is interested in examining lead user effect on NPD quality and speeding its cycle time. Langerak and Hultink (2008) empirically proved that lead users positively affect NPD development speed, as their involvement helps firms to have access to need and solution information. Lead users were among other nine variables studied by Langerak and Hultink (2008) from firms in different industries. However, this research argues that there could be an overlapping effect of variables which can ideally be studied independently with independent samples.

Another performance indicator which is of interest to this research topic, is quality. Lead users' integration can increase new product idea quality as lead users have

certain characteristics which enable them to challenge the current products in a quest to produce better solutions because they possess high expected benefit. Schuhmacher and Kuester (2012) found that lead user characteristics such as being ahead of the trend trigger disappointments if products are not up to the lead user's expectation. Moreover, use experience can increase the probability of lead users enhancing quality as they are able to analyse usage problems to envision higher quality solutions. However, Schuhmacher and Kuester (2012) evaluation of ideas' quality was based on experts' judgment which may exhibit limited ability or biased evaluation of quality in comparison with a quantitative scale devoted to measure quality. Hence, this research will use validated scale to measure quality to overcome the weaknesses of previous research.

In conclusion, variables studied in this thesis have received partial attention in prior research. To fill this gap our research developed a framework to test the simultaneous relationships between knowledge processing capabilities, architectural innovation capability and performance. More specifically, how firms can benefit from having architectural innovation capability to enhance their financial performance and reduce development cost, while at the same time enhancing product quality and development time.

2.2 Innovation

The literature distinguishes between different types of innovation. The most used classification is the one proposed by Damanpour (1991). Based on a meta-analysis, he proposes the following types of innovation; technical and administrative, product and process, and radical and incremental. Technical innovation concerns process, product

and service innovation, while administrative innovation includes innovations in procedures, structure and administrative processes. Product innovations are new products or services introduced to meet new needs, while process innovations are new procedures introduced in product and services operations. Furthermore, incremental innovation (market-pull innovation) causes little departure from existing practices while radical innovation (competence- destroying, technology-push) is considered as a risky departure from existing business practices.

Similar typologies were proposed by Tsai (2001) and Liao, Fei *et al.* (2007). They proposed that innovation capability includes: (1) Product innovation, which provides customers with differentiated, improved or new products. Product innovation includes radical and incremental innovation. (2) Process innovation, which enhances innovation by providing better manufacture or service. (3) Managerial innovation, which is implementing new managerial regulations, systems and methods, which would enhance managerial effectiveness. Henderson and Clark (1990) argue that to successfully develop products, organisations need architectural knowledge and component knowledge. Architectural knowledge is related to the linkages between product components, technologies or subsystems, whereas component knowledge relates to the components themselves, and their underpinning technologies. Henderson and Clark's (1990) view of knowledge departs from the dichotomisation of tacit and explicit knowledge to a more liberated view of knowledge, therefore, they have been able to propose further types of innovations. In their model they combined the two types of knowledge and produced four different types of innovation as shown in Table 2.1: (a) Incremental innovation (b) Radical innovation (c) Architectural (d) Modular innovation.

Table 2.1: Henderson and Clark Model (1990)

Component model	Architectural model	
	Enhanced	Destroyed
Enhanced	Incremental innovation	Architectural innovation
Destroyed	Modular innovation	Radical innovation

In the same vein, Abernathy and Clark's model (1985) (Table 2.2) classified innovations according to their impact on technical capabilities and market knowledge. This combination produced four types of innovation; regular innovation, revolutionary innovation, niche innovation and architectural innovation.

Table 2.2: Abernathy and Clark's model (1985)

Market/ customer linkage	Technical Capabilities	
	Conserved	Disrupted
Disrupted	Niche Innovation	Architectural Innovation
conserved	Regular Innovation	Revolutionary Innovation

Companies may improve their product performance by using one of the four types of innovations introduced by Henderson and Clark (1990). Radical innovation generates the top improvement in performance and at the opposite end is incremental innovation; which tries to maximise the design potential performance. In the middle are modular as well as architectural innovation which generate improvements of a moderate magnitude (less than radical innovation and more than incremental innovation) (McEvily and Chakravarthy, 2002).

Architectural innovation creates new interfaces between components while modular innovation introduces new components and new technologies. For example, the iPod can be considered a type of architectural innovation where Apple used the same technology embedded in the MP3 and mobile phones, and reconfigured its technological components to produce an advanced product with high technical capabilities. Therefore, the introduction of the iPod did not include any significantly new technology (i.e. component knowledge), but required creating a new design that links the components or the subsystems (i.e. architectural knowledge). An example of a modular innovation can be the iPod Nano, where a new technology is embedded in order to create an extension of existing products. Under modular innovation, the product architecture remains the same while the core design concept changes (Henderson and Clark, 1990).

Reflecting on the previous examples, modular innovation can be viewed as an advanced form of incremental innovation. While the core design (component knowledge) is improved in incremental innovation, modular innovation utilises a new or significantly different component knowledge or core design. Therefore, modular innovation offers products extensions which target the same market and have no dramatic change in the design. For example, the clockwork radio developed by Trevor Baylis, this new modular innovation operates on a spring-based clockwork mechanism instead of the conventional source of electrical energy (Baylis, 2001). The new radio has the same design architecture with the only change of exchanging a core component with a new technology. Thus, the market targeted by the new radio was similar to the market of the conventional electrical radios. On the contrary, a famous example of architectural innovation; the Walkman, can show that reconfiguring

components in a different way can help organisations to enter new markets. As the Walkman targeted more active young people who combine an active lifestyle with listening to music.

This research is interested in architectural innovation, which will be further discussed in section 2.6.

2.3 Knowledge Creation

Knowledge creation received a great amount of interest in the literature as a way to systematically produce, process, disseminate, and embody knowledge within organisations' boundaries, which is essential for innovation (Bontis *et al.*, 2002, Danneels, 2008, Nonaka, 1994, Rosenkopf and Nerkar, 2001, Smith *et al.*, 2005).

Innovation is considered an outcome of organisational knowledge creation in which a firm identifies a problem, actively develops new knowledge to solve it, and deploys its resources to articulate this knowledge into new products, services, or processes (Nonaka, 1994). The previous knowledge is created by an ongoing dialogue between tacit and explicit knowledge (the modes of interaction are discussed later in Section 2.5). Furthermore, firms are not machines but social entities in which knowledge is transferred and created, and in which learning takes place. Successful companies, such as Honda, Canon, Matsushita, NEC, and Sharp, respond quickly to market and technological opportunities, and the secret to their success is their unique approach in creating new knowledge (which has been studied by Nonaka (1991, 1994)). Knowledge is a source of competitive advantage in an environment characterised by high uncertainty. Where competition is intense and technologies are

constantly advancing, successful companies are the ones that create new knowledge, disseminate it, and translate it into novel innovative product and services (Nonaka, 1991).

2.4 Knowledge creation background

There are two major views about knowledge creation by researchers; as a "stock" or as a "process". Researchers who believe that knowledge creation is a stock (e.g. (Davenport and Prusak, 1998) argue that it adds to the corporate knowledge stock (Samaddar and Kadiyala, 2006) and that knowledge is subject to depreciation or decline similar to any other physical asset. This point of view can be portrayed in Davenport and Prusak (1998: 52) definition of knowledge creation "the initiative and activities firms undertake to increase their stock of corporate knowledge". The previous definition implies that knowledge can be measured and thus has a tangible measure that enables the measurable performance function (this performance function was discussed later by Samaddar and Kadiyala (2006). This measure captures the benefit of knowledge creation for firms, as Samaddar and Kadiyala (2006) argue that it adds to corporate stock of knowledge and because the outcome of knowledge creation is measurable, then its contribution to the revenue stream can be measured. This stream of research also distinguishes between positive and negative knowledge (Teece, 1998). Positive knowledge is used to inform future improvement while negative knowledge can be used to avoid failures.

The second view looks at knowledge creation as a process or a relationship. This was initiated by Nonaka and Takeuchi (1995, 1996). Knowledge creation is "the capability of a company as a whole to create new knowledge, disseminate it throughout the

organisation, and embody it in products, services and systems" (Nonaka *et al.*, 1996: 3). This definition not only complements the "stock" view of knowledge creation but also expands it to include a dynamic and interactive definition. This was further explained by the knowledge creation model proposed by (Nonaka, 1994) which articulate the process based on two dimensions of knowledge (epistemology and ontology). Furthermore, the knowledge spiral discussed by Nonaka and Von Krogh (2009) defined as a process that includes two interrelated processes: knowledge conversion at the individual level, and knowledge crystallisation and transition between the organisation and its members.

As mentioned in the previous paragraph Nonaka's (1994) definition provides two dimensions of knowledge. An epistemology dimension that supports the process-oriented view of knowledge creation based on tacit and explicit knowledge interaction. The second dimension is the ontological dimension which perceives knowledge creation as the outcome of an exchange process between individuals from the same entity or different entities, supply chains, or dyads and networks. This collaboration creates new knowledge and/or new product designs. For example, if an organisation is working on a new design idea, different divisions can input and aid the improvement of the design during the NPD process (Samaddar and Kadiyala, 2006).

For example, Honda collaborated with ICV and JFC companies (supply chain collaboration) to design and manufacture a cup-holder by using the same collaboration process discussed here (Choi and Lee, 2002). Collaboration is more efficient in such cases because knowledge creation can be costly (Hartley and Benington, 2000). For example, in high technology industries, collaboration is often sought and preferred as it creates advantages for all parties involved, and shortens the

cycle time of innovation, spreading the costs and risks of innovation (Mowery *et al.*, 1996). A study by (Caloghirou *et al.*, 2003) shows that joint research ventures outperform stand-alone research ventures. Co-creation importance can be understood from Leonard (1995: 135) following statement "Technology has become so sophisticated, broad, and expensive that even the largest companies cannot afford to do it all themselves".

Furthermore, firms need complex knowledge during the innovation process and stakeholders are becoming more empowered and willing to share their knowledge with other firms (Day, 2011, Hsiao *et al.*, 2012, Gebauer *et al.*, 2013). The previous trend encouraged researcher (e.g., Hoyer *et al.*, 2010, Mahr *et al.*, 2014) to address firms' co-creation with its stakeholder, as co-creation offers benefits such as access to unique resources and knowledge bases. On the other hand, co-creation can be challenging because of the competing characteristics, goals, and objectives of each stakeholder. Stakeholder co-creation participate in creating exploitative and exploratory knowledge as product innovation requires both the exploitation of existing product innovation competencies and the simultaneous acquisition of new capabilities for product innovation (Harrison *et al.*, 2010).

Although Nonaka (1994) proposed the knowledge creation theory as a dynamic interaction between knowledge, previous empirical research operationalisation of this construct fall shy in capturing its dynamism (Su *et al.*, 2013, Schulze and Hoegl, 2008, Schulze and Hoegl, 2006). The most important reason behind this can be related to the nature of these studies; knowledge creation as a dynamic process can be captured using case research that focuses on a single case over a set period of time

and takes into consideration the peculiar contextual factors of the case's tacit-explicit knowledge exchange. For example, Dyer and Nobeoka (2000) investigated Toyota's ability to achieve high performance and productivity advantageous through following a set of routines dedicated to creating and sharing knowledge.

2.5 Knowledge creation theories:

2.5.1 Nonaka's spiral knowledge creation model SECI

According to the knowledge-based view (KBV), knowledge is a critical source of competitive advantage (Grant, 1996, Kogut and Zander, 1992a). Smith *et al.* (2005: 347) argue that knowledge creation "is essential for the success and survival of firms competing in dynamic environments". Successful organisations are constantly creating, disseminating and embodying knowledge in their new products (Nonaka 1994). Developing new content or changing the existing content in the organisation's tacit and explicit knowledge (Pentland, 1995) as well as creating interplay between explicit and tacit knowledge are essential in today's ever-changing environment (Alavi and Leidner, 2001). Knowledge can be created via four modes; internalisation, socialisation, externalisation and combination (Nonaka, 1994) (Figure 2.1). The knowledge creation process represents successive iterations of following modes, and in each loop the knowledge is amplified.

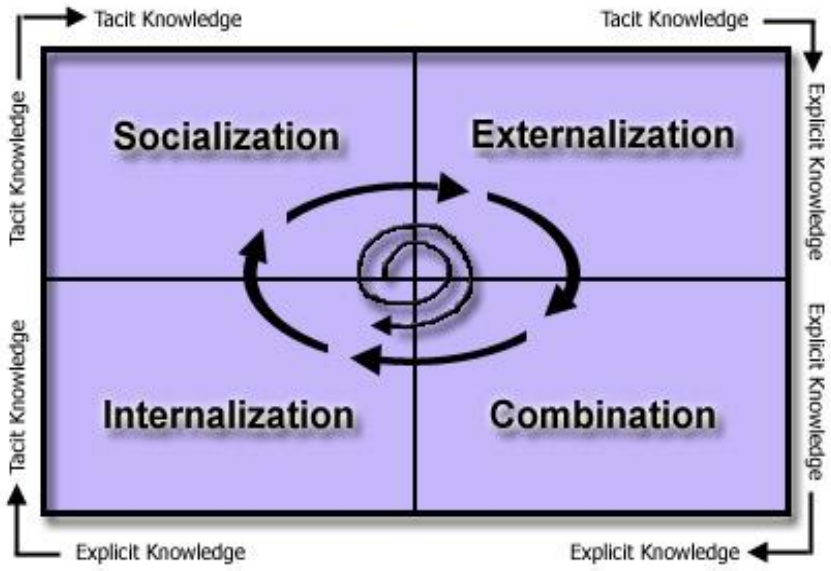

Figure 2.1: Nonaka's (1994) Knowledge Creation Modes

2.5.1.1 Socialisation

The first knowledge conversion mode is socialisation (tacit knowledge to tacit knowledge). This mode requires social interaction and sharing of experience, mental models, and technical skills among individuals. In this first phase of the cycle existing tacit knowledge is converted into a new type of tacit knowledge (Byosiere *et al.*, 2004). Since tacit knowledge is hard to articulate without direct investigation, the ideal way to share it is through social interaction by actively engaging in any specific technological or intellectual field (for example apprenticeships will facilitate the field of interaction and engagement). Typically, socialisation occurs through face-to-face contact such as training, workshops, or even observation, all of which facilitate the interaction of tacit knowledge. These formal or informal activities are important for learning the embedded knowledge that will help to solve problems (Haag *et al.*, 2009, Martin-de-Castro *et al.*, 2008).

2.5.1.2 Externalisation

The next mode in knowledge conversion converts tacit knowledge into explicit knowledge. Thus, the tacit, subjective, intangible knowledge is converted into explicit, objective, tangible knowledge (Nonaka and Takeuchi, 1996). Externalisation is achieved through conversation and collective reflection to articulate best practices and create new concepts. Thus, the dialogue at the workplace is essential to explain abstract concepts and to create shared mental models. Externalisation facilitates clarity in expressing ideas in technical and practical terminologies.

2.5.1.3 Combination

Combination is the next knowledge conversion mode (explicit knowledge to explicit knowledge). Combining knowledge requires merging, categorising, reclassifying, and synthesising existing knowledge. Thus, explicit knowledge is collected from databases and repositories which are assimilated and reconfigured. Exchanging knowledge among individuals can be tangible or intangible, for example in organisational context, combination can take the form of reports or taking notes of meetings or simply it can be a conclusion of a conversation (Huang and Wang, 2002).

2.5.1.4 Internalisation

Internalisation is the next mode (explicit knowledge to tacit knowledge) which aims to convey explicit knowledge into operational knowledge such as know-how (Nonaka *et al.*, 1998b). Explicit knowledge becomes valuable when internalised into individuals through reviewing, interpreting, and symbolising explicit knowledge (Nonaka *et al.*, 1996). This conversion mode elevates individuals' ability to integrate and compare knowledge and so they can avoid mistakes and better comprehend

contextual knowledge (Huang and Wang, 2002). The new internalised knowledge becomes the base of new routines.

2.5.1.5 Critique of Nonaka's SECI model theory

The knowledge creation model proposed by Nonaka received some criticism. For example, Johnson *et al.* (2002) and Brown and Duguid (2001) criticised the distinction of knowledge into tacit and explicit (early distinction has been made by Polanyi (1967)); they propose that there is not a pure type of knowledge that can be labelled as codifiable and non-codifiable knowledge, and that this dichotomisation is rather problematic. They believe that completely codifying knowledge is not possible without losing some of its original characteristics and that most forms of knowledge are mixed. Although Johnson *et al.* (2002) did not immediately criticise Nonaka's model, their perception of knowledge undermines the basis of the knowledge conversion model. On the other hand, the distinction between tacit and explicit knowledge has been both widely argued with and supported (Collins, 2010, Polanyi, 1967).

Another criticism levelled at the knowledge creation mode concerns the process of externalisation. Tsui *et al.* (2009) argue that externalisation is not feasible based on the fact that there are no practical examples in the literature. They suggest that converting tacit knowledge into explicit knowledge is difficult and costly and sometimes is not completely possible based on Polanyi's (1967) argument that we know more than we can tell. Although there are some limitations on explicit-tacit knowledge conversion, externalisation is a natural process that is inevitable in many settings such as apprenticeships (Schulze and Hoegl, 2006).

Nonaka's (1991) metaphor-analogy-model pattern explains how Japanese companies succeed at processing knowledge by using the previously mentioned four modes of knowledge creation. Tacit knowledge includes technical skills as well as cognitive dimensions such as "mental models, beliefs, and perspectives" which are not easily articulated. Because tacit knowledge is hard to express by nature, this type of knowledge is acquired by apprenticeships, observation, imitation, or practice. Through apprenticeships, individuals can directly share tacit knowledge together (socialisation) but this is limited as it does not leverage the organisational knowledge base (Nonaka, 1994). Combining tacit knowledge and synthesising information from different sources is limited as well because it only presents information in a different way and does not extend or leverage the company's knowledge base.

However, knowledge conversion from tacit to explicit (and vice versa) leverages, broadens, extends, and reframes organisational and individual knowledge. The interaction between tacit and explicit knowledge (externalisation) articulates individuals' vision to the world, which is a way to express the inexpressible by using metaphor to understand things intuitively. Although metaphor triggers the knowledge creation process it is not enough; hence analogy is vital to clarify the contradictions presented in metaphors (Nonaka, 1991). For example, a metaphor from Cannon is the link between a pop can and a personal copier. This previous metaphor makes absolutely no sense except when it is explained and harmonised by "analogy". The analogy in the Cannon example comes from the idea of building a reliable personal copier. Since 90% of personal copiers maintenance issues are caused by the drum; the idea of the metaphor was to create a "disposable" drum. The last link to Nonaka's

metaphor-analogy-model pattern is to articulate the metaphor into a model which is a "disposable" cheap drum which is made out of aluminium (similar to a pop can).

Moreover, moving from explicit to tacit knowledge embeds knowledge and extends an individual's knowledge base (internalisation). Reflecting back on Cannon's example, the internalisation would be to embed this same analogy into other products such as microfilm readers and laser printers to facilitate weight reduction and miniaturisation. Therefore, it can be said that internalised knowledge may trigger changes in the organisational wider knowledge system and encourage innovation (Nonaka 1994). The new technology can be incorporated into other products in which components are recombined to utilise the new opportunity (Henderson and Clark, 1990).

However, Nonaka's model only addresses the interaction between tacit and explicit knowledge but does not discuss how firms absorb (scan, import, and assimilate) external knowledge. A later model was developed by Leonard (1995), which proposes that core capabilities can be developed by four critical activities; problem-solving, implementing and integrating, experimenting, and importing knowledge. This model combines an internal and external focus to develop the firm's core capability and overcomes Nonaka's model limitation. Nevertheless, this model does not include knowledge dimensions.

Another model developed by Nahapiet and Ghoshal (1998) proposes that knowledge is created by knowledge exchange and combination, in which knowledge creation depends on individuals' abilities to exchange and combine knowledge. In this process

firms can create social capital (knowledge) by interchanging information and knowledge between organisational members and subunits. Moreover, this combines previously unconnected elements or creates novel ways to combine previously unconnected elements. Hence, knowledge exchange and combination enable firms to restructure their stock of knowledge, merge external and internal knowledge stock, and integrate knowledge acquired from various sources in order to create new knowledge (Collins and Smith, 2006, Smith *et al.*, 2005).

Nahapiet and Ghoshal (1998) argue that knowledge can be created through combination and knowledge exchange. The concept of combination as discussed by Nahapiet and Ghoshal (1998) mirrors Nonaka's (1994) knowledge creation modes. However, knowledge exchange represents additional construct above Nonaka's model. Knowledge exchange holds the assumption that individuals' level of knowledge and information varies and that they are willing to participate in exchanging knowledge even when the payoff is uncertain (Smith *et al.*, 2005). Individuals taking part in the creation process should anticipate value but they might not be certain about the outcome or the payoff of the process (Nahapiet and Ghoshal 1998). In addition, they must be motivated to engage in knowledge exchange and combination (Nahapiet and Ghoshal 1998). Szulanski (1996a) found that lack of motivation inhibits knowledge transfer concerning best practices.

However, the most important condition of exchange and combination is the combination capability: individuals can anticipate value and be motivated to engage in knowledge exchange and combination but might not have the combination capability (Nahapiet and Ghoshal 1998). Combination capability echoes the

assimilation capability proposed by Cohen and Levinthal (1990). As individuals must be able to assimilate and use external knowledge in order to "realise" its value (Zahra and George, 2002, Cohen and Levinthal, 1990). Combinative capability aims "to synthesize and apply current and acquired knowledge" hence organisations learn how to utilise their knowledge and information assets using this capability (Kogut and Zander, 1992a, Van Den Bosch *et al.*, 1999). The limitation to combinative capability is organisational and technological opportunity. Kogut and Zander (1992) propose that these opportunities serve as an incentive to build new skills to respond to future market uncertainties.

Innovations are the outcome of an organisation's combinative capability of generating new applications from existing knowledge. A firm's ability to build in current technology is considered an influential entry barrier, but when this barrier is absent competitors can respond to new innovations by imitation, reverse engineering, or brand labelling. Some competitors can imitate the function of the new innovation by recombining existing components (architectural innovation) without the need to reverse engineer the technology (Kogut and Zander, 1992).

Knowledge exchange is a precursor of knowledge combination because although knowledge is created by combining the knowledge and experience of different parties, it is highly dependent on the knowledge exchange between them (Nahapiet and Ghoshal (1998). The relation between knowledge exchange and knowledge combination was empirically tested by Shu *et al.* (2012). They found that knowledge exchange between a firm's members facilitates sharing tacit and explicit knowledge, which subsequently exposes individuals to new knowledge that in turn will trigger new ideas. Therefore, members will combine their knowledge with the newly

acquired knowledge or recombine their existing knowledge in a better way inspired by the new knowledge (Shu *et al.*, 2012). Furthermore, knowledge exchange and combination increase the rate of new product developments (Smith *et al.*, 2005), and have a positive effect on a firm's performance, in terms of sales growth and revenues from new products (Collins and Smith, 2006).

2.5.2 Communities of practice theory

Although knowledge creation model as explained by Nonaka (1994) is a suitable theoretical underpinning for this research, other models are available. For example communities of practice (CoP) as defined by Jean Lave and Etienne Wenger (Lave and Wenger, 1991, Wenger and Snyder, 2000) are groups of people who learn through participating in a community and engage in a common endeavour. Any community needs to have three characteristics in order to qualify as a community of practice; domain, and community and practice. Hence, it is necessary to have a shared domain of interest and to have members who engage in discussions and activities, and share knowledge within the community. In addition, members are practitioners who share experience.

A community of practice is a domain where individuals learn, but it varies from the concept *ba* which was introduced earlier (Nonaka and Konno, 2005). Individuals in CoP learn the knowledge embedded in a community but do not necessarily create new knowledge such as in *ba*. In addition, the boundary of CoP is determined by the task and the community's history and culture. However, *ba* is more fluid and is more flexible. In terms of change, change in CoP happens at the Micro level that affects individuals only, however, change in *ba* happens at the micro and the macro level, where individuals and *ba* itself can change. In addition, CoP approach has many

weaknesses which were identified by (Wenger *et al.*, 2002). They argue that while CoP evolves over time as new members join or leave (Lave and Wenger, 1991) which shapes the learning within, knowledge creation according to Nonaka (1994) is not defined by the individuals in any organisation. Given the aforementioned differences, the knowledge creation model is more suitable for the purpose of this study.

2.6 Architectural Innovation

Based on previous distinction between architectural knowledge and component knowledge (Section 2.2), architectural innovation (AI) is defined as rearranging the way components are linked together (Henderson and Clark 1990). Architectural innovation is the reconfiguration of product or process components and creating completely new interfaces between them. Architectural innovation is responsible for creating new markets or reforming existing market and may allow new entrants to make inroads into newly developed industries. In addition, AI prevails at the early stage of technological change, thus, researchers believe that AI affects companies' survival and performance. Hence, architectural innovation is of interest to this research to draw attention to the performance enhancement that can be achieved by exploiting architectural innovations, in addition to investigating the knowledge processing capabilities required to nourish this type of innovation.

2.6.1 Architectural Innovation Background

According to Abernathy and Clark (1985) innovation creates new markets, hence the evolution of new industries is the outcome of introducing novel products. Abernathy and Utterback (1978) describe technological or scientific breakthrough as the trigger of highly uncertain research and development (research and development period in

which firms try to experiment in the best way to exploit the breakthrough opportunities). A “normal configuration” will result after this period (Vincenti, 1990: 209) which is defined as “the general shape and arrangement that are commonly agreed to best embody the operational principle”. Hence, new products continue to evolve as a result of refining and experimenting with the materials and features and reconfiguring the component. In other words, architectural innovation creates a new industry or reformulates an established one by “laying down the architecture of the industry, the broad framework within which competition will occur and take place” (Abernathy and Clark, 1985: 7).

The competition in the industry shapes the architecture of the product and the process. For example, the personal transportation market was an attractive emerging market for different players from different industries (for example, the bicycle and waggon manufacturers, as well as manufacturers from the electrical industry). This new market was perceived as economically attractive with high returns and growing demand. As any other emerging market, the transportation market witnessed many competing car designs, however, the dominant producer was Ford and the dominant design was the Model T 1908. The previous one player (Ford) dominated the market and served a large segment of it. Eventually, in the shakeout period companies that were able to imitate the dominant design remained in the market, while other competitors try to serve latent needs through niche creation or they retreat from the market (Abernathy and Clark, 1985). This example portrays how the architecture of a new product was shaped by the fierce competition, and their various product designs. Those variation of product designs represent components or technologies linked together in different ways or interfaces.

An example of architectural innovation from the microprocessor industry is the multi-core processor. Microprocessor developers such as Intel introduced multi-core processor instead of the single-core processor, this innovation is regarded as a revolutionary change in the computing industry with a new trend of high-performance computing (Gepner and Kowalik, 2006). Multi-core processors are designed by including two or more cores within a single processor to enable high computing capabilities and running simultaneous activities (such as downloading music and gaming) (Intel, 2005). A simple analogy to explain how a multi-core processor works can be a highway with two lanes which is widened to include 4 lanes. The performance is enhanced as the new highway can handle twice as many vehicles without increasing their speed.

Intel is the oldest and largest Semiconductor chip manufacturing company, its immaculate success in this industry can be traced back to many factors. Intel pays attention to knowledge acquisition. For example, it provides grants to universities to enable fast knowledge transfer that focuses on developing new knowledge (MacCormack and Herman, 2004). In addition, Intel has "Lablets" set up in around universities to enable close collaborations between Intel employees, graduate students, and academics. The "Lablets" are considered an investment in absorptive capacity as they provided a connection between universities' collaborative networks and academics and Intel. In addition to providing access to knowledge, the "Lablets" help to assimilate the knowledge acquired. Through assimilation, Intel was able to understand and incorporate new knowledge into its knowledge base (Humberstone, 2012).

Insights from Cynthia Pickering; an IT collaboration engineering specialists show that system development in Intel follows a design collaboration process which aims to accelerate production. Under this method, Intel encourages collaboration across multiple product groups in different parts of the production cycle and even in different time zones to design and debug systems efficiently (Pickering, 2013). In addition, Intel applies a system that eliminates potential barriers to collaboration, under which the "not invented here" and information hoarding is eliminated. This encourages knowledge externalisation (as proposed by the knowledge creation theory), where knowledge is shared across individuals to amplify its effect. Moreover, knowledge combination is encouraged under this system where resources and information available inside Intel can be easily located and accessed. All of the aforementioned methods used have improved the time to market in Intel. As epitomised by the Intel experience, building a technological empire and delivering successful innovation require the collaboration of different groups where knowledge is created and internalised.

On the other hand, innovation failure is not out of question. One example is the Walkman which was discussed earlier as an architectural innovation that proved to be successful for a period of time. Walkman exceeded sales targets, but with changes in the environment such as illegal music download, it became obsolete. Sony's commitment to its mini-desk technology and its unwillingness to respond to environmental changes contributed to its Walkman Failure. Apple, on the other hand, developed the iPod in 2001, but Sony was unwilling to respond quickly to preserve their market leadership (Gershon and Albarran, 2013). This example portrays the

implications of organisations commitment to developing and enhancing their products and being responsive to environmental as well as technological changes.

2.6.2 Architectural knowledge vs. component knowledge

There are two types of knowledge which are required in any product development; component knowledge and architectural knowledge. Component knowledge is scientific or engineering knowledge about the core design concept; while architectural knowledge is related to the components' configuration and integration (the interfaces or the linkages between them) (Henderson and Clark, 1990). Architectural innovation capability enables companies to reconfigure components without the introduction of fundamentally new component technology. Therefore, it produces a new architectural knowledge, while at the same time retaining component knowledge (Henderson and Clark, 1990). As discussed earlier in the Rolls-Royce turbofan engines example (Section 1.2), architectural innovation creates new markets by using the same technical capabilities, and capitalising on the modularity embedded in product designs to deploy the same technology across new novel products (Abernathy and Clark, 1985). As a result, AI preserves the technical capabilities to produce a new product with enhanced features (for example portable copiers instead of desk based copiers) that will appeal to customers in a new market (personal copier market).

2.6.3 Architectural innovation and organisational structure

Aligning the organisational structure with innovation can help organisations to avoid hurdles associated with innovation adoption (Damanpour and Gopalakrishnan, 1998, Damanpour and Aravind, 2012). Theories that link organisation structure and

innovation (i.e. the dual-core theory, the theory of innovation radicalness and the ambidextrous theory) achieved inconsistent results over the past years. Those theories aim to identify certain characteristics which can better facilitate innovation. In general, researchers found that organisational effectiveness is positively related to the fit between the structure and the knowledge adopted (Doty *et al.*, 1993, Damanpour and Aravind, 2012, Damanpour and Gopalakrishnan, 1998).

For example, the dual-core theory specifies the organisational structure characteristics associated with administrative innovation and technical innovation (Daft, 1978). While administrative innovation is more related to administrative process, technical innovation is related to products, services, and processes. Hence the theory suggests that an organic organisational structure is needed for technical innovations. Organic structure is characterised by low centralisation, low formalisation, and high professionalism. While the opposite is recommended in administrative innovation, i.e., a mechanistic structure is recommended for administrative innovation.

The theory of innovation radicalness, is another theory that linked the level of innovation radicalness with organisational structure, the two types of innovations addressed in this theory were incremental and radical innovations (Dewar and Dutton, 1986, Ettlie *et al.*, 1984b). According to this theory, centralised and informal structure support radical innovation, while complex and decentralised structure support incremental innovations. The results achieved by this theory can be extended to other types of innovation. Architectural innovations can be supported by a more organic structure which is decentralised and has less bureaucratic control. This type of structure is flexible which allows sharing knowledge across product development

teams to create new ideas that fit with technological and market changes. This conforms with Henderson and Clark's (1990) research, which stresses the challenges faced by incumbents (established organisations) when they intend to adopt architectural innovations. Those incumbents have architectural knowledge embedded in their existing routines, which creates a challenge to accommodate the new architectural knowledge within their old frameworks. However, new entrants to the market can outperform incumbents because they can exploit innovation more effectively as they are free from embedded architectural knowledge. This point will be discussed in more details in the following section.

2.6.4 Architectural innovation challenge

As discussed earlier competing firms can copy or imitate the dominant design to survive. However established or existing companies face a challenge when copying a new architecture (Wade, 1995, Wade, 1996, Henderson and Clark, 1990, Dean and Meyer, 1996). Those companies have architectural knowledge embedded in their existing routines, which creates a challenge to accommodate the new architectural knowledge within their old frameworks. Architectural innovation is considered a competence-destroying change at the system level for established companies because of their internal rigidities and existing routines.

On the other hand, new entrants, unlike existing companies, have no constraints in terms of existing routines, systems, or rigidities that have to be challenged, and they possess the necessary technological know-how. Therefore, new entrants have a superior advantage that enables them to absorb new architectural knowledge and to copy new products (Wade 1995). For example, in the semiconductor

photolithographic alignment industry, new entrants replaced the old established companies after each new wave of architectural innovations, through their ability to accommodate new architectural knowledge swiftly and seamlessly (Henderson and Clark, 1990).

Another challenge faced by established firms, is that architectural innovation reduces the barrier to market entry, allowing new entrants to make inroads. Based on this, Wade (1995) suggests that existing companies should cooperate with a supporter to take advantage of architectural innovation. An example of supporters is a supplier, as firms can build enduring competitive strength by leveraging the specialised knowledge bases of their suppliers' networks (Bozdogan *et al.*, 1998). Christensen *et al.* (1998, 1995) support the previous discussion and recommend companies to target new markets with architectural innovation instead of trying to innovate in component technology, as the former strategy is more profitable.

For example, in the disk drive industry, companies that used proven components technologies to tap into new markets had more survival probabilities than companies that entered established markets with new component technologies. The previous example suggests that strategies that entail market risk (entering new markets with proven component technology) can be less risky than strategies that entail technological risk (entering established markets with new higher performance component technology) (Christensen *et al.*, 1998). By entering new markets, companies can avoid direct competition with established companies. However, this is not to say that market risk is low, as technologically developing industries will pose

future risk on new entrants by making their current technological advantage obsolete (Dean and Meyer 1996).

An example from the imaging industry may further illustrate architectural innovation challenge. In 1981, Sony introduced a camera which used a floppy disk instead of the old fashioned film. Canon and Fujifilm caught up in the 1980's using similar technology. None of the previous companies were successful as the use of floppy disk failed. In the 1990's the digital imaging revolution commenced. Nikon took the lead in 1991, but in 1994 Apple launched the first camera to connect to a PC. In 1995, the dominant design emerged, launched by Casio which incorporated an LCD screen. Nikon and Cannon followed the move, but Kodak still wanted to cannibalise on its armoury of their film business, which was a result of the architectural innovation challenge. However, film sales decreased drastically because of the newly available cameras in the market which did not require films. The film business collapsed with thousands of employees being fired and lots of buildings demolished. Konica and Polaroid who "both were large film manufacturers" left the industry because they could not survive in the digital imaging industry. Many camera manufacturers were affected (e.g. Hasselblad, Leica, and Agfa) because their competence base became obsolete with the domination of digital imaging and electronics cameras. Even Kodak struggled with the fierce competition as new entrants conquered the market (e.g. Sony and Samsung). This example shows that established firms' core capabilities can turn into core rigidities that inhibit innovation, while on the other hand; new entrants can accommodate new architectural knowledge since they do not have previous frameworks to challenge.

However, the adverse consequences of architectural innovation on established firms are possible to be counteracted (Iansiti, 1995). In doing so, firms have to understand the different product architecture in addition to the various knowledge bases available. Through analysing firms developing high performance mainframe computers, Iansiti (1995) found that the successful firms (e.g., Data General, Computervision, Wang, Prime, and Honeywell) had skills and routines aimed at incorporating technologies, and had a broad approach to integrate technical knowledge within a system focused approach (Islam and Meade, 1997). Their broad approach appreciates the nested system of relationship, in which their choices are affected by reconfiguring sub-systems to respond to customers' needs and solve problems (Christensen, 2013) (Figure 2.2).

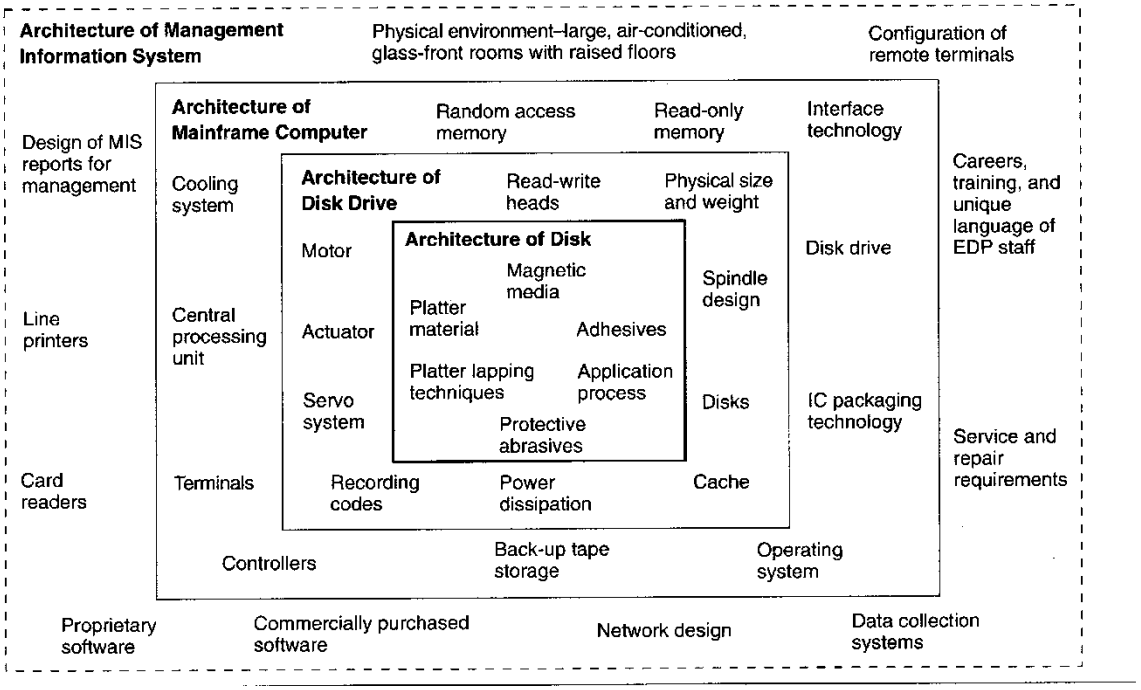

Figure 2.2 A nested hierarchy of product architectures

Reproduced with permission from Fig. 2 in Christensen, C. M., and Rosenbloom, R. S. (1995). *Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value network*. Research policy, 24(2), 233-257.

Architectural innovation received attention in other managerial fields; some researchers investigated inter-industry or inter-organisational networks using the principals of architectural innovation (Jaspers *et al.*, 2012, Grunwald and Kieser, 2007, Lee and Veloso, 2008, Tidd, 1995). Inter-industry architectural innovation is when technologies from different industries can be combined to create new products or services. This was the case in developing mobile communication applications for television, banking, and payment services. The previous inter-industry innovations relied on integrating unconnected technologies in an inter-industry setting, which was only possible by including the specialist from each industry, facilitating an intense coordination between them, and facilitating decision making and conflict resolution. Differentiation, coordination, integration, and decision-making authority are essential and more likely to result in timely and cost efficient development of high-quality products and services (Jasper *et al.*, 2012). Other researchers, such as Grunwald *et al.* (2007), focus exclusively on architectural product innovations that are pursued in alliances; in these innovations partners are usually not interested in sharing knowledge to a greater extent. Their intention rather is to exploit their knowledge bases to economise on resources and to speed up the time to market. Another study by Bozdogan *et al.* (1998) focused on production networks between suppliers and firms to enhance the outcome of the product development process, and build enduring competitive advantages by leveraging the specialised knowledge of their suppliers. They found that integrating suppliers in concept exploration and concept development stages is very likely to facilitate architectural innovation.

Therefore, architectural innovation is considered a tool to enhance performance, including facilitating shorter time to market (Grunwald *et al.*, 2007) or performance

enhancement to new designs offered to customers (Wade, 1995). For example, washing machine size reduction based on the needs of customers who live in smaller apartments or who have smaller families (Lipparini and Sobrero, 1994). The components of the washing machine are the same but this downsizing required re-engineering the interface to create a better and more suitable product.

In summary, architectural innovation received attention in the strategic management literature where researchers were interested in the best strategies to tap into new markets (Wade, 1995). Other fields are interested in architectural innovation and its effects on their performance, such as inter-organisational or inter-industry networks. In this thesis, architectural innovation is at the centre of attention in terms of linking knowledge creation with performance. In other words how organisations can benefit from their architectural innovation capability to enhance their financial performance and reduce development cost, while at the same time enhancing product quality and development time.

2.7 Absorptive capacity (APCA)

This research is interested in absorptive capacity in addition to knowledge creation. Although the knowledge creation model (Nonaka, 1994) provided a great understanding of the way knowledge is created, this model does not specify how firms interact with, and absorb, external knowledge and how a firm can effectively scan, import and assimilate external knowledge. Chesbrough (2006: 130) suggests that “a company that is too focused internally […] is prone to miss a number of opportunities because many will fall outside the organisation's current businesses or will need to be

combined with external technologies to unlock their potential." Therefore, absorptive capacity complements knowledge creation and improves the chances of effectively responding to external changes.

Absorptive capacity is a widely adopted concept in organisational studies which has been researched through various models that explored its antecedents (e.g. path-dependent managerial cognition (Gavetti and Levinthal, 2000), mental models (Lane *et al.*, 2006), and combinative capability (Kogut and Zander, 1992a)), and consequences (e.g. performance, innovation (Tsai, 2001), competitive advantage, and learning (Cohen and Levinthal, 1990)).

The absorptive capacity process model was first introduced by Cohen and Levinthal (1989) as the ability to recognise the value of the external knowledge, assimilate, and apply it. APCA enhances the ability of an organisation to anticipate future technological opportunities more accurately, and hence take advantage of emerging technologies ahead of rivals (Cohen and Levinthal, 1994) and to cope with uncertainty (Patel *et al.*, 2012). Introducing APCA was stimulated by the need to understand an organisation's economic behaviour.

Research and development were considered solely as a method to produce new products, Cohen and Levinthal (1989) proposed that R&D can enhance the organisation's ability to assimilate and exploit existing knowledge. Existing knowledge can originate inside the organisation, originate as R&D spillovers from competitors, or originate outside the industry. Based on the fact that external knowledge is essential, R&D efforts were supported to acquire this knowledge.

Thereafter, Cohen and Levinthal (1990) extended the concept of absorptive capacity to include the cognitive learning of individuals and examined the link between organisation learning and dynamic learning. For example, they proposed that the summation of individual learning is less than the total of organisation learning. They proposed that individuals need pre-existing knowledge which enhances their ability to learn; in a similar vein to individuals, organisations' pre-existing accumulated knowledge determines their effectiveness to acquire external knowledge.

There is an increasing quantity of research in the area of absorptive capacity which tries to apply, measure, or extend the concept. However, Lane *et al.* (2006) propose that the concept is being reified and taken for granted or mentioned marginally in research. The reification is evidenced by the big gap between the speed of the theoretical and empirical contribution and the speed of knowledge accumulation. This reification poses a serious concern about the full exploitation of the absorptive capacity concept (Bosch *et al.*, 2003). Lane *et al.* (2006) reviewed the APCA literature from 1991-2002 (papers citing Cohen and Levinthal (1990)) to attest the concept reification. Although, reification is important in the gradual development of any concept, it can be problematic especially in theoretical development and testing, in particular if researchers choose to use the concept as a solution for a problem while neglecting the underlying assumptions of it. Hence, the concept becomes obscured as more researchers use it to fit the needs of their papers. Overtime researchers may integrate results from different studies that used various definitions for the same concept which is likely to jeopardise their papers' validity.

In this research absorptive capacity has been used as a core and central construct (Section 3.2.3) and was regarded as a firm's capability rather than a resource (in order

to avoid reification), which is in line with the theoretical assumption proposed by Cohen and Leventhal (1990) (further discussion is presented in the following sections).

2.7.1 Absorptive capacity (APCA) Background

Absorptive capacity concept was observed by Tilton (1971: 71) (but was yet to be branded as APCA) as he described it in a semiconductor industry study as " a R&D effort provided an in-house technical capability that could keep […] firms abreast of the latest developments in semiconductor developments and facilitate the assimilation of new technology developed elsewhere". Later, Cohen and Leventhal (1989, 1990, and 1994) defined and labelled the concept, its antecedents and consequences. Cohen and Leventhal (1989) proposed that a firm has the capability to innovate and stay dynamic. This capability is called absorptive capacity wherein knowledge is recognised, assimilated, and applied to commercial ends.

Cohen and Levinthal (1990) extended insights from individuals' cognitive structure and problem-solving to the organisational level. Cohen and Levinthal (1989, 1990) suggest that organisation's APCA is a by-product of R&D efforts, previous learning experience, and the availability of cross-functional interfaces, shared language, and its members' problem solving capacity. Furthermore, a firm's APCA depends, and builds on, individuals' APCA. Individual's APCA is greater when the learning is related to previous acquired or created knowledge. The same analogy was tested by Cohen and Levinthal (1990) and they found that individuals' APCA qualities (which is cumulative and path dependent) apply to the organisation's APCA. An organisation's APCA depends to a large extent on the presence of knowledge and spillovers within

the industry (Cohen and Levinthal, 1990) and on its ability to share knowledge internally (Liao *et al.*, 2007).

In 1994 Cohen and Levinthal's, absorptive capacity definition was adjusted to include the organisation's ability to anticipate future technological opportunities more accurately, and hence take advantage of emerging technologies ahead of rivals. Later on, the absorptive capacity construct has been developed and its definition has been extended or refined by three subsequent papers (Lane and Lubatkin, 1998, Zahra and George, 2002) (discussion follows in the following section).

2.7.2 Absorptive capacity capabilities

APCA consists of four organisational capabilities: acquisition, assimilation, transformation, and exploitation of knowledge (Zahra and George, 2002). The previous capabilities are grouped into potential absorptive capacity (acquisition and assimilation) and realised absorptive capacity (transformation and exploitation). (Figure 2.3)

1. Acquisition: refers to identifying and acquiring externally sourced knowledge that is relevant to the organisation.
2. Assimilation: refers to organisation capability to analyse and interpret the acquired knowledge.
3. Transformation: is combining the newly acquired knowledge with previously owned knowledge in order to be distilled ready for use.
4. Exploitation: is incorporating the acquired, transformed knowledge into the organisation operation.

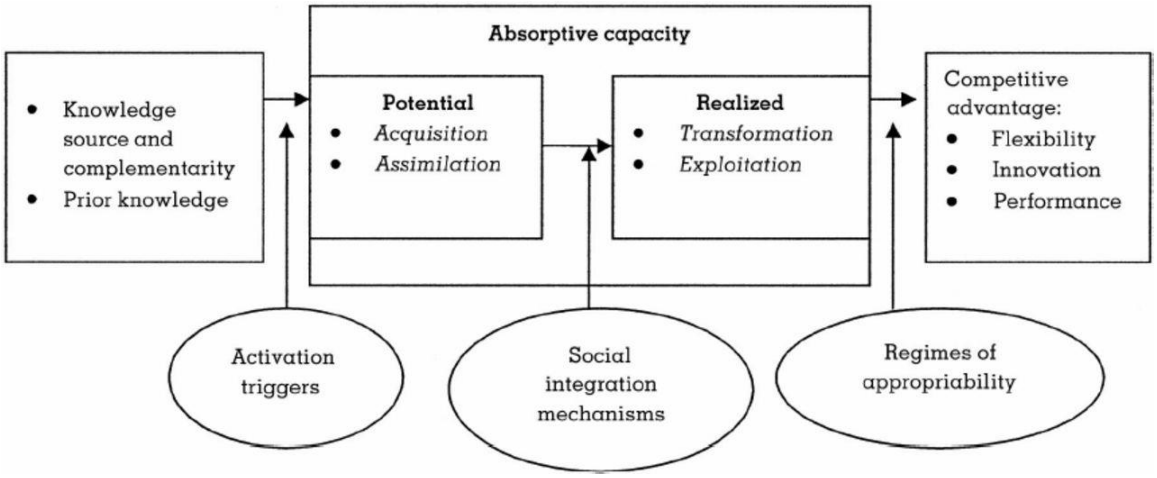

Figure 2.3: Absorptive Capacity Model (Zahra and George, 2002)

2.7.3 Absorptive capacity model conceptualisation

This section will address a few important reconceptualization examples from the extant literature, which either extend or develop the absorptive capacity concept. Although in this research Zahra and George's (2002) model were adopted, it is important to shed light on competing models.

Zahra and George (2002) model of absorptive capacity builds on the seminal work of (Cohen and Levinthal, 1990) and proposes that APCA includes potential as well as realised capacity. Potential APCA includes acquisition and assimilation, and realised APCA includes transformation and exploitation. Each group has a unique role in value creation.

Although APCA capabilities are independent, they have a complementary role to fulfil in improving performance (Zahra and George, 2002). For example, firms can acquire knowledge but not necessarily exploit it; in the same vein firms cannot exploit knowledge which has not been acquired. Firms vary in their ability to create value and consequently due care has to be exercised to maintain an appropriate efficiency factor.

The efficiency factor is the ratio of potential absorptive capacity (PAPCA) to realised absorptive capacity (RAPCA) (Todorova and Durisin, 2007), and it relates to the balance between both absorptive capacities. For example, a firm that has a strong acquisition capability but a weak exploitation capability, might successfully translate new knowledge into new products (Baker *et al.*, 2003). Todorova and Durisin (2007) argue that the efficiency factor variable is important in order to enable organisations to create value.

Although this variable is important, Todorova and Durisin (2007) argue it can be calculated through other measures; for example available and applied knowledge ratio can be measured after each phase, and hence can indicate the efficiency factor. The efficiency factor is a controversial variable that can be ambiguous and misleading as described by Mäkinen and Vilkko (2014). For example, an organisation that has a high PAPCA but insufficient RAPCA will have a low efficiency factor and hence low performance improvement as a result. On the other hand having high RAPCA and low PAPCA can lead to a high efficiency factor that might be misinterpreted by decision makers at the organisation, and can potentially affect their response to opportunities, environmental changes or turbulence. In this study, PAPCA and RAPCA were investigated while ignoring the efficiency factor to avoid the problems of misinterpretations, especially as this study investigated various sub-industries within the manufacturing industry.

Following Zahra and George (2002) model, this coming section will discuss the conceptualisation of each part. Zahra and George 2002 have integrated contingent factors which are: activation triggers, social integration mechanism, and regimes of

appropriability. All the contingent variables moderate the process of absorbing knowledge to a certain extent. Activation triggers are the factors that induce and stimulate the need to utilise the acquired knowledge based on internal or external stimuli (Zahra and George, 2002). Activation trigger might be internal such as organisational events that stimulate changes in a firm's strategy or design, or it can be an external trigger such as disruptive innovations. Activation triggers ignite search activities for new knowledge that is needed to trigger potential absorptive capacity. Activation triggers were not addressed in Cohen and Levinthal (1990) seminal paper as part of the model, however, they acknowledged some events including failure to meet the aspiration level which echoes activation triggers. For example, the aspiration level depends on the innovation level; if a firm's innovation level is low then, they will have little aspiration to acquire and exploit new technological knowledge. On the other hand, if their innovation level is high, it means that they are sensitive to external opportunities and are eager to invest in absorptive capacity (Cohen and Levinthal, 1990).

Zahra and George (2002) explicitly argued that activation triggers induce efforts to seek external knowledge. Therefore, the role activation triggers plays in inducing innovation cannot be ignored as it will motivate firms to allocate additional resources in response to important events (Cohen and Levinthal (1990). One of the external triggers, this research is interested in, is the change in the dominant design; this event is likely to intensify a firm's resources allocated to acquire new related knowledge. Firms are more likely to invest more resources to acquire, assimilate, and transform new knowledge to improve their performance and avoid technological lockout (Tegarden *et al.*, 1999, Eggers, 2014).

Potential absorptive capacity (PAPCA) is demonstrated by management flexibility and the development of its resources and capacities, while realised absorptive capacity (RAPCA) is demonstrated by the development of new processes and or products. Thus, RAPCA's outcome is innovation (Zahra and George, 2002). However, PAPCA is necessary to avoid competency traps, by contentiously renewing its knowledge stock and assimilating it into its knowledge base (Camisón and Forés, 2010).

Knowledge exploitation capability increases the chances of producing innovative products and it requires sharing relevant knowledge among individuals in order to promote mutual understanding (Zahra and George, 2002). This knowledge sharing is facilitated through social integration mechanisms (a contingent factor introduced by Zahra and George (2002)), which is argued to lower the barrier between knowledge assimilation and knowledge transformation and hence increase the efficiency of assimilation and transformation capabilities (Zahra and George, 2002). Todorova and Durisin (2007) reconceptualised social integration mechanisms by proposing that these mechanisms are likely to affect all absorptive capacity capabilities. Todorova and Durisin (2007) base their argument on Zahra and George's (2002) assumption that absorptive capacities are facilitated through social integration; therefore, Todorova and Durisin (2007) propose that any social integration mechanism is likely to affect all absorptive capacities.

It is widely agreed that absorptive capacity is a multidimensional construct that involves knowledge valuing, assimilation and application (Cohen and Levinthal, 1990, Mowery and Oxley, 1995, Kim, 1998, Kim, 1997). In their pursuit to reconceptualise APCA, Zahra and George (2002) present transformation as a consequence of assimilation. Transformation explains how and why organisations

change their “cognitive schemas” in order to facilitate absorbing new knowledge. Zahra and George (2002) refer to assimilation as the process in which an organisation interprets knowledge that fits within its cognitive structure, is in its search zone, and corresponds with its current context. After which, the already-assimilated knowledge has to be transformed, during this process the existing organisational knowledge structure (cognition schema) will be changed.

Other researchers denounce this view (e.g. Todorova and Durisin, 2007). Based on their argument, transformation is an alternative to assimilation (Todorova and Durisin 2007). Organisations have an existing cognitive structure, therefore, when newly acquired knowledge fits adequately with the existing cognitive structure then knowledge will be altered slightly or in other words “assimilated” to improve its fit. If new knowledge cannot be altered to accommodate the existing knowledge structure, then the individual cognitive structure should be transformed to adapt. Then the debate here is whether transformation is an alternative or a subsequent to assimilation. While Zahra and George (2002) propose that already-assimilated knowledge should go through the transformation process regardless of its fit with existing cognitive schema, Todorova and Durisin (2007) propose that only the knowledge that cannot be assimilated will go through the transformation process.

This current research will adopt Zahra and George (2002) argument, because organisations encounter various types of new knowledge, and often they fail to determine if that knowledge requires a change in the structure or if the knowledge can be successfully tweaked in order to fit the existing knowledge structure. For example, this research argues that absorptive capacity is necessary to leverage architectural

innovation, as discussed in Section 2.2, this innovation is based on creating new linkages between existing components, and is culminated in developing new novel products. If external knowledge was overlooked due to the fact that it is not within the firm's search zone, or not compatible within the firm's context, or it does not complement the firm's existing assets, then an opportunity to create an innovative product is most likely to be missed. Thus, it is crucial to have both processes (assimilation and transformation) in the model subsequently to avoid overlooking any important knowledge. Another reason behind our support of the original model by Zahra and George (2002) is that, knowledge that has been acquired from the sector or from another firm, comes from different organisational cultures, contexts, and systems. Thus, this newly acquired knowledge should go through assimilation, in order to be analysed, processed, interpreted, and understood. Assimilation should take place before transformation regardless of the acquired knowledge's fit with the firm's existing cognitive schema (Camisón and Forés, 2010).

As stated earlier organisations' inertia can impede recognising the value of new external knowledge (Henderson and Clark, 1990) and this might lead to organisational failure. For example, firms in the analogue camera industry failed to incorporate knowledge into their existing cognitive structure because they repeatedly tried to assimilate the new knowledge rather than transforming their cognitive structure (Tripsas and Gavetti, 2000). As a result, many firms failed to shift to digital imaging which led to high losses (e.g., Lucas and Goh, 2009, Burgers *et al.*, 2008).

The last issue that will be addressed here is the regimes of appropriability, which was adopted by Zahra and George (2002) from Cohen and Levinthal's model. It is the last contingent factor, and defined as the processes available in place to enable

organisations to claim the returns on their absorbed knowledge and innovations. In their model, Cohen and Levinthal (1990), propose that regimes of appropriability are measures to test the incentive to invest in absorptive capacity. While on the other hand, Zahra and George (2002) argue that the relationship between absorptive capacity and its competitive advantage outcomes is moderated by the regimes of appropriability.

To conclude, from the few issues discussed so far, it appears that the absorptive capacity concept conceptualisation has received great interest and contradictory views. The next sections will examine relevant literature and empirical research on knowledge, performance, and absorptive capacity. In addition it will draw upon the idea of external knowledge absorption and exploitation.

2.7.4 Absorptive capacity and Knowledge

According to Cohen and Leventhal's model, absorptive capacity depends on the previous knowledge of the firm as well as the source of that knowledge. Cohen and Levinthal (1989) described APCA as a way of learning to do things differently; thus it is similar to learning. Firms' willingness to invest in creating APCA is influenced by their perceived incentive for learning. This perception, however, depends on variables such as the scope of technological opportunities; the greater the amount of knowledge available and the potential improvement in technological performance, the greater the organisation's incentive to invest in R&D.

Lane *et al.* (2006) examined the reification of the absorptive capacity construct, and pointed out some limiting assumptions in the literature, one of which is the

assumption that absorptive capacity equals relevant prior knowledge. This assumption is partially true, as possessing prior relevant knowledge is important but certainly is not a sufficient trigger for a firm to invest in APCA. This assumption focuses only on the content of prior knowledge but ignores the knowledge process. In their sample (studies between 1990-2002), Lane *et al.* (2006) found that few studies closely investigated absorptive capacity (e.g., Lane and Lubatkin, 1998, Lane *et al.*, 2001), However those studies did not offer practical recommendations for developing the concept. For instance, Lane and Lubatkin (1998: 474) have offered a very general recommendation that "a firm must develop a thorough understanding of its own knowledge, the processes by which it converts knowledge into capabilities to meet the demands of its environment". To overcome this, this thesis investigated how knowledge created and applied by the firm has led to enhancing innovation capability and performance.

Absorptive capacity enables firms to excel in NPD performance (especially financial performance and development cost) (Kostopoulus *et al.*, 2011). Although the previous study examined how absorptive capacity translates external knowledge inflow into innovation and financial performance, however, it considers knowledge as a stock rather than a process which is considered one of its limitations. External knowledge inflow is proved to be an antecedent of absorptive capacity (Roberts, 2015, Kostopoulos *et al.*, 2011), which is indirectly related to innovation (Tsai, 2001). Although the previous studies added value to the construct of absorptive capacity, however, they focus on knowledge content rather than knowledge processes as they have operationalised APCA by using R&D intensity or an indicator that rely on R&D

and the number of employees instead of focusing on the process itself (*i.e.* acquisition, assimilation, transformation, and exploitation).

Absorptive capacity operationalisation lacks consensus, which proofs its reification (Lane at al., 2006). Measures of APCA used vary between quantitative and qualitative measures. Researchers used quantitative measures (absolute measures) such as R&D expenditure and R&D intensity (R&D expenditure divided by sales) (Tsai, 2001, Cohen and Levinthal, 1990); scientific and technical training investment spending (Mowery and Oxley, 1995), and employees' expertise or number of employees with university education (Grimpe and Sofka, 2009). On the other hand, qualitative measures (perceptual scale) have been used to capture APCA dimensions (Jansen *et al.*, 2005, Camisón and Forés, 2010). The qualitative measures capture the process-based definition of APCA and are far more representative of Cohen and Levinthal (1990) definition. Furthermore, qualitative measures overcome the problems of the quantitative measures (Camisón and Forés, 2010, Jansen *et al.*, 2005). For example some researchers have used the same quantitative measure to capture APCA and innovation (for example, the number of patents) which makes their results questionable and harms their research validity (Lane *et al.*, 2006).

Without prior knowledge, organisations will not be able to determine the value of new knowledge in order to absorb it (Cohen and Levinthal, 1990). Previous research by Henderson and Clark (1990) shows the importance of recognising the value of new information, and their empirical study shows how failing to recognise change in architectural knowledge actually affects the survival of firms in the semiconductor photolithographic alignment equipment industry: they fail to appreciate new

knowledge which was filtered out. In this case, old architectural knowledge was emphasised at the expense of seizing new technological opportunities. Hence, firms failed to capitalize on new knowledge to create new architectural innovations.

The previous example demonstrated the need to have the capability to scan the environment for important new knowledge and internalise it (through acquisition capability), analyse it (assimilation capability), combine it with existing knowledge (transformation capability), and utilise it in producing innovative commercial output (exploitation capability). Hence it can be argued that without absorptive capacity, architectural innovation capability is not enough to realise important changes in the external environment. Architectural innovation capability allows firms to reconfigure product components in order to create architectural innovation. However, without absorptive capacity, firms are less likely to be competent in discerning the value of external new knowledge in order to internalise it. Thus, the risk of failing is higher if firms do not invest in absorptive capacity and overlook relevant, important, external (technological or market) knowledge. Especially that technological and market knowledge are essential to enhance innovation and performance (Lane *et al.*, 2006, Song *et al.*, 2005).

Previous research has investigated why organisations fail to recognise the value of external knowledge. There are two streams of research: one proposes that inertia is attributed to cognition; for example, path-dependence managerial cognition (Gavetti and Levinthal, 2000, Tripsas and Gavetti, 2000) and how this negatively affect an organisation's adaptive intelligence. The other stream of research attributes inertia to organisational capabilities; for example rigid capabilities (Leonard-Barton, 1992). Tripsas and Gavetti (2000) looked at organisational inertia from both perspectives

(cognitive and firms' capabilities) and they suggest that managerial cognition can affect firms' capabilities which, in turn, affects their performance.

Empirical research proves that APCA is a tool to realise better financial performance over time through innovation (Kostopoulos *et al.*, 2011). Firms which are involved in innovation are exposed to a more enriched knowledge base (knowledge complementarity as described by Zahra and George (2002)), and are able to better assimilate and exploit external knowledge. APCA explains why some organisations are better than other while they are exposed to the same knowledge. Potential absorptive capacity in terms of acquisition and assimilation enable firms to identify and acquire external knowledge. This capacity enables firms to achieve innovation outcomes based on accumulating relevant knowledge to be internalised and used. The realised absorptive capacity reflects firms' ability to leverage the acquired knowledge. Hence, Zahra and George (2002) absorptive capacity model enables the creation of commercial products based on acquiring relevant knowledge and incorporating this knowledge with existing knowledge.

A firm's responsiveness to external changes affects its tendency to be flexible and swift in responding to technological changes (having greater APCA) (Welsch *et al.*, 2001). Therefore, it can overcome the established firms' inertia and will have a better capacity to analyse the environment and incorporate technological advances which, in turn, positively enhance its capability to produce architectural innovations.

As discussed earlier (Section 2.7.3), change in the dominant design triggers absorptive capacity activities "a change in the dominant design within an industry will compel the firm to expend efforts into acquiring the information necessary to develop the new

technology-a process that will broaden its potential absorptive capacity" (Zahra and George, 2002: 194). Absorptive capacity has a mediating role on the relationship between external knowledge and financial performance which means that APCA is essential to advance financial performance (Kostopoulos, 2011). APCA may positively affect performance through exploiting external knowledge, but firms require additional resources and capacities to enhance innovation performance and output, such as innovation capability (Liao *et al.*, 2007). As a result, innovation capability affects innovation performance, while absorptive capacity plays a moderator role affecting innovation performance (Kostopoulos *et al.*, 2011).

The previous finding supports APCA theory that firms will derive innovation out of the new knowledge only if they recognise its value, internalise it, and utilise it (Cohen and Levinthal, 1990, Zahra and George, 2002). Absorptive capacity role is more pronounced in stimulating innovation outcomes in sectors with high knowledge turbulence and tight intellectual property protection (The degree of legal appropriability) (Escribano *et al.*, 2009). This presence of prerequisites, including, R&D cooperation, external knowledge acquisition and experience with knowledge searches are vital to exploit external knowledge (Fosfuri and Tribó, 2008).

2.7.5 Absorptive capacity and performance

Previous conceptual and empirical research on absorptive capacity support its positive effect on higher financial performance (Chen *et al.*, 2009, Rhee, 2008, Tsai, 2001, Zahra and Hayton, 2008, Zahra and George, 2002, Forés and Camisón, 2016, Leonard-Barton, 1998, Lane *et al.*, 2001). It is argued that absorptive capacity

enhances innovation through contributing to knowledge transfer. New knowledge absorbed by firms is likely to contribute to its competitive advantage through innovation. The literature on learning advocates this view and suggest a strong positive relationship between absorptive capacity and innovation (Cepeda-Carrion *et al.*, 2012).

Firms need to keep abreast of high-velocity technological changes in order to develop new products (Teece *et al.*, 1997). This is certainly not an easy task in the today's technological proliferation. Firms that respond to technological changes tend to have high performance (Lavie *et al.*, 2011). Technological innovations require the ability to produce new products that are nested in new technologies. New technologies induce firms' engagement in innovation, as firms which constantly scan the environment for new technologies are more likely to identify gaps in the market (Arora and Gambardella, 1994). Therefore, APCA are more likely to enhance firms' ability to capture and exploit opportunities (Jansen *et al.*, 2005).

The previous mentioned benefits are evident in the existing literature. For example, APCA enhances innovation speed and frequency (Tsai, 2001) and innovative performance (Kostopoulos *et al.*, 2011, Alegre *et al.*, 2013, Cepeda-Carrion *et al.*, 2012, Fosfuri and Tribó, 2008), and financial performance (Kostopoulos *et al.*, 2011, Chen *et al.*, 2009). Financial performance is crucial for firms' survival, however not all innovations are guaranteed to have high returns on investment (Tsai, 2001). Hence, the extant literature proposes that firms that invest in acquiring, assimilating, and exploiting knowledge are more likely to generate financial benefits.

2.8 Lead Users

The locus of innovation has witnessed a shift from producing firms to users. Von Hippel (2005) describes this trend as democratising innovation. “Today, in many industries, the logic that supports an internally oriented, centralised approach to R&D has become obsolete” (Chesbrough, 2006: 41). Closed innovation is basically “self-reliance” in which an organisation feels an urging demand for control and so it tends to keep R&D in-house. According to Enkel, Gassmann *et al.,* (2009) open innovation hampers long-term innovation success because organisations will lose control and core competencies. On the other hand, closed innovation does not guarantee short innovation cycles or a short time to market and it comes with a high risk of product failure. Thus, Enkel, Gassmann *et al.* (2009) emphasise pursuing a balance between closed and open innovation. Firms can become ambidextrous by simultaneously exploring and exploiting opportunities by integrating external (lead users) as well as internal actors (Hienerth *et al.*, 2014).

Hienerth *et al.* (2014) found that integrating lead users helps to continuously expand product lines and to explore and tackle new market segments. Firms must find the right balance between introducing new products and improving existing ones (trade-off between exploration and exploitation) (March, 1991). Integrating product experts, including key suppliers and lead users, is proposed to affect the level of innovation as close collaboration is proposed to promote incremental improvements of existing products. On the other hand, irregular collaboration with lead users is more likely to support exploration and create new products (Tsinopoulos and Al-Zu’bi, 2014).

Firms are proactively involving customers in the new product development process using one or multiple user innovation methods (lead user, mass customisation toolkit, or retreat conferences). Currently, more established producer firms are benefiting from bilateral interaction by employing the lead user method (Lazonick and Prencipe, 2005). “Research shows that many commercially important innovations are initially thought of and even prototyped by lead users rather than the manufacturers” (Von Hippel, Thomke *et al.,* 1999: 4).

Lead users are an important source of innovation in various industries, including medical equipment, sporting equipment, scientific instruments, and IT solutions (Baldwin *et al.,* 2006, Lüthje and Herstatt, 2004, Dyer and Nobeoka, 2000, Jeppesen and Frederiksen, 2006, Lettl *et al.*, 2006, Morrison *et al.*, 2000, Urban and Von Hippel, 1988b, Von Hippel, 1986a). The percentage of user innovation is 37% of outdoor consumer products (Lüthje, 2004) and 32% of sporting equipment (Franke and Shah, 2003). Many products are being developed by integrating lead users around the world. For example, Sony has integrated users to develop games that can be played on its Sony PlayStation (Von Hippel *et al.*, 1999). Also, in the medical imaging industry, lead users in pattern recognition were integrated to develop a software which has the capability to detect small features of abnormality like tumours (Von Hippel *et al.*, 1999). In addition, Rodeo kayaking is a sport and industry that has been developed by users. Many innovations by lead users have become commercial products (Baldwin *et al.,* 2006).

Ideas generated through traditional market research are less likely to produce breakthrough innovations; they tend to contribute marginally to the firm’s products portfolios (Eliashberg *et al.,* 1997). The difference between both traditional and non-

traditional market research, is that traditional market research collects information from users at the centre of the intended target market; this information only describes their need, while the task of finding a solution is assigned to the manufacturers (Eliashberg *et al.*, 1997). On the other hand, the lead user method provides firms with needs and solutions at the same time from users ahead of the trend, both within and beyond the intended target market (Von Hippel, 1986b). In addition, ideas generated by lead users are more novel, they address genuine consumer needs, and result in a higher market share (Lilien *et al.*, 2002). This will be explained further by using the lead user theory in the next section.

2.8.1 Lead user theory

In general, the "lead user" literature is classified into two major streams of research: a stream that focuses on lead user characteristics (e.g., Lüthje and Herstatt, 2004, Franke *et al.*, 2006, Bilgram *et al.*, 2008, Schreier and Prügl, 2008), and the other stream focuses on the lead user method (Dyer and Nobeoka, 2000, Urban and Von Hippel, 1988a, Lilien *et al.*, 2002).

Customer involvement was first introduced by Von Hippel (1986a); his work focused on the lead user approach and user communities. Lead user theory has two tenants; lead users are ahead of the trend and expect high benefits from obtaining a solution to their needs (Von Hippel 1986).

The first component means that lead users experience needs ahead of other ordinary users, hence the solutions to those needs appeal to a broader part of the market. It is reported that 70% of lead users' innovations enhanced the commercial attractiveness

of existing products (Morrison *et al.*, 2000). This "Ahead of the trend" quality represents the commercial attractiveness of user innovations. They have strong latent needs which are expected to become general, months or years into the future (Von Hippel, 1986a). Von Hippel describes lead users as a "need-forecasting laboratory". They are ahead of the field in use and adoption of new technology, they can provide ideas for new product and modify existing ones, and they scrutinise a product's functionality (Urban and Von Hippel, 1988b). Furthermore, customer integration improves product-market fit, thus minimising the cost and risk of new product development (Gassmann *et al.*, 2006). The second tenet is that lead users are believed to benefit significantly from receiving a solution to those needs. The high perceived benefit is likely to be related to a greater effort to find a solution for their needs (Von Hippel, 1986).

However, the theory is rather limited; firstly, in terms of what factors impact lead users, and secondly, there is the problem of how firms can distinguish the lead user from the ordinary user. Schreier and Prügl (2008) extended the lead user theory by identifying factors that indicate lead userness. Indicators such as consumer knowledge, use experience, locus of control, as well as innovativeness, are factors that can help firms to identify lead users from ordinary users (Schreier and Prugl 2008). Later, this section will identify the relationship between some lead user indicators and generated idea quality as well as reducing development cycle time.

2.8.2 Lead user and performance

There are lots of benefits gained from integrating lead users. "Researchers found that many commercially important products are initially thought off by users" (Von Hippel, Thomke *et al.* 1999: 4). Firms collaborating with lead user report an increased

rate of new product success (Gruner and Homburg, 2000) greater product variety (Al-Zu'bi and Tsinopoulos, 2012) and sales potential (Lilien *et al.*, 2002). In comparison to in-house product development, lead users are likely to produce less risky products (Gruner and Homburg, 2000). In addition, lead users' integration can reduce product development cost (Tsinopoulos and Al-Zu'bi, 2012). This research is interested in two performance variable; cycle time and product quality.

2.8.3 Lead user and NPD cycle time

Integrating lead user is known to enhance new product development performance (Lilien *et al.*, 2002, Schuhmacher and Kuester, 2012, Langerak and Hultink, 2008). It can help decrease the development time as lead users can provide ideas and generate product designs and component specifications (Langerak and Hultink, 2008, Thomke and von Hippel, 2002). Lead users with real life experience can provide insights that are superior to market research (Von Hippel, 1988). Therefore, accurately understanding the need will help organisations accelerate NPD and reduce errors.

Lead users are argued to often have complete solutions because they already have developed and tested the product themselves. Thus, the collaboration with lead users will increase the speed of product development. In the early stages of NPD, lead users can provide accurate product specifications to inform the market research process, as they are expert about the need. During the prototyping period, lead users can test the product and provide workable modifications which can be used in the modification stage. Consequently, the assessment stage will be faster as lead users can easily assess the product's knowledge (Tsinopoulos and Al-Zu'bi, 2012). Testing the product will be easier and faster with lead users as they are technically competent and have a passion for trying the developed product as early as possible. Usually products are

specifically designed to solve their problems; thus, the output will be as accurate as possible to satisfy that need. This will relatively shorten the NPD process. Thereby, it is highly important to systematically involve them in the process. Lead users provide significant value as previous studies show that they affect development speed (Langerak and Hultink, 2008, Langerak *et al.*, 2008, Langerak *et al.*, 1999, Thomke and von Hippel, 2002). Finally, they provide important insight into product needs and solutions which prevent delays in later new product development stages.

Millson *et al.* (1992) proposed that certain techniques and methods implementation can accelerate new product development time (MRW hierarchy). They have clustered these techniques into five generic categories and ordered them in terms of implementation. The techniques aim to simplify NPD operations, eliminate unnecessary NPD activities, and identify activities that can be operated in parallel in order to reduce delay. Langerak *et al.* (1999) investigated the MRW hierarchy based on experience surveys with academics and practitioners in addition to reviewing the literature and they produced nine generic approaches to accelerating the NPD process. Lead users' integration has found to be an activity that adds value and provides the firm with important need and solution information (Millson, Raj *et al.* 1992, Langerak, Peelen *et al.* 1999). The shortcomings of the previous two articles are; firstly, they have not empirically tested each category and technique, therefore, their results have an explorative nature; secondly, the data have not been derived from "best practice" firms in accelerating NPD process. In a later study Langerak and Hultink (2008) empirically accentuated that lead users' integration accelerates the NPD cycle time, especially for products new-to-the firms.

Conversely, Lilien *et al*., (2002) found that project idea generation from lead users takes more time and costs to develop than projects from non-lead users. They found that generating idea in a lead user project took on average 154 days, while in non-lead users' projects the average was 60 days. Further research will need to be conducted to test the previous argument.

2.8.4 Lead user and product quality

Lead users' integration can increase product quality (Monika and Kuester, 2012), as the main drive behind lead user involvement is to develop a product that is not currently available in the market, this new product might have a minor improvement; and quality is considered one of the sought after improvements. "Minor improvement innovations were defined as those that gave the user any improvement in any dimension important in processing such as cost reduction, increased speed, quality, consistency, and so on" (Von Hippel, 1988: 22). Unlike the traditional idea generation techniques based on computer input from random or ordinary customers, lead users have unique characteristics and needs, which will increase the quality of the ideas generated by them (Lilien *et al.*, 2002).

Boland Jr (1978) found that integrating users in system design, produced higher quality designs, through incorporating and integrating user mental scheme. However, Boland did not investigate the reason behind his findings. Contests are very popular method of lead users' integration, wherein they are asked to input ideas about challenges they face in their lives or ideas about developing products and/or services that solves a certain problem. For example, Volkswagen's call for ideas to improve its eco-mobility. A study by Schuhmacher and Kuester (2012) investigated lead user

characteristics which are linked to the quality of ideas in an “ideas contests” setting. Schuhmacher and Kuester (2012) argue that lead users characteristic of being ahead of the trend and having a deep need for a better solution, may help users to identify high benefits from innovation (*i.e.* product), thus, they may become dissatisfied if the innovation does not satisfy their need (Franke and Shah, 2003). There is also a link between dissatisfaction and quality. Dissatisfied users explore the domain as they are co-producing the product or the service, hence they become aware of their needs which motivate them to articulate the cause of their dissatisfaction and consider how it can be changed (Lee, 2010). As a result, lead users are able to challenge the status quo to produce high-quality products ideas.

Schuhmacher and Kuester (2012) found that use experience affects idea quality as lead users are experts in their field. Use experience is knowledge and learning gained from usage (Schreier and Prügl, 2008), and it indicate lead userness and their innovation activities (Lüthje, 2004, Lüthje *et al.*, 2005). The more use experience gained, the more lead users will be in a “better position to perceive and analyse existing usage problems more systematically to conceive solutions” (Schreier, Prugl, 2008: 336).

Furthermore, another important charesteristic of lead users is their intrinsic motivation, which is argued to positively affects ideas quality (Schuhmacher and Kuester, 2012). Intrinsic motivation is the degree lead users are excited by an activity for the sheer benefit of the product itself. Intrinsic motivation increases the likelihood of lead users creativity as the outcome is considered valuable for them (Audia and Goncalo, 2007, Schuhmacher and Kuester, 2012, Wang and Ahmed, 2004). Lead user

intrinsic motivation encourages them to invest significant energy to produce highly creative ideas (Füller *et al.*, 2011).

The following section is going to present the hypotheses development in relation to lead users' integration and performace.

2.9 Summary

This chapter has reviewed the relevant literature related to the variables of interest, and is considered the base for the next chapter which will aim to establish a conceptual framework for analysing how knowledge creation will lead to better performance through focusing on the architectural innovation capability. Moreover, how absorptive capacity moderates the relationship between architectural innovation capability and performance.

CHAPTER THREE: HYPOTHESES DEVELOPMENT

3.1 Introduction

Drawing on the conceptual and theoretical backgrounds from the previous chapter, this chapter will present the underlying theory used and the proposed conceptual model. The conceptual model is based on proposing relationships between the variables of interest which include knowledge creation, architectural innovation capability, absorptive capacity, lead user integration, and performance. This chapter will present the proposed hypotheses which will be developed based on the underpinning theoretical framework.

3.2 Theoretical framework and hypothesis development

3.2.1 Knowledge creation: hypotheses development

The underlying proposition in the extant literature is that firms which can create knowledge are better at delivering value by generating superior products (Kogut and Zander, 1992a, Su *et al.*, 2013, Song *et al.*, 2012, Schulze and Hoegl, 2006, Smith *et al.*, 2005, Von Krogh *et al.*, 2000). Previous research argues that innovation is the outcome of new knowledge creation (Kogut and Zander, 1992a, Leiponen, 2006, Madhavan and Grover, 1998, Nonaka and Takeuchi, 1995, Daniel Sherman *et al.*, 2005, Song *et al.*, 2005, Jiang and Li, 2009, Smith *et al.*, 2005, Tödtling *et al.*, 2009). For example, Kogut and Zander (1992: 392) propose that "innovations are new combinations of existing knowledge and incremental learning". Furthermore, Leiponen (2006) claims that innovation is the result of creative reconfiguration of firm's knowledge. In addition, new knowledge was described by Madhavan and Grover (1998) as a prerequisite of product innovation. New knowledge can be

generated through knowledge creation efforts geared by their employees' skills, knowledge, and experience (Smith *et al.*, 2005). In addition, knowledge can be acquired (absorbed) from external sources (Cohen and Levinthal, 1990).

New product development depends on the creation of new knowledge (Madhavan and Grover, 1998). As Nonaka and Takeuchi (1995: 50) pointed out, "understanding how organisations create new products . . . is important. A more fundamental need is to understand how organisations create new knowledge that makes such creations possible". Knowledge creation enables organisations to produce innovative products ideas. According to Nonaka's (1994) conceptualisation, knowledge creation builds the knowledge base through socialisation, externalisation, combination, and internalisation. The spirals of knowledge creation spark innovation and creative ideas. Informal interaction between individuals during socialisation creates a common base of understanding and creates a chance to envision novel products ideas. Subsequently common terms and articulated concepts are generated in externalisation, which enhances the creation of explicit knowledge. In particular, exposure to diverse ideas in the concept phase enables individuals to capture new architectural knowledge. Reconfiguring the explicit knowledge helps individuals in creating valuable knowledge from explicit knowledge to generate innovative product ideas. Moreover, combination facilitates applying current and acquired knowledge from various domains to envision potential innovative ideas. Reflecting on the knowledge created is encouraged in the internalisation phase, in which organisations creates new interfaces and different possible outcomes using the same components or subsystems. According to aforementioned model, creating knowledge through the four spirals

creates increased possibility of reconfiguring knowledge to enhance products innovativeness.

The role of tacit knowledge in NPD is defined by Polanyi (1967) as a central part of knowledge that resides in individuals' minds while explicit knowledge resides in textbooks, documents and formulae. A great amount of organisational knowledge remains tacit because it is extremely hard to describe it. Therefore, tacit knowledge tends to be embedded in individual or social groups' minds. Hence, new products are considered embodied knowledge and are largely affected by the input of NPD team and how the NPD manager facilitates the transition from embedded to embodied knowledge (Madhavan and Grover, 1998). In this vein, Schulze and Hoegl (2006) quantitative empirical study tested how knowledge creation modes operate in the concept and development phase of NPD to increase or decrease NPD success, at the project level.

Socialisation offers an informal interaction to develop a common understanding of the new product and its features. For example, team members have the potential to create knowledge as soon as they get together (Madhavan and Grover, 1998). Therefore, they are better positioned to integrate their knowledge bases because they have a shared understanding of the product idea and its features, especially at the concept phase (Schulze and Hoegl, 2006). On the other hand, Schulze and Hoegl (2006) propose a negative effect of socialisation in the development phase of product development because this phase requires the implementation of the product concept efficiently to meet various project objectives.

Combination, on the other hand, has a positive effect on the development phase. As team members are required to synthesise knowledge acquired from different sources (combinative capability discussed earlier) in order to create solutions to technical challenges and avoid mistakes from old projects.

There is limited evidence and few empirical studies that focus on each knowledge creation mode and its effect on NPD and innovation, and their results are inconsistent. For example, Schulze and Hoegl (2006) fail to prove that combination is important in the concept phase while other scholars such as (Clark and Fujimoto, 1991, Corti and Storto, 2000) argue that socialising individuals from different groups outside or inside the organisation from different experience, background is key in the concept phase of NPD.

Jiang and Li (2009) found that innovation mediates the effect of knowledge management (interfirm knowledge sharing and creation) on performance. Their study shows that knowledge management does not always have a direct effect on economic and business performance, but instead it has a higher probability of affecting innovation and innovative performance. Innovation is the outcome of an organisation's combinative ability to exploit and recombine its knowledge (Kogut and Zander, 1992a, Van Den Bosch *et al.*, 1999). Knowledge creation is a complex interactive process which includes learning from experience, explorative learning and creative learning (Jiang and Li, 2009). These forms of learning are essential for knowledge creation. For example, absorptive learning aims to "access, assimilate, absorb and exploit existing knowledge beyond its boundaries to create values" (Jiang and Li, 2009: 360). Furthermore, absorptive learning encourages exploiting

knowledge that is not necessarily newly created. On the other hand, Creative learning is radical-oriented and tend to explore knowledge which is unique and original to the firm. Hence, it aims to develop new knowledge.

3.2.1.1 Socialisation and architectural innovation

As mentioned earlier, Nonaka's knowledge conversion model (1994) has four modes of interplay between tacit and explicit knowledge; socialisation, externalisation, combination, and internalisation. The first knowledge conversion mode is socialisation (tacit knowledge to tacit knowledge). This mode requires social interaction, and the sharing of experience, mental models, and technical skills among individuals. Therefore, socialisation depends on sharing experiences; as " the key to acquiring tacit knowledge is experience" (Nonaka, 1994: 19). This requirement of experience echoes a fundamental foundation of the resource-based view "specialisation in knowledge acquisition" (Grant, 1996: 112). The Specialisation in knowledge acquisition foundation argues that the human brain has a certain capacity to acquire, store, and process knowledge (bounded rationality principle (Simon, 1991)). This means that in order to create or acquire knowledge, individuals need to be specialised in a particular area of knowledge. Individuals who have the experience and the specialisation are more capable of sharing and acquiring tacit knowledge (Nonaka, 1994, Nonaka and Takeuchi, 1995). However, tacit knowledge is characterised as being difficult to codify and transfer, which generally referred to as "sticky" (Collins, 2010, Von Hippel, 1994, Szulanski, 1996b), therefore, a mechanism is needed to share tacit knowledge among individuals. Arguably, socialisation creates a space for tacit knowledge to be shared (what Nonaka and Konno (2005) refer to as *Ba*). As discussed in the literature review *Ba* can be a formal or informal setting, such

as an apprenticeship that facilitates the place or a field of interaction. Sharing tacit knowledge is essential for architectural innovation as "architectural knowledge tends to be embedded in the tacit knowledge of the organisation" (Henderson, 1991: 44). Socialisation enables individuals to share tacit knowledge and expertise which facilitate ideas generation (Schulze and Hoegl, 2006).

Since new product developments are usually attributed to knowledge gained from experience (Levinthal and March, 1993), new product knowledge resides in the minds of individuals (experts) responsible for innovations (Drazin and Rao, 2002). Ideas generated based on shared understanding are more likely to be transformed into innovative products. For example, a team of individuals who possess a variety of different experiences is better positioned to innovate, because members are able to get a better comprehension of each other's perspective in order to explore new product characteristics based on different viewpoints (Schulze and Hoegl, 2006). As a result, this research can argue that socialisation is considered a tool for sharing tacit knowledge (architectural knowledge) which enhances the capability to create new linkages between existing product components.

Based on the previous argument, this research posits that socialisation is more likely to enable firms to produce architectural knowledge (knowledge about reconfiguring existing product components), and therefore can enhance architectural innovation capability. Based on the previous argument the following hypothesis is proposed:

> *H1: Socialisation is positively related to firms' architectural innovation capability.*

3.2.1.2 Externalisation and architectural innovation

Although socialisation represents the first step to convert tacit knowledge, it is not enough to create knowledge; Nonaka (1994) argues that knowledge creation is a continuous process that requires all knowledge creation modes respectively. Hence, the next mode after socialisation is externalisation.

Externalisation is about articulating tacit knowledge into explicit concepts which "helps promote reflection and interaction between individuals" (Nonaka and Takeuchi, 1995: 64). Externalisation is triggered by dialogue or collective reflection and is useful in the concept phase to articulate tacit knowledge as Peltokorpi *et al.* point out that "exposure to diverse ideas during the externalisation phase is important as every step in the innovation process is proposed to be about someone asking about imaginary possibilities, speculating about what would happen if, and reflecting on yet unrealised and perhaps unrealisable solutions" (Peltokorpi *et al.*, 2007: 56).

Acquired tacit knowledge from the socialisation process is of little use unless externalised and used in a concept or a prototype. Thus, externalisation is the true knowledge creation amongst all four modes as this is where true, new, explicit concepts are created through using sequential serials of metaphor, analogy, and model (Nonaka, 1994, Nonaka and Takeuchi, 1995, Peltokorpi *et al.*, 2007). Subsequently, as externalisation is facilitated by formal exchange of knowledge and experience, it will enable firms to efficiently realise the ideas generated and integrate them to facilitate the expeditious development of new products. As a result, this research argues that this conversion process is important to articulate the informal ideas shared in the socialisation stage into product properties using a formal agenda.

Architectural innovation capability is likely to be enhanced by efficiently applying the product properties which were identified previously. Thus, the following hypothesis is proposed:

> *H2: Knowledge externalisation is positively related to firms' architectural innovation capability.*

3.2.1.3 Combination and architectural innovation

After the creation of various explicit concepts, combination is important to aggregate them using various communication channels. This process includes documentation, meetings, networking, and conversation, which are essential to create new knowledge by reconfiguring existing knowledge. Here, explicit knowledge is exchanged and combined to be integrated into the knowledge system (Nonaka and Takeuchi, 1995). Furthermore, combination integrates the newly created explicit knowledge with the organisation's knowledge base to facilitate innovation (Shu *et al.* 2012). As a result of knowledge integration, technological advancements can be interpreted in a new innovative way, which is more likely to facilitate knowledge reconfiguration. Therefore, knowledge configuration facilitates translating new concepts to marketable products. Knowledge combined from different domains can help in realising new innovative solutions based on looking at challenges from different perspectives. Hence, this research proposes that combination is likely to positively affect architectural innovation capability, which is articulated in the following hypothesis:

> *H3: Knowledge combination is positively related to firms' architectural innovation capability.*

3.2.1.4 Internalisation and architectural innovation

Internalisation then takes place to transfer explicit knowledge into tacit knowledge which is connected to "learning by doing" (Nonaka, 1994: 20). The explicit knowledge is captured in a form of mental models or technical know-how (Nonaka *et al.*, 1998b, Nonaka and Takeuchi, 1995).

Individuals possess know-how in the form of mental models or personal skills and know-how. Knowledge internalisation includes efforts to absorb accumulated organisational know-how, in which individuals strive to learn the recipe of 'how to do it' (Kale and Singh, 2007). Knowledge internalisation requires team members to be familiar with each other's expertise and skills which helps them to comprehend the pool of available knowledge. This potential to identify and recognise peers' knowledge, to understand the available pool of knowledge, and how each other's unique knowledge fits together, will enable individuals to efficiently use it collectively to create innovative products (Cohen and Levinthal, 1990, Kale and Singh, 2007, Nonaka, 1994, Tiwana and Mclean, 2005, Tiwana, 2008, Lee, 2001, Van Den Bosch *et al.*, 1999). This process of recognising, assimilating, and exploiting peers' specialised knowledge is essential in facilitating the capability of reconfiguring architectural knowledge. Locating and leveraging knowledge possessed by different team members, and "the constant interaction of a multidisciplinary team whose members work together from start to finish" (Nonaka and Takeuchi, 1995: 242), allow organisations to create new products or modify existing ones (Rothaermel and Hess, 2007).

Thus, this research argues that internalisation facilitates architectural innovation capability through individuals' absorption of each other's know how; wherein team members recognise, interrelate, and leverage organisational know-how. This ability is essential to stimulate creativity (Tiwana and Mclean, 2005). Thus, knowledge internalisation requires team members to absorb each other's specialised knowledge, and not just transferring knowledge between individuals in order to collectively and efficiently use it for product development (Nonaka, 1994; Kale and Singh, 2007). To recapitulate, knowledge internalisation encourages the collective use of teams' individual knowledge which is more likely to enable creating new links between existing components. Architectural innovation capability is based on tacit knowledge ("architectural knowledge tends to be embedded in the tacit knowledge of the organisation") (Henderson, 1991: 44)), therefore, it is vital that the organisation is able to convert explicit knowledge into tacit knowledge that can be utilised to produce architecturally innovated products. Based on the previous argument, this research proposes that internalisation is more likely to positively affect architectural innovation capability, which is captured in the following hypothesis:

> *H4: Knowledge internalisation is positively related to firms' architectural innovation capability.*

3.2.2 Architectural innovation hypotheses development

The following two important issues clarify architectural innovation and performance link. Firstly, firms that possess architectural innovation capability are better positioned to focus their limited resources on reconfiguring product components, rather than developing new components (Henderson and Clark, 1990). Thus, they have an efficient utilisation of their resources. Another issue is related to the nature of

architectural innovation, as it taps into new markets by using the same technical capabilities (Abernathy and Clark, 1985). As a result, AI preserves the technical capabilities to produce a new product that will appeal to customers in a new market. Furthermore, architectural innovations have enhanced features (for example portable copiers instead of desk based copiers; all the components of the copier are the same, but they are reorganised so that their relation to each other is changed significantly), have a better fit with customers need, and hence, are more likely to positively affect firms' development cost and financial performance.

Two types of knowledge are required in any product development: component knowledge and architectural knowledge. Component knowledge is scientific or engineering knowledge about the core design concept; while architectural knowledge is about the components' configuration and integration. Architectural innovation capability reconfigures the component while retaining the sub-systems technologies. Therefore it produces a new architectural knowledge while at the same time retains component knowledge. Hence architectural innovation is less costly than radical innovation, as the latter will impose changes on component as well as architectural knowledge (Henderson and Clark, 1990). Different types of innovations require different sets of capabilities. As capabilities are difficult to create and are costly to adjust (Hannan and Freeman, 1984), utilising the available capabilities in an organisation is advised when they endeavour to tap into unknown areas.

Previous studies addressed the effect of product innovativeness on development speed. Developing a more innovative product will slow down the innovation speed (Ali *et al.*, 1995, Lin *et al.*, 2012). Thus development speed is dependent on the

products' degree of innovativeness. Lin's (2012) study has different implications related to the type of knowledge. Radical innovation requires high time investments in acquiring knowledge to reduce costly expenses and errors associated with venturing into unexplored technical areas (Chang and Cho, 2008, Lin *et al.*, 2012). On the other hand, incremental innovation requires management to accelerate the development speed by efficiently utilising resources (Lin *et al.,* 2012), in order to avoid losing their competitive position to fast innovators (Stalk Jr and Hout, 1990). However, architectural innovation speed was not addressed.

The cost implications of architectural capability can be explained by the dominant design process. The evolutionary process of the dominant design requires organisations to evaluate and refine component knowledge as well as architectural knowledge. Once the dominant design is accepted, "firms cease to invest in learning about alternative configurations of established set of components" (Henderson and Clark, 1990: 3). In this stage organisations shift their attention to learning about different components and the architectural knowledge of that certain product is stabilised. Thus, there is an opportunity in the market to produce a better version of the same product (for example portable copiers instead of desk based copiers). This opportunity can be seized by learning about different possible components' reconfiguration. Using previous product development experience means that organisations may spend less time developing the product (prototyping, testing, etc.), which will reflect favourably on the development cost.

New product development performance can be measured by multiple criteria, such as efficiency or effectiveness (Chen *et al.,* 2008, Johnson *et al.*, 2009). Researchers

frequently argued for trade-offs among those proxies (Chen *et al.*, 2008, Johnson *et al.*, 2009). Efficiency is related to development time and development cost (Chen *et al.*, 2008). On the other hand, effectiveness is associated with product quality and financial performance (Johnson *et al.*, 2009). However, another stream of research advocates the synergistic effect of fast development in which they propose that rapid innovation speed may help in decreasing the development cost and enhancing quality (Kessler and Bierly III, 2002, Ittner and Larcker, 1997, Jayaram and Narasimhan, 2007, Langerak and Hultink, 2008).

This research argues that architectural innovation capability plays an integral part in reducing the development cost by reducing the development time (AI supports the synergistic effect among innovation speed and cost); this causal relationship is mediated by reducing the development time (as this type of innovation has better product fit to customer needs) (Kessler and Bierly III, 2002), requiring less modification and hence less development cost. The following hypothesis is postulated based on the previous argument:

> *H5: A company's architectural innovation capability has a positive indirect effect on development cost through the mediating effect of development time.*

Architectural innovation capability is often triggered by the introduction of a new technology (*i.e.* change in a component, for example, a change in size due to a new technological advancement). This incremental improvement in technology is very likely to be associated with innovation speed.

For example, in the 1970s Xerox, a pioneer copier producer, lost half of their market share to competitors who produced a smaller and more reliable copier. It took Xerox eight years to catch up and produce a competitive product (Clark, 1987). This illustrates the importance of speed when new technology is introduced. Newer technology is believed to push new products faster and it "increases the allure of new product development" (Kessler and Chakrabarti, 1996: 1157), because it increases the possibility of new products development that satisfy new niches in the market. This argument accents Tushman *et al.* (1997) description of architectural innovation as a scenario where incremental technological improvement creates new markets. Based on these technologies there will be much experimentation in the market until a dominant design becomes accepted (Henderson and Clark, 1990). These experiments will give an opportunity for organisations to quickly develop a new product based on the new technology. In contrast to this scenario, is an environment with less technological dynamism wherein there are less opportunities prompting speedy innovations (Kessler and Chakrabarti, 1996).

Innovation speed is positively associated with financial performance, as the quickest organisations will capture new product opportunities which will reflect positively on their performance. Research has shown that a product that enters the market at the right time gains customer preference and shapes the standard for future products (Langerak and Hultink, 2008). These preferences positively drive a new product's sales volume. Another argument can be made about first mover advantages and the associated attractive position of the organisation. First movers (pioneers) will get ample chance to predominate the market and pre-empt new entrants (Ettlie *et al.*, 1984a, Porter, 1980). Despite the counter argument of new entrants, that shed the light

on high failure rate (Dunne *et al.*, 1988, Audretsch and Mahmood, 1994), new entrants generally succeed at architectural innovation and possess advantages over incumbent firms (Christensen and Rosenbloom, 1995, Henderson and Clark, 1990). Based on the previous argument, the following hypothesis is proposed:

> *H6: A company's architectural innovation capability has a positive indirect effect on financial performance through the mediating effect of development time.*

The more innovative the product is, the higher the risk; this affects the overall quality as highly innovative NPD are associated with high uncertainty and complexity. These dimensions, uncertainty and complexity, are related to high-velocity technological and market changes (Salomo *et al.*, 2007). Implications on quality entail later modification of the product which carries additional financial burdens (Brettel *et al.*, 2011). This study argues that architectural innovation's positive effect on development cost is mediated by quality.

Previous research has a varied stance regarding effectiveness and efficiency. Some argue that a trade-off exists between creating faster, better, and cheaper products (Gupta *et al.*, 1992, Bayus, 1997, Murmann, 1994). While another stream of research advocate the synergistic effect of fast development, wherein they propose that rapid innovation speed may help to decrease the development cost and enhance quality (Ittner and Larcker, 1997, Jayaram and Narasimhan, 2007, Kessler and Bierly III, 2002).

In order to further explain these relationships, this research proposes the following hypotheses (H8 and H9), in which quality mediates the effect of architectural innovation capability on development cost as well as financial performance. Hence, this study proposes that quality is likely to strengthen the causal relationship. As architectural innovation demands organisations to create new linkages and interfaces between product components, if the product is of a high quality, less time is likely to be required in order to configure and integrate components. Less testing and reconfiguration inevitably lead to less development cost. Furthermore, as the new product offers unique benefits to customers which meets their needs, financial performance will increase from higher sales potentials. In order to further explain these relationships, this study proposes the following hypotheses, in which quality mediates the effect of architectural innovation capability on development cost, as well as, financial performance. Hence, this study proposes that quality will strengthen architectural innovation and performance relationship:

H7: A company's architectural innovation capability has a positive indirect effect on development cost through the mediating effect of product quality

H8: A company's architectural innovation capability has a positive indirect effect on financial performance through the mediating effect of product quality

3.2.3 Absorptive capacity hypotheses development

This section will develop the hypotheses related to absorptive capacity's moderation role on the relationship between architectural innovation capability and performance. It should be noted here that absorptive capacity is not the final goal in itself, however, it strengthens innovation capability and innovation performance (Cohen and Levinthal, 1990, Fosfuri and Tribó, 2008).

Absorptive capacity enhances the magnitude of innovation, but there is limited empirical research that investigated this relationship (Lane *et al.*, 2006). This work focused on investigating the role of absorptive capacity in an empirical manner that will add to existing theoretical argument, and will helps unpack the role of absorptive capacity.

Potential and realised absorptive capacities are highly integrated. Potential APCA, *per se*, does not guarantee leveraging and exploiting the acquired knowledge. Dominance of potential APCA without realising the acquired knowledge is dysfunctional. Thus, APCA plays two integral, but separate, roles: the first is to identify external knowledge flows and the second is to derive benefits. The first role has been labelled by researchers as the ability to identify and evaluate knowledge (potential APCA), whereas the latter role is the ability to use and exploit knowledge (realised APCA) (Cohen and Levinthal, 1989, Zahra and George, 2002, Arora and Gambardella, 1994). The following four sections will address developing the hypotheses related to each absorptive capacity.

3.2.3.1 Acquisition moderation effect

Effectiveness in acquiring relevant knowledge is crucial for learning the new knowledge needed to create new linkages between existing components. For example, a change in the dominant design will induce firms to utilise more resources and effort to acquire new knowledge necessary to develop new products (this will broaden both acquisition and assimilation (Cohen and Levinthal, 1990). As discussed earlier (Section 2.6), creating new products that satisfy new needs in new markets and capturing emerging opportunity is possible by responding to technological dynamism.

The importance of absorptive capacity is more pronounced in environments characterised by high knowledge turbulence (*i.e.* environments where underlying knowledge base is continuously evolving and changing) (Escribano *et al.*, 2009). Therefore the intensity of the external events will compel firms to intensify their resource allocation and investment in absorptive capacity.

Moreover, if firms do not invest in APCA they may not appreciate new opportunities (Cohen and Levinthal, 1990). The absorption role becomes vital only when an external knowledge flow is added to firms current knowledge base (Escribano *et al.*, 2009), in order to renew their knowledge base and to renew the skills required to compete in the changed market. Thus this study proposes that acquiring new knowledge will create the necessary initial step in the path towards appreciating new technologies and creating a new architectural knowledge, which will be culminated in creating architectural innovations.

In addition, high absorptive capacity is closely related to high performance (Tsai, 2001). Firms with well-developed potential absorptive capacity (acquisition and assimilation) are more likely to continuously build their knowledge base by scanning the external environment and internalising new knowledge. Firms that are versed in acquisition and assimilation can overcome competency traps such as familiarity, maturity, and propinquity (Ahuja and Morris Lampert, 2001, Levinthal and March, 1993) and they are more likely to seize the window of opportunity (Section 2.6.4). Hence, firms that capture acquisition and assimilation in their routines are more likely to reduce the cost associated with capability development (Teece *et al.*, 1997, Zander and Kogut, 1995). Due to accumulating knowledge, firms are more likely to have

better experiences of dealing efficiently with new knowledge acquisition and assimilation.

In addition, this research argues that absorptive capacity increases firms' ability to identify new technological trends and opportunities which is needed for architectural innovation capability. Consequently, innovations and acquisition capability leverage the benefits of actualised knowledge on firms' financial performance, and can mitigate the cost associated with innovation development (Fernhaber and Patel, 2012, Kostopoulos *et al.*, 2011). Hence, high acquisition capability strengthens the effect of architectural innovation on reducing the development cost and increasing financial performance.

In order to isolate the role of absorptive capacity, this study will test its moderating effect on the impact of architectural innovation capability on development cost and financial performance as proposed by the following two hypotheses:

> *H9: A company's acquisition capacity positively moderates the relationship between architectural innovation capability and development cost.*

> *H10: A company's acquisition capacity positively moderates the relationship between architectural innovation capability and financial performance.*

3.2.3.2 Assimilation moderation effect

Assimilation is the second capability of the absorptive capacity model and together with acquisition capability represent potential absorptive capacity. Firms'

assimilation capability aims to analyse and interpret the acquired knowledge which is vital to comprehend knowledge acquired from external sources. Cohen and Levinthal (1990) argue that assimilating external knowledge encourages investment in R&D. However, knowledge acquisition is not sufficient to absorb external knowledge. Investing in R&D (R&D intensity) increases firms ability to absorb knowledge in general but more importantly, R&D contributes to absorbing knowledge spillovers (others' discoveries) (Griffith *et al.,* 2003). To a certain extent, the higher the R&D investment, the more likely firms will be able to capture new knowledge and assimilate it (APCA is perceived as a by-product of organisation's R&D investment since R&D promotes absorptive capacity). This is more likely to prevent the organisation from being "locked-out" from technological development. Furthermore, firms that initially invest in R&D will be encouraged to make further investments as technological opportunities emerge, to reduce sunk costs.

This capability of internalising externally sourced knowledge (assimilation) is likely to affect an organisation's architectural innovation capability and its impact on development cost. By assimilating externally sourced knowledge, firms are more likely to shorten their development process by being adept at knowledge analysis and interpretation. Acquiring knowledge is a precursor to developing a relevant cognitive map for assimilation (Huber, 1991), which helps to incline knowledge analyses' efforts to areas most valuable to the product development process (Todorova and Durisin, 2007, Tripsas and Gavetti, 2000).

For example, having competency in assessing the value of new knowledge is more likely to focus individual's attention on assimilating only valuable knowledge. This

rational applies to any expert in any field, who will only use his time and effort on valuable knowledge; this is because the expert has the necessary competence to identify that knowledge which is valuable. Focusing on valuable areas is more likely to reduce development cost by overcoming any competency traps and being responsive to technological opportunities. In the case of architectural innovation, valuable areas are related to developing architectural knowledge (*i.e.* the way components are linked to produce new innovations). Hence, R&D efforts are more likely to be concentrated in assimilating technological knowledge that will help to create and advance architectural knowledge while avoiding wasting resources. Using available resources to assimilate and analyse valuable knowledge is proposed to lessen development cost. In addition, firms are more likely to have a first mover advantage by being versed in analysing its knowledge base to explore new technology-based products; this in turn will positively affect their financial performance by producing innovative products superior to competitors.

The following two hypotheses are proposed based on the previous argument:

H11: A company's assimilation capacity positively moderates the relationship between architectural innovation capability and development cost.

H12: A company's assimilation capacity positively moderates the relationship between architectural innovation capability and financial performance.

3.2.3.3 Transformation moderation effect

This research proposes that transformation moderates the relationship between architectural innovation and financial cost. Transformation aims to combine newly

acquired and assimilated knowledge together with existing knowledge. This research argues that transformation allows firms that possess architectural innovation capability to be competent in using their limited resources on reconfiguring product components (Henderson and Clark, 1990). Transformation capability enables firms to combine new knowledge with existing knowledge which then becomes part of firms' procedures and policies; being adept in combining knowledge means that firms are more likely to minimise the time needed to innovate because the need for innovation is triggered by the external knowledge that has been assimilated. Subsequently, reducing the development process time translates into reducing the development cost associated with NPD process as fewer resources and less time are needed to develop innovative products. Hence, it is more likely that transformation positively moderates the relationship between architectural innovation capability and development cost.

Moreover, this research argues that transformation positively moderates the relationship between architectural innovation capability and financial performance. Transformation aims to combine the newly assimilated knowledge with previously owned knowledge in an effort to internalise it. Therefore, after the knowledge has been assimilated, it needs to become part of firms' daily operations and become embedded into firm's routines and procedures. Transformation can be achieved by adding or deleting knowledge, or interpreting the same knowledge in a new way (Zahra and George, 2002). This can explain how and why organisations change their "cognitive schemas" in order to facilitate the embedding of new knowledge and transforming the collective schema (Lane *et al.*, 2006), so that this new knowledge becomes operational in the firms' daily routines and procedures.

Transformation lays the foundation for knowledge exploitation, therefore firms with higher transformation capacity can better utilise and exploit external, ambiguous and complex knowledge, which is necessary to create innovations that respond to external customer demands or competition (Wang and Han, 2011). Innovations will help firms in adapting to external customer demands, competition, and adapting to constantly changing requirement for better products; this in turn is more likely to have a positive impact on their financial performance (Jansen *et al.*, 2005, Walker, 2004).

The same theorising applies to architectural innovation capability; firms competent in transforming and combining new assimilated knowledge with their existing knowledge base have what is called combinative capability (Kogut and Zander, 1992b). By combining external and internal knowledge, firms can learn new skills or conceive innovative ideas that will enable them to experiment with configuring current product's components (to create architectural knowledge which will be used in the next process (*i.e.* exploitation) to create architectural innovations). Creating new architectural innovation that meets customer demands or outperforms competitors is proposed to leverage firms' financial performance. Hence, this research argues that the interaction between transformation and architectural innovation capability enhances financial performance.

By following the previous line of argument, this research argues that transformation is likely to moderate the impact of architectural innovation capability on development cost and financial performance as proposed by the following two hypotheses:

H13: A company's transformation capacity positively moderates the relationship between architectural innovation capability and development cost.

H14: A company's transformation capacity positively moderates the relationship between architectural innovation capability and financial performance.

3.2.3.4 Exploitation moderation effect

Moving forward, the last capability to discuss is the exploitation capability. This research argues that exploitation actually weakens the relationship between firms' architectural innovation capability and development cost and financial performance.

First of all it cannot be denied that "The ability to exploit external knowledge is a critical component of innovative capabilities" (Cohen and Levinthal, 1990: 128). An organisation that has the ability to exploit, build in, and use assimilated knowledge is likely to successfully commercialise new products (Van Den Bosch *et al.*, 1999, Tiwana and Mclean, 2005, Zahra *et al.*, 2009). Thus, realised absorptive capacity (i.e. transformation and exploitation) is vital to leverage the absorbed knowledge (Zahra and George, 2002).

This research argues that exploitation facilitates leveraging new knowledge but it has an adverse effect on the relationship between architectural innovation capability and development cost. Firms that strive to exploit new information will have less

expeditious process partly because they need to gain a deep-rooted understanding of the newly acquired knowledge. In the case of the architectural innovation development process, exploiting new knowledge is vital to keep abreast of new technological knowledge, however, exploitation means experimenting with different possible combinations of product components to reach the required design. This capability is likely to require more time to be effective and to realise creative, feasible designs of architectural innovation products. Thus, firms may face efficiency issues as they move forward towards the development process as more time allocation translates into demanding more resources. This is the proposition postulated in hypotheses 18. This is likely to have an effect on financial performance because the higher development time needed inevitably slows down the speed to market and hence increases the risk of losing market share to competitors (refer to Xerox example, Section 3.2.2). As a result, further implications and exploitation are more likely to negatively affect the financial performance.

Another plausible argument is that adopting a absorptive capacity is costly. As noted earlier in the literature review, acquisition, assimilation, and transformation of new knowledge is costly for firms. Absorptive capacity requires constant scanning of the external environment in a pursuit to identify new knowledge that can be leveraged to add value and promote innovation. In addition, firms have limitations in achieving sufficient knowledge diversity to evaluate all the acquired knowledge. Therefore, it is argued that high absorptive capacity can lead to lower financial performance (Wales *et al.*, 2013), because the cost of absorptive capacity after are more likely to outweigh its added value.

Based on the previous argument the following two hypotheses are proposed:

H15: A company's exploitation capacity negatively moderates the relationship between architectural innovation capability and development cost.

H16: A company's exploitation capacity negatively moderates the relationship between architectural innovation capability and financial performance.

Absorptive capacity efforts need to be in tandem with other efforts, therefore APCA should never be addressed in isolation but in a wider context of efforts (e.g. lead users' integration) to realise innovations (Cepeda-Carrion *et al.*, 2012, Kostopoulos *et al.*, 2011, Vega-Jurado *et al.*, 2008, Volberda *et al.*, 2010). To embrace this integrated view, this research investigated the role of absorptive capacity and lead users' integration (more details in the following section). Integrating lead users in the NPD process is a method used by many firms to create novel products, this method complement the absorptive capacity efforts, where a synergy between multiple constructs is more likely to enhance innovation and performance.

3.2.4 Lead user: Hypotheses development

Following the discussion in the previous literature review, lead users are those customers who experience needs ahead of the market, and they perceive great value from solutions to their needs. In addition, they have unique and useful data related to new products needs and solutions, and they have the competence to provide accurate data (Von Hippel, 1986a). They are ahead of the field in use and adoption of new technology, and they can provide ideas for new products, modify existing ones, and

scrutinise a product's functionality. The next section will discuss the theoretical argument that underpins lead user hypotheses development.

The main drive behind lead user involvement is the developing of a product that satisfies a latent need in the market; this new product has enhanced characteristics, such as enhanced quality, which is one of the sought after improvements. Despite the acknowledged importance of lead users' contribution to enhance idea generation (Lilien *et al.*, 2002) and service quality (Schuhmacher and Kuester, 2012), there is not any empirical research on lead users' integration link with product quality. However, it can be argued that certain characteristics, such as use experience and intrinsic motivation, are likely to enable lead users to provide novel product concepts which are of a superior quality.

This study argues that integrating lead users in the following front end stages of NPD (setting general product definition, setting lead time requirements, and setting product specifications) is positively related to quality, as these NPD stages are associated with the conceptual early part of the new product development process (the fuzzy-front-end). In this stage, the ideas generated by lead users will inform the market research process and will positively affect the product quality. Unlike the traditional idea generation techniques based on computer input from random or typical customers, lead users have unique characteristics and needs which are likely to increase the quality of idea generation (Lilien *et al.*, 2002) and hence the overall product quality. Therefore, based on the previous argument, this research proposes the following hypothesis:

H17: Lead users' integration in the front end of the NPD process is positively related to product quality.

Collaboration with lead user is known to increase NPD performance. It can help decrease the development time as lead users can provide ideas and generate product designs and component specifications. Lead users with real life experience can provide insights for accurate market research (Von Hippel, 1988). Therefore, accurately understanding the need will help organisation to save NPD time and reduce errors. Lead users are argued to often have complete solutions because they already have developed and tested the product themselves. Thus, the collaboration with lead users will increase product development speed. In the early stages of NPD, lead users can provide accurate product specifications to inform the market research process, as they are expert about the need. Moreover, during later stages of NPD process (including generating products' blueprints, designing product detailed component specification, and prototyping), lead users can test the product and provide workable modifications which can be used in the modification stage.

Consequently, the assessment stage will be faster as lead users can easily assess the product's knowledge (Tsinopoulos and Al-Zu'bi, 2012). Testing the product will be easier and faster with lead users, as they are technically competent and have a passion for trying the developed product as early as possible. Usually products are specifically designed to solve their problems and so they will be as accurate as possible to satisfy this need. This will relatively shorten the NPD process. Thus, it is highly important to systematically involve them in the process. Lead users provide significant value as previous studies show that their engagement in idea regeneration is positively related

to the rate of major line generation in comparison to the historical rate (based on a study on 3M) (Lilien *et al.*, 2002).

Lead users pivotally affect development speed (Langerak *et al.*, 2008, Langerak *et al.*, 1999, Thomke and von Hippel, 2002) because they provide important insights into product need and solutions which prevent delays in later NPD stages.

This study argues that integrating lead users in the following NPD late stage (generating products' blueprints/drawings, designing product detailed component specification, product prototyping, and overall product development process) is positively related to accelerating development time. NPD late stages are related to product prototyping and assessment which can be accelerated by lead users' collaboration due to their unique characteristics (including, use experience and intrinsic motivation).

Hence, the following hypothesis is postulated based on the previous argument:

H18: Lead users' integration in late stages of the NPD process is positively related to development time.

3.3 Summary

This chapter has reviewed the relevant literature related to the variables of interest, and presented the hypotheses development and their underpinning theoretical argument. The literature review demonstrated the importance of innovation in enhancing performance in general, and ratified the role played by knowledge processing capabilities, absorptive capacities, and lead users' integration in leveraging

the synergetic efforts towards innovation. The hypotheses developed are summarised below (Figure 3.1).

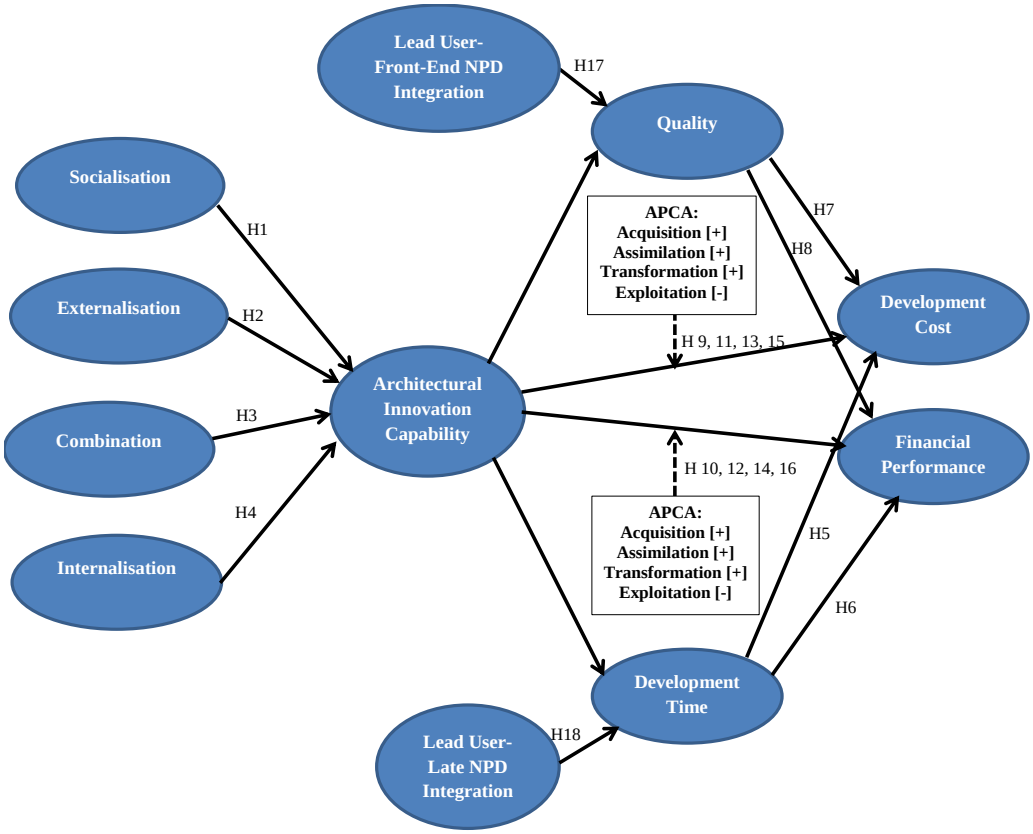

Figure 3.1: Conceptual Model

Hypotheses 1, 2, 3, & 4 are concerned with knowledge creation modes effect on architectural innovation capability. Hypotheses 5 & 6 represent the mediating role of development time on the indirect relationship of architectural innovation capability and development cost, and financial performance. Hypotheses 7 & 8 represent the mediating role of quality on the indirect relationship of architectural innovation capability and development cost, and financial performance. The moderation hypotheses of absorptive capacity on the relationship of architectural innovation capability and performance (development cost and financial performance) are captured by hypotheses 9-16. Hypotheses 17 & 18 represent lead users' integration in

the new product development process and its effect on performance (product quality and development time).

The next chapter will explain the paradigms, methods and techniques underlying the research process and data collection of this research and sets the scene for analysing the data to test the conceptual model.

CHAPTER FOUR: RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

This chapter will cover the process of identifying and debating the most suitable research method, identifying the research instrument, setting the scales, establishing validity and reliability, setting data collection plan, and identifying data collection method.

The research methodology, strategy, and approaches were carefully selected to achieve the research objectives. Saunders *et al.* (2011) described research as an 'onion' in the central part is data collection (Figure 4.1). However, before commencing with data collection there are layers that have to be "peeled", including philosophies, approaches, strategies, choices, time horizon, and last but not least, techniques and procedures. All of the aforementioned research methods will be covered in this chapter.

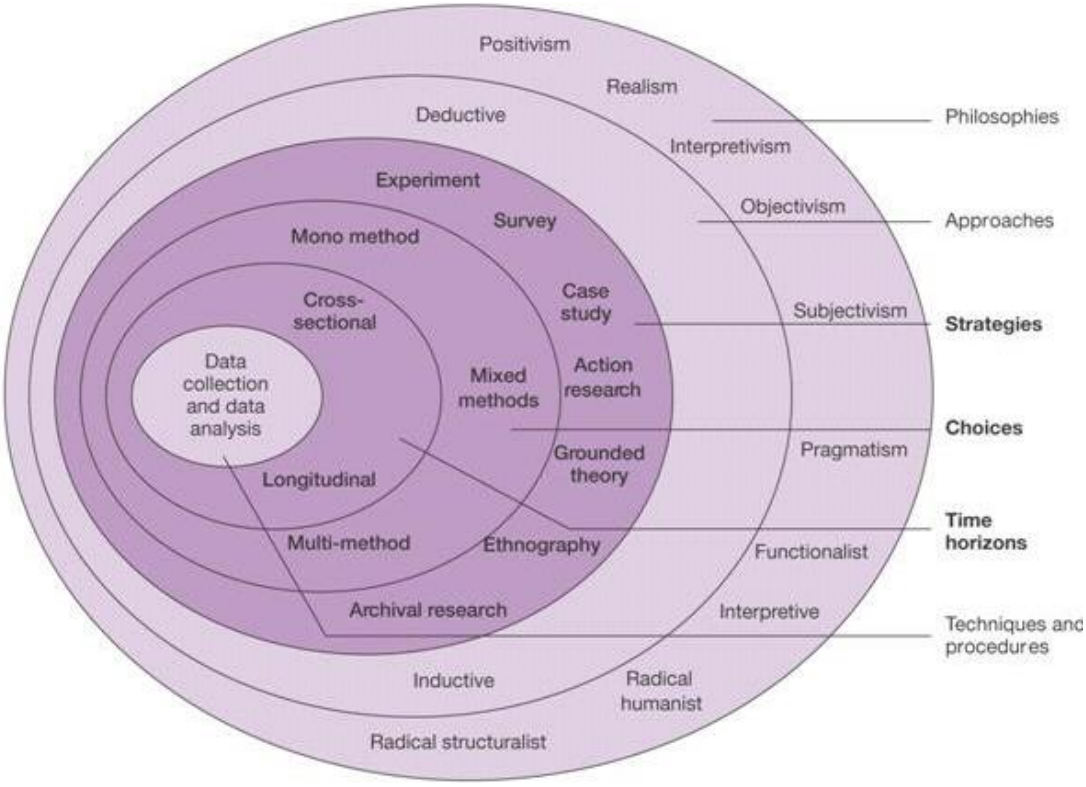

Figure 4.1: Research "onion" (Saunders *et al.*, 2011)

4.2 Research philosophy

Researchers are advised to choose the most appropriate approach of science to follow. This includes an assumption of which way the world will be viewed. There are four different approaches and they vary in terms of philosophical assumptions, principles, and the approach of how to do research. Each approach is trying to answer the following question differently "What is scientific about social scientific research" (Neuman, 2000: 64).

Epistemology is the theory of knowledge and it includes what is acceptable in a field of knowledge. This is related to reality and how each researcher has a different perception of reality. It is, therefore, important that researchers are aware of different philosophical assumptions. There are four main research philosophies; positivism,

realism, interpretivism, and pragmatism (Uma and Roger, 2003). The main two paradigms are positivism and interpretivism as each is placed at the extremities of a continuous line of paradigms. Along the continuum lies other paradigms, in which the assumptions of each paradigm is relaxed to allow the introduction of the next.

Positivism is the oldest and most popular philosophy. It is usually associated with deductive reasoning in which the researcher develops hypothesis/ hypotheses, based on reviewing the literature and the related theoretical underpinning in order to confirm or refute the proposed hypotheses. Realism approach deals with objects independently of the human mind. Similar to positivism it assumes a scientific approach to develop knowledge and it has two types, direct realism and critical realism. Interpretivism approach advocates the importance of understanding the differences between humans in which the researcher should adopt an empathetic stance. Therefore, interpretivists view reality as highly subjective and socially constructed due to being shaped by their perception. The aim of this approach is to explore the complexity of social phenomena which is hard to be measured by a quantitative approach. Thus, interpretivist interacts with the phenomena and focuses on the primacy of subjective consciousness.

The last philosophical stance is the pragmatism approach, which is driven by the need to answer research questions that require a combination of positivism and interpretivism philosophical stance. It is usually used in mixed-methods studies where quantitative and qualitative methods are used to achieve the aim of the research. Pragmatists are not committed to a single paradigm, instead, they have freedom of choice to mix methods from different paradigms. Therefore, they emphasise the

socially constructed nature of research and view the current truth as tentative and prone to change over time.

After reviewing the four common research paradigms used in business and management studies, the researcher found that each approach has its own unique advantages that disseminate valuable knowledge and expand literature. After considering the previous research methods philosophies and taking into consideration the dominant paradigm followed in business studies, this study employed the positivism philosophy standpoint as the best match to the researcher's philosophical orientation (Table 4.1). After reviewing the relevant literature, hypotheses were proposed based on existing theories (causal relationships were established between variables). The researcher maintained independence, especially in the data collection process which produced precise and objective quantitative data. Following this philosophy allows the results to be generalised from the sample to the population.

Table 4.1: Positivism philosophy assumptions adapted from (Collis and Hussey 2013)

Assumption	Question	Positivism
Ontological assumption	What is the nature of reality?	Reality is objective and external to the researcher.
Epistemological	What the researcher accept as valid knowledge?	Researcher is independent and objective.
Axiological	What is the role of values?	Research is value-free process and the objects under investigation are unaffected by the researcher.
Methodological	What is the process of the research?	• Deductive process cause and effect • Static design- categories isolated before study • Context-free • Generalisation leading to prediction, explanation and understanding • Accurate and reliable through validity and reliability

4.3 Research approach

After choosing the research philosophy that best matches research questions; the research approach has to be identified. Approaches include deductive and inductive approach. Deductive approach is the most common view of nature between theory and research (Bryman and Bell, 2015). It is very similar to scientific research in which the researcher deduct a hypothesis (or hypotheses) from theory, operationalise the hypothesis to propose relationships between pre-identified variables, collecting data to test the hypothesis, confirm or refute the hypothesis/es based on the results, and if necessary modify the theory (Figure 4.2) (Robson, 2002). Quantitative data has to be collected to carry out research under this approach. Qualitative data can still be used here, but the main issue is to operationalise concepts in a way that minimise the

researcher intervention in the data collected. Another important issue is generalisation of results, which can be satisfied by selecting appropriate and sufficient numerical sample size. Thereby, positivists are more confident than interpretivist in affirming that the characteristics found in the sample will be presented in the population from which they drew the sample.

The steps of following a deductive approach are outlined in Figure 4.2. Although the deductive approach might appear to be a linear process, there are several reasons why researchers might not follow a linear process as their views of the theory or the literature change. This change can be caused as a result of new theoretical ideas or findings; the data might show relevance to theory after data collection, or the data might not fit the proposed model (Bryman and Bell, 2015).

On the other hand, inductive approach researchers collect data on a pursuit of forming a theory "theory follows data" (Saunders *et al.*, 2011). A commonly used framework used under inductive research is grounded theory, in which qualitative data is collected, coded, and analysed using a systematic set of procedures to develop a theory (Collis and Hussey, 2013). Therefore, general inferences are induced based on individual instances. Inductive researchers are likely to be interested with the context more than the sample size as the main concern is specific rather than general.

Some research fields are more established than others which lend themselves naturally to deductive approach. However, new fields of knowledge which lack theories and models usually witness using the inductive approach. Given that each approach is advantageous in certain scenarios and that research can take new routes depending on the fit between data and theory, researchers might opt to use a

combination of research approaches. Researchers can start by studying the literature and proposing hypotheses based on extant theories, however, data analysis may bring up an interesting relationship which merits further analytical and predictive research (inductive) to build or revise theory. Therefore, it is possible to combine deductive and inductive approaches (Bryman and Bell, 2015, Saunders *et al.*, 2011).

Based on understanding and evaluating both approaches (*i.e.*, deductive and inductive) this research will adopt a deductive approach. In the field of knowledge management and innovation, there is a wealth of literature which makes it more natural to identify hypotheses based on the available literature and theories (Creswell, 2013). Quantitative method is considered to be appropriate for this research, as the objective is to empirically investigate the causal relationship among the research constructs. Hence, after a careful analysis of the literature, hypotheses were deduced and translated into operational terms.

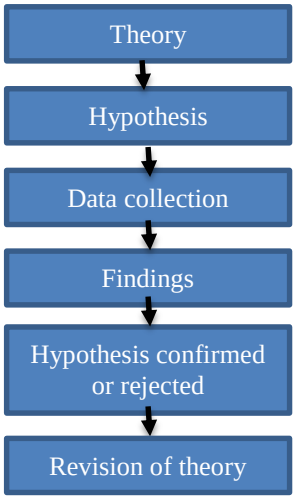

Figure 4.2: Deduction approach (Bryman and Teevan 2004)

4.4 Research strategy

Quantitative and qualitative approaches are used in academic research to identify trends, themes, and relationship among variables. The use of qualitative or quantitative approach depends on the field of knowledge examined. Some fields are more developed and mature than others, in which theories and models are well established. In well-established fields, where theories are well developed, conceptual frameworks can be developed and hypotheses can be proposed and tested by either quantitative or qualitative approaches. On the other hand, new areas of research or less developed fields where theories are not well-established, researchers will most likely rely on qualitative approach (Hair *et al.*, 2015).

While quantitative studies use numbers to represent the characteristics of variables, qualitative studies use text or visual data. However, the distinction between quantitative and qualitative research strategy rely on other factors. The following table (Table 4.2) outlines the fundamental differences between quantitative and qualitative research approach. The quantitative approach entails a deductive approach, has positivism epistemological orientation under which the practices and norms of the natural scientific model are incorporated, and it embodies a view of social reality (Bryman and Bell, 2015, Hair *et al.*, 2015).

On the contrary, the qualitative approach enables inducing and generating a theory, it rejects the underpinning norms of the natural scientific model, and views social reality as inconsistent. However, it should be noted that there is no hard and fast rule to decide which approach is more suitable. The choice should be based on many factors; such as the research problem, the study nature (explorative, descriptive, causal, or

predictive), the study objectives, and the information needed (Blumberg *et al.*, 2014). According to the table below, it is evident that quantitative approach matches the chosen research philosophy and approach discussed earlier.

Table 4.2: Differences between quantitative and qualitative research strategies (Bryman and Bell 2015)

	Quantitative	Qualitative
Role of theory in research orientation	Deductive; testing of theory	Inductive; generation of theory
Epistemological orientation	Positivism	Interpretivism
Ontological orientation	objectivism	Constructionism

There are different research strategies available such as experiment, survey, observation, case study, action research, or mixed methods (Table 4.3). After considering the vast options of research strategies available, the survey research strategy was chosen as the best fit with this research's questions and objectives. Survey is defined as, a system to collect data from or about individuals in order to describe, compare, or explain their behaviours, attitudes, and knowledge (Uma and Roger, 2003). The survey system includes setting objectives, designing the study, developing the survey instrument, administering the survey, analysing the data, and presenting the results.

Table 4.3: Main research strategies (Yin 2013)

Research strategy	Form of research question	Control over behavioural events?
Experiment	How, why	Yes
Survey	**Who, what, where, how many, how much**	**No**
Case study	How, why	Yes

4.5 Research tool (survey)

The survey strategy is a popular data collection method in business studies, as it allows the researcher to collect qualitative and quantitative data. In addition, it can be used in exploratory, descriptive and causal research. Furthermore, surveys can be cross-sectional at one specific point in time, or longitudinal to observe changes in behaviours, attitudes, and knowledge over time (Uma and Roger, 2003).

Survey is a process of asking people for information by using a structured format such as the web, mail, telephone, or face to face. Data are collected from a fraction of the population which represent the study sample (Malhotra and Grover, 1998). Surveys can be exploratory or explanatory. Each type can be used in certain contexts. In a situation where there is no developed model and the concepts need to be measured; exploratory survey can be used. Exploratory surveys can be used for descriptive research as well, especially in early stages of describing a phenomenon. On the other hand, explanatory survey is used for discovering causal relationships among variables in order to test hypotheses that could be basic (existence of a relationship), or directional (positive or negative). Surveys can be cross-sectional or longitudinal based on the nature of the study. A cross-sectional survey is collected in one setting while longitudinal is collected over a span of time to test the changes in phenomenon over a certain period (Saunders *et al.*, 2011). Malhotra and Grover (1998) advised that research strategy used should match the maturity cycle of research (Figure 4.3). Thus, exploratory and descriptive are appropriate for early stages of research into a phenomenon. At later stages variable can be studied using explanatory surveys as shown in the figure below (Figure 4.3).

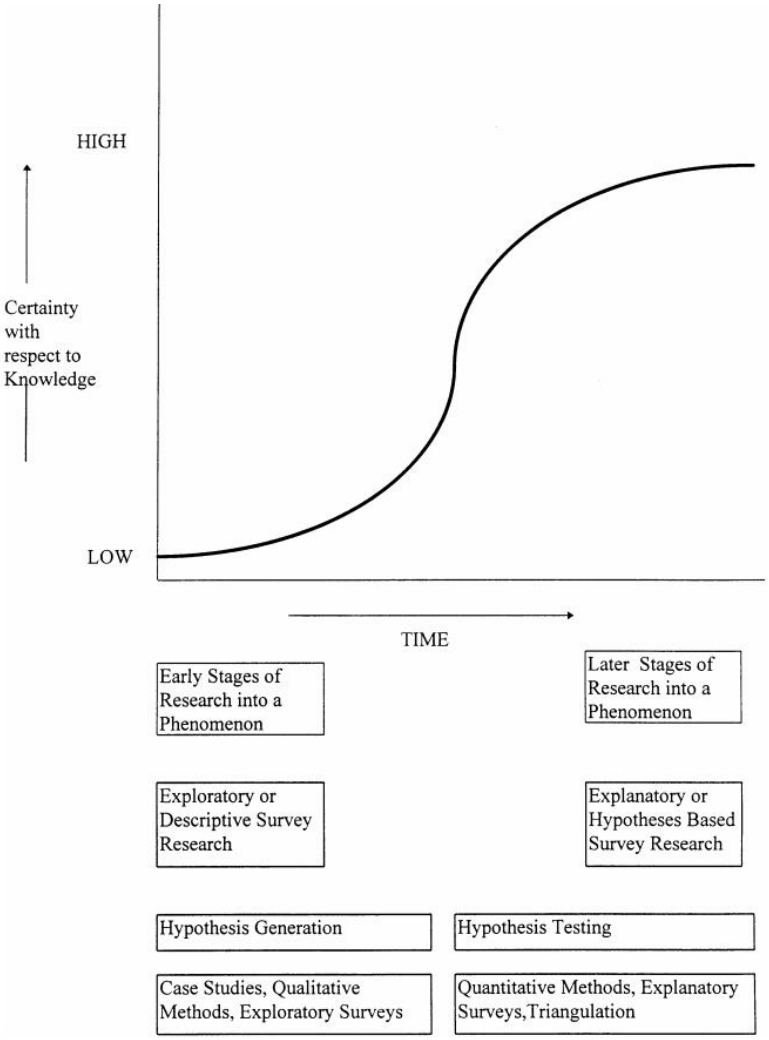

Figure 4.3: The maturity cycle of research (Malhotra and Grover 1998)

4.6 Data collection method rationale

Survey strategy consists of three main data collection methods; interviews, observation, and questionnaires. Questionnaires were used in this research as the best method available to collect primary data due to different consideration of cost, time-frame, geographical coverage, reliability, and generalizability. Questionnaires can be administered using various techniques, Uma and Roger (2003) laid out the advantages and disadvantages of each technique as presented in Table 4.4.

Table 4.4: Advantages and disadvantages of different survey method (Uma and Roger 2003)

Mode of data collection	Advantages	Disadvantages
Personally administered questionnaire	Ability to rapport & motivate respondents Doubts can be clarified High response rate ensured Anonymity of respondent is high	Explanation may introduce a bias. Take time and effort.
Mail questionnaire	Anonymity is high Wide geographic region cover Respondents can answer at their convenience	Response rate is almost always low Cannot clarify questions Follow-up is necessary
Electronic questionnaire	Easy to administer Can reach globally Inexpensive Fast delivery Respondents can answer at their convenience	Respondents must have computer literacy and access to internet

The population has changed whereas a tech-savvy younger generation of workers represent a high percentage of the workplace in comparison to the preceding generation of baby-boomers, and the advancement in technologies year after year urged the need to move away from mail questionnaire. Therefore, electronic survey (via the email or the web) is becoming more widespread (Porter, 2004). In addition to the cost and other benefits associated with using such a method, web-based questionnaires can cover a wide geographical area at the lowest cost possible. Furthermore, respondents can complete the questionnaire at their convenience, in term of time and pace. Survey has a high level of objectivity, as self-administered surveys neutralise the researcher bias that is common in interviews (Saunders *et al.*, 2011).

Saunders and Bristow (2015) identified issues likely to be encountered when distributing internet survey using questionnaires. Hurdles identified include, gaining access to potential respondents and dealing with low response rate (Bryman and Bell, 2015, Saunders *et al.*, 2011). Gaining access is challenging; especially in research conducted at the organisational level or top executive level which is likely to be translated into lower response rate (Baruch and Holtom, 2008, Cycyota and Harrison, 2006).

4.7 Response rate

Web-based questionnaires usually have a low response rate, Uma and Roger (2003) suggested based on previous research that 30% response rate is considered acceptable for electronic questionnaires. The response rate from data collected through distributing questionnaire to respondents' emails is even lower (Dillman *et al.*, 2014). In addition, academic studies that involve top management have an average response rate of approximately 35% (Baruch, 1999). This research benchmarked the estimate of the acceptable response rate in the field of knowledge management and innovation by considering the response rate of similar studies that used similar data collection method (Table 4.5).

Table 4.5: Similar studies' response rates

Study	Sample	Response rate
Lee and Choi (2003)	Middle managers	22%
Song *et al.* (2005)	Senior managers	40%
Gold *et al.* (2001)	Senior executives	32%

Albeit the fact that web-based surveys receive low response rates; some recommendations from previous research were followed to enhance this study's response rate. In terms of questionnaire administration, personalising emails can improve the response rate. Furthermore, obtaining advance consent to participate can improve the response rate (Cycyota and Harrison, 2006). Therefore, an invitation email was sent to respondents in advance requesting their consent to participate in this research study (Appendix 1), which is a necessary step to establish a social exchange between the researcher and the respondent and avoid cold calling (Gupta *et al.*, 2000).

In addition, sending reminders to follow-up is advised to enhance the response rate (Appendix 2, reminder email) (Dillman *et al.*, 2014). Moreover, research topic relevance is associated with enhancing response rate especially if the questionnaire captures executives' firm-specific or personal interest (Cycyota and Harrison, 2006, Heberlein and Baumgartner, 1978, Gupta *et al.*, 2000). Executives are interested in knowledge and innovation-oriented processes in their organisation. Therefore, this study topic was carefully selected, which is related to executives' interest in general, as knowledge management, innovation, and performance issues are directly related to manufacturing organisations, and are linked to executives' responsibilities.

This research targeted the UK manufacturing industry. The researcher investigated and analysed multiple options available to collect the contact details of managing directors. However, due to restricted time frame allocated for data collection, and large population targeted; a database was acquired from a well-known databases specialist. The database included contact details (including name, email address, position, company name, and industry). The data received were examined and

cleaned, for example, hard bounce back email addresses were excluded after sending the first round of survey invitations.

In order to determine the response rate, the traditional method of dividing the collected questionnaires over the distributed questionnaires is not rigorous or relevant to this study. However, other metrics should be used to measure the response rate. The first measure is bounce rate, which is essential as databases are compiled manually and carry out the possibility of errors, in addition to the possibility of outdated emails. Bounce rate can be either hard bounce back rate (as a result of invalid email address or domain failure) or soft bounce back rate (in which an email was not delivered due to a full inbox or delivery problem). The second measure is deliverability rate which is based on the actual email delivered. The third measure is open rate and it is calculated by dividing the total emails opened by the emails delivered. The last two important measures are started questionnaires rate and completed questionnaires rate (Saunders and Bristow, 2015). All of these figures were monitored through the web-based survey tool (Qualtrics), and will be reported in the following chapter.

4.8 Research instrument development

This section discusses the process of developing the questionnaire (Appendix 3) and the administration process.

Considerable effort was made to review the aims, hypotheses, and research variables. Variables were operationalised based on previous studies, and the measurement scale was adapted from validated scales published in top-ranked journals. The decision to

adopt certain scales over others was based on the reliability and the validity of the instrument used (Punch, 2013). (Appendix 4 for comprehensive list scales used).

The design of the questionnaire affects the response rate, reliability, validity of the collected data (Saunders *et al.*, 2011). To maximise response rates, validity and reliability; researchers should carefully design individual questions, develop a clear layout of the questionnaire, pre-test data collection instrument, and carefully administrate data collection.

This research applied the total design method (TDM) detailed by (Dillman *et al.*, 2014), to plan and design the research instrument. In addition, Dillman's 19 principles of question construction were followed to minimise the influence of questions' wording on the responses (Appendix 5). Moreover, open questions were avoided to avoid respondent bias caused by social desirability. The next section discusses questionnaire items in detail.

4.8.1 Demographic variables

This section was developed to capture sample characteristics. Background information captured organisations' and respondents' characteristics which were used as control variables (Section 5.10). The following information was collected:

Organization characteristics:

1. Organization age
2. Sector
3. Number of employees
4. Sales

Respondent characteristics:

1. Age
2. Education level
3. Position
4. Experience

4.8.2 Dependent and independent variables

In a quantitative approach, the researcher must redefine all the concepts into the language of variables.

All items were measured on a seven-point Likert scale referring to respondents' degree of agreement. Likert scale helps in standardising and quantifying the relative effect. This study mainly used existing scales from previous research. However, appropriate and relevant measures for architectural innovation were not available. A scale was created following the guidelines of DeVellis (2011). The questionnaire was pretested before distribution (Section 4.10).

4.8.2.1 Architectural innovation

Architectural innovation capability captures the ability to reconfigure product components in order to create new innovative products. Although architectural knowledge is changed when developing AI, component knowledge remains intact. The following steps were followed to develop architectural innovation scale. After a review of all the relevant literature, a range of possible items was identified. Four of these items were selected to measure architectural innovation capability.

4.8.2.2 Knowledge creation

According to Nonaka (1994) there are four different modes of knowledge conversion; in which tacit and explicit knowledge interact together to create new knowledge: (1) socialisation; from tacit knowledge to tacit knowledge, (2) externalisation; from explicit knowledge to explicit knowledge, (3) combination; from tacit knowledge to explicit knowledge, and (4) externalisation; from explicit knowledge to tacit knowledge. The first mode takes place when individuals interact and acquire tacit knowledge, this process is called socialisation. The second mode is combination, which can be described as the knowledge created when individuals share explicit knowledge through meeting or telephone call for example. The last two modes capture the idea that tacit and explicit knowledge are complementary. Converting tacit knowledge into explicit knowledge is called externalisation. Finally, converting explicit knowledge into tacit is called internalisation.

Each mode was captured through four items adopted from Schulze and Hoegl (2006). The measurement scales for all four modes of knowledge creation were generated by Schulze and Hoegl (2006). Items were developed originally to target project team and because this present study is targeting managing directors and executive managers; the items were modified to capture this difference (Appendix 4). Schulze and Hoegl (2006) knowledge creation scale was adopted due to its relevancy. Although it can be argued that it does not capture the dynamism of creating knowledge, however, this current research is not targeting a particular specific context, but instead, it captures the planned knowledge creating practices across the UK manufacturing industry. Hence, the previously mentioned scale is best suited for the nature of our research.

4.8.2.3 Absorptive capacity

According to Cohen and Leventhal (1990: 128) firms must have absorptive capacity in order to "recognise the value of new, external information, assimilate it, and apply it to commercial ends which is critical to its innovative capabilities". According to Zahra and George (2002), absorptive capacity is composed of two parts; potential capacity, and realised capacity. Absorptive capacity includes a set of organisational processes and routines in which firms acquire, assimilate, transform, and exploit knowledge to promote a dynamic organisational capability.

Each one of these capabilities was captured through a range of items adopted from Jansen *et al.* (2005). The items originally targeted units, thus, the items were slightly modified to fit this current study. Each construct was measured by a number of questions (some of which were reverse-coded) as follow (Table 4.6):

Table 4.6: Absorptive capacity measurement items

Construct	Items
Acquisition	5
Assimilation	3 (one reverse coded question)
Transformation	6 (two reverse coded question)
Exploitation	6 (two reverse coded question)

4.8.2.4 Lead user's integration in NPD process

Lead users' integration received great interest in the field of open innovation and proved to be an important source of innovative ideas in various industries.

Lead users' integration was captured by adopting a scale developed by (Zu'bi and Tsinopoulos, 2012). The scale is composed of eight items which reflect on new product development process and aim to assess respondents' perception of the level of lead user engagement in each activity. Activities represent different stages in new product development. The first three questions (setting general product definition, setting lead time requirements, and setting product specifications) represent the front-end of the NPD process. The second part of activities articulates late stages of the product development process.

4.8.2.5 Performance

Performance measures included questions of the efficiency and effectiveness of product development. All the constructs are measured by multi-items perceptual scales. The construct of efficiency included two parts; development time and development cost, which are adopted from Lynn *et al.* (1999). Development time was assessed by four items (the higher the score, the shorter the development time). Development cost measurement scale was adopted from Kessler *et al.* (2000) and Langerak *et al.* (2008). The scale includes four items (the higher the score, the lower the development cost).

Effectiveness was measured by financial performance and product quality. Financial performance measurement items were adopted from Cooper and Kleinschmidt (1994). While product quality measurement items were adopted from Lin and Huang (2012).

4.9 Conceptual definitions

The following constructs were used in this research:

Knowledge creation

Knowledge creation is a widely used construct that measure knowledge conversion and the interaction of tacit and explicit knowledge through multiple spirals in order to create value (Nonaka, 1994). The model adopted in this research to capture knowledge creation is Nonaka's (1994) model which encompasses four modes; socialisation, externalisation, combination, and internalisation. Following are their conceptual definitions:

Socialisation: measures the informal interactions and exchanges within projects, as well as with relevant departments.

Externalisation: measures formal knowledge gathering, including interviews with knowledgeable individuals.

Combination: measures the systematic collection and processing of explicit knowledge from various sources.

Internalisation: measures the creation of tacit knowledge and internalising knowledge.

Architectural innovation capability:

Architectural innovation capability enables firms to keep abreast of external changes in rapidly evolving customer needs and high-velocity environments, through reconfiguring product components to create improved or new product.

Architectural innovation capability: measures firms' ability to generate architectural innovations through reconfiguring product components. Hence, architectural knowledge (knowledge about the components' configuration and integration) will change while component knowledge remains the same (scientific or engineering knowledge about the core design concept).

Absorptive capacity:

Absorptive capacity is the firm's ability to recognise the value of the external knowledge, assimilate, and apply it (Cohen and Levinthal, 1990). This ability enhances firms' ability to detect and acquire relevant external knowledge, analyse and interpret the new knowledge, combine assimilated knowledge with internal stock of knowledge, and last but not least, exploit this knowledge in novel commercial output (Zahra and George, 2002). Acquisition and assimilation represent potential absorptive capacity, while transformation and exploitation represent realised absorptive capacity.

Acquisition capability: measures the capability to scan the external environment for relevant technological or market knowledge.

Assimilation capability: measures the capability to analyse and interpret the previously acquired knowledge.

Transformation capability: measures the capability to combine assimilated knowledge with firms' existing knowledge.

Exploitation capability: measures the capability to derive new insights from the combination of newly transformed knowledge, and the existing knowledge, and to incorporate and leverage new knowledge into a novel commercial outcome.

Lead user integration:

Lead users are those customers who face needs ahead of the market, and they are very likely to benefit significantly if they obtain solutions to their needs (Von Hippel, 1986a). Lead users' integration measures lead users' contribution to new product development processes which are; setting general product definition, setting lead time requirements, setting product specifications, generating products' blueprints/drawings, designing product detailed component specification, product prototyping, product testing (Tsinopoulos and Al-Zu'bi, 2012).

During early product development stages, product ideas are generated through market research and customer focus groups. However, in later stages of product development, testing prototypes takes place to measure the manufacturability of products. This represents a more traditional Stage-Gate product development approach of identifying new products ideas, setting specifications in the early stages, while prototyping usually happens in the later stages to explore manufacturability (Cooper, 2001, Luchs *et al.*, 2015). In this research, the traditional view of new product development was adopted in order to study new innovative products development in the manufacturing industry.

Another approach to NPD is Design thinking approach, which can be described as iterative steps of identifying and solving problems through discovering and defining

problems, as well as creating and evaluating solutions (Brown, 2008). Unlike the design thinking approach (Sims, 2013) where prototyping takes place in the front-end to gather market feedback, Stage-Gate NPD process starts with generating product ideas through learning customer needs and proposing possible solutions. As the design thinking approach is not as clear as the traditional Stage-Gate approach, this research opted to use the latter to achieve the highest possible level of consistency for data collection.

Performance efficiency and effectiveness:

The conceptual model developed in this research incorporates efficiency and effectiveness as being one of the most important performance indicators. Efficiency is captured through development time and development cost, while effectiveness is captured through financial performance and product quality.

Development time: measures new product development time cycle, in comparison with similar products or competitors' products.

Development cost: measures new product development process budget meeting, compared with previous similar products, and compared with competitors' similar products.

Financial performance: measure new product development technical financial success, as well as meeting domestic market share expectations and overall profit ratings.

Product quality: measures new product development meeting of performance specifications, and it measures quality compared to competitors' similar products' quality, and previous similar products' quality.

4.10 Pilot study

A pilot test was carried out to refine the questionnaire, and to discover any issues in the research instrument such as wording, format, and clarity. A pilot test was conducted where 60 executives MBA students from different manufacturing companies were asked to fill the survey, evaluate the construct, and give feedback on the clarity. Based on the received feedback, necessary modifications were made in accordance with the comments provided. Some words were substituted and a question was added to tackle the architectural innovation construct. After evaluation, this study concluded that it is more appropriate to have a wider range of choices. Therefore, a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree) was used. Cronbach's alpha of all variables was tested to attest instrument reliability (as presented in Table 4.7).

Table 4.7: Pilot test measurement items reliability

Construct	Items	Reliability
Architectural innovation	3	0.78
Knowledge socialisation	4	0.74
Knowledge externalisation	4	0.71
Knowledge combination	4	0.75
Knowledge internalisation	4	0.79
Potential APCA- Acquisition	5	0.73
Potential APCA- Assimilation	3	0.70
Realised APCA- Transformation	6	0.74
Realised APCA- Exploitation	6	0.70
Leda users' integration	8	0.76
Development time	4	0.78
Development cost	4	0.92
Financial performance	5	0.91
Product quality	4	0.91

Three purposes were fulfilled by the pre-testing process: (1) assess the quality of the instrument (whether the required information can be obtained by the instrument); (2) ensure the applicability of the questionnaire (whether executive managers can understand questions properly); and (3) make potential but unwarranted problems apparent before the final data collection.

4.11 Study population

This research targeted the UK manufacturing industry as the sampling frame and used key informant method to carry out the empirical research of knowledge processing capabilities and their effect on architectural innovation capability and performance. According to Department for Business, Innovation & Skills (BIS) (2010), manufacturing will remain the major importance to the UK economy. The importance of this industry comes from its contribution to the well-being of the nation; it affects employment, wealth creation, international standing and quality of life. It accounts for two-thirds of UK's exports, accommodates 4.3 million job holder and accounts for 20% of GDP. Other sectors in the UK are interlinked with the manufacturing sector and cannot survive without it. One of these sectors is the service sector which largely depends on the wholesale and retail distribution, maintenance and after sale. The UK manufacturing is an important part of the global knowledge-driven economy. In addition, the UK manufacturing industry is an established leading manufacturer in the world, being the sixth largest manufacturer globally by output, and a leading exporter of technology-intensive manufacturing goods (BIS, 2010).

The researcher investigated and analysed multiple options available to collect the contact details of managing directors. However, due to restricted time frame allocated

for data collection and large population targeted; a database was acquired from a well-known databases specialist (more details in the analysis chapter).

4.12 Reliability

Reliability and validity are used to establish the goodness of measures used. Reliability ensures that a measure is without bias (free of error), and supplies consistent results across time and various items in the instrument (Hair *et al.*, 2015). Therefore, reliable measures are robust because their application yields the same results regardless different times and conditions. Internal consistency is a frequently used perspective of reliability that tests the degree to which the instrument's items are homogeneous and reflect the same underlying construct. One way to test internal consistency is the split-half technique. This technique can be used when having a measurement tool with similar questions, so the results well be separated into two halves. The correlation between the two-halves is to be tested, high correlation indicates high reliability. However, there are downfalls of split-half technique; it might lead to potential incorrect inferences about high internal consistency.

Other indexes are available to measure internal consistency without the need to split the test's items. One of the most frequently used tools to measure internal consistency for multi-point scaled items, is Cronbach's coefficient alpha. Cronbach's coefficient alpha values vary between 0 and 1, and the acceptable threshold is 0.70 (Hair *et al.*, 2015). Composite reliability is another tool to measure internal consistency for multi-point scaled items, and it is considered more accurate that Cronbach's coefficient alpha (Section 5.6.2). The last test is Kuder-Richardson formula 20 (KR20) which is used for dichotomous items (Uma and Roger, 2003).

Measurement items used in this research are validated reliable measures adopted from previous studies. Also, reliability was attested after the pilot test and after data collection using Cronbach's coefficient alpha for the pilot test and composite reliability for the data collection (Details in the analysis chapter).

4.13 Validity

There are two types of validity that any research should test, external and internal validity. External validity is concerned with whether the results can be generalised beyond the specific research context. External validity is highly related to the sample selected and the population, having a representative sample enhances external validity. Sampling used in this research was discussed under the population and sampling procedures. On the other hand, internal validity is how well a measure is testing what it was intended to measure and whether the collected data represent a true picture of the conceptual model. Internal validity is concerned with the differences found among participants, and whether these differences are genuine. Three validity tests are used to measure goodness of measure, content validity, criterion-related validity, and construct validity (Ghauri and Grønhaug, 2005).

Content validity ensures that the measure includes an adequate and representative composite of measurement scales that provide adequate coverages of the concept. If the instrument includes a set of representative scale items of the concept being measured, then content validity is high. Determining content validity is judgmental, careful definition of the concept, its items and scale can be used. Moreover, seeking expert opinion can attest to the instrument's content validity. Face validity is the

minimum requirement to assure content validity, and it means that the instrument, at the face of it, measures the concept.

Content validity was attested by conducting a pilot test asking experts to pass judgement on the suitability of the items chosen to represent each construct. Moreover, content validity was assured by adopting validated scales from previous research (validated scales used are attached in Appendix 4). For example, the measure of knowledge creation modes have been developed and tested by Schulze and Hoegl (2006), this study provided the first quantifiable measurement scales. The validity and composite reliability of the scales were above the recommended thresholds. Moreover, the same measurement scale was used in a subsequent study by the same authors in a different context which confirmed the measures reliability and validity.

Criterion-related validity intends to measure the extent to which the predictor is adequate in measuring the relevant aspects of the criterion. This validity can be achieved by establishing concurrent validity or predictive validity. This type of validity is used for prediction or estimation, and the two validity types represent different time perspective. Concurrent validity is the criterion validity at present, in which a researcher employ a criterion on which individuals are known to differ. Predictive validity is future-oriented, in which the researcher use future criterion measures to predict or estimate certain concepts (Bryman and Bell, 2015, Ghauri and Grønhaug, 2005).

Construct validity test how well the results obtained fit the theoretical underpinning around which the test is designed. Researchers deduce hypotheses from a relevant theory, however, results that contradict with the theory, should be dealt with

accordingly. The reason behind the contradiction might be due to incorrect deduction, or invalid measures. There are two types of construct validity, convergent validity and discriminant validity. Convergent validity is used to assess scales correlation with other factors of the same construct, while discriminant validity is to identify whether the scales are different from other constructs (Uma and Roger, 2003). In this research, construct validity (the convergent and discriminant validity of the data) was established using factor analysis (exploratory and confirmatory factor analysis) and correlation matrix (presented in the analysis chapter, Sections 5.6 and 5.7).

It is vital to test and understand validity, as it has an effect on the research findings. If the study lacks construct validity, the findings are meaningless. Consequently, this can harm the internal and external validity of the findings (Ghauri and Grønhaug, 2005).

4.14 Ethical considerations

Ethics consideration addresses how researchers can carry out research in a moral and responsible manner. Also, ethics are concerned with applying the chosen methodology properly. Any research that involves collecting data from human subjects should consider ethical issues. For example, individuals' anonymity and confidentiality should be clearly identified and communicated to participants (Saunders *et al.*, 2011). Researchers should explain the benefit of the study, the participant's rights and protection, and obtain informed consent

There are two philosophical branches that govern the ethical issues in empirical research, deontology and teleology (Blumberg *et al.*, 2014). Under deontology ends

never justify means, therefore, no excuses are acceptable to tolerate the ethical consideration that breaks moral principles and norms. Information that might affect participants will be communicated, albeit if fully informing the respondents might affect their response or behaviours. On the other hand is the teleological standpoint that most business researchers adopt, which means that ends justify the morality of the means. Therefore, the benefits of the study are weighted against the cost of harming participants. However, researchers have the responsibility to find a middle ground in which research morality and integrity is maintained. This is more likely to take consideration of all parties participating in the study.

Furthermore, participants should learn the benefits of partaking in the research, and the norm when distributing questionnaires is to attach a covering letter that includes all related information. A covering letter fully disclosing the researcher name, institution, research purpose, benefits, confidentiality, participant right of withdrawal, and post-study sharing of results. Moreover, an informed consent, that fully shows the study procedure, must be signed by the participants before commencing with data collection.

The researcher maintained research integrity and morality by fully disclosing research information to participants. Furthermore, participants were asked for their consent to take part in this research, and the data handling procedures which comply with Durham University data use policy were shared with the respondents (Appendix 6).

4.15 Survey administration

Pre-notification letter was distributed via email (Appendix 1). This email comprised information about the study and informed respondents that a survey will be sent to them. Respondents were given the option to opt-out from the study, and were given the course of action to be followed accordingly. Some respondents opted-out (due to different reasons such as busy schedule, some companies ceased operations or even declared bankruptcy). On the other hand, 120 respondents replied voluntarily about their willingness to partake.

The web-based survey was distributed via Qualtrics web-based survey account which was provided by Durham University, and the personalisation of the survey was achieved through different ways as suggested by Dillman *et al.* (2014). For example, the covering letters were addressed directly to each respondent. In addition, an incentive was offered to encourage participation (Yu and Cooper, 1983). Moreover, respondents were offered the opportunity to receive an executive summary of the results.

The issue of confidentiality and anonymity of companies is a sensitive issue for respondents. Thus, a separate letter was emailed to reassure respondents about confidentiality and anonymity (Appendix 6), this letter was printed on university headed paper and signed by one of the supervisory team, to increase its credibility.

4.16 Summary

This chapter has discussed the research philosophy, approach, strategies, and choices and techniques for data analysis in this present research. The determination of research design and approach were based on logical argument.

This chapter also highlighted analysis, techniques and justification used with the quantitative data. The next chapters will report the analysis techniques employed and the results obtained, in order to answer research questions and test the hypotheses.

CHAPTER FIVE: DATA ANALYSIS

5.1 Introduction

This chapter presents the analysis of the questionnaire results and quantitative findings. It starts with presenting a portfolio of the research sample, and measuring the goodness of measures through validity and reliability. The measurement model was analysed using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). Research conceptual model was analysed using structural equation modelling technique (SEM).

5.2 Research design

The aims of this research are threefold; (1) to assess the impact of knowledge creation on firms' architectural innovation capability, (2) to assess the interaction effect of absorptive capacity and architectural innovation capability on development cost and firms' financial performance, (3) and to assess the effect of lead users' integration on product quality and development time. The entire model was measured at the organisational level.

This research used survey strategy to test the postulated research hypotheses. Survey is well suited to meet the requirements of this research and it is widely acknowledged as the most frequently used empirical method in business and management research (Malhotra and Grover, 1998, Saunders *et al.*, 2011). Low cost and ease of data collection make survey a good method for collecting data. Responses were gauged based on a seven-point Likert scale. After reviewing the literature; scales were adopted or modified to suit this study. An exception was made in the architectural innovation capability scale which was created by the researcher. This exception was made due the unavailability of a relevant and comprehensive scale to measure architectural innovation capability. A scale for architectural innovation

capability composed of four items was developed following the guidelines of DeVellis (2011) and Churchill (Churchill Jr, 1979). Items were generated from the understanding of architectural innovation literature.

5.3 Sample profile

The following section presents analysis on the data collected from 196 subjects. All participating companies are from the UK manufacturing industry and the following analysis describes the sample portfolio.

The following Table (5.1) shows the properties of the participating companies (age and size), and the respondents characteristics (academic degree, job, and tenure). The age of the companies ranges from less than five years to 250 years. The size of the companies (proxy: number of employees) ranges from less than 10 to 160000 employees. The Skewness and Kurtosis of company age are above +1 which indicates that it is left-skewed. Looking at the *z*-score of Kurtosis of 14.8, it shows that the data has a peak value around the mean (51). Company size skewness was tested and it is found to be left-skewed. The median is 95; this indicates that there is a pile up of cases in around this value. Company size variable kurtosis was examined and it was positive which indicates a pointy and heavy-tailed distribution. Data about the respondents' characteristics (academic degree, job, and tenure) has been collected. The respondents' academic degrees range from GCSE to Ph.D. Most of the respondents are managers who hold top-level managerial position like CEOs, Managing Directors, manufacturing director, etc. With respect to employee tenure, the values range from less than 5 years to 46 years.

Table 5.1: Sample properties

Company description	Level	Frequency	Percent	Total	Mean (Std. Deviation)	Skewness (SE)	Kurtosis (SE)
Company Age	X<= 5	5	2.6	N=196	51.69 (43.857)	2.039 (.174)	5.118 (.346)
	5<X<=10	13	6.6				
	10<X<=20	21	10.7				
	20<X<=35	51	26.0				
	35<X<=50	37	18.9				
	50<X<=100	49	25.0				
	100<X<=150	12	6.1				
	X>150	8	4.1				
Number of company employees (Size)	X<= 10	13	6.6	N=196	2763.89 (16329.907)	7.526 (.174)	60.540 (.346)
	10<X<=50	31	15.8				
	50<X<=100	66	33.7				
	100<X<=300	50	25.5				
	300<X<=500	11	5.6				
	500<X<=1000	8	4.1				
	1000<X<=5000	10	5.1				
	X>5000	7	3.6				
Respondent academic degree	GCSE	8	4.1	N=196	-		
	A Level/ ONC	16	8.2				
	HND	18	9.2				
	Diploma	8	4.1				
	Degree	65	33.2				
	Master	48	24.5				
	Professional Qualification	22	11.2				
	PhD	11	5.6				
Respondent Job	Chairman-CEO	22	11.2	N=196	-		
	Managing Director	63	32.1				
	General Manager	18	9.2				
	Quality Director	4	1				
	Innovation Director	2	1				
	Manufacturing Director	3	1.5				
	R&D Director	8	4.1				
	Product/Project Director	8	4.1				
	Supply chain/ Operation Director	13	6.6				
	Other*	55	28.1				
Respondent Tenure	X<= 5	16	8.2	195	17.79 (10.505)	.597 (.174)	-.423 (.346)
	5<X<=10	43	22.1				
	10<X<=20	66	33.8				
	20<X<=30	48	24.6				
	30<X<=40	18	9.2				
	X>40	4	2.1				

*Other: Financial Director, Technical Director, Engineering Director, and Systems Manager

All the respondents companies belong to the manufacturing industry. According to the UK Standard Industrial Classification (SIC) (2007), the companies fall in the following sub-sectors (Table 5.2):

Table 5.2: UK SIC classification codes (2007)

UK SIC (2007) classification code	Sub-sector	Frequency
6	Extraction of crude petroleum and natural gas	1
10	Manufacture of food products	3
13	Manufacture of textiles	3
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	1
17	Manufacture of paper and paper products	3
18	Manufacture of paper and paper products	3
20	Manufacture of chemicals and chemical products	4
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	4
22	Manufacture of rubber and plastic products	14
23	Manufacture of other non-metallic mineral products	2
24	Manufacture of basic metals	5
25	Manufacture of fabricated metal products, except machinery and equipment	20
26	Manufacture of computer, electronic and optical products	10
27	Manufacture of electrical equipment	6
28	Manufacture of machinery and equipment n.e.c.	52
29	Manufacture of motor vehicles, trailers and semi-trailers	3
30	Manufacture of other transport equipment	1
31	Manufacture of furniture	2
32	Other manufacturing	56
33	Repair and installation of machinery and equipment	3

5.4 Response rate

As discussed in the methodology chapter the response rate of this research cannot be identified using the conventional method of dividing the collected questionnaires over the distributed questionnaires. The reasons behind this limitation are that (1) the researcher used a ready compiled database from a well-known data specialist, which included contact details

of executives and top level managers in the UK manufacturing industry. This database went through a long process of checking and cleaning (bounce-back, outdated, irrelevant emails). (2) The second reason is the platform used to distribute the data which is a web-based survey tool; Qualtrics, which enables the researcher to know how many emails were opened.

Although this research considers all the emails that bounced back and failed to be delivered and excluded them from the study population, this was not a guarantee that all the cases left in the databases are relevant to the population. This research used Qualtrics, which is a web-based survey tool, to distribute the questionnaire. The questionnaire distribution data shows that out of the 1607 emails received by respondents, 452 questionnaire links were opened, and 202 questionnaires were completed. Considering the above discussion, this research had a response rate of 28%.

5.5 Normality tests

Before conducting factor analysis, a number of tests must be carried out. The following section will present data normality, dimensionality, and reliability.

5.5.1 Skewness and kurtosis

Normality can be examined using skewness and Kurtosis. Skewness is a measure of lack of symmetry, whereas kurtosis is a measure of whether the data is peaked or flat (Field, 2013). The value of skewness and kurtosis is zero in a normal distribution. In research, it is not necessarily to have a value of zero if the population is very big and the sample drawn from the population is small. Bowley (1920) recommended a rule of thumb to check the sample normality which states that a skewness value that falls between -1 and 1, indicates a normal distribution.

Skewness can be spotted visually by using stem-and-leaf plots and box plots (box-and-whisker plots) (Kline, 2011). Kurtosis is harder to spot using the previously mentioned techniques. According to Kline (2011), Skewness index (SI) and Kurtosis index (KI) serve as a way to standardise the measure so it can be compared against the normal curve. The ratio of SI or KI over its standard error SE is considered the Z-test for the null hypothesis of no skewness or kurtosis. Kline (2011) recommends evaluating the absolute value of SI and KI especially in the case of big samples because even a small discrepancy between the data distribution and normal distribution could be statistically significant (Table 5.3). Transformations can be used to deal with univariate normality.

Table 5.3: Kurtosis index

KI>3.0	Extremely skewed
KI From 8.0 to 20.0	Extremely kurtosis
KI> 20.0	Serious problem

Skewness and kurtosis can be tested by looking at the z-scores. Skewness and kurtosis can be converted to *z*-scores by subtracting the mean of the distribution then divide it by the standard deviation error using the following formulas:

$$\mathbf{Z}_{Skewness} = \frac{S - 0}{SE_{skewness}}$$

$$\mathbf{Z}_{kurtosis} = \frac{K - 0}{SE_{Kurtosis}}$$

An absolute value greater than 1.96 is significant at p <0.05, which means the researcher cannot reject the null hypothesis of no skewness or no kurtosis. It is recommended to look at the shape of the distribution rather than the absolute number because these numbers can be

problematic with large samples bigger than 200. In this study, the researcher followed the previous recommendation and examined the histogram for each question and all questions were normal (Field, 2013).

5.5.2 Mean and standard deviation

The mean and standard deviation of the measured variables are presented in the following section. The mean is a measure of central tendency which describes the central of the distribution. The standard deviation was also examined to describe the extent to which the data values of each variable are spread around its mean (Saunders *et al.*, 2011). Descriptive statistics are represented in Table 5.4:

Table 5.4: Measured variables descriptive information (mean and standard deviation)

Latent variable	Item	Mean		Standard Deviation	
Socialisation	We spent a lot of time in personal interaction aside from organised meetings with other people in the company to discuss suggestions, ideas, or solutions	5.31	5.07	1.417	1.55
	We spent a lot of time in personal interaction aside from organised meetings with people from other departments in the company in order to discuss suggestions, ideas, or solutions	5.10		1.572	
	We spent a lot of time in intense discussions about suggestions, ideas, or solutions in face-to-face meetings with people from different departments in the company	4.90		1.679	
	We spent a lot of time in the conscious creation of a common understanding of a problem with people from other departments in the company	4.99		1.557	
Externalisation	We spent a lot of time reflecting collectively and framing our ideas or solutions with regard to customer needs	5.59	5.06	1.398	1.56
	We spent a lot of time interviewing competent people about ideas or solutions with regard to relevant technologies	4.83		1.584	
	We spent a lot of time interviewing competent people about ideas or solutions with regard to customer needs	5.03		1.595	
	We spent a lot of time creating detailed descriptions containing newly developed knowledge about customer needs	4.81		1.671	
Combination	Focusing on the product, we systematically process the technical knowledge collected	5.57	5.37	1.100	1.22
	Focusing on the product, we systematically process the knowledge collected about customer needs	5.63		1.136	
	Focusing on the product, we systematically edited the collected knowledge about the procedure of creating,	5.18		1.326	

	evaluating, and selecting a product concept/developing products				
	Within the company, we distributed our newly gained insights about customer needs	5.13		1.337	
Internalisation	We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding the functionality of the product	4.76	4.62	1.712	1.68
	We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding customer needs	4.58		1.651	
	We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding the procedure of creating, evaluating, and selecting a product concept/ developing products	4.53		1.678	
Architectural innovation capability	The new product development processes that we followed to develop this product: encouraged us to explore new linkages between existing technologies	5.49	5.11	1.445	4.42
	has led to significant changes in the way product technologies interact	4.65		1.507	
	has led to significant changes that influenced the overall performance of the product	5.21		1.465	
Development Time	Top management was very pleased with the time it took us to bring this product to market	4.53	4.25	1.544	1.6
	This product was launched on or ahead of the original schedule	4.14		1.700	
	This product was completed in less time than what was considered normal and customary for our industry	4.08		1.544	
Development cost	This product met the budget specifications for the development costs	4.83	4.54	1.438	1.38
	The development cost of this product is less than previous projects for similar products	4.17		1.328	
	Top management was very pleased with the development cost of this product	4.63		1.377	
Financial performance	This product was successful based on financial performance	5.33	5.25	1.226	1.27
	This product met domestic market share expectations	5.15		1.326	
	This product met sales and profit objectives	5.21		1.321	
	This product met overall profit ratings	5.31		1.210	
Quality	This product met the present performance specifications	5.96	5.73	.960	1.1
	This product provided better quality than previous projects for similar products	5.49		1.303	
	This product provided better quality than competitor projects for similar products	5.63		1.176	
	This product met technical success ratings	5.85		.980	
Acquisition	We collect industry information through informal means (e.g. lunch with industry friends, talks with trade partners)	5.32	4.92	1.287	1.53
	My company periodically organises special meetings with customers or third parties to acquire new knowledge	5.07		1.593	
	Employees in my company regularly approach third parties such as accountants, consultants, or tax consultants	4.38		1.710	
Assimilation	We are slow to recognise shifts in our market (e.g. competition, regulation, demography) (reverse-coded)	3.03	4.53	1.453	1.24
	New opportunities to serve our clients are quickly understood	5.37		1.104	
	We quickly analyse and interpret changing market demands	5.20		1.162	

Transformation	My company regularly considers the consequences of changing market demands in terms of new products and services	5.33	5.22	1.197	1.22
	Employees in my company record and store newly acquired knowledge for future reference	5.08		1.286	
	My company quickly recognises the usefulness of new external knowledge to existing knowledge	5.24		1.168	
Exploitation	It is clearly known how activities within our company should be performed	5.67	5.56	1.066	1.14
	Our company has a clear division of roles and responsibilities	5.50		1.238	
	Employees have a common language regarding our products and services	5.51		1.121	
Lead users' integration-early NPD stages	lead users contribution to the following activities:				
	Setting general product definition	5.29	5.19	1.285	1.38
	Setting lead time requirements	4.90		1.502	
	Setting product specifications	5.38		1.340	
Lead users' integration-late NPD stages	Generating products' blueprints/drawings	4.27	4.44	1.774	1.66
	Designing product detailed component specification	4.15		1.761	
	Overall product development process	4.89		1.449	

5.5.3 Dimensionality

Before carrying out factor analysis, statistics, such as Kaiser–Meyer–Olkin measure of sampling adequacy and Bartlett's test of sphericity, were conducted to test the appropriateness of the factor model.

Kaiser–Meyer–Olkin KMO statistic is a good indicator of sample size adequacy. "It represents the ratio of the squared correlation between variables to the squared partial correlation between variables" (Field, 2013: 647). KMO values range from 0 to 1. Kaiser (1974) recommends a minimum acceptable value of 0.50 in order to conduct factor analysis. The results range from good to great sample adequacy. Hutcheson and Sofroniou (1999) classified the acceptable values as depicted in Table 5.5:

Table 5.5: KMO acceptable values

KMO value	Evaluation
Between 0.05 and 0.07	Mediocre
Between 0.7 and 0.8	Good
Between 0.8 and 0.9	Great
Values above 0.9	Superb

Bartlett's test of sphericity tests "whether our correlation matrix is significantly different from an identity matrix" (Field, 2013: 648). If the Bartlett's test is significant, it appears that the correlations between the variables are significantly different from zero. Bartlett's test is statistically significant for all factors in this study.

5.6 Exploratory factor analysis

Factor analysis is a widely used tool to identify the dimensionality of measured constructs and to confirm the validity of the data collection instrument. There are two types of factor analysis: exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). According to Hair (2009), EFA can be used to examine the underlying pattern of a large number of variables and/or for the purpose of data reduction. Data reduction aims to reduce the items that indicate a variable. In exploratory factor analysis indicators are allowed to load on all factors in order to test unidimensionality. Unrestricted factor models are estimated in EFA while restricted factor models are estimated in CFA.

Unidimensionality is a good indicator of construct validity "which concerns whether scores measure the hypothetical construct the researcher believes they do" (Kline, 2011: 71). Unidimensionality was examined in the exploratory factor analysis. This test is used to measure if each indicator loads on a single factor, and whether the error terms are independent (Kline, 2011). If any indicator loads on more than one factor this implies multidimensionality (considering cut-off number for cross loadings is ≥ 0.3). Based on exploratory factor analysis, items were removed based on their factor loading. The criterion was to remove items that load into more than one factor. The deleted items are presented in Table 5.8 under the CFA column. Only the items with high factor loading were used in the confirmatory factor analysis.

Confirmatory factor analysis CFA is used to test convergent and discriminant validity. Discriminant Validity is "the extent to which independent assessment methods diverge in their measurement of different traits" (Byrne, 2013: 275). Discriminant validity can be of concern if the square root of the average variance extracted (AVE) for each factor is less than all absolute value of all inter-factors correlations. As shown in Table 5.6 this data set has no issues regarding discriminant validity.

Table 5.6: Factor correlation matrix with square root of AVE on the diagonal

		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X1	**AI**	0.793														
X2	**KC1**	.44	0.86													
X3	**KC2**	.39	.68	0.974												
X4	**KC3**	.31	.52	.64	0.774											
X5	**KC4**	.42	.40	.35	.32	0.916										
X6	**LU1**	.08	.12	.18	.28	.15	0.734									
X7	**LU2**	.12	.15	.25	.34	.19	.57	0.842								
X8	**Time**	.14	.09	.12	.14	.10	.19	.33	0.774							
X9	**Cost**	.17	.11	.15	.20	.08	.19	.22	.73	0.768						
X10	**Fin**	.16	.12	.09	.10	.07	.22	.13	.30	.47	0.854					
X11	**Qual**	.32	.17	.17	.18	.17	.33	.21	.10	.23	.48	0.721				
X12	**AC1**	.06	.13	.06	.24	.07	.15	.12	.04	.04	.07	.06	0.70			
X13	**AC2**	.06	.01	.12	.06	.11	.25	.04	.01	.003	.13	.06	.37	0.748		
X14	**AC3**	.03	.03	.01	.24	.09	.10	.21	.07	.11	.06	.04	.65	.34	0.768	
X15	**AC4**	.05	.01	.12`	.04	.06	.23	.10	.03	.21	.09	.06	.59	.88	.68	0.663

AI: Architectural Innovation Capability
KC1: Socialization
KC2: Externalization
KC3: Combination
KC4: Internalization
AC1: Acquisition
AC2: Assimilation
AC3: Transformation
AC4 : Exploitation

The Average Variance Extracted (AVE) was calculated (Table 5.8) to test for convergent validity (Kline, 2011). "Convergent validity is the extent to which different assessment methods concur in their measurement of the same trait (*i.e.* construct)" (Byrne, 2013: 275). For all factors, the Average Variance Extracted was above 0.50 except for potential absorptive capacity - acquisition, which was close at 0.49 and realised absorptive capacity-

exploitation, which was close at 0.44. However, as both factors are minimally correlated with other factors in the model, and because the reliability scores (0.73 and .70 respectively) were greater than 0.70, both factors have not been removed and are maintained in the model.

All items show sufficient convergent validity as all the loading were well above the recommended threshold of 0.45 for a sample size of 150-200 (Hair, 2009). Sufficient convergent validity implies that the items under each factor load together and that the loadings are above 0.7 and/or their average are above 0.70.

5.6.1 Multicollinearity

The tolerance and variance inflation factor (VIF) was tested using SPSS to assess multicollinearity. Tolerance is the percentage of variance in the independent variable that is not accounted for by the other independent variable(s). Tolerance can be calculated through $1-R^2$. Tolerance values less than 0.1 flag a problem (Menard, 1995). VIF indicates the degree to which the standard errors are inflated due to the levels of multicollinearity. Tolerance and variance inflation factor is the reciprocal of tolerance value. VIF values larger than 10 indicate collinearity problems according to (Field, 2013, Myers, 1990). VIF results indicate that variables in this study do not have multicollinearity issues.

5.6.2 Reliability

Reliability is the degree to which the observed variable measures the true value and is error free (Hair, 2009). Reliability is a measure of internal consistency and means that the measure must consistently reflect the construct that it is measuring (Field, 2013). All composite reliability (CR) values are above the recommended threshold (.700) (Table 5.8). Some of the items have relatively low loadings but they have been retained as a good practice, to maintain

the full spectrum of results. Composite reliability was calculated based on Fornell and Larcker's (1981) work.

5.7 Measurement model (Confirmatory factor analysis)

Two measurement models were estimated, the variables used in each measurement model and their fit statistics are presented in Table 5.7. The exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) factor loadings are presented in Table 5.8 below.

Table 5.7: Measurement models

	CFA1	**CFA2**
Constructs used	Socialisation, Externalisation, Combination, Internalisation, Lead users' integration-front-end NPD, and Lead users' integration- late NPD.	Architectural Innovation, Acquisition, Assimilation, Transformation, Exploitation, Time, Cost, Financial Performance, and Quality.
Model fit	χ^2=315.97, d.f.=174, RMSEA=0.065 SRMR=0.0628 CFI=0.972	χ^2=581.034, d.f.=341, RMSEA=0.060 SRMR=0.0608 CFI=0.946

Table 5.8: Factor loadings, CR, & AVE

Factors	**Items**	**Eigen Value**	**% of variance**	**KMO Test**	**EFA**	**CFA**	**Composite Reliability**	**Average variance explained AVE**
Architectural Innovation	AI1	2.584	64.594	.734	.843	.73	.83	.63
	AI2				.667	deleted		
	AI3				.800	.80		
	AI4				.831	.84		
Socialisation	S1	3.199	79.978	.812	.846	.81	.92	.74
	S2				.871	.90		
	S3				.842	.88		
	S4				.755	.83		
Externalisation	E1	2.719	67.985	.774	.584	.60	.85	.59
	E2				.853	.85		
	E3				.878	.87		
	E4				.607	.71		
Combination	C1	2.767	69.184	.804	.850	.79	.86	.60
	C2				.844	.83		
	C3				.751	.72		
	C4				.693	.73		
Internalisation	I1	2.682	89.388	.754	.936	.92	.94	.84
	I2				.938	.96		
	I3				.879	.88		
	I4				.511	deleted		
Potential Absorptive Capacity								
Acquisition	Ac1	2.770	55.405	.711	.749	deleted	.73	.49

	Ac2				.779	deleted		
	Ac3				.709	.75		
	Ac4				.687	.80		
	Ac5				.692	.51		
Assimilation	As1	2.030	67.668	.616	.691	.49	.78	.56
	As2				.819	.76		
	As3				.835	.93		
Realised Absorptive Capacity								
Transformation	Tr1	2.157	71.886	.695	.663	.70	.81	.59
	Tr2				.834	.77		
	Tr3				.798	.82		
	Tr4				.621	deleted		
	Tr5				.715	deleted		
	Tr6				.428	deleted		
Exploitation	Ex1	1.899	62.184	.663	.707	.79	.70	.44
	Ex2				.433	deleted		
	Ex3				.797	.54		
	Ex4				.632	deleted		
	Ex5				.495	deleted		
	Ex6				.755	.63		
Performance								
Time	T1	2.165	72.170	.670	.883	.84	.82	.60
	T2				.891	.85		
	T3				.629	.61		
Cost	C1	2.159	71.970	.699	.554	.81	.81	.59
	C2				.756	.65		
	C3				.571	deleted		
	C4				.655	.82		
Financial performance	F1	3.158	78.958	.797	.824	.77	.91	.73
	F2				.412	deleted		
	F3				.825	.75		
	F4				.905	.96		
	F5				.846	.91		
Quality	Q1	2.544	63.610	.719	.711	.77	.80	.52
	Q2				.819	.60		
	Q3				.804	.57		
	Q4				.703	.88		
Lead users' integration								
Lead users' integration-front-end NPD	LU1	2.045	68.060	.665	.853	.80	.77	.54
	LU2				.689	.60		
	LU3				.839	.79		
Lead users' integration-late NPD	LU4	3.052	76.306	.778	.850	.89	.88	.71
	LU5				.871	.96		
	LU6				.880	deleted		
	LU7				.622	deleted		
	LU8				.771	.65		

5.8 Structural equation model testing

Structural equation modelling (SEM) is used in this research to test the proposed hypotheses. SEM is a statistical tool that combines factor analysis and mathematical modelling, used for testing causal relationship between the latent and the observed variables (Blunch, 2008). SEM has many advantages over other methods of analysis, such as its ability to combine factor analysis (from a confirmatory perspective) with econometric modelling. SEM model

consists of observed (manifest) variables and latent variables. Latent variable "correspond to hypothetical constructs or factors, which are explanatory variables presumed to reflect a continuum that is not directly observable" (Kline, 2011: 9). And observed variables which are captured through data collection. SEM allows for the simultaneous estimation of a number of separate, yet interdependent equations incorporating both latent and observed variables, as well as direct, indirect and total associations, even if there are variables acting as both dependent and independent (Hair, 2009).

James, Mulaik and Brett (2006) Anderson and Gerbing (1988) propose two steps modelling approach. This approach emphasises the use of measurement model and a structural model. The measurement model identifies how each construct is operationalised by its manifest indicator. The measurement model produces important information, such as reliability and validity (convergent and discriminant).

Before conducting measurement model which is confirmatory factor analysis, it is advised to conduct exploratory factor analysis. In EFA, there is no preceding identification of the number of factors composing a construct. Analysing the construct using EFA approach will help the researcher to specify a hypothesised number of underlying factors (depending on how many variables are being tested at one EFA). After this step, the measurement model (confirmatory factor analysis) is conducted, in which a priori model has to be specified and the parameters are freely estimated.

Measurement model gives us the information about how each construct is operationalised and includes dimensionality, validity and reliability tests, etc. On the other hand, the structural model delivers the associations between the construct and the significance of those

associations. In addition, it provides the amount of variance in dependent variable(s) which was successfully explained by independent variable(s).

This research adopted the two-step analytical strategy (Anderson and Gerbing, 1988, James *et al.*, 1982) to test the hypothesised model (Figure 5.1). After validating the measurement model, the structural relationships between latent variables have been estimated. The two-step approach for conducting structural equation modelling consists of the measurement model and the structural model. The measurement model is helpful to identify the reliability and validity of the items which indicates each construct. The measurement model is used to indicate convergent and discriminant validity, while the structural model is used to indicate a predictive validity (Anderson and Gerbing, 1988). Thus; according to the previous two-step approach the measurement model has to be tested first and model fit criteria must be met before conducting the second step; which is the structural model analysis.

5.8.1 Structural equation modelling strategies

There are three strategies that can be implemented to test structural equation models according to (Jöreskog and Sörbom, 1993):

1. Strictly confirmatory: This strategy requires the researcher to construct one model based on literature where appropriate data is collected and then the fit of the collected data to the model is analysed. If the model does not fit the data, then the researcher cannot support the model and no further action can be taken. This strategy is not used very often because it is not as a practical as the following two strategies.

2. Model comparison strategy: Under this strategy the researcher specifies alternative models and fits each model to the data set. The alternative models may represent competing models or models based on contradicting research findings.

3. Model generation strategy: under this strategy the researcher starts with specified model and test the fit with appropriate data. After this test, the researcher can try to improve the parsimony and/or the fit of the model to the data. Researchers can employ Lagrange Multiplier (LM) test to determine how much the model fit can improve if certain a parameter is introduced. One special case which is very commonly used is the modification indices (unlike the first strategy, this process is exploratory). Researchers must use this strategy with caution, as any change to the model has to be meaningful and justifiable.

This research is following the strictly confirmatory strategy to test the hypothesised model (Figure 5.1).

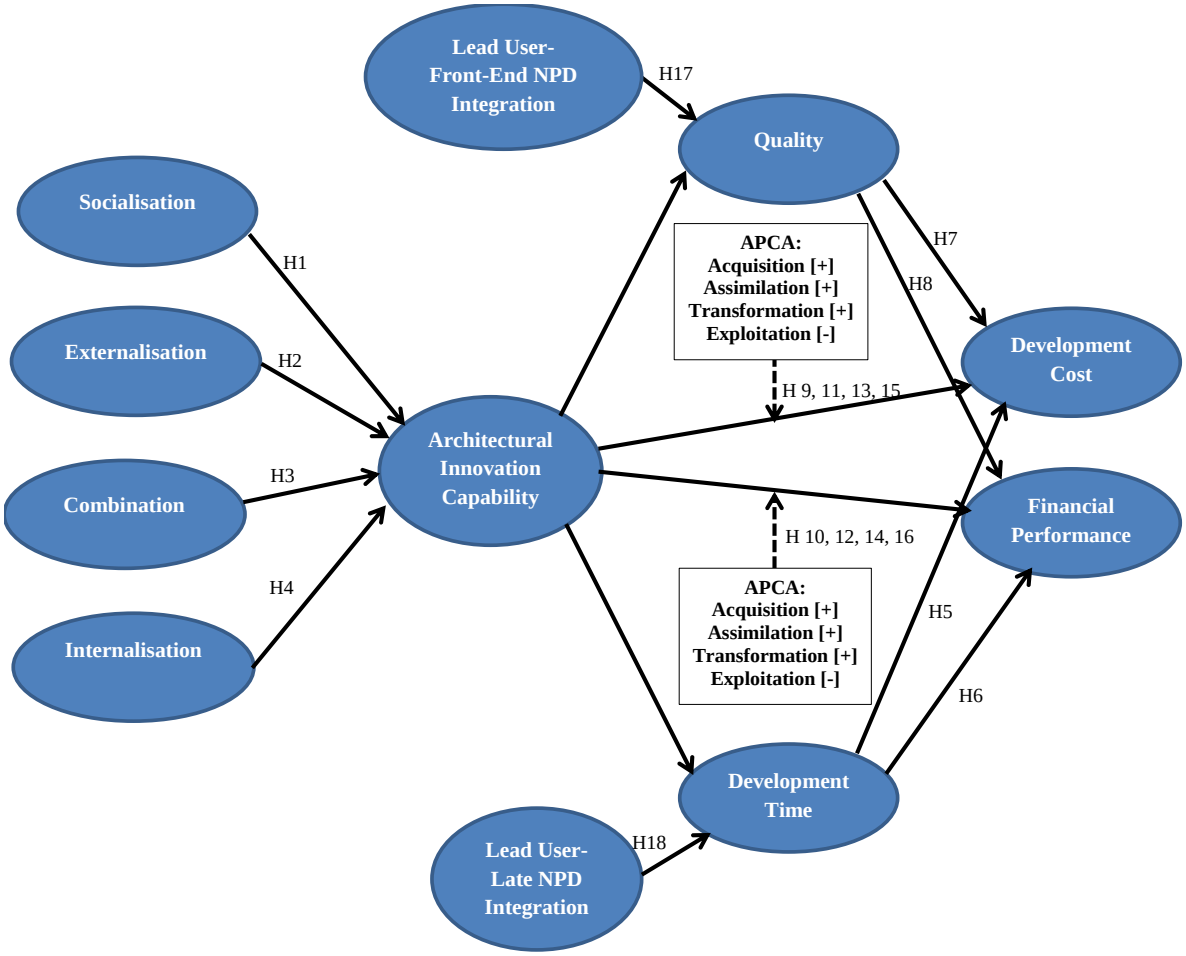

Figure 5.1: Conceptual Model

The following part reports the structural model data analysis incorporating 16 latent variables. The 15 latent variables are architectural innovation capability, knowledge socialisation, externalisation, combination, internalisation, acquisition, assimilation, transformation, exploitation, lead users' integration in front-end NPD, lead users' integration in late NPD, time, cost, financial performance, and quality.

Listed below are research hypotheses for ease of reference:

H1: Socialisation is positively related to firms' architectural innovation capability.

H2: Knowledge externalisation is positively related to firms' architectural innovation capability.

H3: Knowledge combination is positively related to firms' architectural innovation capability.

H4: Knowledge internalisation is positively related to firms' architectural innovation capability.

H5: A company's architectural innovation capability has a positive indirect effect on development cost through the mediating effect of development time.

H6: A company's architectural innovation capability has a positive indirect effect on financial performance through the mediating effect of development time.

H7: A company's architectural innovation capability has a positive indirect effect on development cost through the mediating effect of product quality.

H8: A company's architectural innovation capability has a positive indirect effect on financial performance through the mediating effect of product quality.

H9: A company's acquisition capacity positively moderates the relationship between architectural innovation capability and development cost.

H10: A company's acquisition capacity positively moderates the relationship between architectural innovation capability and financial performance.

H11: A company's assimilation capacity positively moderates the relationship between architectural innovation capability and development cost.

H12: A company's assimilation capacity positively moderates the relationship between architectural innovation capability and financial performance.

H13: A company's transformation capacity positively moderates the relationship between architectural innovation capability and development cost.

H14: A company's transformation capacity positively moderates the relationship between architectural innovation capability and financial performance.

H15: A company's exploitation capacity negatively moderates the relationship between architectural innovation capability and development cost.

H16: A company's exploitation capacity negatively moderates the relationship between architectural innovation capability and financial performance.

H17: Lead users' integration in the front end of the NPD process is positively related to product quality.

H18: Lead users' integration in late stages of the NPD process is positively related to development time.

The model was estimated using robust maximum likelihood. LISREL 8.8 software was used conduct full structural equation modelling test (SEM). LISREL was used because it is capable of examining simultaneous relationships between several endogenous and exogenous variables. The goodness-of-fit indices indicated a good fit as shown in Table 5.9.

Table 5.9: Model test

				SEM Model Fit Statistics			
	χ^2	**df**	**χ^2/df**	**RMSEA**	**CFI**	**IFI**	**NNFI**
SEM Model	77.471	47	1.64	0.058	0.97	0.97	0.90
				Hypothesis Testing Results			
Variables				**Dependent Variables** Standardized Path Coefficient (*t*-value)			
	Architectural Innovation Capability		**Development Cost**	**Financial Performance**	**Development time**		**Quality**
Independent Variables							
Knowledge Socialisation	0.24 (2.09*)						
Knowledge Externalisation	0.12 (0.93)						
Knowledge Combination	0.01 (0.06)						
Knowledge Internalisation	0.27 (3.38**)						
AI Capability			0.02 (0.27)	-0.04 (-0.45)			
Development Time			0.73 (9.58**)	0.27 (3.69**)			
Product Quality			0.15 (1.85*)	0.46 (5.75**)			
Lead User-Front-end NPD							0.31 (3.61**)
Lead User-Late NPD					0.31 (3.79**)		
Moderating Variables							
AIC * Acquisition			0.89 (0.48)	0.05 (0.26)			
AIC * Assimilation			6.63 (0.49)	0.77 (1.70*)			
AIC * Transformation			3.21 (0.47)	0.71 (2.38**)			
AIC * Exploitation			-9.08 (-0.50)	-1.26 (-2.13*)			
Control Variables							
Tenure	-0.09 (-1.18)		-0.31 (-0.32)	-0.15 (-1.17†)			
Company Size	0.09 (1.20)		0.59 (0.50)	0.22 (1.60†)			
Company Age	0.001 (0.02)		-0.59 (-0.42)	-0.02 (-0.16)			
High/ Low Tech			1.26 (0.49)	0.12 (0.85)			
Squared Multiple Correlations (SE)	0.29		2.14	0.38	0.12		0.19

** Significant at 0.01 level (critical Z-value = 2.326)
* Significant at 0.05 level (critical Z-value = 1.645)
† Significant at 0.10 level (critical Z-value = 1.282)

5.8.2 Mediation

Baron and Kenny (1986) recommend the following criteria in order to determine if the mediator mediates the effect of the predictor variable on the dependent variable; four conditions need to be met: 1. the path between the predictor variable and the mediator variable must be significant, 2. The path between the mediator variable and the dependent variable must be significant, 3. The path between the predictor and the independent variable must be significant. 4. After controlling for the mediator the path between the predictor and the independent variable must be reduced or not significant.

If the path significance was reduced then the mediation is considered partial mediation, while on the other hand, if the path were to lose significance then it is full mediation. In the case of full mediation adding the path from the predictive variable to the independent variable should not improve the fit. In the case of partial mediation, chi-square values should be compared; this is called the Chi-square difference test, in which two models' chi-square has to be compared and the difference must be calculated with respect to the difference in degrees of freedom. Baron and Kenny (1986) advised that it is more practical to seek a mediator that reduce the significance of the path between the predictor and the dependent variable instead of eliminating the path altogether; because in social sciences there must be other variables that mediate the desired path.

Sobel test is a method for assessing the significance of indirect effects in structural equation models (Sobel, 1982). The Sobel test was employed (Table 5.10) to determine whether the link between architectural innovation and performance is mediated. Sobel test reveals significant full mediation effect on development cost via development time (Z=1.36†) and on financial performance via development time (Z =1.30†). Furthermore Sobel test results reveal significant full mediation effect on development cost via product quality (Z =1.67*) and on financial performance via product quality (Z =3.07**).

Table 5.10: Sobel test results

	a	SE_a	b	SE_b	Z	c	Effect Ratio	Mediation
***Mediator: Development Time* [AI→DT→Cost] [AI→DT→Perf]**								
Development Cost	0.11	0.08	0.73	0.08	1.36†	0.02	4.02	Full
Financial Performance	0.11	0.08	0.27	0.07	1.30†	0.04	0.83	Full
***Mediator: Product Quality*[AI→Q→Cost] [AI→Q→Perf]**								
Development Cost	0.29	0.08	0.15	0.08	1.67*	0.02	2.18	Full
Financial Performance	0.29	0.08	0.46	0.08	3.07**	0.04	3.34	Full

a Unstandardized path coefficient from independent variable to the mediator variable.
SE_a Standard error of the relationship between the independent variable and the mediator variable.
b Unstandardized path coefficient from the mediator variable to the dependent variable.
SE_b Standard error of the relationship between the mediator variable and the dependent variable.
Z Sobel test statistic: $Z = ab/\sqrt{((a^2SE_b^2) + (b^2SE_a^2))}$
c Unstandardized path coefficient from independent variable to the dependent variable.
Effect Ratio = *ab/c*
** Significant at 0.01 level (critical *Z*-value = 2.326).
* Significant at 0.05 level (critical *Z*-value = 1.645).
† Significant at 0.10 level (critical *Z*-value = 1.282).

Listed below (Table 5.11) is a summary of the supported and rejected hypotheses:

Table 5.11: Summary of hypotheses test

Hypothesis	Path	Findings
Direct Effects		
H1	Knowledge socialization → Architectural innovation capability	Supported
H2	Knowledge externalization → Architectural innovation capability	Not supported
H3	Knowledge combination → Architectural innovation capability	Not supported
H4	Knowledge internalization → Architectural innovation capability	Supported
Mediated Effects		
H5	Architectural innovation capability → Development time→ Development cost	Supported
H6	Architectural innovation capability → Development time→ Financial performance	Supported
H7	Architectural innovation capability → Product quality→ Development cost	Supported
H8	Architectural innovation capability → Product quality→ Financial performance	Supported
Moderated Effects		
H9	Acquisition strengthens (+): Architectural innovation capability → Development cost	Not supported
H10	Acquisition strengthens (+): Architectural innovation capability → Financial performance	Not supported
H11	Assimilation strengthens (+): Architectural innovation capability → Development cost	Not supported
H12	Assimilation strengthens (+): Architectural innovation capability → Financial performance	Supported
H13	Transformation strengthens (+): Architectural innovation capability → Development cost	Not supported
H14	Transformation strengthens (+): Architectural innovation capability → Financial performance	Supported
H15	Exploitation weakens (-):Architectural innovation capability → Development cost	Not supported
H16	Exploitation weakens (-): Architectural innovation capability → Financial performance	Supported
H17	Lead users' integration in early stages of NPD → Product quality	Supported
H18	Lead users' integration in late stages of NPD → Development time	Supported

5.8.3 Fit indices

One of the most important aspects of CFA is assessing the model fit. The model fit shed light on how well the empirical data fit with the measurement model. There are many fit indices that can be used to examine the goodness of fit. Researchers recommend the use of more than one fit index to examine models as the use of only one index is rather deceiving (Hair, 2009). Most commonly used fit indices are non-normed fit index (NNFI), comparative fit index (CFI), the root mean squared approximation of error (RMSEA), $\chi 2$ statistic ($\chi 2$/ d.f.) (Garver and Mentzer, 1999). There are three types for model fit assessment in literature, according to Hooper *et al.* (2008), (1) absolute fit indices, (2) incremental fit indices, (3) and parsimony fit indices.

Absolute fit indices indicate the fit of sample data with a priori model, and in particular, which model has the best fit. This category includes Chi-square test, RMSEA, GFI, AGFI, RMR, and SRMR.

5.8.3.1 Chi-square $\chi 2$

Chi-square fit index is one of the most popular fit indices. Chi-square ($\chi 2$) value relative to the degrees of freedom indicates the difference between observed matrix and the estimated matrix. The cause of this difference is sampling variation. As this test is very sensitive to sample size (Jöreskog and Sörbom, 1993), researchers recommend using of $\chi 2$/df ratio (Wheaton *et al.*, 1977). Values less than or equivalent to 2, indicates a good fit between the sample data and the proposed model. Under the confirmatory factor analysis, achieving a non-significant $\chi 2$ associated with the degrees of freedom indicates a good fit between the model and the data. Kline (2011) refers to chi-square as the “badness of fit” because a good model fit provides an insignificant result at 0.05. Chi-square is not a powerful model fit if the sample is small, since it is very sensitive to sample size (Jöreskog and Sörbom, 1993). Researchers use other model fit statistics to overcome the pitfalls of chi-square. Ultimately,

researchers are recommended to look at a bundle of fit indices instead of relying on one index.

5.8.3.2 Goodness-of-fit index (GFI)

Goodness-of-fit index (GFI) is a commonly used measure of the relative amount of variance and covariance in observed matrix S that is jointly explained by estimated matrix Σ (Byrne, 2013). Adjusted goodness-of-fit index (AGFI) differs from GFI, as it takes into consideration degrees of freedom and additional parameters. These two types of fit indices are considered absolute indices and range from 0 to 1. Values close to one indicates a good fit (Byrne, 2013). It is recommended to look at these indices with caution as they are highly arbitrary (Kelloway, 1998).

5.8.3.3 The root mean square residual (RMR)

The root mean square residual (RMR) is "a measure of mean absolute covariance residual" (Kline, 2011: 209). Root-mean-square-residual is used to estimate the average fitted residual in the data. The root mean square residual is based on unstandardised residuals which are hard to interpret (Hu and Bentler 1995), as a consequence, it is recommended to use the standardised RMR which is calculated using the standardised residuals.

5.8.3.4 The root-mean-square error of approximation (RMSEA)

The root-mean-square error of approximation (RMSEA) represents the error of approximation in population. It measures how well the model would fit the population covariance matrix if it were available. RMSEA is sensitive for degrees of freedom. Although it tends to have a very large value in complex models; this is subject to the size of the sample. RMSEA values less than 0.060 indicate a good fit (Hu and Bentler, 1999).

5.9 Common method bias

Measurements error has random and systematic components. One of the systematic errors is method variance (Bagozzi and Yi, 1991). Common method variance can negatively influence empirical results and give misleading conclusions. According to Podsakoff *et al.* (2003: 882) there are potential sources of common method bias that varies from "common rater effect", bias related to the measurement items, or context within which the measures were obtained.

Podsakoff *et al.* (2003) argue that researchers where possible need to control for common method variance. “This can be done by considering four key questions: (a) Can the predictor and criterion variables be obtained from different sources? (b) Can the predictor and criterion variables be measured in different contexts? (c) Can the source of the method bias be identified? And (d) Can the method bias be validly measured?” (Podsakoff *et al.*, 2003: 897). In this research, the researcher endeavoured to minimise the ambiguity as much as possible in the questionnaire by following Dillman's Total Design Method (TDM) (Appendix 5). One of the solutions to avoid common method bias from the early stage of questionnaire design is to use different scale descriptors for different sections (Podsakoff *et al.*, 2003). The researcher carefully designed the questionnaire items, including defining ambiguous or unfamiliar terms, avoiding vague concepts, keeping questions specific and concise, and decomposing complex questions into simpler questions (Tourangeau *et al.*, 1991). The possibility of the data being affected by single respondent bias was minimised by targeting executive managers who are best positioned to provide information about the knowledge processing capabilities followed, innovation, and performance.

Key informant responded for the predictor and criterion items. This may present "Consistency motif" bias (Johns, 1994, Podsakoff and Organ, 1986), which is respondent's tendency to assure consistency throughout answering the questionnaire. However to overcome this bias, questions related to predictor and criterion items were mixed. Social desirability is another source for common method bias. Social desirability is the desire to get social approval and conformity by following a certain socially appropriate behaviour (Crowne and Marlowe, 1964), this type of bias is very harmful as it can change the true relationship between variables (Ganster *et al.*, 1983).

Although utmost care was taken to avoid common method bias while preparing the questionnaire, this issue is very important to be dealt with using post-hoc mechanisms. One of the most common ways is to use Harman's single-factor test (Podsakoff *et al.*, 2003). Traditionally researchers used this technique in the EFA by loading all the variables into one exploratory factor using the un-rotated factor solution and examining the amount of variance explained by this factor. A more sophisticated approach is to use it in the CFA. The common variable is used to determine the common variance between all the observed items. This method is a diagnostic technique rather than a remedy, and usually is used to assess the extent of the problem. This method was applied and the results show no common method bias, $\chi 2$ = 6739.778; df = 1175; $\chi 2/df$ = 5.736; RMSEA = .156; CFI = .678; IFI = .679; NNFI = .664. All statistics exceed the cut-off for a healthy model which means, this model has to be rejected ($\chi 2/df > 2$, RMSEA >.08[1], and fit indices <.09). This means that the research variables do not load on one factor and indeed have multidimensionality.

To get a more accurate representation of the common variance, marker variable method were used; marker variables are those that are seemingly unrelated to other variables in the model.

[1] .08 is suggested by Hu and Bentler (1999)

The existence of shared variance indicates common method bias. Including "theoretically unrelated, proximally located marker variables" is very useful to determine if the explained variance was inflated by common method bias CMB (Lindell and Whitney, 2001: 116). Social desirability was used as a marker variable in this study (Williams *et al.*, 2010). The researcher followed the method proposed by (Conway and Lance, 2010), through subtracting the correlation between the marker variables and the focal variables from the correlation among the focal variables. This method was adjusted by taking into considerations only the focal variables that were affected by common method bias (this method was proposed by (Hughes *et al.* (2014), Lindell and Whitney (2001))). This method was applied to CFA1 and CfA2 by creating a CMV-modified covariance matrix, which was used to re-specify the original matrix. The results below (Tables 5.12 & 5.13) shows that the changes in CFA1 and CFA2 were not significant and the fit did not significantly deteriorate.

CMV-Adjusted CFA Model 1, $\chi 2$ = 317.32; df = 174; RMSEA = .065; CFI = .972; IFI = .972; NNFI = .966. ($\Delta\chi 2$ = 1.35 [increase]; Δdf = 0; ΔCFI = 0, ΔIFI, ΔNNFI = .03 [positive improvement]). CMV-Adjusted CFA Model 2, $\chi 2$ = 583.604; df = 341; RMSEA = .06; CFI = .95; IFI = .95; NNFI = .95. ($\Delta\chi 2$ = 2.57 [increase]; Δdf = 0; ΔCFI, ΔIFI, ΔNNFI = .01 [positive improvement]). The change on the model statistics is negligible and the model fit statistic gone up which means that there is no effect significant effect of common method bias.

Table 5.12: Confirmatory Factor Analysis 1

	CFA1		
	Original	CMV-adjusted	Δ
χ^2	315.97	317.32	1.35
d.f.	174	174	0
RMSEA	0.065	0.065	0
CFI	0.972	0.972	0
IFI	0.969	0.972	0.03
NNFI	0.963	0.966	0.03

Table 5.13: Confirmatory Factor Analysis 2

	CFA2		
	Original	CMV-adjusted	Δ
χ^2	581.034	583.604	2.57
d.f.	341	341	0
RMSEA	0.06	0.06	0
CFI	0.94	0.95	0.01
IFI	0.94	0.95	0.01
NNFI	0.935	0.95	0.015

5.10 Control variables

This research considered four control variables to test the theoretical model. Based on literature conducted, some variables are deemed important to be considered as control variables. Such as the impact of company size, age, respondents' tenure, and industry, on development cost, financial performance, and architectural innovation capability (Table 5.9). Respondent's tenure positively affects company's architectural innovation capability and its financial performance. It is evident from the analysis that company size positively affects the financial performance.

5.11 Summary

This chapter provided a detailed overview of the quantitative data collected and the sample portfolio. In addition, variables were analysed using the measurement model, and hypotheses were tested using the structural model.

In general, the data analysis method (structural equation modelling) demonstrated a good fit with this research data. Structural equation modelling is a powerful tool because it enables testing simultaneous relationship between dependent, independent, mediating, moderating variables. The results presented in this chapter are consistent with the results of previous studies with some minor inconsistencies (in-depth discussion is presented in the next

chapter). The reliability and validity of this research confirm the rigorousness of the used measures. Exploratory factor analysis and confirmatory factor analysis presented the factor loadings of indicators, which were overall above the recommended threshold. Model fit indices were presented as well, and they show the fit between the empirical data and the measurement model.

The analysis shows that firms' architectural innovation capability depends on knowledge creation, which his confirms Nonaka's (1994) knowledge creation model. In addition, the findings shows that absorptive capacity interaction with architectural innovation capability is vital for firm's financial performance and development cost, this relationship represents an important contribution of this research (section 6.4.3).

The moderation effect analysis shows that absorptive capacity moderates architectural innovation capability on financial performance and development cost. In addition, this study conducted Sobel test for mediation effect of development time and product quality. The test showed that development time fully mediates the indirect effect of architectural innovation capability on development cost as well as financial performance. On the other hand, product quality shows full mediation on the indirect effect of architectural innovation capability on development cost, and a partial mediation on the indirect effect of architectural innovation capability on financial performance. Moreover, lead users' integration analysis proves a positive effect on product quality and development time. Chapter six will discuss all the findings in future details.

CHAPTER SIX: DISCUSSION

6.1 Introduction

This chapter will discuss the findings in-depth while reflecting on the literature review and the relevant theories used in developing the hypotheses argument. The chapter will start with discussing the research contributions in light of the findings, which will be followed by a discussion of the results from a theoretical and applied perspective.

6.2 Research contribution

This research addresses and contributes to several gaps in the literature. Firstly, this research examines the link between knowledge and innovation by providing empirical evidence supporting the conceptual argument of previous researchers (Helfat and Raubitschek, 2000a, Nonaka, 1994, Nonaka and Takeuchi, 1995, Pitt and Clarke, 1999, Von Krogh *et al.*, 2000).

Secondly, by providing quantitative empirical evidence our study contributes to the theory of knowledge creation and builds on Nonaka's knowledge creation model to specify how each knowledge creation mode enables architectural innovations. Previous research discussed knowledge creation model, but have not empirically investigated its assumptions (e.g., , 2003, Boisot, 2002, Choo and Bontis, 2002, Leonard, 1998). An exception is the research of Lee and Choi (2003) and Schulze and Hoegl (2006, 2008), who have empirically investigated knowledge creation-innovation link. However, the previous three studies had contradicting results which

call for further investigations for their reconciliation. This research provides insights into the knowledge creation modes that drive architectural innovation capability.

Thirdly, this research follows previous researchers' calls for further insights on lead users' integration and quality. For example, Schuhmacher and Kuester (2012) and Füller *et al.* (2011) identified lead user characteristics which drive the quality of service and product innovation ideas, however, the quality of ideas was evaluated exclusively by juries in their sample. This research adopted a robust scale to measure quality which overcomes individuals' limited ability to evaluate quality. Thereby, this research contributes to the lead user and product innovation literature by exploring the importance of lead users' contribution in driving quality especially if integrated in the fuzzy-front-end of the NPD process because of their unique characteristics (including, use experience and intrinsic motivation).

Finally, this research investigated interaction effects that emerge from the combined impact of architectural innovation capability and absorptive capacity on development cost and financial performance. The findings contribute to the wide research on absorptive capacity in terms of analysing each capacity moderating effect on leveraging innovation capability and performance.

6.3 Evaluation of the methodology

The methodological tool used in this research was extensively discussed in the methodology chapter. The research method was chosen after an extensive analysis of the relevant literature and the available methods. However, as discussed earlier in Chapter 4 (Methodology), the used method has many limitations. Hence, it is

recommended to re-evaluate the used method in the light of data collection and analysis. This section will review and re-evaluate the data collection strategy, the data collection instrument, the pilot study, and the sample selection.

Given the nature of the research question and the conceptual relationship between variables, the most suitable strategy for this research was the use of surveys. In particular, questionnaires were used to collect the primary data. Questionnaires were the most suitable method given the nature of the data needed, the time, and financial constraints. Web-based questionnaires were used (instead of traditional mail questionnaires), due to their cost and time advantages. Another important reason behind selecting this method includes the ability to generalise the results, and to avoid any personal bias due to the researcher-participants interaction. However, this method has disadvantages too, including the associated low response rate. Rigorous efforts were made to enhance the response rate which was embedded throughout the instrument design process, and questionnaire administration, including following Dillman's total design method (TDM) (Appendix 5). These efforts arguably enhanced the response rate. Furthermore, most of the variables were captured using validated scales from high quality published research, this enhanced the validity of the research tool.

In addition, pre-testing the research instrument helped to overcome any potential ambiguity in wording or structure. Based on the recommendations of the pilot study and experts in the field, some amendments were taken into consideration and some questions were refined. This helped to avoid any bias that could be caused by the research instrument.

Another important methodological issue is the sample determination. This study targeted the UK manufacturing industry and the key respondent in each case was from the managing directors or the executive managers. Due to the fact that there is no exact record of all managing directors and executive managers' contact details, and the amount of time needed to compile this data manually, the researcher opted to source this data from a databases specialist. The available database was not a comprehensive list of all manufacturing company and a great amount of emails bounced back or were inaccurate due to outdated data. This could have been overcame if a more accurate database were manually compiled; however time constraints posed a challenge in this research, and hence this must be considered as a limitation.

6.4 The results of hypotheses testing

The empirical tests carried out in this study confirm most of the pronounced hypotheses as will be discussed in the next section. In addition, the findings answer the research questions raised in the introduction chapter.

6.4.1 Knowledge creation and innovation capability

As discussed in the literature chapter (Section 2.5), knowledge creation modes form a spiral in which tacit and explicit knowledge interaction are amplified, over time the spiral becomes larger and triggers a new spiral of knowledge creation. Knowledge creation starts at the individual level and then transcends throughout the organisation boundaries (Nonaka *et al.,* 2000). The shifts between the different modes are the result of different triggers. For example, in new product development, socialisation is

triggered by forming teams or building a field of interaction (*Ba*), in which experiences and perspectives are shared. The use of dialogue and metaphor triggers externalisation of tacit knowledge as team members articulate their perspectives. Coordination and documentation of tacit knowledge trigger combinations of explicit knowledge which in turn can create concepts. Team members articulate and develop product concepts in a process of experimentation that triggers internalisation, hence, explicit knowledge becomes integrated in individuals' mental models (Nonaka *et al.*, 1994).

6.4.1.1 Socialisation

Socialisation is a process of sharing tacit knowledge, interaction, and sharing experience among individuals. Tacit knowledge can be shared through apprenticeships, observation, or imitation. For example, apprenticeships enable the physical proximity that helps newcomers to capture tacit knowledge. This process helps in creating a common place (*Ba*) where personal knowledge is shared and individuals' knowledge is enlarged (Nonaka, 1994, Nonaka *et al.*, 1998a). Shared experience is a prerequisite for socialisation as without shared experience, acquired tacit knowledge will be difficult to understand or will not make sense. Socialisation facilitates creating common perspectives and a common base for understanding.

The innovation process commences by creating or defining problems which depend on tacit knowledge as Polanyi (1967: 24) states "tacit knowing is shown to account for a valid knowledge of a problem". Hence it is critical that tacit knowledge is shared through socialisation to direct further development of product concepts and solutions. Socialisation stimulates concept sparks and facilitate their development (Schulze and

Hoegl, 2008). Nonaka and Takeuchi (1995) reported how Japanese companies succeed in knowledge creation and innovation. For example, team members in Honda share their sparks in an informal setting which facilitate developing and articulating concepts.

Sharing tacit knowledge includes sharing architectural knowledge, which "tends to be embedded in the tacit knowledge of the organisation" (Henderson, 1991: 44). This study findings show that sharing architectural knowledge helps in developing architectural innovation, given the fact that architectural innovation depends on components' configuration and integration. As a result, socialisation is considered a tool to facilitate architectural innovation development. This is in line with previous research of Schulze and Hoegl (2006 and 2008), who empirically proved that socialisation positively affects new product success and promotes the generation of novel ideas.

Socialisation helps create a shared space where individuals from various functional units in the organisation (with a variety of knowledge and expertise), develop a common base of understanding, and share each other's thinking processes (Nonaka, 1994). Team members with various skills and knowledge are in a better position to develop innovative ideas through informal interaction, because the socialisation mode usually starts within a field of interaction (Nonaka, 1994). In this field of interaction (which may be any setting such as teams or apprenticeships) individuals gain a great understanding of others' perspectives about concepts for new products. Socialisation in the early stages of product development is recommended for idea generation as it facilitates sharing experiential knowledge assets (Kogut and Zander, 1992b, Nonaka

and Takeuchi, 1995, Lee and Choi, 2003, Schulze and Hoegl, 2006). Thereby, they can envision product ideas that differ from existing product characteristics.

6.4.1.2 Externalisation

Externalisation's positive effect on architectural innovation capability was not supported by the analysis conducted. Externalisation includes articulation of tacit knowledge using techniques to turn it into explicit knowledge, such as words, concepts, metaphors, analogies, and dialogue. Another important part of externalisation is the translation of customers' tacit knowledge into explicit knowledge which is easy to understand (Nonaka and Konno, 2005).

Acquired tacit knowledge from the socialisation process is of little use unless externalised and formed into a concept or a prototype. "Exposure to diverse ideas during the externalisation phase is important, as every step in the innovation process is proposed to be about someone asking about imaginary possibilities, speculating about what would happen if, and reflecting on yet-unrealised and perhaps unrealisable solutions" (Peltokorpi *et al.*, 2007: 56). Therefore, externalisation enhances the potential of creating true new explicit concepts through using sequential serials of metaphor, analogy, and model (Nonaka *et al.*, 1994, Nonaka and Takeuchi, 1995, Peltokorpi *et al.*, 2007). Although the relationship between externalisation and architectural innovation was not supported empirically, exposure to diverse ideas in the concept phase enables individuals to capture new architectural knowledge and articulate it into explicit knowledge to start the dialogue and reflection among individuals. This reflection can facilitate the production of architectural innovations.

Individuals' exposure to knowledge from different domains can enhance creativity which in turn promotes strategic benefits (Lee and Choi, 2003).

Schulze and Hoegl (2006) proposed a positive impact of externalisation in the new product development phase. As the development phase is characterised by formal interaction, which supports project progress by sharing a clear agenda of time allocation (Clark and Fujimoto, 1991). It is evidenced from their findings that articulating mental models, skills, and customer knowledge into explicit knowledge helps to promote creativity and new product development progress, which can facilitate producing innovative products.

6.4.1.3 Combination

The combination of explicit knowledge aims to edit and synthesise documented knowledge using social processes such as meetings and conversations (Nonaka *et al.*, 1994). It involves acquisition and integration via collecting externalised knowledge, and assembling external and internal data (Nonaka *et al.*, 2000). Sorting, adding, and categorising existing knowledge can lead to creating new knowledge; however, pure combination of explicit knowledge has drawbacks as it lacks the necessary dialogue with tacit knowledge. Knowledge combination effect on innovation and creativity received mixed results in previous research, and in the current study its link with architectural innovation capability was not supported.

Lee and Choi (2003) empirically supported the positive effect of combination on innovation and organisational creativity, which was defined as "the creation of valuable, useful, product, idea,…by individuals working together in a complex social

system" (Lee and Choi, 2003: 4). However, they did not provide a critical argument for their findings. Furthermore, Schulze and Hoegl (2006) argued that combination has a positive effect on new product success at both the concept and the development phase (their study supported the effect during the development phase, while it failed to support the effect during the concept phase). Their argument to support the previous propositions, is that combination helps in creating valuable knowledge from explicit knowledge to generate innovative product ideas (Crawford and Di Benedetto, 2008). Problem-solvers decompose, and recombine pieces of information in order to examine the cause-effect linkages and specify requirements for more useful and differentiated products (e.g., Clark and Fujimoto, 1991, Corti and Storto, 2000, Dougherty, 1992).

Furthermore, combination embarks and builds on the organisation current capability in order to verify the feasibility of the initial product idea. Hence, "combinative capability" as proposed by Kogut and Zander (1992a) aims to synthesise and apply current and acquired knowledge from various domains to envision potential reconciliation between current limitations and technologies, in order to create product ideas with differentiated characteristics (e.g., applying technologies from the optical signal processing for mobile phones systems, adapted from Schulze and Hoegl 2006). In addition, combinative capability can use reports of previous unsuccessful product ideas to avoid falling into the same mistakes. Hence combination facilitates new product development through quick idea generation within the specified timeframe and budget (Schulze and Hoegl, 2006, Nonaka and Takeuchi, 1995).

However, contrary to our expectation, this study did not support the proposition that combination supports architectural innovation capability. Although a new case study

shows that highly codified knowledge is found to foster architectural innovation (Xie *et al.*, 2015), it is speculated that the cause behind failing to support combination's positive effect on architectural innovation capability is because this study did not explicitly specify the source of combined explicit knowledge (distant or local). Hence, individuals surveyed in this research may have been considering local knowledge while ignoring valuable distant knowledge. Scanning technological and organisational boundaries to combine acquired distant tacit knowledge with local knowledge may create valuable knowledge for new innovations. Another possible justification is that there can be problems when explicit knowledge is shared though documents rather than between people directly: the more this knowledge is combined and documented into product specifications, the more it may impede the ability to conceive innovative products.

Schulze and Hoegl (2008) argued that although combination is negatively related to novel product ideas, it can support incremental innovations. They propose that (based on Henderson and Clark's (1990) study), pure re-combination of product components leads to incremental innovation, and that novel ideas require organisations to create knowledge about alternative components. However, Henderson and Clark (1990) refer to "reconfiguration" from a product component perspective rather than "re-combination" from a knowledge perspective. For example, if a product is composed of five components, reconfiguring the components will create a new linkages or interface between the five components which will produce architectural innovation. For instance, any basic ceiling fan is composed of motor, blades, and control system; reconfiguring the previous components can create a portable fan which is considered an architectural innovation. On the other hand, changing the blades design is

considered incremental innovation, while creating knowledge about alternative components is "modular innovation". Hence, architectural innovation is not incremental innovation as presumed in Schulze and Hoegl (2008) argument, hence their results may have been obscured.

This study investigation does not support our proposition that combination positively affects firms' capability to produce architectural innovations. However, it is likely that in a larger sample, the positive relation postulated in this thesis may show statistical significance. And this is the scope of future research that may refute or support knowledge combination positive link with innovation.

6.4.1.4 Internalisation

Consistent with our hypothesis, the findings from this study support a positive relationship between internalisation and architectural innovation capability. Tacit and explicit knowledge are complementary, and the conversion process of explicit into tacit knowledge by practising is similar to learning by doing (Nonaka *et al.*, 1994). Thus internalisation relies on two dimensions; embodying tacit knowledge into practice and action, and the availability of a process for practice and simulation to trigger learning by doing (Nonaka and Konno, 2005, Helfat and Raubitschek, 2000b, Leonard, 1998).

Internalisation has received mixed empirical evidence from different researchers. For example, Schulze and Hoegl (2006) argued that it negatively affects new product success, especially in the development phase. Their argument is that internalisation is counterproductive in the technical development phase, because in this knowledge

creation mode, individuals try to gain understanding of the product in an effort to embody explicit knowledge gained, into action and practice. Hence, team members working on developing a product concept will be very unlikely to proceed in the NPD without jeopardising efficiency in terms of the budget and time schedule.

However, the previous argument overlooks the fact that internalisation is effective in simulation, experimentation, and facilitating prototyping (Nonaka, Toyama, and Konno, 2000) which can speed up the engineering process and enable early detection of problems, which is better than discovering problems downstream (Clark and Fujimoto, 1991). Therefore, building and testing prototypes represent an important phase in new product development that can be facilitated through internalisation.

Furthermore, according to the conceptual model of technological change, the emergence of a new technology is a period of great confusion. In this period there are a lot of experimentations with reconfiguring the major subsystems (*i.e.* creating new interfaces and different possible outcomes using the same components or subsystems) (Henderson and Clark, 1990). Thus, the findings of this study supports internalisation role in helping individuals to experiment with subsystems and components in order to create a new architectural knowledge aiming towards creating architectural innovation designs. Therefore, this research provides empirical evidence for the conceptual research of many scholars (e.g., Henderson and Clark, 1990, Brown and Eisenhardt, 1997, Hatten and Rosenthal, 2000, Helfat and Raubitschek, 2000a, Koberg *et al.*, 2003, Leonard, 1998, Monteverde, 1995).

Although Schulze and Hoegl in their 2006 paper argued that internalisation has a negative effect on new product development success in both the concept as well as the

development phase, in 2008 they found that internalisation actually has a positive effect on generating novel product ideas. They argue that absorbing explicit knowledge to create tacit knowledge enables imagining the product in use and a sensing of user problems and how they can be solved by technology. This embodied tacit knowledge relies on professional know-how, and it is gained through experience as well as experiment. In addition, experiment helps to imagine and create products useful to customers. For example, if technical people are asked to develop a "useful product", this would not be a helpful guideline for them. However experimenting with existing products and their use provides insights into the technologies used so they can be improved to overcome their limitations (Dougherty, 1992, Hargadon and Sutton, 1997). Furthermore, experimenting enhances the potential of creating innovative products. Henderson and Clark (1990) point out that the period of technological or scientific breakthrough is a highly uncertain period, in which competing designs are produced based on experimenting with the components and their configuration. Hence, experiment helps to envision new linkages between components which can ultimately produce architectural innovations.

This study finding supports Schulze and Hoegl (2008) and extends the literature by giving empirical evidence of the importance of internalisation on the capability to produce architectural innovations.

6.4.2 Innovation and performance

This research has evaluated new product development by multiple criteria under the umbrella of efficiency and effectiveness. Efficiency is related to development time

and development cost (Chen *et al.*, 2008), while effectiveness is related to financial performance and product quality (Johnson *et al.*, 2009).

Firms innovate in order to respond to environmental changes or demands which will affect their performance (Jansen *et al.*, 2005, Damanpour *et al.*, 2009). However not all innovations are successful (Henard and Szymanski, 2001), therefore empirical research on the innovation-financial performance link has contradicting results (Gatignon *et al.*, 2002a, Morgan and Berthon, 2008, Walker, 2004). One stream of research argues in favour of ambidexterity, whereas a positive link between innovation and financial performance is more pronounced; for example, Walker (2004) studied 30 empirical research studies and reported that the majority support a positive link between innovation and financial performance.

Various advantages of innovation have been reported. For example, "early mover" advantage will lead to superior performance and long-term profitability (Lieberman and Montgomery, 1988, Roberts and Amit, 2003, Sorescu *et al.*, 2003). Firms which respond to shifting customer demands and preferences by producing innovative products are more likely to achieve higher sales and market growth (Bayus *et al.*, 2003, Srinivasan *et al.*, 2009). Firms can realise performance benefits by targeting the same customer base with new products or improved version of old products: in this case they will have relatively less advertisement expenditure (Bayus *et al.*, 2003). On the other hand, innovation can have a better effect on financial performance when it is introduced for new markets (new market entry) rather than innovations offering a minor update (Gielens and Steenkamp, 2007). While minor updates are important to maintain positive performance, new market entry has more potential to enhance

financial performance and especially cash flow (however, it is a U-shaped curvilinear effect) (Kleinschmidt and Cooper, 1991).

Architectural innovation is long-term oriented as it targets new markets (Tushman *et al.*, 1997). For example, a smaller washing machine is an architectural innovation in which the core components (motor, pump, drum, programmer, chassis, door and body) remained the same, but reconfigured or reintegrated to produce a washing machine with better performance. Old washing machines were twin tub operated, where the washer and the spinner are separate and required a manual intervention to transfer clothes from the washer to the spinner. Components were then reconfigured to include the washer and the spinner in a single drum by producing a new interface (new architectural knowledge), and it required no human interventions to complete the washing cycle. Thus, the new washing machine targeted a new market; customers living in smaller houses or flats who are busy working individuals. Hence, our result empirically confirms previous research that new market entry enhances financial performance (Kleinschmidt and Cooper, 1991).

In addition, architectural innovation has an indirect positive effect on financial performance through development time. Development cycle time is the elapsed time from idea generation to the time of market introduction. Consistent with our hypotheses, development time mediates the positive effect of architectural innovation capability on development cost and financial performance.

Development cycle time's effect on performance (effectiveness and efficiency) received divergent findings in the previous literature. Supporters of shortening the development cycle believe that it can bring many advantages. For example, increase

teams effective coordination and communication which reduces the probable mistakes after launching the product (Chen *et al.,* 2005). In addition, speed-to-market extends the sales life and increases the opportunity to charge a premium price (Karagozoglu and Brown, 1993).

However, evidence from the literature shows that speed-to-market has many disadvantages too. Tighter deadlines may tempt teams to shorten or skip processes which can affect quality and new product development success (Lukas *et al.,* 2002). Furthermore, shortening development cycle can harm responsiveness to customer-driven changes (Crawford, 1992). Also, Working under a tight time schedule can impede team members' chances to explore various alternatives to enhance product specifications. All of which can compromise products' ability to meet customers' needs and will require post-launch product's debugging, which can damage its perceived quality.

Accelerating the cycle time has been linked with the innovativeness of products and it witnessed contradictory results. For example, Lin *et al.* (2012) recommend that radical innovations managers must invest more time and acquire the necessary knowledge to reduce errors and recycling costs; while under incremental innovations, development time should be shortened to capture temporary advantages. Previous research (Griffin, 1997, Ali, 2000, Langerak and Jan Hultink, 2006) shows that shortening the cycle time of radical innovation products is riskier than shortening the cycle time of incremental innovation products. New evidence shows that shorter cycle time has no effect on product financial performance (sales) regardless of product innovativeness (Langerak *et al.,* 2009). In contrast, a longer development time surmounts most of the disadvantages faced by shorter cycle time, yet longer

development time is proven to negatively affect sales. The rationale is that products with longer development time have already incurred higher development cost as they require more resources allocation.

As discussed above, previous research lacks consensus on the relationship between shorter development cycle and performance. This research's analysis supported the postulated hypothesis that development time mediates the effect of architectural innovation capability on development cost and financial performance. This finding is congruent with the findings of Chen *et al.* (2005); that time-based strategies are advised to be implemented in an unfamiliar, emerging or fast changing market. As low market uncertainty requires higher speed-to-market that will promote new product success. As discussed in the literature review chapter architectural innovation taps into new markets (Tushman *et al.*, 1997), in which technological changes are fierce. Hence, tightening the development time can provide higher chances of early-mover advantage that will enable firms to charge a premium price in the opportunity window. In addition, product with shorter development cycle has less development cost as a result of reducing costly work redundancy and using resources more efficiently (Harter *et al.*, 2000, Clark, 1989). In addition, compressed development time has predetermined goals, therefore, fewer goal changes are likely to be made (Lynn *et al.*, 2000). Thus, architectural innovations that have shorter development time will positively affect the development cost.

Moreover, in an environment of high technological change, products rapidly become obsolete, hence, firms should forecast customer needs and predict market changes; this can be more accurate over a shorter period of time rather than attempting to predict these changes over longer periods (Yu-Yuan Hung *et al.*, 2007, Kessler and

Chakrabarti, 1996). Therefore, architectural knowledge developed over a shorter period of time tends to be more accurate in responding to customer needs, which leads firms to develop new products with advanced features that are perceived as more current.

Furthermore, architectural innovation has an indirect positive effect on financial performance through product quality. The analysis supports our postulated hypotheses that product quality mediates the positive effect of architectural innovation capability on development cost and financial performance. Quality is defined as meeting or exceeding customers' needs and achieving their satisfaction, and providing unique benefits to customers (Lin and Huang, 2012). Product quality is evaluated in comparison with previous similar products and/or competitors' products.

Previous research shows that speed, cost, and quality are highly interrelated; however, the nature of the relationship is inconsistent in the literature (Kessler and Bierly III, 2002). There are two streams of research on the relationship among competitive capabilities (speed, quality, and cost). The first stream of research represents the trade-off school (e.g., Bayus, 1997, Boyer and Lewis, 2002, Cohen *et al.*, 1996, Gupta *et al.*, 1992), which is based on the argument that high performance in one of the competitive capabilities prevents high performance on one of the other competitive capabilities (for example, new product development with high quality cannot be shortened in terms of time). The second stream of research is the synergy school (Ittner and Larcker, 1997, Raia, 1991, Valentino and Christ, 1989) which argues that there can be synergies in achieving simultaneous NPD competitive capabilities. In this research, the researcher adopts the synergy school point of view to test its assertions

and empirically extend this perspective by investigating innovativeness implications (in particular, architectural innovation).

A balance between product quality, development speed and development cost is ultimately the goal of any new product development efforts (Norling, 1998). This is an important issue that affects resource deployment decisions (Nijssen *et al.*, 1995). Architectural innovation capability enables organisations to focus their limited resources on reconfiguring product components, rather than learning and incorporating new components (Henderson and Clark, 1990). Thus, organisations will have an efficient utilisation of their resources.

6.4.3 Absorptive capacity moderating effect

This research investigated the interaction effects emerging from the combined impact of architectural innovation capability and absorptive capacity on development cost and financial performance. Our findings will be discussed in this section.

Previous research empirically supported the positive link between absorptive capacity and financial performance (Chen *et al.*, 2009, Rhee, 2008, Tsai, 2001, Zahra and Hayton, 2008). Absorptive capacity has a direct positive effect on innovation performance by enhancing firms' ability to acquire, analyse, interpret external knowledge, combine newly acquired external knowledge with existing knowledge, and exploit new external knowledge to produce innovative products. Firms' absorptive capacity determine their ability to innovate (Chen *et al.*, 2009), as it helps organisations to expand their knowledge base. Further, developing APCA is path-dependant and overlooking the need to invest in APCA can adversely affect technical

capabilities in the future (Cohen and Levinthal, 1990). Hence, the absorptive capacity of any firm can determine its organisational adaptability (Cohen and Levinthal, 1990).

Two important features of APCA, cumulativeness and expectation formation, drive the importance of knowledge absorption. Previous APCA accumulation will affect effective accumulation in future periods, as firms that have developed APCA in certain areas will have higher ability to identify important external knowledge. Accumulation, in turn, affects the ability to interpret technological advances and accurately predict applying technological advances into commercial products (Cohen and Levinthal, 1990). Therefore, being competent in assimilation and transformation can help firms to discern technological advances (appreciate their significance on their operation) and visualise their commercial implications. Congruent with previous research, this research found that assimilation and transformation moderate the relationship between architectural innovation capability and financial performance.

A firm's responsiveness to external changes (as discussed in Section 2.7.4) affects its tendency to be flexible and swift in responding to technological changes (having greater APCA) (Welsch *et al.*, 2001). Therefore, it can overcome the established firms' inertia and will have a better capacity to analyse the environment and incorporate technological advances which, in turn, positively enhance its capability to produce architectural innovations.

External activation triggers, such as a change in the dominant design, are important to motivate firms to intensify and allocate extra resources in their absorptive capacity process. Therefore, a change in the dominant design places pressure on firms to

acquire new knowledge. This absorbed new knowledge contributes to stimulating firms' architectural innovation capability, as it will broaden their knowledge base. Furthermore, the "enlightened" individuals, who have incorporated this new knowledge, are in a better position to make innovative commercial outcomes. Therefore, absorptive capacity strengthens a firm's ability to leverage new technological knowledge into innovative products. For example, external knowledge about technological changes, if managed well through absorptive capacity (through acquisition, assimilation, and transformation), will contribute to developing new ways in which product components can be reconfigured and integrated (architectural innovation). Hence, absorptive capacity enhances architectural innovation capability and expends new technological opportunities.

It is worth noting that the extant literature on the absorptive capacity outcome lacks integrative examination (Lane *et al.*, 2006), therefore, this empirical research has added to the field of knowledge and will help to explain some issues as will be discussed in the next section.

6.4.4 Potential absorptive capacity (acquisition and assimilation)

Contrary to our expectation, this study did not support the proposition that that acquisition and assimilation strengthen the relationship between architectural innovation capability and development cost. Acquisition refers to identifying and acquiring externally sourced knowledge that is relevant to the organisation, while assimilation refers to firm's capability to analyse and interpret the acquired knowledge (Zahra and George, 2002). Acquisition and assimilation are considered

potential absorptive capacity according to Zahra and George's (2002) model which represents the ability to identify and evaluate knowledge.

Acquisition capacity enables firms to better identify external tacit knowledge and influences the firms' flexibility in resources deployment (Zahra and George, 2002). The ability to produce architectural innovation depends on firms' ability to identify tacit knowledge and to integrate specialised knowledge inputs (Cohen and Levinthal, 1990).

According to previous literature, knowledge acquisition influence new product development by enhancing the breadth and depth of knowledge (knowledge diversity), renewing knowledge stock (Jansen *et al.*, 2005) and by speeding the development time (Yli-Renko *et al.*, 2001). Knowledge diversity increases the speed of processing knowledge (Zahra *et al.*, 2000). Higher acquisition and assimilation capacity enable firms to better identify external tacit knowledge, while firms that have higher assimilation capacity are better at absorbing external ambiguous knowledge (Wang and Han, 2011). The next section will discuss each capability in more detail.

6.4.4.1 Acquisition moderation effect

Acquisition capability is the first absorptive capacity process which aims to scan the market, identify, and filter relevant external knowledge. This capability is found to be essential for innovation as it enables firms to capture new technological knowledge which will be used in subsequent new product development processes. Furthermore, it enables firms to appreciate new relevant knowledge which might be overlooked otherwise (refer to semiconductor example in Section 2.6.4). Although further

absorptive capacity capabilities assimilate and transform this knowledge ready for exploitation into a commercial innovative outcome, the role of acquisition capability remains the most important in its scanning of the external environment.

As proposed by this research hypothesis, the interaction between knowledge acquisition and architectural innovation capability can reduce development cost. As acquisition contributes to building firms' knowledge stock which helps firms to discern technological opportunities, overcome competency traps, and envision innovative product ideas.

It is argued that architectural innovation capability depends in the first place on identifying new knowledge, and being adept at knowledge acquisition which is important for filtering the necessary relevant knowledge. Nevertheless, being capable of identifying external knowledge will minimise losing technological opportunities, which can be justified as follows: if a firm is incapable of identifying new knowledge, it will be less competent in filtering external knowledge about new needs. Hence, it is more likely to develop products that might not be innovative or that are not required in the marketplace. Moreover, this firm may take longer than competent firms to create an innovative product. As its product development process is not consistent with opportunities in the market, it may require more time and effort which will lead to increased development costs.

Contrary to the previous example, is a competent firm that realises and actualises external knowledge towards producing innovative products while mitigating costs associated with innovation development. In addition, it has lower acquisition costs as

it develops its ability to identify, assimilate, and exploit external knowledge (Cohen and Levinthal, 1989). This is in line with previous research that supported the positive effect of acquisition on reducing development cost in general (Teece *et al.*, 1997, Zander and Kogut, 1995, Escribano *et al.*, 2009).

This research could not support acquisition capability moderating effect of architectural innovation capability and development cost and financial performance. From examining the findings, it appears that this finding may have been contaminated by external variables such as market or technological turbulence. Although acquisition positively affects innovation (Kostopoulos *et al.*, 2011, Todorova and Durisin, 2007), the effect of a firms' absorptive capacity on performance depends on market and technological uncertainties (Vasudeva and Anand, 2011). Uncertainties in the external environment certainly increase the need to speed new product development process which may affect the financial performance and the development cost.

Moreover, it can be argued that not all acquisition-oriented efforts aim at enhancing financial performance and the motivation behind acquisition can differ from one firm to another (Ahuja and Morris Lampert, 2001). Last but not least, a recent research proposes that high acquisition have a negative effect on financial performance (Walker *et al.*, 2013). Acquisition capability is increasingly costly, as it requires firms to keep abreast of changes in the external environment in order to acquire new knowledge. After a certain point, firms' investment in searching for new knowledge will increase and overtake any actualised financial performance benefits.

6.4.4.2 Assimilation moderation effect

This study found that assimilation capability positively moderates the relationship between architectural innovation capability and financial performance. However, the moderation effect of assimilation on development cost was not supported.

Assimilation capability is usually defined as analysing, disseminating, and integrating knowledge; however, the concept has hardly been investigated on its own and is usually addressed as part of potential absorptive capacity. From the few studies that empirically addressed assimilation (e.g. Griffith *et al.* (2003)), they found that it enhances a firm's ability to absorb knowledge spillovers. Therefore, firms can use this knowledge to innovate new products and avoid being locked-out of technological development. Additionally, analysing, interpreting and internalising such knowledge are more likely to create a cognitive map (Huber, 1991) which in turn is more likely to incline R&D efforts to the most valuable areas in product development (Tripsas and Gavetti, 2000), and hence allocate extant resources efficiently to the most important areas of the project in order to reduce development cost and enhance financial performance. In the case of architectural innovation, valuable areas are related to developing architectural knowledge (the way components can be reconfigured to produce new innovations), hence, R&D efforts are more likely to be concentrated in assimilating technological knowledge that will help utilise technological opportunities to create and advance architectural innovation.

Therefore, based on this research's findings, assimilation produces a cognitive map, which can facilitate the ability to identify more worthwhile areas for technological knowledge investment. Henceforth, in the presence of assimilation, architectural

innovation capability increases the chances of outperforming competitors and hence assimilation contributes towards enhancing firms' financial performance.

As discussed earlier in the literature review chapter, potential absorptive capacity (*i.e.* acquisition and assimilation) is necessary to identify and distil external knowledge; however, it is not sufficient for producing innovative commercial products if such knowledge was not processed internally through realised absorptive capacity (*i.e.* transformation and exploitation) (Fosfuri and Tribó, 2008, Zahra and George, 2002).

Hence, absorptive capacity has two roles in dealing with external knowledge; first, it helps the firm to identify and distil external relevant knowledge. Therefore, the amount of relevant knowledge acquired is related to the level of absorptive capacity. On the other hand, deriving benefits from the external knowledge depends on absorptive capacity, in particular realised absorptive capacity; transformation and exploitation. The next section includes the findings related to realised absorptive capacity.

6.4.5 Realised absorptive capacity (transformation and exploitation)

Our analysis supported the proposed hypothesis that transformation positively moderates the relationship between architectural innovation capability and financial performance. Transformation refers to combining the newly acquired knowledge with previously owned knowledge in order to be distilled ready for use (Zahra and George, 2002). Integrating new knowledge with existing cognitive structure is necessary for innovation, especially architectural innovation. Architectural innovation aims to capture technological advances and integrating it into existing systems by reorganising subsystems. Hence, congruent with Wang and Han (2011), this study

found that firms with higher transformation capacity can better utilise external ambiguous and complex knowledge that will have a positive impact on financial performance.

Considering the results, this study supports the hypothesis that exploitation weakens the relationship between architectural innovation capability and financial performance. Exploitation capacity aims to incorporate acquired and assimilated knowledge into firms' operations to produce innovative products. Exploitation positively affects innovation through leveraging acquired knowledge into commercial ideas. However, knowledge exploitation requires internal knowledge development through R&D (Zahra and Hayton, 2008). R&D activities affect the development cost as they require more time and resources. Therefore, exploitation is beneficial for innovation but negatively affects financial performance and development cost. The following discussion will address each capacity in more detail.

6.4.5.1 Transformation moderation effect

Contrary to this study expectation that firm's transformation capability is likely to moderate the relationship between architectural innovation capability and development cost, the postulated relationship, was not supported by the tests conducted. One possible explanation is that transformation aims to embed assimilated (analysed and interpreted) knowledge into firms' routines and procedures; therefore this knowledge will become operationalised in firms' everyday life and will modify their cognitive schema accordingly. This process should be implemented ahead of time in order to become part of the everyday operation. This process of embedding knowledge requires the participation of individuals across different departments,

including R&D and production. Hence, this explains why transformation is regarded as a complex and demanding task (Escribano *et al.*, 2009).

Based on the previous justification, transformation's cost might not outweigh the benefits it provides; it can result in surges in the associated development cost. This finding unpacks the effect of transformation as a moderator and adds to the conceptual understanding of this concept; this is important in the light of the dearth of literature which examines transformation in particular and/or implicitly includes it within assimilation or else neglects it (Lane *et al.*, 2006).

In line with this research proposition, transformation capability intensifies the relationship between architectural innovation capability and financial performance. As discussed earlier, transformation combines externally acquired knowledge (which has been assimilated) with existing knowledge (previously owned) through embedding assimilated knowledge in routines and processes. Therefore, transformation integrates valuable knowledge (Lane *et al.*, 2006) (for example spillovers knowledge), and prepare it for the next step which is exploitation. Firms that exploit such valuable knowledge can achieve first-mover advantage. In the context of architectural innovation this same theorising applies, transforming valuable knowledge can support firms to advance their capability to produce architectural knowledge. Using this knowledge ahead of competitors is found to enhance the financial gains through first-mover advantage.

6.4.5.2 Exploitation moderation effect

The research findings do not support the conceptual proposition that firms' exploitation capability weakens the relationship between architectural innovation capability and development cost. However, this does not mean that exploitation is not important for innovation. In the contrary, exploitation is vital to leverage newly acquired knowledge into innovative commercial outcomes (Zahra and George, 2002, Kogut and Zander, 1992a). As exploitation capability is based on the routines that have been developed by transformation capability, and hence exploitation enables firms to leverage and create competencies through utilising and incorporating acquired, assimilated, and transformed knowledge. Exploitation incorporates and leverages valuable transformed knowledge in order to exploit technological opportunities by producing innovative commercial output (Forés and Camisón, 2016).

In the same vein, this research supported the proposition that exploitation weakens the relationship between architectural innovation and financial performance. The main reason can be traced to the level of absorptive capacity adopted by firms. Absorptive capacity requires constant scanning of the environment for relevant new knowledge which is then assimilated and transformed in order to be ready for exploitation. Exploitation, although beneficial for innovation can have negative effect on financial performance (Wales *et al.*, 2013) which means that high exploitation cost will outweigh it benefits leading to diminishing financial performance.

Although exploiting and embedding new knowledge is necessary for architectural innovation capability, it may prolong the product development process. Combining external knowledge with internal knowledge requires time to realise creative ideas

using exploitation capability. As newly acquired technological knowledge will be combined with already existing knowledge to envision new architectural knowledge, this will highlight new ways to combine different product components and developing new linkages. However, increasing the development time, requires more resource allocation which may negatively affect financial performance.

To conclude, absorptive capacity enables firms to identify, absorb, analyse, and utilise tacit, complex and ambiguous knowledge in order to produce technical innovation characterised by originality of technology and design. However, firms are advised to be cautious in their absorptive capacity decisions, as certain capacities can have an adverse effect on performance.

6.4.6 Lead users' integration and performance

The analysis supports the positive impact of lead users on accelerating development time and product quality. The first lead user hypothesis is related to product quality. Previous research emphasises the importance of lead users within the early stages of innovation development (e.g., Von Hippel, 1986a, Kratzer and Lettl, 2008, Füller *et al.*, 2011), yet lead user and innovation quality link is still under-researched. Lead users have unique characteristics and needs which will increase the quality of the idea generation stage (Lilien *et al.*, 2002) and system designs (Boland Jr, 1978). Lead users' involvement in the fuzzy-front-end of new product development affects generating products of a better quality. Due to lead users' characteristics such as use experience and intrinsic motivation which positively affect the quality of ideas generated by them (Schuhmacher and Kuester, 2012). Hence, lead users are in a better

position to systematically analyse problems faced in conceiving solutions. Being intrinsically motivated and enthused, increases the probability of lead user creativity. Lead users' involvement promotes quality and improves innovation development, however, which particular lead user characteristics promote product quality extends beyond this research.

Lead users are ahead of the trend, since they experience needs months or years ahead of the marketplace; they expect high benefits from the developed products that satisfy their needs. Hence, they might attempt to meet their needs by inventing product concept and design (Von Hippel, 1986a). Therefore, integrating lead users is essential for accurate market research, which has a positive consequence on new product development effectiveness (quality). Lead users can provide important input in the fuzzy-front-end of NPD process (*i.e.* setting general product definition, setting lead time requirements, and setting product specifications), as they are competent at providing novel ideas, generating product designs, and component specifications. Moreover, in the early fuzzy-front-end of NPD, lead users can provide accurate product specifications to inform the market research process. Lead users' integration adds value by providing the firm with important need and solution information (Millson *et al.*, 1992, Langerak *et al.*, 1999) especially in developing innovative products (Langerak and Hultink, 2008).

Consistent with previous research (Langerak and Hultink, 2008, Langerak *et al.*, 1999, Thomke and von Hippel, 2002, Tsinopoulos and Al-Zu'bi, 2012, Millson *et al.*, 1992), this current research empirically proves that lead users' integration can enhance NPD efficiency, via reducing product development time, especially when they are integrated in the late stages of new product development. For example, if lead

users are integrated during the prototyping period, they can test the product and provide workable modifications which can be used in the modification stage. Consequently, the assessment stage can be faster as lead users can assess product's knowledge due to their technical competencies and use experience.

Therefore, this study advice to systematically involve lead users in the process of developing new products, as their integration proves to be a very important source of innovation. This finding is consistent with previous research (Von Hippel, 1986a, Urban and Von Hippel, 1988b, Herstatt and Von Hippel, 1992, Morrison *et al.*, 2000, Franke and Von Hippel, 2003, Lüthje *et al.*, 2005, Baldwin *et al.*, 2006).

6.5 Summary

This chapter has discussed the findings of this study. On the basis of the statistical analysis, each hypothesis has been accepted or rejected, and each finding was discussed in the light of previous studies and relevant theories. This work has enabled the study of the relationships proposed by the hypotheses. To conclude, this research found that, knowledge creation is one of the underlying capabilities that leverage innovation. In addition, absorptive capacities have different effects on innovation and performance, and firms that invest in improving their ability to absorb external knowledge are more likely to optimise their use of resources and leverage this knowledge into better performance. Hence, it is evident from the analysis that both knowledge processing capabilities and absorptive capacity affect the capability to create new linkages between product components and technologies. Moreover, this

research found that lead users' integration in the NPD process especially in the fuzzy-front-end is epitomised in enhancing product quality and accelerating cycle time.

This work has immediate application for both theory and practice, as will be discussed in the following chapter. The scope for future research will also be outlined, along with the limitations of the study.

CHAPTER SEVEN: CONCLUSION AND IMPLICATIONS

7.1 Introduction

This chapter presents an overview of the results and key research findings outlined in this research, theoretical contributions and managerial implications of the research model, the limitations of the study, and suggestions for future research.

7.2 Overview of research questions and outcomes

The main purpose of this research is to identify the relationships between knowledge creation, architectural innovation capability, absorptive capacity, lead users' integration, and performance. This study carried out empirical research which supported extant theories, models, and findings of previous research. The interest in knowledge management arose from the knowledge-based view and the knowledge creation modes which both suggest that knowledge management drives success and competitive advantage in this ever-changing environment.

In addition, studies on innovation rely to a great extent on knowledge and how it can be leveraged to increase innovativeness of any shape and form; such as product innovation (incremental, radical, modular, or architectural innovation), service innovation, process innovation, or managerial innovation. However, empirical research on the knowledge creation-innovation link is minimal and lacks consistency (Table 7.1). Although architectural innovation's importance has been acknowledged in previous research, it is surprisingly under-researched using empirical research.

However, on the conceptual level, the subject of architectural innovation seems to have created a rising interest in different fields. For example, strategy researchers are interested in the concept of architectural innovation from a strategic perspective (e.g. Wade, 1995). Another field interested in conceptualising architectural innovation is inter-organisational or inter-industry networks (Attour and Della Peruta, 2014, Jaspers *et al.*, 2012). However, empirical evidence is needed to support Henderson and Clark (1990) architectural innovation's conceptualisation, or else this concept is more likely to be used abundantly without much consideration of its theoretical underpinning and hence, it might suffer from reification.

This research provided an empirical evidence which supports the positive effect of socialisation and internalisation on firms' architectural innovation capability. This finding enabled the researcher to answer the first research question:

Q1.How does knowledge creation affect architectural innovation capability?

Based on the conducted literature review, the analysis, and the theoretical background, it is evidenced that technological and market changes require a responsive mechanism in place to use relevant knowledge in developing novel outcomes (in this research novel outcomes refer to architectural innovations). Therefore, organisations developing new products are able to integrate external triggers from the environment with their created knowledge to produce architectural innovations. However, it is worth noting that architectural innovations are the outcome of architectural innovation capability. This means, that the capability that the organisations developed, based on their knowledge creation capabilities, is called architectural innovation capability, that enables them to conceive novel ways of

combining existing components to create improved products (refer to the turbofan engines example (Section 1.2), and the washing machine example (Section 6.4.2)).

It is necessary to exploit external knowledge (*i.e.* absorptive capacity) (Matusik, 2000). As noted in previous research, both inward-looking and outward-looking are pivotal elements of learning. This school of knowledge links strongly with absorptive capacity, and it motivated the researcher to ask the following question:

Q2. How does the interaction between architectural innovation capability and absorptive capacity affect firms' performance?

Based on the analysis carried out and the underpinning theoretical assumptions, this research was able to offer evidence to suggest that performance can depend on both knowledge creation and absorptive capacity, hence, both knowledge processing capabilities drive organisational performance. Using structural equation modelling empowered the researcher to test simultaneous effects; those of the knowledge creation, architectural innovation capability, and absorptive capacity. The analysis provided a rather interesting finding, that although knowledge creation supports architectural innovation capability, absorptive capacity is important to transcend the benefits of architectural innovation capability into financial outcomes.

To explain further, architectural innovation capability depends on knowledge creation; however, without absorptive capacity, the benefits or architectural innovation capability are less likely to be translated into better performance. Absorptive capacity enhances firms' timely response to important relevant external changes or knowledge in the external environment. Firms which are unable to scan and filter external knowledge are less likely to respond to customer demands or

competition and therefore are less likely to have the capability to reconfigure product's components accordingly. The external environment is filled with triggers which will activate potential and realised absorptive capacity, if firms combine their architectural innovation capability with absorptive capacity, they are more likely to improve their financial performance.

However, what is the best way to meet customer demands for new, novel, improved products? This matter motivated the last research question in this study which is:

Q3. How does lead users' integration affect product quality and development time?

Based on the research analysis, relevant findings, and lead user theory, it appears that lead users' integration accelerates development time and enhances product quality. Firms which are highly interested to deliver what the market and customers demand, are advised to consider lead users' integration. Lead users are not ordinary customers; rather, they are ahead of the trend and are expected to benefit significantly from getting a solution to their need. Hence, integrating lead users is generally acknowledged to keep firms abreast of customers' needs. Although the link between lead users' integration and accelerating development time is well-established, the link to product quality has not been much investigated. However, this research found that integrating lead users enhances product quality especially when they are integrated at the fuzzy-front-end of new product development process.

Previous research has already shown the significance of lead users in generating new ideas that satisfy their needs (Baldwin *et al.*, 2006, Dyer and Nobeoka, 2000). Therefore, lead users can add value in setting general product definition, lead time requirements, and product specifications. In addition, the role of lead users is well-

established in generating creative ideas (Lilien *et al.*, 2002). Lead users have competence, use experience, and possess intrinsic motivation which will enable them to develop high applicable product definition and specifications that offer practical solutions to their needs, and are more likely to contribute to the overall product quality.

The next section of this chapter presents a summary of key research findings, presents key contributions and theoretical implications, as well as managerial and practical implications that emerged from this research.

7.3 Summary of key research findings

Based on an extensive literature review and consideration of the current research, a theoretical model was developed to capture the relationships between the study's variables (Figure 7.1). This research was designed to explore the impact of knowledge creation on enhancing firms' architectural innovation capability. In addition this research also examined the combined impact of architectural innovation capability and absorptive capacity on development cost and financial performance. Data were collected via a self-administered web-based questionnaire targeting executive managers in the UK manufacturing industry. Data were analysed using structural equation modelling. Based on the analysis, most of the proposed hypotheses were supported (Figure 7.1). The results of the hypotheses testing contribute to knowledge creation theory, architectural innovation capability literature, and absorptive capacity model as will be discussed later in this chapter (Section 7.4).

The survey results supported Nonaka's (1994) model of knowledge creation. Previous empirical studies yielded contradicting results regarding knowledge creation (Schulze and Hoegl 2006, 2008, Lee and Choi 2003); hence, there is a need to examine Nonaka's (1994) knowledge creation model in different empirical contexts to gain further insights.

This study confirmed the knowledge creation model, and supported the positive effect of knowledge creation modes (namely socialisation and internalisation) on driving architectural innovation capability. Socialisation is needed to facilitate sharing tacit knowledge which is embedded in individuals' mental models and is hard to be articulated without direct investigation or interaction. Applying socialisation is deemed to create an environment in which individuals are able to exchange important tacit knowledge, which is the first step in building an environment for learning. This environment triggers sharing tacit knowledge (e.g. architectural knowledge), which promotes architectural innovation capability. Although externalisation effect on architectural innovation capability was not supported in this research, it is necessary to convert tacit knowledge into explicit knowledge, which is transferable and can be shared to create a common mental model, thereby promoting practices of reflection and interaction. This practice of reflection promotes architectural innovation capability through formal and informal exchanges of knowledge about new product properties and ideas.

The next mode tested was knowledge combination. Although the knowledge combination effect on architectural innovation capability was not supported in this research, innovation in general (especially process innovation), requires aggregating

explicit knowledge, using both formal and informal ways. Aggregating knowledge through meetings, networking, and conversation solidifies ideas through integrating explicit knowledge (the outcome of the previous mode- externalisation), with existing knowledge. This step might not generate new knowledge, *per se*, but it helps to audit what any firm has in terms of its knowledge. Finally, knowledge internalisation mode is considered by previous researchers as having an influential role on leveraging architectural innovation capability. Embedding knowledge in mental models of technical know-how enables individuals to reflect on this knowledge and to be familiar with each other's mental models. This makes individuals working on developing new products familiar with each other's knowledge, so they will be able to leverage each other's knowledge and envision new tacit knowledge to create innovative ideas.

There were also significant findings relating to the connection between architectural innovation capability, absorptive capacity and performance. Potential absorptive capacity moderating effect shows that assimilation (potential absorptive capacity), strengthen the positive relationship between innovation and financial performance. Identifying and acquiring externally sourced knowledge that is relevant to the firm, in addition to analysing and interpreting the acquired knowledge, promotes architectural innovation capability relationship with performance. In terms of realised absorptive capacity (transformation and internalisation), the interaction between transforming assimilated knowledge and architectural innovation capability enhances financial performance. Transformation capability creates changes in firms' routines and processes in order to integrate valuable knowledge. Newly acquired knowledge is

combined with existing knowledge to translate new innovative ideas into architectural innovation commercial outcomes.

Although arguments based on previous research supports a positive effect of realised absorptive capacity on innovation in general, the analysis carried out shows that taking financial performance into account changes this effect. Exploitation capacity, through leveraging acquired knowledge into commercial ideas, is likely to enhance innovation using R&D activities. However, high exploitation may outweigh its associated benefits, as this current study supported that exploitation can weaken the positive relationship between architectural innovation capability and financial performance. This means that exploitation can harm the positive relationship between innovation and financial performance. The main reason behind this finding can be related to the level of absorptive capacity adopted by firms, as high exploitation requires high investment, in terms of combining external knowledge (which was acquired, assimilated, and transformed) with internal knowledge to realise creative ideas. Thus, although exploitation capability can enhance innovative capability, high exploitation is more likely to negatively affect financial performance.

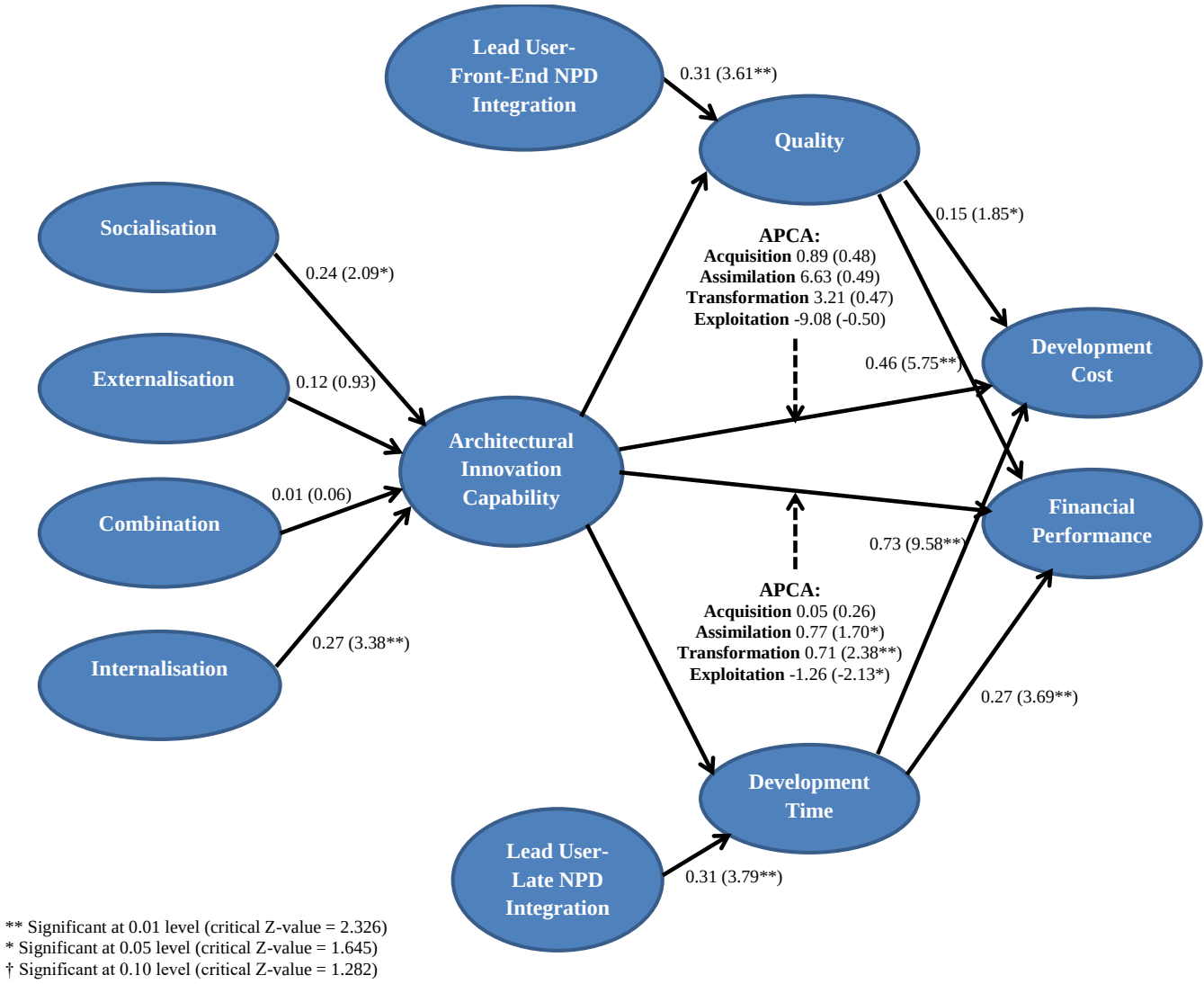

Figure 7.1: Summary of the results of hypotheses testing

This research provides theoretical as well as managerial implications which are the main focus of the next section.

7.4 Key contributions and theoretical implications

Previous research on the field of knowledge management investigated different aspects of knowledge, in different contexts (organisational or individual), and different areas of knowledge management; such as, knowledge creation (Nonaka 1994), knowledge sharing (Dyer and Nobeoka, 2000), and knowledge application (Holzner and Marx, 1979). This research examines how knowledge created at the organisational level contributes to innovation.

This research contributes to the theory of knowledge creation by providing necessary empirical evidence for a knowledge creation conceptual model. Limited previous empirical research has empirically investigated Nonaka's (1994) knowledge creation model. For example, Schulze and Hoegl (2006) investigated the effect of socialisation, externalisation, combination, and internalisation on new product success, product quality, and project efficiency. Also, Schulze and Hoegl (2008) linked the four knowledge creation modes to the novelty of generated product ideas. In addition Lee and Choi (2003) linked knowledge creation modes with organisational creativity. However, previous studies have produced contradictory results (Table 7.1) which merit further research and clarifications. Hence, this current research adopted Nonaka's (1994) model to investigate each mode's effect on innovation.

Table 7.1: Previous empirical research on knowledge creation

	Schulze and Hoegl 2006 (Concept phase)	Schulze and Hoegl 2006 (Development phase)	Schulze and Hoegl 2008	Lee and Choi 2003
Socialisation	+ (Supported)	- (Supported)	+ (Supported)	+ (Supported)
Externalisation	- (Supported)	+ (Not supported)	- (Supported)	+ (Supported)
Combination	+ (Not supported)	+ (Supported)	- (Supported)	+ (Supported)
Internalisation	- (Not supported)	- (Supported)	+(Supported)	+ (Not supported)

+ Positive effect
- Negative effect

In addition, this study employed structural equation modelling to analyse the simultaneous interactions of multiple variables; knowledge creation, innovation, and performance. Thus, this study provided a comprehensive analysis of the role of knowledge creation in enhancing architectural innovation capability.

This research contributed to the lead user theory by providing empirical application and examining the enhanced quality of new product ideas as a result of lead users' integration. This empirical research proved that lead users' input in the fuzzy-front-end of new product development promotes quality. Lead users have the necessary knowledge and experience, combined with and strengthened by, their high interest in finding solutions ahead of the trend. Due to certain characteristics they possess, they are competent at systematically analysing problems to generate applicable, practical high-quality solutions and product ideas.

Furthermore, this research has contributed to the seminal work of Henderson and Clark (1990) on architectural innovation, by empirically supporting their previous conceptual perspective. In this vein, these research findings reveal the relative importance of knowledge creation in enhancing architectural innovation capability.

Studying architectural innovation has offered an intriguing perspective from which to view technological changes in the external environment and internalising these changes, to create novel products with improved characteristics.

In addition, this research addresses the interaction effect of absorptive capacity and architectural innovation capability on financial performance and development cost. The results of this research are largely consistent with previous views on how absorptive capacity supports product innovation (Zahra and George 2002; Cohen and Levinthal 1990; Tsai, 2001, Gebauer *et al.*, 2013; and Cepeda-Carrion *et al.*, 2012). However, the findings also suggest some different conclusions from the conventional view of absorptive capacity.

First, this research challenges the theoretical assumption that the availability of prior knowledge is the main motivation that drives absorptive capacity. This assumption was partially derived from misunderstanding the work of Cohen and Levinthal (1990) in which it has been argued that APCA depends on prior knowledge stock. This current study extends the previous assumption by including knowledge creation which act as prerequisite for innovation. Hence, overcoming the limitation of the theoretical assumption encompassed in previous research, which focuses on the content of prior knowledge (Ahuja and Katila, 2001; Kim, 1998; Mowery, Oxley, and Silverman, 1996), and extending the focus on knowledge processes as one factor among many others which drive absorptive capacity.

Second, this research emphasises the importance of potential absorptive capacity, in realising the value of new information. The link with innovation, and especially

architectural innovation, in this research is manifested through capturing new technological changes or information related to new needs in the market. Moreover, this research has shown that although exploitation capability is vital to both utilise and leverage the acquired knowledge into novel commercial outcomes, exploitation negatively affects firms' financial performance. As high exploitation is associated with high resources deployment with can harm financial performance. This finding raises an important implication regarding absorptive capacity level to be adopted.

Furthermore, in general, previous empirical research has focused on R&D and knowledge acquisition, while overlooking the process aspect of absorptive capacity. Few researchers operationalised assimilation and application as part of their investigations into the absorptive capacity process (e.g. Lane and Lubatkin, 1998; Lane *et al.*, 2001). To overcome this limitation, this research used a robust scale to measure absorptive capacity as a process (including, acquisition, assimilation, transformation, and exploitation). This measurement was achieved by adopting and validating the scale developed by Jansen (2005). Contrary to the stream of research that measures and operationalises absorptive capacity using absolute measures and proxies, such as R&D expenditure or the number of employees with bachelor degree, among many others proxies. Jansen's (2005) scale is comprehensive as it includes the four absorptive capacity components of acquisition, assimilation, transformation, and exploitation in order to capture its process-based definition. Therefore, by adopting Jansen's (2005) perceptual measurement scale, this research may be regarded as an objective and unbiased estimation of absorptive capacity.

7.5 Managerial implications

This study has many important managerial implications derived from the findings. Project managers and product development team members have to continuously examine their knowledge base. Relevant prior knowledge enhances organisations ability to evaluate the relevance and value of external knowledge, which affects the decision to acquire new knowledge. As identified from the empirical analysis carried out, socialisation is key for product development, for example, in the concept phase team managers and members can add value by informally interacting within and beyond their organisation. In addition, managers can gather information from new product development production teams, engaging in extra-firm social information collection (informal meeting with external experts and competitors), engaging in intra-firm social information collection, and by creating a learning environment where craftsmanship and expertise are shared and welcomed.

Furthermore, externalisation is necessary to articulate knowledge gained in the socialisation process, efforts to facilitate dialogue and metaphors should be endeavoured by managers to enhance concept creation. Any externalised knowledge should be combined with existing knowledge, as synthesising knowledge facilitates integrating it into current knowledge system. This requires managerial efforts to combine external and internal knowledge and gathering technical knowledge and information, in addition, managers should arrange knowledge dissemination platforms such as presentations to share new knowledge. Internalisation enables individuals to absorb and embody accumulated know-how. For example, a product concept has to be actualised through practice for learning to take place. Internalisation can be achieved by cross-functional development teams and overlapping product development, and

through simulation and experimentation. The previous managerial implications highlight practical routines to manage the dynamic process of knowledge creation which needs to become a discipline for individuals, how they think, act, and how they solve problems.

Research findings show the importance of lead users' integration in speeding up new product development process and improving the quality of new products ideas. There are several managerial implications for this finding. Managers should actively seek to include lead users in new product development processes, as lead users can have enduring consequences on speeding new product development process and enhancing products ideas quality. For example, at the concept phase, lead users can be integrated by using co-creation platform such as virtual design competitions, or by using collaborative product development models. Online idea management and community participation in product development are two ways to integrate customers (Enkel *et al.*, 2009) .

The findings of this research indicate the importance of absorptive capacity in leveraging the innovation-performance link. Absorptive capacity enhances the ability to analyse and interpret new external knowledge. However, this capacity highly depends on the ability to scan and filter relevant technological and market knowledge from the external environment which determines the ability to successfully applying absorbed knowledge to commercial ends. Furthermore, absorptive capacity enhances the ability to share best practices within the firm (Szulanski, 1996), and updating its knowledge in order to overcome rigidities. However, it is essential to maintain the

appropriate level of absorptive capacity; otherwise, high exploitation can harm financial performance.

Last but not least, this research has managerial implications for the UK manufacturing industry. This research provides insights into architectural innovation and shows the benefits of adopting this type of innovation, such as entering new markets, enhancing flexibility, and following a moderately risky product innovation strategy. This is important especially under the current state of the UK economy and the possible harmful consequences of leaving the European Union. As organisations need (more than ever) to focus on enhancing profit, adopting architectural innovation focus on developing new interfaces between products components instead of changing the component knowledge (core technologies). Following this strategy can benefit firms in unstable environments.

7.6 Research limitations

This study has several limitations that should be considered in future research. First, the measures of the predictor and criterion variables were collected from one source (key informant method) which might develop common method bias, also referred as self-report bias. According to the consistency motif theory (John, 1994; podsakoff and Organ, 1986; Schmitt, 1994), people try to maintain consistency and rational in their responses by trying to produce relationships between questions asked. Therefore, it is advised to have two respondents from each unit, each respondent answers either predictor or criterion questions. Social desirability plays a role in common method bias as well, as respondents tend to present the opinions that would be considered

culturally acceptable as a mean to seek social approval and acceptance (Crowne and Marlowe, 1964). The previous are two potential sources of common method bias among many others sources, such as leniency bias, illusory correlations, and affectivity (Podsakoff *et al.*, 2003).

Although considerable care was taken in designing the questionnaire in terms of items and structure (following Dillman's total design method TDM), and pretesting through a pilot study, the issue of common method bias cannot be ultimately ruled out. However, this research targeted executive and senior managers who are best placed to respond to the study's questionnaire as they have wider knowledge about innovation and performance of their organisations. The method of targeting knowledgeable respondents in questionnaire topic is advised to reduce common method bias. Additionally, Harman's one-factor analysis provided evidence against common method variance in our data.

Second, although the majority of the scale items used in this research is validated scales from high-ranked journals, a new scale was developed to capture architectural innovation capability. In spite of the fact that this scale was pilot tested and further tests were conducted to assess its validity, it would be useful to further enhance this scale and develop an elaborated measurement scale for architectural innovation capability.

Third, as this research model was tested in the UK manufacturing industry, empirical studies in different industries are necessary to further generalise the findings. This study recommends further research in a variety of organisations in different industries,

and recommends addressing new service development in addition to new product development. In addition, the data captured in this research were cross-sectional. Although most of the proposed research hypotheses were supported, further longitudinal research would have provided more robust empirical finding and may empirically establish the proposed model.

Fourth, this research has used survey as a data collection method in this research. Although the questionnaire was carefully designed following the recommended questionnaire administration steps, it is inevitable that some factors such as the respondents' bias can take place. In addition, the data collected using questionnaire method is not as wide-ranging as those collected by interview. Research shows that long questionnaires tend to receive low response rate and occasionally receive superficial answers (tick box). Thereby, it is recommended that future research adopt mixed methods in capturing different research constructs.

Another limitation is related to the performance proxies. The data collected flags that the majority of the companies in the research sample met high performance targets (for example, being successful in terms of development cost, development time, and financial performance). This data was interpreted with cautious taking into consideration the sample bias towards successful products. It is worth nothing that this can be a limitation when using validated performance scales, which could be addressed in future research.

Finally, the knowledge creation model proposed by Nonaka (1994) is a dynamic model which is widely used by researchers. The model consists of four knowledge

creation modes which form a spiral model with constant interaction between tacit and explicit knowledge. The aim of the model is to convert existing knowledge into a new knowledge to be used in creating novel and innovative ideas. The application of the knowledge creation model followed in this research could yield some limitation due to the fact that this model is a dynamic model, which needs to be studied over a period of time. However, in this research, organisations application of knowledge creation is addressed at one point of time. This can create issues when interpreting the results due to a static evaluation of knowledge creation activities followed. Hence, it is recommended that future research tries to overcome this issue by studying knowledge creation model at different points to capture the dynamic characteristics of it.

7.7 Suggestions for future research

This study has suggested a model to enhance organisational performance through its architectural innovation capability and knowledge management practices. Although the data supported this model to a large degree, there is much value in further refining and developing the conceptual model. Therefore, the following are few avenues for future research.

The primary variable of interest in this research was architectural innovation capability. Evidence from previous research suggests that architectural innovation is prevalent, and it provides insights into understanding technology-based competition. It is also important to comprehend that architectural innovation is a concept that can be applied to a wide range of frameworks. For example, architectural innovation concept can be reflected in managerial, marketing, or financial tasks. The focus of this

research was on products and reconfiguring products components. The seminal work by Henderson and Clark (1990) inspired this current research, as this current research addressed the effect of architectural innovation capability to enhance new product development effectiveness and efficiency. Future studies could identify further factors and variables that influence and are influenced by architectural innovation capability in an effort to develop a valid conceptual model.

Although this research has identified that lead users' integration can speed up new product development process, future research can be conducted to address how to best implement lead users' integration method in the concept generation phase and testing phase. In addition, future research can explore post-launch phase so that lead users can be employed as opinion leaders. A luring research opportunity to further explore ways to integrate lead users can be addressed by future research. In addition, future research can look into the effect of speeding new product development and enhancing product ideas' quality and product profitability captured by proxies other than development cost and financial performance.

Another area for future research is to further explore absorptive capacity under market and technological uncertainty. Uncertain and turbulent technological environment can impose a higher need to speed products to market and more demand for innovative products which can be realised by absorptive capacity. It is interesting to investigate how this would affect the degree of absorptive capacity efforts. In addition, another important area could be an empirical research to study absorptive capacity model with and without the assimilation process. This research is important to develop absorptive

capacity model further, taking into consideration the factors that affect the need for assimilation.

This research studied performance using validated measurement scales which captured development cost and financial performance. Future research may measure performance using objective measures and compare both measures (perception and objective) to obtain more robust results. In addition to enhance the generalisability of this research, future studies may test the suggested framework in other industries and extend the model application to new services.

7.8 Summary

In summary, this study found that knowledge creation modes have a positive effect on enhancing architectural innovation capability. In addition, having architectural innovation capability enables firms to develop new products which play a major role in tapping into new markets. Taking into consideration new product development performance, this study found that absorptive capacity plays a moderator role to strengthen the effect of innovation capability on financial performance. Moreover, lead users' integration is found to enhance product quality, and shorten new product development cycle time.

This chapter demonstrated that the previous variables make a significant contribution to academic and management practices, indicating the contribution of this research. Albeit some limitations that can be acknowledged in future research, this study was able to achieve its aim and objectives and contributed to theoretical and managerial

fields alike. Finally, this chapter presented practical suggestions that can be used in the management field.

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APPENDICES

Appendix 1: pre-notification letter

Dear (Insert respondent name),

My name is Ala'a Azzam, and I am a doctoral researcher from Durham University Business School (DUBS) at Durham University. As part of my doctorate, I am conducting a study on Knowledge management practices and their effect on innovation and performance. I am studying knowledge creation and its effect on the ability to innovate new architectural innovation products. This is important to companies and managers as knowledge management and architectural innovation are frequently linked with greater profitability.

Your company has been selected as an appropriate source of information for this study.

The study will take the form of a questionnaire, which should not take more than 15 minutes of your time. The survey will be launched in November 2013, and if you agree to participate, **the questionnaire will be mailed to you next week**. **All replies will be treated with the strictest confidence** and all information will be treated with absolute confidentiality. The results of this survey will be used for academic purposes and are completely independent of any commercial entity and any data obtained will not be shared or distributed with anyone outside of the research team. In a bid to encourage you to fill the questionnaire **a summary of the main results will be sent to all companies that request it.**

If you are unwilling to assist me in this important study please reply to this email.

We take this opportunity to ask you to please consider the importance of this national study and we thank you in advance for your cooperation. However, if you require do any further information, please do not hesitate to contact me at a.m.azzam@durham.ac.uk.

Yours faithfully,

Ala'a Azzam

Appendix 2: Reminder email

Dear (insert respondent last name),

Further to my previous email please find enclosed the link to the questionnaire. The questionnaire has been designed to collect information about Knowledge management processes, product innovation and lead users' integration in this process.

I do hope that you can put aside 15 minutes to assist with my research into this topic, as your views are vital and will enable my study to be more comprehensive and as it is important to hear from the widest range of experts possible. All replies will of course be treated in the strictest confidence and I can assure you that any responses you give will be anonymised and retained securely. The results of this survey will be used for academic purposes and are completely independent of any commercial entity and any data obtained will not be shared or distributed with anyone outside of the research team.

In a bid to encourage you to fill the questionnaire a summary of the main results will be sent to all companies that request it.

I have also enclosed a letter confirming that this research project is approved by the Research Ethics Committee of Durham University Business School.

The questionnaire link:

Follow the link to opt out of future emails:

If you require any further information, please do not hesitate to contact me at a.m.azzam@durham.ac.uk

Thank you once again for your time and very much appreciate your support of my research.

I look forward to receiving your completed questionnaire.

Yours faithfully,
Ala'a Azzam

Appendix 3: Research questionnaire

Default Question Block

Thank you for taking part in this survey.

I am a doctoral researcher from Durham University Business School (DUBS) conducting a study about knowledge management, innovation and lead user integration.

This questionnaire has been designed to collect information about knowledge management activities such as knowledge creation, dissemination and application and their effect on the ability to innovate new products.

All responses will be confidential and will not be shared with anyone outside of the research team compromising of myself and my supervisors (Professor Christos Tsinopoulos, Professor Carlos Sousa and Dr Paul Hughes). Your responses will be treated anonymously and any responses will only be considered in aggregate form along with the responses of all other survey respondents. The responses given will be held securely in compliance with Durham University's Data use policy .

Please make each question a separate and independent judgment. Work at a fairly high speed through the questionnaire and do not worry or puzzle over individual items. It is your first impression, the immediate feelings about the questions that we want. On the other hand, please do take care to answer the questions as fully and accurately as you can. The questionnaire has been designed for you to be able to tick most of the items to enable you to complete the questionnaire in the shortest possible time.

Your responses are highly appreciated.

Yours faithfully,

Ala'a Azzam

Organisation Demographics

When was your company established?

What is the sector in which your company operates?

How many years has your company been operating (approximate number)?

How many full time employees presently work in your company (approximate number)?

What is the annual level of your company sales? (Optional)

How many new products has your company produced in the last five years?

Respondent Characteristics

What is your age? (Optional)

What is your educational level?

What is your job title?

How many years of working experience do you have with your current business?

How many years of working experience do you have in total?

Please answer the following questions as they apply to a recent product.

Please name this product

The new product development processes that we followed to develop this product:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
encouraged us to explore new linkages between existing technologies	○	○	○	○	○	○	○
encouraged us to integrate existing product technologies	○	○	○	○	○	○	○
have led to significant changes in the way product technologies interact	○	○	○	○	○	○	○
have led to significant changes that influenced the overall performance of the product	○	○	○	○	○	○	○

How would you describe this product?

Core design concepts were unchanged ○ ○ ○ ○ ○ ○ ○ Core design concepts were changed

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
We spent a lot of time in personal interaction aside from organized meetings with other people in the company to discuss suggestions, ideas, or solutions	○	○	○	○	○	○	○
We spent a lot of time in personal interaction aside from organized meetings with people from other departments in the company in order to discuss suggestions, ideas, or solutions	○	○	○	○	○	○	○
We spent a lot of time in intense discussions about suggestions, ideas, or							

solutions in face-to-face meetings with people from different departments in the company							
We spent a lot of time in the conscious creation of a common understanding of a problem with people from other departments in the company							

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
We spent a lot of time reflecting collectively and framing our ideas or solutions with regard to customer needs							
We spent a lot of time interviewing competent people about ideas or solutions with regard to relevant technologies							
We spent a lot of time interviewing competent people about ideas or solutions with regard to customer needs							
We spent a lot of time creating detailed descriptions (e.g., protocols, presentations, reports) containing newly developed knowledge about customer needs							

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
Focusing on the product, we systematically process the technical knowledge collected							
Focusing on the product, we systematically process the knowledge collected about customer needs							
Focusing on the product, we systematically edited the collected knowledge about the procedure of creating, evaluating, and selecting a product concept/developing products							
Within the company, we distributed our newly gained insights about customer needs							

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the

following statements:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding the functionality of the product	○	○	○	○	○	○	○
We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding customer needs	○	○	○	○	○	○	○
We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding the procedure of creating, evaluating, and selecting a product concept/ developing products	○	○	○	○	○	○	○
We spent a lot of time systematically testing our knowledge about customer needs	○	○	○	○	○	○	○

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements.

My company:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
Has processes for acquiring knowledge about our customers	○	○	○	○	○	○	○
Has processes for generating new knowledge from existing knowledge	○	○	○	○	○	○	○
Has processes for acquiring knowledge about our suppliers	○	○	○	○	○	○	○
Uses feedback from projects to improve subsequent projects	○	○	○	○	○	○	○
Has processes for distributing knowledge throughout the company	○	○	○	○	○	○	○
Has processes for exchanging knowledge with our business partners	○	○	○	○	○	○	○
Has processes for interorganizational collaboration	○	○	○	○	○	○	○
Has processes for acquiring knowledge about new products within our industry	○	○	○	○	○	○	○
Has processes for acquiring knowledge about competitors within our industry	○	○	○	○	○	○	○
Has processes for benchmarking performance	○	○	○	○	○	○	○
Has teams devoted to identifying best practice	○	○	○	○	○	○	○

Has processes for exchanging knowledge between individuals	○	○	○	○	○	○	○

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements.

My company:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
Has processes for applying knowledge learned from mistakes	○	○	○	○	○	○	○
Has processes for applying knowledge learned from experiences	○	○	○	○	○	○	○
Has processes for using knowledge in development of new products	○	○	○	○	○	○	○
Has processes for using knowledge to solve new problems	○	○	○	○	○	○	○
Matches sources of knowledge to problems and challenges	○	○	○	○	○	○	○
Uses knowledge to improve efficiency	○	○	○	○	○	○	○
Uses knowledge to adjust strategic direction	○	○	○	○	○	○	○
Is able to locate and apply knowledge to changing competitive conditions	○	○	○	○	○	○	○
Makes knowledge accessible to those who need it	○	○	○	○	○	○	○
Takes advantage of new knowledge	○	○	○	○	○	○	○
Quickly applies knowledge to critical competitive needs	○	○	○	○	○	○	○
Quickly links sources of knowledge in solving problems	○	○	○	○	○	○	○

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
My company has frequent interactions with corporate headquarters to acquire new knowledge	○	○	○	○	○	○	○
Employees of my company regularly visit other branches	○	○	○	○	○	○	○
We collect industry information through informal means (e.g. lunch with industry friends, talks with trade partners)	○	○	○	○	○	○	○
My company periodically							

organizes special meetings with customers or third parties to acquire new knowledge	○	○	○	○	○	○	○
Employees in my company regularly approach third parties such as accountants, consultants, or tax consultants	○	○	○	○	○	○	○

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
We are slow to recognize shifts in our market (e.g. competition, regulation, demography)	○	○	○	○	○	○	○
New opportunities to serve our clients are quickly understood	○	○	○	○	○	○	○
We quickly analyze and interpret changing market demands	○	○	○	○	○	○	○

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
My company regularly considers the consequences of changing market demands in terms of new products and services	○	○	○	○	○	○	○
Employees in my company record and store newly acquired knowledge for future reference	○	○	○	○	○	○	○
My company quickly recognizes the usefulness of new external knowledge to existing knowledge	○	○	○	○	○	○	○
Employees in my company hardly share practical experiences	○	○	○	○	○	○	○
We struggle to grasp the opportunities for our company from new external knowledge	○	○	○	○	○	○	○
Employees in my company periodically meets to discuss consequences of market trends and new product development	○	○	○	○	○	○	○

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
It is clearly known how activities within our company should be performed	○	○	○	○	○	○	○
Client complaints fall on deaf							

ears in my company	○	○	○	○	○	○	○
Our company has a clear division of roles and responsibilities	○	○	○	○	○	○	○
We constantly consider how to better exploit knowledge	○	○	○	○	○	○	○
Our company has difficulty implementing new products and services	○	○	○	○	○	○	○
Employees have a common language regarding our products and services	○	○	○	○	○	○	○

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements.

My company:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
Has processes to share information and knowledge necessary for the tasks	○	○	○	○	○	○	○
Has processes to improve task efficiency by sharing information and knowledge	○	○	○	○	○	○	○
Has processes to promote sharing of information and knowledge with other teams	○	○	○	○	○	○	○
Has developed information systems like intranet and electronic bulletin boards to share information and knowledge	○	○	○	○	○	○	○

For the next 8 Questions we will be asking you to respond about lead users. Lead users are those who face needs that will be general in the market place and face them before the rest of the market place, and benefit significantly if they obtain a solution to those needs.

Some well-known examples are 'TipEx', which was invented at the end of the 1950s by a secretary. The athletes' drink 'Gatorade' was developed by the trainer of a college football team. The early versions of protein shampoos go back to recipes of house wives and the same is true for baking recipes of ready-mixed cakes. In general, the recreation and sport markets are rich in examples for lead user innovations.

Please rate the extent to which lead users contributed to the following activities of your chosen product:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
setting general product definition	○	○	○	○	○	○	○
setting lead time requirements	○	○	○	○	○	○	○
setting product specifications	○	○	○	○	○	○	○
generating products' blueprints/drawings	○	○	○	○	○	○	○
designing product detailed	○	○	○	○	○	○	○

component specification							
product prototyping	○	○	○	○	○	○	○
product testing	○	○	○	○	○	○	○
overall product development process	○	○	○	○	○	○	○

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
Top management was very pleased with the time it took us to bring this product to market	○	○	○	○	○	○	○
This product was launched on or ahead of the original schedule	○	○	○	○	○	○	○
This product was completed in less time than what was considered normal and customary for our industry	○	○	○	○	○	○	○
This product was developed and launched faster than a similar product of a major competitor	○	○	○	○	○	○	○

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
This product met the budget specifications for the development costs	○	○	○	○	○	○	○
The development cost of this product is less than previous projects for similar products	○	○	○	○	○	○	○
The development cost of this product is less than competitor projects for similar products	○	○	○	○	○	○	○
Top management was very pleased with the development cost of this product	○	○	○	○	○	○	○

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
This product was successful based on financial performance	○	○	○	○	○	○	○
This product met technical success ratings	○	○	○	○	○	○	○
This product met domestic market share expectations	○	○	○	○	○	○	○
This product met sales and profit objectives	○	○	○	○	○	○	○

This product met overall profit ratings	○	○	○	○	○	○	○

Please answer the following questions by clicking the circle that best represents your (dis)agreement with the following statements

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
This product met the present performance specifications	○	○	○	○	○	○	○
This product provided better quality than previous projects for similar products	○	○	○	○	○	○	○
This product provided better quality than competitor projects for similar products	○	○	○	○	○	○	○
The new product offered unique benefits to customers	○	○	○	○	○	○	○

To what extent do you feel you possess knowledge regarding the questions asked in the questionnaire?

No knowledge ○ ○ ○ ○ ○ ○ ○ Full knowledge

To what extent do you believe the responses given by you accurately reflect the 'realities' of your company?

Not accurate at all ○ ○ ○ ○ ○ ○ ○ Completely accurate

Listed below are a few statements about your relationships with others.
Please choose one choice from the drop down list.

I am always courteous even to people who are disagreeable	▾
There have been occasions when I took advantage of someone	▾
I sometimes try to get even rather than forgive and forget	▾
I sometimes feel resentful when I don't get my way	▾
No matter who I'm talking to, I'm always a good listener	▾

We may like to invite a sample of respondents to be in involved in future research activities linked to this study, for instance an interview or focus group. If you are happy to be involved in these activities, please fill in your contact details below. This information will be stored separately from the questionnaire once the data has been processed to guarantee confidentiality.

	Name:	Email address:	Telephone number:
I am happy to be contacted for future research activities			

Thank you very much for your co-operation in this study

Appendix 4: Research instrument scale

Construct	Original items	Source	New items
Architectural innovation capability	1. INNOVATION led to significant changes in the linkages between SUBSYSTEM and at least one subsystem in PRODUCT other than SUBSYSTEM. 2. INNOVATION led to significant changes in the way SUBSYSTEM interacts with other subsystems. 3. INNOVATION led to tighter integration between SUBSYSTEM and at least one other subsystem. 4. INNOVATION made the integration of SUBSYSTEM with at least one other subsystem a more important factor influencing the overall performance of product.	(Gatignon *et al.*, 2002b)	The new product development processes that we followed to develop this product: 1. encouraged us to explore new linkages between existing technologies 2. encouraged us to *integrate* existing product technologies 3. have led to significant changes in the way product technologies interact 4. have led to significant changes that influenced the overall performance of the products.
Knowledge Creation	*Socialization* We spent a lot of time in personal interaction aside from organized meetings with other people in the organization to discuss suggestions, ideas, or solutions. We spent a lot of time in personal interaction aside from organized meetings with people from other departments	(Schulze and Hoegl, 2006)	

	in the company in order to discuss suggestions, ideas, or solutions. We spent a lot of time in intense discussions about suggestions, ideas, or solutions in face-to-face meetings with people from different departments in the company. We spent a lot of time in the conscious creation of a common understanding of a problem with people from other departments in the company. *Externalization* We spent a lot of time reflecting collectively and framing our ideas or solutions with regard to customer needs. We spent a lot of time interviewing competent people about ideas or solutions with regard to relevant technologies. We spent a lot of time interviewing competent people about ideas or solutions with regard to customer needs. We spent a lot of time creating detailed descriptions (e.g., protocols, presentations, reports) containing newly developed knowledge about customer needs. *Combination* Focusing on the project, we systematically edited the		

	technical knowledge collected. Focusing on the project, we systematically edited the knowledge collected about customer needs. Focusing on the project, we systematically edited the collected about the procedure of creating, evaluating, and selecting a product concept/developing products. Within the organization, we distributed our newly gained insights about customer needs. *Internalization* We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding the functionality of the technology. We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding customer needs. We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding the procedure of creating, evaluating, and selecting a product concept/ developing products. We spent a lot of time systematically testing our theoretical knowledge about customer needs.		

APCA	*Potential Absorptive Capacity* *Acquisition* 1. Our unit has frequent interactions with corporate headquarters to acquire new knowledge. 2. Employees of our unit regularly visit other branches. 3. We collect industry information through informal means (e.g. lunch with industry friends, talks with trade partners).a *4.* Other divisions of our company are hardly visited. (reverse-coded) *This item was deleted* 5. Our unit periodically organizes special meetings with customers or third parties to acquire new knowledge. 6. Employees regularly approach third parties such as accountants, consultants, or tax consultants. *Assimilation* 7. We are slow to recognize shifts in our market (e.g. competition, regulation, demography). (reverse-coded) 8. New opportunities to serve our clients are quickly understood. 9. We quickly analyze and interpret changing market demands. *Realized Absorptive Capacity* *Transformation* 10. Our unit regularly considers the consequences of changing market demands in terms of new products and services. 11. Employees record and store newly acquired	(Jansen *et al.*, 2005)	*Potential Absorptive Capacity* *Acquisition* 1. My organisation has frequent interactions with corporate headquarters to acquire new knowledge. 2. Employees of my organization regularly visit other branches. 3. We collect industry information through informal means (e.g. lunch with industry friends, talks with trade partners).a 4. My organization periodically organizes special meetings with customers or third parties to acquire new knowledge. 5. Employees in my organization regularly approach third parties such as accountants, consultants, or tax consultants. *Assimilation* 1. We are slow to recognize shifts in our market (e.g. competition, regulation, demography). (reverse-coded) 2. New opportunities to serve our clients are quickly understood. 3. We quickly analyze and interpret changing market demands. *Realized Absorptive Capacity* *Transformation* 1. My organization regularly considers the consequences of changing market demands in terms of new products and services.

	knowledge for future reference. 12. Our unit quickly recognizes the usefulness of new external knowledge to existing knowledge. 13. Employees hardly share practical experiences. (reverse-coded) 14. We laboriously grasp the opportunities for our unit from new external knowledge. (reverse-coded) 15. Our unit periodically meets to discuss consequences of market trends and new product development. *Exploitation* 16. It is clearly known how activities within our unit should be performed. 17. Client complaints fall on deaf ears in our unit. (reverse-coded) 18. Our unit has a clear division of roles and responsibilities. 19. We constantly consider how to better exploit knowledge. 20. Our unit has difficulty implementing new products and services. (reverse-coded) 21. Employees have a common language regarding our products and services		2. Employees in my organization record and store newly acquired knowledge for future reference. 3. My organization quickly recognizes the usefulness of new external knowledge to existing knowledge. 4. Employees in my organization hardly share practical experiences. (reverse-coded) 5. We struggle to grasp the opportunities for our organization from new external knowledge. (reverse-coded) 6. Employees in my organization periodically meets to discuss consequences of market trends and new product development. *Exploitation* 1. It is clearly known how activities within our organization should be performed. 2. Client complaints fall on deaf ears in my organization. (reverse-coded) 3. Our organization has a clear division of roles and responsibilities. 4. We constantly consider how to better exploit knowledge. 5. Our organization has difficulty implementing new products and services. (reverse-coded) 6. Employees have a common language regarding our products and services
Lead users' integration	Please rate the extent to which lead users contributed to the following activities:	(Al-Zu'bi and Tsinopoulos	Please rate the extent to which lead users contributed to the following activities:

	setting general product definition setting lead time requirements setting product specifications generating products' blueprints/drawings designing product detailed component specification product prototyping product testing overall product development process	, 2012)	setting general product definition setting lead time requirements setting product specifications generating products' blueprints/drawings designing product detailed component specification product prototyping product testing overall product development process
Performance	*Development time* 1. Top management was very pleased with the time it took us to bring this product to market. 2. This product was launched on or ahead of the original schedule. 3. This product was completed in less time than what was considered normal and customary for our industry. 4. This product was developed and launched faster than a similar product of a major competitor. *Development cost* 5. This product met the budget specifications for development costs. 6. The development cost of product less than	(Lin and Huang, 2012)	*Development time* 1. Top management was very pleased with the time it took us to bring this product to market. 2. This product was launched on or ahead of the original schedule. 3. This product was completed in less time than what was considered normal and customary for our industry. 4. This product was developed and launched faster than a similar product of a major competitor. *Development cost* 1. This product met the budget specifications for the development costs. 2. The development cost of this product is less than

	previous projects for similar products. 7. The development cost of product less than competitor projects for similar products. 8. Top management was very pleased with development cost of this product. *Effectiveness* *Financial performance* 9. This product was successful based on financial performance. 10. This product met technical success ratings. 11. This product met domestic market share expectations. 12. This product met sales and profit objectives. 13. This product met overall profit ratings. *Product quality* 14. This product met the present performance specifications. 15. This product provided better quality than previous projects for similar products. 16. This product provided better quality than competitor projects for similar products. 17. The new product offered unique benefits to customers.		previous projects for similar products. 3. The development cost of this product is less than competitor projects for similar products. 4. Top management was very pleased with the development cost of this product. *Effectiveness* *Financial performance* 1. This product was successful based on financial performance. 2. This product met technical success ratings. 3. This product met domestic market share expectations. 4. This product met sales and profit objectives. 5. This product met overall profit ratings. *Product quality* 1. This product met the present performance specifications. 2. This product provided better quality than previous projects for similar products. 3. This product provided better quality than competitor projects for similar products. 4. The new product offered unique benefits to customers.

Appendix 5: Dillman's 19 principle of question construction

1. Choose simple over specialised words	Simpler version of words are more likely to be understood by more people	Yes
2. Choose as few words as possible to pose the question	People tend to give uneven attention to words if the question is long	Yes
3. Use complete sentences to ask questions	To avoid receiving erroneous answers from informants	Yes
4. Avoid vague quantifiers when more precise estimates can be obtained	To achieve more accurate answers	
5. Avoid specificity that exceeds the respondents potential for having an accurate, ready-made answer.	Some people may not have a ready answer so they tend to skip the question	Yes
6. Use equal numbers of positive and negative categories for scalar questions	People tend to treat the visual midpoint as the "neutral" point	Yes
7. Distinguish undecided from neutral by replacement at the end of the scale.	To distinguish true opinion holders from those who are being "forced" to choose while they have little or no choice.	No
8. Avoid bias from unequal comparison	To avoid bias (when respondent choose the most obvious choice)	N/A
9. State both sides of attitude scales in the question stems	This will help respondents choose to agree or disagree.	Yes
10. Eliminate check-all-that-apply question formats	To reduce primacy effects; when respondent try to "satisfice" by ticking as much answers	N/A
11. Develop mutually exclusive response categories.	To increase accuracy	N/A
12. Use cognitive design techniques	to improve recall and accuracy	Yes
13. Provide appropriate time referents	To avoid harming the surveyor's credibility	N/A
14. Be sure that each question is technically accurate	To avoid erroneous questions	Yes
15. Choose question wording that allow essential comparison to be made with previously	In order to measure change	N/A

collected data		
16. Avoid asking respondents to "say" yes in order to mean "no"	Because it is likely that some will miss the word "not"	Yes*
17. Avoid double-barrelled questions	To avoid confusing respondents	Yes
18. Soften the impact of potentially objectionable question	To avoid non-response rate	Yes
19. Avoid asking respondents to make unnecessary calculations	To improve accuracy	N/A

* In some questions I used reversed coded questions as a way to control for respondents accuracy and weather they were just "ticking boxes"

Appendix 6: Ethics letter

Durham University
Business School

BETTER BUSINESS THINKING

To whom it may concern

Durham University has a responsibility for ensuring that the research undertaken in its name is conducted in accordance with the law, in the public interest and is consistent with best practice.

This survey on Knowledge management and innovation is part of a research project at Durham University and is being conducted by Ala'a Azzam, PhD student under the supervision of Dr Christos Tsinopoulos, Professor Carlos Sousa and Dr Paul Hughes.

Your response to this survey as well as your email address will remain strictly confidential and anonymous. Your answer will be non-attributable and anonymous in all reports and outputs.

Thank you very much for your participation.

Durham University Business School Mill Hill Lane Durham City
DH1 3LB United Kingdom
Telephone +44 (0) 191 334 5200 Fax +44 (0) 191 334 5201
www.durham.ac.uk/business
Durham University is the trading name of the University of Durham