DEVELOPING RADICAL INNOVATION IN TELECOMMUNICATIONS:

AN R&D MANAGEMENT PERSPECTIVE

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Abstract

Radical innovation has been identified as one of the central topics of innovation management, being relevant to the development process, the categories, and the R&D department's responsibilities for development. Based on the above three individual research conversations, this research aimed to determine, when the R&D department of a large telecommunications operator[1] engaged in radical innovation, which capabilities they used and how the use of these capabilities was affected by different contextual factors at each stage of the radical innovation development cycle. By comparing the aim of the current research with other researchers' findings on relevant topics, three gaps in the research were identified, and two research questions were raised, as below:

- RQ1: What capabilities do the R&D department of an STO use for each separate activity during its radical innovation development process?
- RQ2: Within the radical innovation development process of an STO, which contextual factors explain the differential uses of the R&D department's capabilities?

Following the above research questions and based on the philosophical views of interpretivism and social constructivism, this PhD study uses a qualitative research strategy and a case study research approach for guiding the research design. Based on the data collected from 29 interviews plus a three-month, full-time participant observation, four case studies were conducted, which are the

[1] Recognised as the second type of telecommunications operator (STO) in the current research

telematics service within China Mobile, the Xi-He system within China Telecom, and 21CN and BT Fusion within British Telecom (BT). By comparing the four cases, the R&D departments' uses of capabilities in each separate activity of its radical innovation development cycle were identified, and the reasons for the different uses of these capabilities were described in relation to six contextual factors derived from the literature.

Based on the four case studies and the data analysis, from the perspective of the R&D department eight theoretical propositions were put forward for an STO to develop its radical innovation. The propositions concerned the capabilities involved at each stage of the R&D department's radical innovation development cycle, as well as the contextual factors that played the most significant roles in affecting these capabilities at all of the radical innovation development stages. In addition to the eight theoretical propositions, practically, five guidelines were also proposed in this study, which contributes to the understanding of the R&D managers and strategy people of other Chinese and British STOs, in terms of the impacts that the contextual factor of cultural contexts would have on their radical innovation development activities.

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Chapter 1 Introduction

In a rapidly developing market environment, radical product innovation plays a significant role, since it can make dramatic changes to processes, products, or services in an existing or a new market, and has a close connection with technologies (Leifer et al. 2000). Although it has been said that "small entrepreneurial firms are the sources of most radical innovations while large companies have a tough time getting it done" (Leifer et al. 2000, p.1), as addressed by Christensen (referring to Bennett's interview to Christensen in 2014[2]) and Gilbert (2014), radical innovation is not about survivability of incumbents, but inspirations in the market. In the telecommunications industry, the large operators, recognised as the second type of telecommunications operators (STO) in this research (Li & Whalley 2002), have invested significant resources and capabilities in radical innovations. British Telecom's (BT) involvement in the Voice over IP (VoIP) service and its enormous investment in the Next Generation Network, and China Telecom's success with its 3G mobile brand 'e-surfing' are both examples of it. Among all the departments within an STO for the development of radical innovations, the R&D department plays an essential role, since it can transfer the knowledge into products, and it is the source of most internal innovations (Thamhain 2003).

According to previous research undertaken by the above-mentioned researchers, the aim of the current research is attempting to determine when the R&D department of an STO engaged in radical innovation, which capabilities it used,

[2] Source: http://www.bloomberg.com/bw/articles/2014-06-20/clayton-christensen-responds-to-new-yorker-takedown-of-disruptive-innovation

and how the use of these capabilities was affected by different contextual factors at each stage of the radical innovation development cycle. In some other research work[3], even though radical innovation development approaches and the R&D department's capabilities were considered, they were not specifically related to the telecommunications industry, and the contextual factors affecting the R&D department's radical innovations development capabilities were not focused on. Therefore, their usefulness for this PhD study has been limited.

1.1 Theoretical Perspective

Following the research aim as discussed above, the radical innovation development capabilities concentrated on in this research will be explored within the research conversations of the radical innovation development process, the R&D department's capabilities, and the category of radical innovations.

From the research conversation of radical innovation development processes, standing in the position of the R&D department, a conceptual framework as shown in Figure 1.1 is first developed in this research according to other pieces of research work (Tidd & Bessant 2009; Leifer et al. 2000; Dodgson et al. 2008; Davies & Hobday 2005; Prencipe et al. 2005; Crawford & Benedetto 2008; Bremser & Barsky 2004; Song 2012). Holding the assumption that when engaging a radical innovation, the R&D department of an STO would undertake all these innovation development activities, this conceptual framework will act as the construct for undertaking data collection and analysis work in this study.

[3] e.g.: Leifer et al. (2000), Tidd and Bessant (2009), Dodgson et al. (2008), Davies and Hobday (2005)

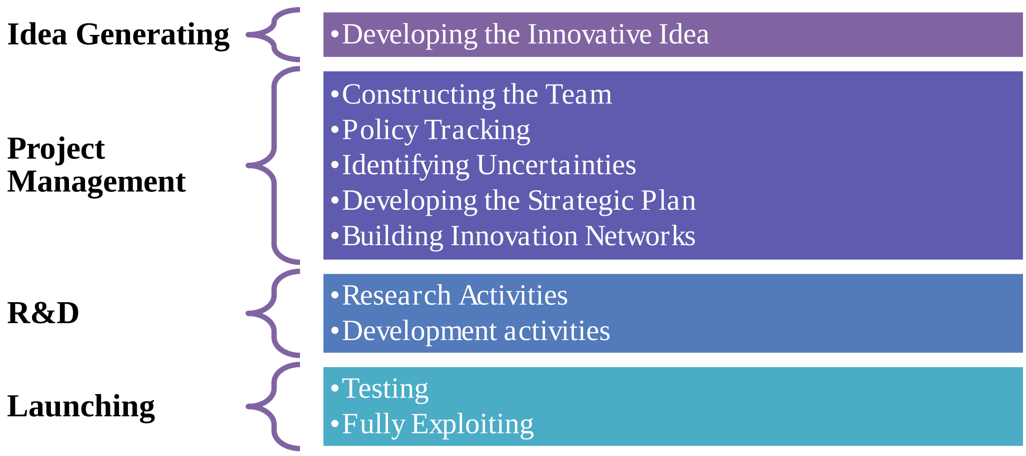

Figure 1.1: The Conceptual Framework for the R&D Department to Develop its Radical Innovation[4]

In the context of the R&D department's capabilities, referring to the literature, ten capabilities can be involved in the R&D department's radical innovation development cycle, as shown in Table 1.1. In this research, these capabilities play significant roles for the R&D department to develop its radical innovations.

Lastly, from the perspective of the categories of radical innovation, according to other researchers, the radical innovations in this study can be categorised using the criteria of project narrative (Green et al. 1995), source of innovation (Freeman & Soete 1997; Tidd & Bessant 2009), project complexity (Tatikonda & Rosenthal 2000), cultural contexts (Bourreau & Doğan 2001), technology content (Balachandra & Friar 1997; Tatikonda & Rosenthal 2000), and market concentration (Balachandra & Friar 1997), which can all be used to classify the radical innovations concentrated on in this research into different types and identify the contextual factors that can influence the R&D department's capabilities at different stages of the process.

[4] Source: Tidd and Bessant (2009); Leifer et al. (2000); Dodgson et al. (2008); Davies and Hobday (2005); Prencipe et al. (2005); Crawford and Benedetto (2008); Bremser and Barsky (2004), Song (2012)

Table 1.1: A Comprehensive Literature Review on the R&D Department's Capabilities for the Development of Radical Innovations

Capability	Supporting Literature
Creativity Capability	Mel Rhodes (1961), Godoe (2000), Lawson and Samson (2001), Alves et al. (2007), Azadegan et al. (2008), Zott and Amit (2008), De Rassenfosse and Van Pottelsberghe de la Potterie (2009)
Organisational Capability	Grant (1996), Lawson and Samson (2001), Slater et al. (2013)
Technology Capability	Montoya-Weiss and Calantone (1994), Gatignon and Xuereb (1997), Moorman and Slotegraaf (1999), Song et al. (2007)
Internal Collaborations Capability	Saghafi et al. (1990), Olson et al. (1995), Griffin and Hauser (1992), Brown and Svenson (1998), Bremser and Barsky (2004), Song et al. (2007)
Opportunities and Threats Sensing Capability	Teece (2000; 2007), Gilbert (2006), Schreyögg and Kliesch-Eberl (2007), Barreto (2009)
External Collaborations Capability	Saghafi et al. (1990), Tripsas (1997), Bremser and Barsky (2004), Feller et al. (2005), Walter et al. (2014)
Knowledge Identifying Capability	Cohen and Levinthal (1990), Tsai (2001), Zahra and George (2002), Lane et al. (2006), Fosfuri and Tribó (2009), Tidd and Bessant (2009)
Knowledge Learning Capability	Cohen and Levinthal (1990), Tsai (2001), Zahra and George (2002), Lane et al. (2006), Escribano et al. (2009), Fosfuri and Tribó (2009), Tidd and Bessant (2009)
Knowledge Reframing Capability	Cohen and Levinthal (1990), Zahra and George (2002)
Knowledge Transforming Capability	Cohen and Levinthal (1990), Zahra and George (2002)

1.2 Research Gaps

As discussed in the previous section, this study is positioned at the overlapping boundaries of three identified research conversations, which are the radical innovation development process, the R&D department's capabilities, and the categories of radical innovation. Despite these being areas where research has already been undertaken, comparing the research aim with the literature on the proposed research conversations, three research gaps were indicated in this PhD research.

Firstly, since this research concentrates on the radical innovations which are engaged in by STOs, the conceptual framework derived from other studies as shown in Figure 1.1 was not specific to the telecommunications industry.

Secondly, for the R&D department within an STO, the previous research work did not place any emphasis on capabilities in each activity of the radical innovation development cycle.

Lastly, in relation to the R&D department's capabilities on developing a radical innovation, the previous research work did not place any emphasis on how these capabilities were affected by the different contextual factors of radical innovations in the telecommunications industry.

1.3 Research Questions

To explore the R&D department's role in the radical innovation development cycle, this research is concerned with the capabilities that the R&D department of an STO uses in its radical innovation development process. Referring to other studies on the research conversations of the radical innovation development process and the R&D department's capabilities, this research raises the question of how to record the correct capabilities of different radical innovation development activities. This leads to the first research question:

- RQ1: What capabilities do the R&D department of an STO use for each separate activity during its radical innovation development process?

The second research question builds upon the first research question, to assess how the R&D department's capabilities can be affected by the contextual factors of different types of radical innovations. According to other researchers' work on the research conversation of the categories of radical innovations, the radical innovations in this research are recorded using six contextual factors, which lead to the second research question:

- RQ2: Within the radical innovation development process of an STO, which contextual factors explain the differential uses of the R&D department's capabilities?

1.4 Proposed Contributions

For presenting the research contributions of this PhD study, standing in the position of an R&D department, eight propositions are put forward for an STO to develop its radical innovation. The propositions concern the capabilities involved in each stage of the R&D department's radical innovation development cycle and the contextual factors that play the most significant roles in affecting these capabilities.

In addition to the eight theoretical propositions, practically, five guidelines are also proposed in this study, which contributes to the understanding of the R&D managers and strategy people of other Chinese and British STOs, in terms of the impacts that the contextual factor of cultural contexts would have on their radical innovation development activities.

1.5 Research Methodology

Using the philosophical views of interpretivism and social constructivism, this PhD study employs a qualitative research strategy and a case study research approach to guide the research design. In this PhD study, four cases selected from three case sites in both the UK and Chinese telecommunications industries are concentrated on, including the telematics service within China Mobile, the Xi-He system within China Telecom, and 21CN and BT Fusion within British Telecom (BT). For conducting the case studies, 29 interviews plus a three-month, full-time participant observation (PO) were undertaken at the selected telecommunications operators, the co-operators for the cases, and some related departments of the governments. The advantages for collecting data from different perspectives are two: firstly, it can enhance the creative potential of the research, since different perspectives can increase the opportunities to capitalise on any novel insights which are contained in the data; secondly, it can enhance confidence in the findings, since the integration of data from different perspectives can avoid the problem of biased data to a certain extent (Eisenhardt 1989).

Based on the case studies of the R&D departments' radical innovation development processes, the R&D departments' capabilities addressed in Table 1.1 are incorporated into each activity of the conceptual framework, and all the capabilities are marked from level zero to level three in each case, where the general measurement criteria can be discussed as follows:

- Level 0: The R&D department did not concentrate on the capability for developing its radical innovation.

- Level 1: The R&D department had some concentration on the capability but not much.
- Level 2: The R&D department concentrated on the capability but neglected a few significant perspectives.
- Level 3: The R&D department concentrated on the capability from all the significant perspectives.

By comparing the capabilities involved in each activity with the measurement criteria for the four cases, the reasons for the differences between the marking levels of the R&D departments' capabilities can be inferred from the six contextual factors on categorising radical innovations, which is helpful when aiming to discover which contextual factors played the more significant roles on affecting the R&D departments' capabilities in each stage of the radical innovation development cycle.

1.6 Format of the Thesis

The thesis is divided into seven subsequent chapters. Chapter 2 is a literature review that explores other researchers' work on the three research conversations involved in this research, including the radical innovation development process, the R&D department's capabilities, and the category of radical innovations. The literature review provides context and justification for finding the research gaps and posing the research questions. Chapter 3 outlines the research design and methodology, addressing the selection process for the cases, the data collection methods, and the data analysis approach, in detail. Specific attention is given to the measurement of the R&D department's capabilities, where each capability is measured on four levels in this research, from level 0 when the R&D department did not have any concentration on the capability, to level 3 when the R&D department concentrated on the capability from all the significant perspectives. Chapter 4 presents the data from the four exploratory case studies, providing details about the activities that the R&D departments undertook when developing the cases concentrated on, which are related to the contents developed in the conceptual model presented in Chapter 2.

Chapter 5 undertakes a comparison analysis across the four cases concentrated on. In this chapter, based on the conceptual model, the capabilities that the R&D departments used for each activity in their radical innovation development cycles are addressed and analysed with the capability measurement method identified previously, and the reasons for the differences between the R&D department's radical innovation development capabilities in each of the four cases are described in relation to the six contextual factors on categorising radical innovations. Chapter 6 reviews the findings of the previous data analysis chapter, and these are discussed in relation to each of the research questions in turn. The last chapter, Chapter 7, presents the key research findings of this research, which are eight theoretical propositions on identifying the R&D department's capabilities at each stage of the radical innovation development cycle, and the contextual factors that played the most significant roles in affecting these capabilities in all of the radical innovation development stages, before addressing practical implications, research limitations, further research areas, and summaries of the thesis.

Chapter 2 Literature Review

Chapter 1 briefly explained the research aim and the initial motivation, and outlined the primary objectives of this PhD research. In this chapter, the research background on the STO, the definition of radical product innovation, and the general roles of the R&D department are presented first, followed by a critical analysis of the three research conversations, which are the radical innovation development process, the R&D department's capabilities, and the contextual factors affecting the R&D department's radical innovation development capabilities, respectively. Comparing the aim of this PhD research with the literature on the proposed three research conversations, three research gaps are identified and two research questions are also raised in this chapter.

2.1 Research Background

2.1.1 Second Type of Telecommunications Operator (STO)

On reviewing the literature, during recent years, the global telecommunications market is "undergoing a radical transformation, creating exciting new opportunities and new challenges for infrastructure and service providers" (Li & Whalley 2002, p.451), which makes all telecommunications firms start to evaluate their strategies and their market positions, and reinvent their business models all at the same time (Johnson et al. 2008). Since the modern economy is characterised by greater trade liberalisation and increasing information needs, the telecommunications industry provides a way of achieving competitive advantages. As such, investments and reforms in the telecommunications market become a priority for many governments and international development agencies (Madden & Savage 1999).

The reforms of the telecommunications industry mentioned above can be embodied in the value chain. On the one hand, with powerful new players entering the market and radically restructuring the industry, the established value chains are gradually deconstructed; on the other hand, with multiple entry and exit interfaces, the value chains are rapidly evolving into value networks, which creates enormous complexity for all the players to be involved in (Li & Whalley 2002). According to Fransman (2001), in relation to the increasing structural complexity of the telecommunications industry, in particular with the advent of the Internet technologies, the structure of the telecommunications industry has been changed from three layers, the layers of equipment, network, and service, into six layers, which are the equipment and software layer, the network layer, the connectivity layer, the navigation and middleware layer, the applications layer, and the customers layer, respectively. In the global telecommunications industry, Ericsson, Alcatel-Lucent, Huawei, and ZTE are examples of the firms in the equipment and software layers; for the next four layers in the value chain, telecommunications operators, such as China Mobile and China Telecom in China, British Telecom, Vodafone and T-Mobile in Europe, and AT&T in North America, all aim to cover business in any of the layers. Take China Mobile for example: in their innovative 3G brand ‘G3’, in addition to basic mobile communications functions, the location-based service product ‘Qin Qing Tong’ for locating old people and children in the family, and ‘Mobile Market’, which is the platform for users to download mobile phone applications and games, are also part of their business.

According to Li and Whalley (2002), in the modern telecommunications industry, there are arguably three different types of service operators: the first type chooses to concentrate on just one particular part of the telecommunications industry and provides services to a limited part of the market; the second type provides services to a broad range of customer types in a multitude of markets. Resellers are the third type, who purchase certain capacities from the STOs, then repackage these capacities into business and sell them to customers. In this research, the three case sites concentrated on, China Telecom, China Mobile, and British Telecom, hold stable market shares in different industry segments and provide a variety of types of services to customers. Therefore, they can all be categorised as STOs, which will replace the concept of the large telecommunications operator in this PhD thesis.

Referring to Leifer et al.'s research work (2000), in the rapidly- developing telecommunications market, STOs can face significant challenges when engaging in radical product innovations, since innovations which are radical can bring dramatic changes in processes, products, or services in an existing or new market, and have a close connection with technologies. In addition, according to Thamhain (2003), among all the departments within an STO, the R&D department plays an essential role in the radical innovation development process, since it can transfer knowledge into products, and is the source of most internal innovations. Based on the statements above, it can be stated that for an STO, radical product innovation should be significantly emphasised within a group, and its R&D department's role in this process should be central.

2.1.2 The Definition of Radical Product Innovation

Schumpeter, who is called the "father" of innovation study (Godin 2008), defined innovation as "creative destruction", which can "incessantly revolutionise the economic structure from within, incessantly destroy the old one, incessantly creating a new one" (Schumpeter 1942, pp.82–83). In the short term, innovation can be defined as a source of economic changes (Schumpeter 1942) or a source of continuing business cycles (Schumpeter & Elliott 1982; Schumpeter 2006).

Innovation can be classified into five functions, which include the introduction of new goods, new methods of production, the opening of new markets, the conquest of new sources of supply, and the carrying out of a re-organisation of any industry (Schumpeter & Elliott 1982). According to Freeman and Soete (2009), another approach for classifying innovation is referring to its extent of radicalness. From this perspective, the process of technical change in the industry takes two main forms: radical innovations which increasingly originate in R&D labs, universities, companies, and government; and incremental innovations associated with an increasing scale of investment and learning from experience (Freeman & Soete 2009).

According to Barczak (1995), a continuous flow of product innovation becomes the lifeblood for companies to remain competitive in high-technology industries, such as telecommunications. Additionally, since the global telecommunications industry is positioned at a radical transforming stage (Li & Whalley 2002), referring to Godoe (2000), technological development in the telecommunications industry is based on a stream of innovations, especially radical ones. Therefore, based on the literature above, radical product innovation, which plays a significant role in the global telecommunications industry, becomes the focus of this study.

The definition of radical product innovation can be reviewed from two perspectives. The first perspective originates from disruptive innovation. According to other researchers (Tushman & Anderson 1986; Christensen 1997; Danneels 2004), disruptive innovation can bring a remarkably different value proposition to the market and can significantly challenge the market positions of established products. Based on this definition, Markides (2006) classified disruptive innovation into two types: business model innovation and radical product innovation. Compared to the business model innovation which redefines "what an existing product or service is and how it is provided to the customer" (Markides 2006, p.20), radical product innovation is defined as the disruptive innovation that "creates new-to-the-world products" (Markides 2006, p.22).

The second way of defining radical product innovation is from the perspective of radical innovation. Leifer and McDermott et al. (2000) defined radical innovation as a product, process, or service with any features which can offer potential for significant improvements in performance or cost. Similarly, Markides and Geroski's definition (2005) is that a radical innovation could give rise to new-to-the-world markets and can have a disruptive effect on both customers and producers. According to Schumpeter's theory (Schumpeter & Elliott 1982) on categorising innovation, radical product innovation could be defined as radical innovation which focuses on products, and is either non-existent or requires dramatic behaviour changes in existing markets (O'Connor & McDermott 2004).

Based on the above two ways of defining radical product innovation, and considering the specific features of the telecommunications industry, this research follows the definition of radical product innovation from the following two aspects: from the customer's aspect, a radical product innovation will fulfil the un-met communications needs of customers, whilst from the firm's aspect, a radical product innovation will provide new communicating functionalities to customers, replace existing products in the market, and significantly reduce the firm's cost-structure. In this research, except for in special circumstances, the two terms, 'radical product innovation', and 'radical innovation', are used interchangeably.

2.1.3 The Review of the R&D and the General Roles of an R&D Department

According to Ettlie (2000) and Bremser and Barsky (2004), innovation cannot exist as an isolated operation. All the capabilities, including marketing, R&D, and operations, must be integrated to satisfy customers. Among all these capabilities, the definition of industrial R&D was increasingly criticised as being too restrictive (Freeman & Soete 2009). From the definition, R&D is a prime source for the rejuvenation and growth of companies, and could be recognised as a core activity and starting point for innovation (Kratzer et al. 2006; Dodgson et al. 2008). Compared with incremental innovation, due to the high level of uncertainty in radical innovation, R&D plays a more prominent role (McDermott & O'Connor 2002), and from this perspective, the creation of radical innovation could be explained in terms of serendipity, chance or haphazard scientific discoveries (Godoe 2000).

Most firms have significant concentrations and heavy investments in their R&D activities, and the reasons emanate from four perspectives: firstly, firms' expectations of R&D are high (Dodgson et al. 2008); secondly, R&D activities play a dominant role in acquiring and sustaining the competitive advantage of firms (Kim et al. 1999); thirdly, R&D can transform new knowledge into a commercial outcome (Thamhain 2003; Hirst & Mann 2004); and finally, R&D activities are considered essential for efficient innovation and are often predominant in the diffusion of technical changes (Freeman & Soete 2009). In the telecommunications industry, empirical evidence suggests a systemic relationship between R&D and the emergence of radical product innovations, and the high R&D intensity of the telecom sector leads telecommunications operators to make significant investment in their R&D activities (Godoe 2000).

The management of R&D activities is essential, since the managerial leadership style has a significant impact on the creativity that ultimately affects radical product innovation performance (Thamhain 2003). According to Kratzer et al. (2006), R&D activity is typically executed in a project-management-like approach, which means that the management of R&D inherently stands for the management of teams. However, the R&D capabilities are different from the R&D teams' capabilities. According to Kerssens-van Drongelen and Bilderbeek (1999), the objective of R&D capabilities is to successfully initiate, coordinate and accomplish the technology process and product development activities of a firm. In this definition, it is supposed that R&D capabilities can be achieved without having an R&D team. However, it is usually found that, for most medium-sized and large firms, they do have their own R&D team to support their R&D capabilities. In this case, the objective of an R&D team can be defined as creating, sustaining, and exploiting the technological knowledge base needed by the company effectively and efficiently (Kerssens-van Drongelen & Bilderbeek 1999). Since this study concentrates on how the telecommunications firms create and develop their radical innovations, from this perspective, compared with the R&D capabilities, the R&D department's capabilities will be a better position from which to review the topic.

In the traditional view of the R&D department, their roles include researching, developing, testing, and reporting results (Brown & Svenson 1998; Kerssens-van Drongelen et al. 2000). However, the R&D department is involved in a wider range of activities. Based on the definition of radical product innovation, and referring to Dodgson et al. (2008), the current roles of the R&D department for developing radical innovation within the firm can be summed up as the following functions:

- Supporting existing radical innovation
- Establishing new radical innovation development
- Facilitating the radical innovation-related business diversification
- Helping predict future technological trends
- Complying with regulations and social and political expectations
- Participating in research networks
- Portraying a positive corporate image
- Creating future options through new knowledge and technology

2.1.4 Research Aim

Based on an overview of the current research in the relevant areas, this research is attempting to determine when the R&D department of an STO engaged in radical innovation, which capabilities they used and how the use of these capabilities can be affected by different contextual factors at each stage of the radical innovation development cycle. Within this research aim, three research conversations can be identified, including the radical innovation development process, the R&D department's capabilities, as well as the category of radical innovations. In the following part of this literature review chapter, these three research conversations are critically discussed based on other researchers' work.

2.2 Literature Review on the Three Research Conversations

2.2.1 Research Conversation on the R&D Department's Radical Innovation Development Process

According to Christensen's classic theory (1997) on how incumbents failed when engaged in radical innovations, it can be summarised that an established firm can face dilemmas from seven perspectives when developing its radical innovation, as follows:

> **Dilemma 1**: Market process is different from technology process, and the potential market for radical innovation could not be easily learned from the current needs of the customers.
>
> **Dilemma 2**: The resources required by radical innovations are different from the firm's existing projects.

Dilemma 3: Since radical innovations could create a new market, large firms may find that radical innovations are less relevant to the old customers who are the current main source of their profit.

Dilemma 4: Firms may find that the capabilities required by radical innovations are different from their existing ones.

Dilemma 5: Firms lack information for making investment decisions for radical innovations.

Dilemma 6: It is not wise to always be a leader or always a follower for radical innovations.

Dilemma 7: For radical innovation projects, small entrant firms enjoy protection since the things they have done are not sensed by the industry leaders.

In spite of the above seven dilemmas, as addressed in Christensen's later statements[5] and Gilbert's research work (2014), radical innovation is not about survivability of incumbents, but inspirations in the market. Therefore, radical innovations raised great interests in some research work of incumbents, and the development processes of them were specifically focused on from different perspectives.

From the organisational perspective, Leifer et al. (2000) divided the radical product innovation development process into three categories, including

[5] Source: Bennett's interview to Christensen in 2014, http://www.bloomberg.com/bw/articles/2014-06-20/clayton-christensen-responds-to-new-yorker-takedown-of-disruptive-innovation

generating the innovative ideas, managing radical innovative projects, and making the transition to operations, as shown in Figure 2.1:

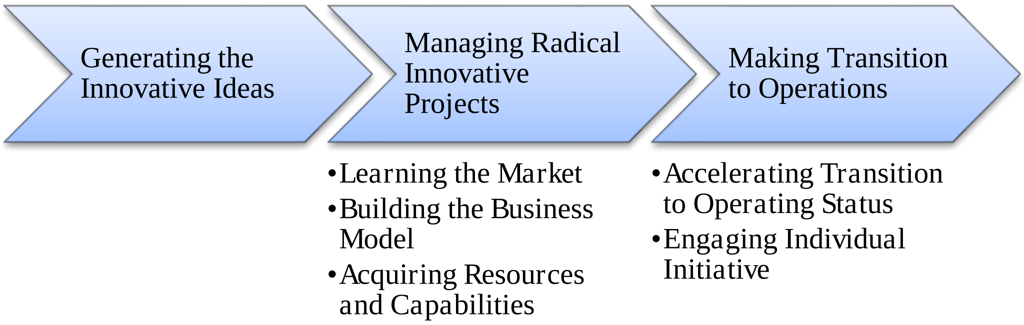

Figure 2.1: Radical Innovation Development Model 1 (Leifer et al. 2000)

Similarly, in Tidd and Bessant's (2009) research work, the radical innovation development process is divided into four stages. They are searching, selecting, implementing, and capturing, as shown in Figure 2.2:

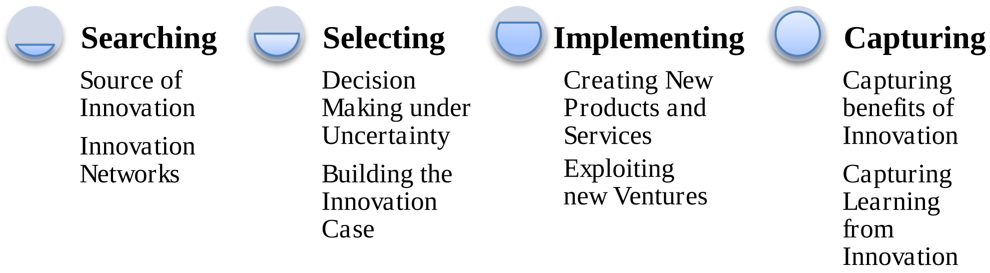

Figure 2.2: Radical Innovation Development Model 2 (Tidd & Bessant 2009)

From the same perspective, Dodgson et al. (2008) introduced their ten-stage model on the same topic. Differently from the above two approaches, they focused on the organisational willingness for developing radical innovation, the investment and reshaping of the firms, and awareness of the customers' behaviour. In addition, after categorising radical innovations in the increasingly competitive and global business environment (e.g. telecommunications industry) into CoPS

(Complex Products and Systems) from the organisational perspective, firms are advised to use project-based management approaches to create competitive advantage, enable organisation transformation and build entirely new markets (Davies & Hobday 2005), and to undertake system integrations to join different types of knowledge, skills, activities, and capabilities to produce new products (Prencipe et al. 2005). Additionally, in McDermott and O'Connor's (2002) research work, they also emphasised the importance of dealing with people issues in the radical product innovation development process.

From the position of product manager, Crawford and Benedetto (2008) proposed five phases for the development process, which are: opportunity identification and selection, concept generation, concept/project evaluation, development, and finally, launch. With a similar perspective, separately from Crawford and Bendetto's proposal, Bremser and Barsky (2004) addressed the activities of developing the business model, testing the products, and undertaking the continuous development of the products, in their research work.

Finally, from the position of a marketing director, Song (2012) divided the radical innovation development process into seven stages which were: policy studying, market learning, product positioning, business model building, allocating the work to individuals, exploiting the innovation in testing cities, and fully exploiting. By comparison with other researchers, the policy studying activity, which was considered to be vital to develop radical innovations in some developing countries, was a particular focus.

Regarding the general roles of the R&D department, a literature review on the above radical innovation development processes can be helpful to develop a conceptual framework which consists of ten activities that the R&D department needs to undertake for developing its radical innovations. As shown in Figure 2.3, the activities involved in the conceptual framework are listed in four stages, which are: idea generating, project management, R&D, and launching. Holding the assumption that when engaging a radical innovation, the R&D department of an STO would undertake all these innovation development activities, this conceptual framework will act as the constructs for undertaking data collection and analysis work in a later part of this research.

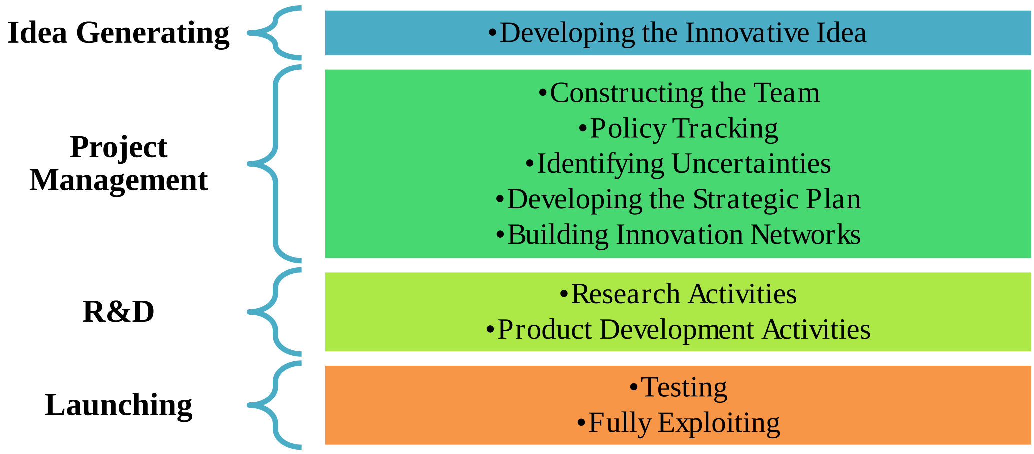

Figure 2.3: The Conceptual Framework for the R&D Department to Develop its Radical Innovation[6]

2.2.2 Research Conversation on the R&D Department's Capabilities

In the review of the literature, the R&D department's capability to develop a radical innovation can be assessed from three perspectives, which are: the resource-based view, the dynamic capabilities, as well as the absorptive capacity.

[6] Source: Tidd and Bessant (2009); Leifer et al. (2000); Dodgson et al. (2008); Davies and Hobday (2005); Prencipe et al. (2005); Crawford and Benedetto (2008); Bremser and Barsky (2004), Song (2012)

2.2.2.1 The Resource-Based View

The resource-based view (RBV) is a fundamental theoretical framework for a firm to understand how to achieve competitive advantage in a market and how to sustain these strengths (Eisenhardt & Martin 2000). According to Baker and Sinkula (2005), a firm's resources and capabilities can be distinguished with the help of RBV, where the resources can be recognised as the "stocks of available factors that are owned or controlled by the firm", whilst capabilities refers to the capacity for deploying the resources (Amit & Schoemaker 1993, p.35).

Based on the above definition of the RBV, Miles et al. (1978) divided a firm's strategy on new products into four categories, including prospectors, reactors, analysers and defenders. Among these four strategies, the prospector is the one who leads changes in the industry, and can be understood as embodying a firm's strategic attitude on radical innovation. Referring to Song et al.'s research work (2007) and the general roles of the R&D department, three capabilities can be involved in an R&D department's strategy on developing a radical innovation, which are: the technology capability, the internal collaborations capability, and the external collaborations capability.

In terms of the R&D department's technology capability, according to Moorman and Slotegraaf (1999), it not only relates to the R&D department's activities on formulating and developing new products, but also involves technical considerations in related activities of the new product development cycle. Based on the conceptual framework developed in Figure 2.3, as indicated by other researchers, the technology capability can be utilised by the R&D department for their activities of idea generating (Gatignon & Xuereb 1997), uncertainties identifying (Song et al. 2007), strategic plan developing (Montoya-Weiss & Calantone 1994), and innovation networks building (Song et al. 2007) in the idea generating and project management stages, as well as for activities on researching, product development, testing, and fully exploiting (Song et al. 2007) in the R&D and launching stages.

For the R&D department's internal collaborations capability on developing a new product, according to Song et al. (2007), this facilitates the R&D department's internal communications and cross-functional integrations within the firm, and moreover, it can have a positive impact on the success of new products (Griffin & Hauser 1992). On reviewing other researchers' work, when developing a radical innovation, the internal collaborations capability is mainly used by the R&D department in the R&D stage when integrating its work with marketing and senior management members of the group (Saghafi et al. 1990; Olson et al. 1995; Bremser & Barsky 2004).

For the external collaborations capability, as discussed by other researchers, collaborating with partners can help the R&D department gain great learning opportunities, access rare resources (Feller et al. 2005; Walter et al. 2014), integrate with external marketing people (Saghafi et al. 1990), build the innovation network (Tripsas 1997), develop the strategic plan (Bremser & Barsky 2004), and transfer technology into products (Tripsas 1997), which are all consistent with most of the radical innovation development activities as indicated in the conceptual framework.

2.2.2.2 Dynamic Capabilities

The RBV explains the conditions for firms to achieve a sustained competitive advantage based on their bundles of resources and capabilities. However, the RBV is considered to be essentially static in its nature and inadequate to explain a firm's competitive advantage in changing environments. Therefore, Teece and Pisano (1994) proposed the concept of dynamic capabilities to fill this gap. According to other researchers (Zahra et al. 2006; Zollo & Winter 2002), dynamic capabilities have a more significant role in a rapidly changing environment such as the telecommunications industry, and when compared with the RBV, some new R&D department capabilities can be considered in relation to dynamic capabilities, when developing radical innovations.

Teece et al. (1997) defined dynamic capabilities as the abilities that help the firm integrate, build, and reconfigure its internal and external capabilities for addressing rapidly changing environments. Similarly, Eisenhardt and Martin (2000) defined dynamic capabilities as the firm's processes for matching and creating market changes, using its resources and capabilities, as well as routines for achieving new resources configurations. Moreover, Zollo and Winter (2002, p.340) asserted that "a dynamic capability is a learned and stable pattern of collective activity through which the organisation systemically generates and modifies its operating routines in pursuit of improved effectiveness".

Drawing on the above definitions from other researchers, except for the three capabilities derived from the RBV, three new R&D department capabilities can be considered from the perspective of dynamic capabilities, including creativity capability (Azadegan et al. 2008), organisational capability (Lawson & Samson

2001; Slater et al. 2013), in addition to opportunities and threats sensing capability (Barreto 2009).

The R&D department's creativity capability, according to Rhodes (1961), can represent the R&D department's process for generating new ideas. Referring to other researchers, creativity capability is usually utilised by the R&D department from three perspectives, including: (a) getting innovative ideas on new products (Rhodes 1961; Godoe 2000; Alves et al. 2007; Azadegan et al. 2008); (b) designing a new product-developing strategy (Lawson & Samson 2001; Zott & Amit 2008); as well as (c) generating ideas on patents and applications of new products (Alves et al. 2007; de Rassenfosse & van Pottelsberghe de la Potterie 2009), which correspond to the R&D department's innovative idea generating activities, strategic plan development activities, research activities, and product development activities, as indicated in the conceptual framework.

Other researchers have noted that organisational capability has a direct impact on the R&D department's radical innovation development process (Slater et al. 2013), and it can help the R&D department manage its human resources, transfer knowledge into new products, and undertake R&D product and process development for developing its radical innovation (Grant 1996; Lawson & Samson 2001). Therefore, referring to the conceptual framework, it can be concluded that when developing a radical innovation, organisational capability can mainly be addressed by the R&D department for its team construction activities, research activities and product development activities.

For achieving competitive advantages (Teece 2000; Teece 2007; Barreto 2009), the opportunities and threats sensing capability is recognised as one key element of dynamic capabilities (Gilbert 2006), and it should incorporate a continuously scanning function on industry changes (Schreyögg & Kliesch-Eberl 2007). According to Gilbert (2006) and Teece (2007) and based on the conceptual framework, the opportunities and threats sensing capability can be utilised by the R&D department in its activities of idea generating, policy tracking, uncertainties identifying, strategic plan developing, and product development, during its radical innovation development cycle.

2.2.2.3 Absorptive Capacity

From the perspective of adopting external knowledge, absorptive capacity can also be helpful in understanding the R&D department's capabilities for new product development. According to some researchers (Cohen & Levinthal 1990; Zahra & George 2002; Mowery & Oxley 1995), absorptive capacity is the dynamic capability to create, utilise, value, assimilate, transfer, and even modify external knowledge so as to gain and sustain competitive advantages. It has been suggested that the R&D department can have a direct impact on a firm's absorptive capacity from two perspectives. Firstly, the R&D department not only generates new knowledge, but also contributes to the firm's absorptive capacity. Secondly, the R&D department's incentives to build absorptive capacity can also have an impact on its R&D spending (Cohen & Levinthal 1990).

Referring to Zahra and George's research work (2002), four capabilities can be involved in an R&D department's absorptive capacity, including knowledge identifying capability, knowledge learning capability, knowledge reframing capability, as well as knowledge transferring capability, and these four capabilities are also helpful in understanding the R&D department's role in radical innovation development processes, which are concentrated on in this research.

Knowledge identifying capability refers to the R&D department's capability of identifying and selecting external knowledge for adopting (Zahra & George 2002), and this external knowledge is not only from the perspective of technology, but also from the perspective of marketing and regulations. In a review of the literature, an R&D department's knowledge identifying capability can be involved in six activities of the conceptual framework, which are: idea generating activities (Cohen & Levinthal 1990; Escribano et al. 2009), industrial policy-learning activities (Cohen & Levinthal 1990; Lane et al. 2006), technological opportunities and challenges identifying activities (Tidd & Bessant 2009), strategic resources-assessing activities (Tsai 2001), as well as research and product development activities (Cohen & Levinthal 1990; Lane et al. 2006; Tidd & Bessant 2009). Based on externally-generated knowledge identified through the knowledge identifying capability, the knowledge learning capability can be utilised by the R&D department for analysing, processing, interpreting, and understanding the above knowledge (Zahra & George 2002). Therefore, it can be said that the R&D department needs to adapt its knowledge learning capability for all radical innovation activities which involve its knowledge identifying capability.

Finally, in relation to the knowledge reframing capability and the knowledge transferring capability, these can help the R&D department combine existing knowledge and newly-identified and learned knowledge, and build external knowledge into its operations (Zahra & George 2002). Referring to Zahra and George's research work (2002), these two capabilities are more likely to be utilised by the R&D department in its R&D stage, as indicated in the conceptual framework.

2.2.3 Contextual Factors Affecting the R&D Department's Radical Innovation Development Capabilities

In reviewing the literature, the contextual factors that have an impact on the R&D department's radical innovation development capabilities can be discussed mainly from the perspective of the categories of radical innovation, as discussed below:

Firstly, from the perspective of project narrative, radical product innovation can be categorised based on whether it is only radical to the firm itself, or radical to the global industry. For product innovation that is only radical to the firm, it is proposed that due to lack of experience, a firm usually needs to undertake new practices and incorporate new kinds of knowledge, new skills, and even new manufacturing technologies for developing it (Tyre & Hauptman 1992; Souder 1987). Moreover, for this kind of radical product innovation, there can be a gap between the firm's existing knowledge and the knowledge that the firm needs to develop. Therefore, some types of technological knowledge must be brought into the firm, and it has been said that "the more an innovation relies on technology where the firm has technical inexperience, the more it might be regarded as a radical innovation for that firm" (Green et al. 1995, p.204). In comparison, for product innovation that is radical to the global industry, since the new technological knowledge for developing this type of innovation may not exist anywhere else, the innovation is likely to be unpredictable, complex, and difficult to understand (Tyre & Hauptman 1992). Therefore, it is suggested that when developing this kind of innovation, the firm can face greater technological uncertainty, and there can be increasing demands for information and communications from the firm (Allen & Hauptman 1987). It has been said that "the more an innovation undertaking relies on technology that is not well understood or that is rapidly developing in the general scientific community, the more it might be regarded as a radical innovation" (Green et al. 1995, p.204).

The second contextual factor affecting the R&D department's radical innovation development capabilities is the source of innovation. According to Tidd and Bessant (2009), innovation source can be analysed from two perspectives, which are the perspective of knowledge push or need pull, and the perspective of internal or external source. From the perspective of knowledge push or need pull, according to Freeman and Soete (1997), knowledge push innovation usually involves technical knowledge gained as a result of original research activity, whilst need pull innovation originates from internal or external needs for a new product or process. From the perspective of internal or external source, it is specified that compared with internal source innovation, when the idea of innovation is from an external source, external knowledge of similar products in the industry, regulations and user behaviour need to be identified by the R&D department (Tidd & Bessant 2009). Referring to the research (Leifer et al. 2000; Tidd & Bessant 2009), it can be stated that during the idea-generating stage and the project-management stage of the radical innovation development cycle, as addressed in the conceptual framework, the contextual factor of source of innovation is more critical for a large company to generate and search for its innovative ideas.

Thirdly, the contextual factor of project complexity can divide radical innovations into highly complex innovation, moderately complex innovation, and low complex innovation. According to Tatikonda and Rosenthal (2000), the interactions among different sub-tasks of a radical innovation can be recognised as significant criteria for identifying the contextual factor of project complexity, where the R&D department's internal collaborations capability for developing its radical innovation can be assessed. Moreover, referring to Leifer et al.'s (2000) and Tidd and Bessant's (2009) research work, it has been proposed that the contextual factor of project complexity can have a greater impact on the R&D department's activities in the project management stage and in the launching stage within the conceptual framework for the development of its radical innovation.

The fourth contextual factor that has an impact on the R&D department's radical innovation development capabilities is cultural contexts. In the review of the literature, cultural contexts can be considered from two aspects: competition in the market (Bourreau & Doğan 2001; Lu & Wong 2003) and regulatory interventions in the industry (Bourreau & Doğan 2001). Since the Chinese and British telecommunications industries are the main focus of this research, in relation to the contextual factor of cultural contexts, it is possible to divide the radical innovations considered into innovation in the Chinese telecommunications industry, where competition is relatively lower, and the regulator mainly plays an ex-post regulatory interventions role (Bourreau & Doğan 2001), and innovation in the UK telecommunications industry, where competition is extremely high (Cave & Williamson 1996) and the regulator usually plays an ex-ante regulatory interventions role (Bourreau & Doğan 2001). According to other researchers, the contextual factor of cultural contexts can affect the R&D department's opportunities and threats sensing capability (Hofstede 1984; Hofstede 2001; Bourreau & Doğan 2001; Wan et al. 2014), external collaborations capability

(Ettlie 2000; de Man & Duysters 2005; Bourreau & Doğan 2001; Ganotakis & Love 2012), technology capability (Riordan 1992; Lal et al. 2004), organisational capability (Bourreau & Doğan 2001; Garrett et al. 2006), knowledge identifying capability, and knowledge learning capability (Bourreau & Doğan 2001; Ganotakis & Love 2012) for developing radical innovation. Moreover, it has been proposed that during the radical innovation development cycle, the factor of cultural contexts could have a greater impact on the R&D department's capabilities in the project management stage and the R&D stage within the conceptual framework (Ettlie 2000).

Fifthly, for the contextual factor of technology content, which relates to the novelty of the technologies employed in the product development effort (Tatikonda & Rosenthal 2000), radical innovations can be divided into innovation with high technology content, and innovation where the technology content is relatively lower. Balachandra and Friar (1997) state that for radical innovation with high technology content, the R&D department's capabilities related to technologies are more critical, whilst for innovation with low technology content, the R&D department has to refer to existing standards and practices in the industry, and develop products using its own strengths. In addition, it has been suggested that compared with other factors, the contextual factor of technology content can have a greater impact on the R&D department's capabilities in the R&D stage within the conceptual framework of the development of its radical innovation (Balachandra & Friar 1997; Tidd & Bessant 2009).

The last contextual factor affecting the R&D department's radical innovation development capabilities is market concentration, which can be defined as the nature of the market that a radical innovation is entering (Balachandra & Friar

1997). From this perspective, radical innovations can be divided into innovation facing an existing market of mature products and innovation facing a completely new market. Maidique and Zirger (1985) address this issue and claim that the factor of market concentration can affect the R&D department's strategic plan-development activities at the product management stage, where the strategic plan in an existing market can be derived from passive understanding of existing products and user needs, but in a new market, the strategic plan should come from proactive approaches. Moreover, it is also proposed that the factor of market concentration can have a greater impact on the R&D department's radical innovation development activities in its R&D stage of the conceptual framework (Tidd & Bessant 2009).

Based on the discussions above, the contextual factors to be addressed in this study and their distinctions of radical innovations are shown in Table 2.1 below:

Table 2.1 The Contextual Factors to be Addressed and Their Distinctions of Radical Innovations

Contextual Factor	Distinctions of Radical Innovations
Project Narrative	• Innovation Radical to the Firm Itself • Innovation Radical to the Global Industry
Source of Innovation	• Knowledge Push Innovation • Need Pull Innovation • Internal Source Innovation • External Source Innovation
Project Complexity	• Highly Complex Innovation • Moderately Complex Innovation • Low Complex Innovation
Cultural Contexts	• Innovation in the Chinese Telecommunications Industry • Innovation in the British Telecommunications Industry
Technology Content	• Innovation with High Technology Content • Innovation where the Technology Content is Relatively Lower
Market Concentration	• Innovation Facing an Existing Market of Mature Products • Innovation Facing a Completely New Market

2.3 Research Gaps

As indicated in the previous sections, the current research is attempting to determine, when the R&D department of an STO engaged in radical innovation, which capabilities they used and how the use of these capabilities can be affected by different contextual factors at each stage of the radical innovation development cycle. This research is positioned at the overlapping boundaries of the research conversations of a radical innovation development process, the R&D department's capabilities, and the categories of radical innovation. Despite the fact that all of these three research conversations are well-researched by other researchers, as discussed in Section 2.2, comparing them with the research aim, three research gaps have been identified in this PhD research.

Firstly, although this research concentrates on the radical innovations which are engaged in by an STO, the conceptual framework derived from other research work shown in Figure 2.3 was not specifically into the telecommunications industry.

Secondly, for the R&D department within an STO, previous research work did not emphasise its capabilities within each activity of the radical innovation development cycle.

Finally, in relation to the R&D department's capabilities for developing radical innovations, previous research work did not emphasise how these capabilities were affected by the different contextual factors of radical innovation in the telecommunications industry.

2.4 Research Questions

After assessing the research gaps between the aim of the current study and the other researchers' work, two research questions have been formulated about how to bridge these research gaps, as discussed below:

Firstly, for exploring the R&D department's role in the radical innovation development cycle, this research concerns the capabilities that the R&D department of an STO uses in its radical innovation development process. Referring to other studies on the research conversations of the radical innovation development process and the R&D department's capabilities, this research raises the first question on how to divide the correct capabilities into different radical innovation development activities:

- RQ1: What capabilities do the R&D department of an STO use for each separate activity during its radical innovation development process?

The second research question builds upon the first research question, to assess how an R&D department's capabilities can be affected by the contextual factors of different types of radical innovation. Having reviewed the literature within the research conversation related to the categories of radical innovation, the radical innovations in this research are considered in relation to six contextual factors, leading to the second research question:

- RQ2: Within the radical innovation development process of an STO, which contextual factors explain the differential uses of the R&D department's capabilities?

2.5 Summary

This chapter presented the background to the current research and critically reviewed the literature on the three research conversations, which are the radical innovation development process, the R&D department's capabilities, and the contextual factors affecting the R&D department's radical innovation development capabilities. After comparing the research aim of this thesis with existing findings from other researchers, three research gaps have been identified and two research questions were raised in this chapter. Chapter 3 will present the research design for undertaking the current PhD study from specific philosophical and methodological perspectives, and it will also outline the research method and the data collection approach for answering the research questions.

Chapter 3 Research Design

3.1 Introduction

Chapter 2 critically reviewed the literature of the current research into radical innovation, and the literature on the three research conversations. Comparing the research aim with the existing findings of other researchers, three research gaps were identified and two research questions were raised. In order to answer the research questions stated at the end of Chapter 2, this chapter outlines and addresses the research design considerations that are vital when carrying out empirical research.

Research design is not simply a work plan, it is the blueprint for research, and can help researchers to avoid situations in which the empirical data do not address the research questions (Yin 2009). Previous researchers put significant emphasis on the importance of research design and propose ideas about how to design research, in particular Denzin and Lincoln (2011), before the researcher goes on to consider the design of any research work. There can be five elements for researchers to consider: research philosophy, research methodology, research target, research strategy, as well as data collection methods. In Crotty's research work (1998), he listed four components when developing a research proposal. They are: research method, research methodology, the ontological perspective of research, and the researcher's epistemological position. Based on Crotty's ideas, Creswell (2008) integrated the ontological and epistemological views of research into research philosophy, and identified three aspects central to the design of research: research philosophy, research strategy, and research method.

Based on previous researchers' guidelines, Chapter 3 discusses the research design of this study from two perspectives: research design, which includes research strategy and research philosophy, and research methodology, addressing research approach and research method.

3.2 Research Design

3.2.1 Research Philosophy

Although the philosophical ideas are usually hidden in the research, they need to be identified, since they can influence the practice of research (Williams & Slife 1995). According to other researchers, research philosophy relates to the development and the nature of knowledge (Saunders et al. 2007), and can reflect the researcher's philosophical worldview (Creswell 2008). These worldviews can underpin different research designs and methodologies in different pieces of research work (Saunders et al. 2007).

Based on the definition of research philosophy, the development and the nature of knowledge could be understood from two different philosophical perspectives: epistemology and ontology (Benton & Craib 2001), which are recognised as two foundational elements in social science research study (Saunders et al. 2007). From the philosophical perspective, in this research, the interpretivist epistemology and the social constructionist ontology are core to the design and strategies of this study.

An epistemological issue concerns the question of what should be regarded as acceptable knowledge in a discipline (Bryman 2012). From the epistemological view, different from positivists who hold the view that "only phenomena that can be observed will lead to the production of credible data" (Saunders et al. 2007, p.113), in this study, due to the research target of the R&D department being constituted by staff with different roles, this study holds the worldview of interpretivism, which will emphasise the differences between humans in their roles as social actors (Saunders et al. 2007). According to Crotty (1998, p.67), contrary to positivism, the interpretivist approach will "look for culturally derived and historically situated interpretations of the social life-world", where the compulsory considerations for understanding the role of the R&D department and the radical innovation development process in this research is an example of this epistemological approach.

On the other hand, ontology, which concerns the nature of social entities, has two different positions: objectivism and social constructionism (Saunders et al. 2007). Objectivists hold the view that social entities exist in the reality external to social actors; whilst social constructionism holds the position that social phenomena are created from the perceptions and consequent actions of social actors (Saunders et al. 2007; Bryman 2012). This study holds the ontological view of social constructionism, due to the essence of this research, where it is believed that the entire radical product innovation development process is constructed by the generating of innovative ideas and capabilities of the staff from the R&D department. According to Crotty (1998, p.42), in social constructionism, "all knowledge, and therefore all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context". Therefore, linking social entities and human beings, this research reviews radical innovation development activities from the perspective of the R&D department's capabilities.

3.2.2 Quantitative versus Qualitative Research

The above ontological and epistemological issues have raised methodological concerns in this study, and the initial concern was whether to choose a quantitative or qualitative approach in this research. Different from quantitative research, where reality exists independent of human perception, qualitative research, from an ontological view, can incorporate multiple realities or multiple truths referred to one's construction of reality, and acknowledges that reality is socially constructed and is constantly changing. On an epistemological level, there is no access to reality independent of the mind, and no external referent through which to compare claims of truth in qualitative research (Sale et al. 2002).

Referring to the real-life setting of the current research, relationships between different stages in the radical product innovation development process are less emphasised (Bryman 2012). The innovation development process is difficult to measure with numerical data (Creswell 2008). Therefore, for the current research a qualitative set of methodological approaches was selected, including face-to-face interviews, as well as participant observations, in order to collect data for answering the research questions in this study.

According to Flick (2002), qualitative research methods are focused on the relations between social entities, "owing to the fact of the pluralisation of life worlds" (p.12). Quantitative research is a deductive process which concentrates on making a hypothesis and developing measurements to test the hypothesis empirically (Singh 2007). The differences between qualitative research and quantitative research are listed in Table 3.1.

Table 3.1: The Comparisons between Quantitative Methodology and Qualitative Methodology (Sarantakos 2005, p.47)

Feature	Quantitative Methodology	Qualitative Methodology
Nature of Reality	Objective; simple; single; tangible sense impressions	Subjective; problematic; holistic; a social construct
Causes and Effects	Nomological thinking; cause-effect linkages	Non-deterministic; mutual shaping; no cause-effect linkages
The Role of Values	Value-neutral; value-free inquiry	Normativism; value-bound inquiry
Natural and Social Sciences	Deductive; model of natural sciences; nomothetic; based on strict rules	Inductive; rejection of the natural sciences model; ideographic; no strict rules: interpretations
Methods	Quantitative, mathematical; extensive use of statistics	Qualitative, with less emphasis on statistics, verbal and qualitative analysis
Researcher's Role	Passive, distant from the subject: dualism	Active; equal; both parties are interactive and inseparable
Generalisations	Inductive generalisations; nomothetic statements	Analytic or conceptual generalisations; time-and-context specific

As mentioned above, this study adopts a qualitative approach to guide the research process. The reasons for this are based on three perspectives:

From the philosophical consideration, holding the world-views of interpretivism from the epistemological perspective, and social constructionism from the ontological perspective, this study can be recognised as qualitative research. Quantitative researchers usually base their work on positivist and objectivist criteria.

Considering the research aim, qualitative research is often used for exploring the constructing processes of social situations, guiding and explaining the researchers' views and opinions (Sarantakos 2005) on matters such as the radical product innovation development process in this study. However, a quantitative approach is usually used for testing the relationship between each of the constructs and the correlations among them with a large amount of numerical data.

From the data consideration, since this research concentrates on the radical product innovation development process within an R&D department, qualitative research methods can help get closer to the R&D staff's perspectives through interviews and observations; when using quantitative research, researchers are "*seldom able to capture the subjects' perspectives because they have to rely on* more remote, inferential empirical methods and materials" (Denzin & Lincoln 2011, p.9).

3.2.3 Case Study Research Design

Following a qualitative research strategy, building theory from case studies will be the main research approach in the current research. Differently from other qualitative research approaches, the case study focuses on understanding the dynamics present within single settings (Eisenhardt 1989), and will significantly emphasise the implementation of this new approach (Yin 2003).

In the current research, the reasons for choosing case study design are based on the theory-driven research questions, which are attempting to yield theories which are not concentrated on by other researchers in depth (Eisenhardt & Graebner 2007; Denzin & Lincoln 2011). Moreover, this research is generating theory from an external perspective on the STO, and for most of time, the study cannot have control of any behavioural events (Yin 2009). All of the above considerations have led the utilisation of case study research as the research design in this study. Other research approaches for building theories, such as experiment and some statistical methods could also answer similar research questions posed by this PhD research. However, experiment needs the researcher to be a participant (Yin 2009); and statistical methods can answer a research question in breadth but not in depth; it very much relies on numeric data but not qualitative data (Denzin & Lincoln 2011). Accordingly, theory-building from a case study approach is appropriate research for this study.

From the review of the literature, the advantages for undertaking case study research design lie in the following perspectives: firstly, since case study attempts to reconcile "the empirical evidence across cases, type of data, and different investigators, and between cases and literature increase the likelihood of creative reframing into a new theoretical vision", theory building from cases can generate novel theories (Eisenhardt 1989); secondly, since case study is tied into evidence, and the resultant theories should be consistent with empirical observations, the theories generated from case study research are empirically valid, accurate, and engaging (Eisenhardt 1989; Blaxter et al. 2006; Eisenhardt & Graebner 2007); finally, referring to the constructs built before the data analysis, an emergent theory can be tested and can even be proven false (Eisenhardt 1989; Eisenhardt & Graebner 2007).

Besides their strengths, scholars also outline some of the weaknesses of case studies. According to Eisenhardt (1989), in case study research, from a data perspective, the intensive use of empirical evidence could make theory too complex. Moreover, from a methodological perspective, since case studies rely heavily on the interviewees' experience and the researcher's personal opinions, theory building from case studies can be narrow, biased, and idiosyncratic (Eisenhardt 1989). Additionally, from the perspective of research outcomes, the significance of a research result is often unknown or unclear (Denzin & Lincoln 2011).

Among all the different types of case study research, multiple case studies are chosen as the main research design in the current study. According to Eisenhardt (1989), the concept of the population of cases is crucial, since it can define the set of entities and the research sample. Differently from a single case study, which typically exploits opportunities to explore a significant phenomenon under rare or extreme circumstances, multiple cases can richly describe the existence of a phenomenon, and typically provide a stronger base for theory building (Eisenhardt & Graebner 2007). According to Yin (2009), multiple case studies can be treated as a series of experiments, each case serving to confirm or deny the inferences drawn from previous ones. The reasons for using multiple case studies in this research are: the analytic benefits from having two (or more) cases is more substantial; the evidence coming from multiple cases is more powerful than using a single case; and a multiple-case study design can expand the external generalisability of what the researchers have found (Yin 2009). The process of multiple case study designs is shown in Figure 3.1:

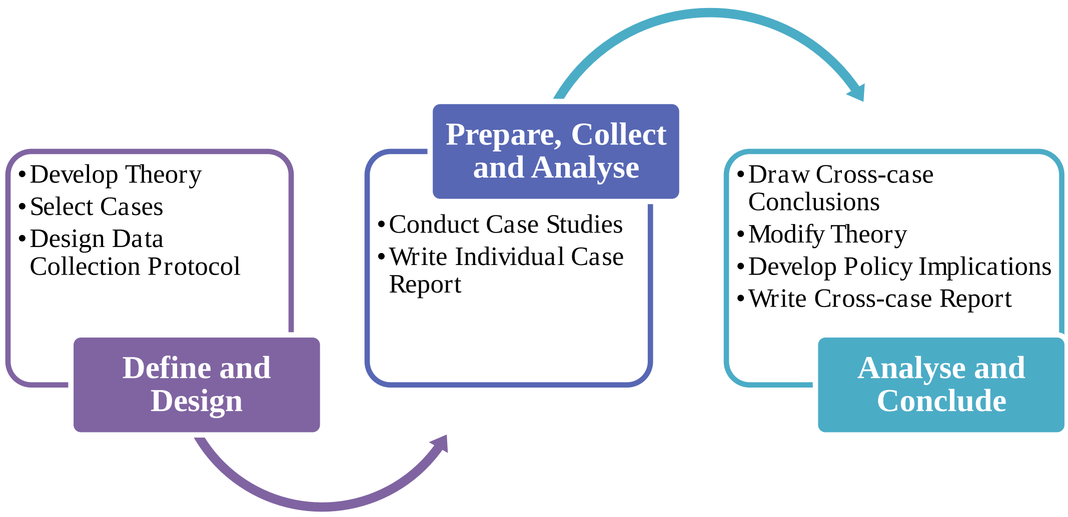

Figure 3.1: Multiple-case Study Design (Yin 2009, p.57)

In the next section, the case study protocol of this research will be reviewed, based on Yin's multiple-case study design approach (2009).

3.3 Case Study Protocol

According to Yin (2009), when designing case study research, five components are significantly notable, including a study's question, propositions, the unit(s) of analysis, the logic linking data to propositions, and the criteria for interpreting findings. Based on these five components, there can be four stages in the case study process. They are conducting constructs, identifying cases, data collection, and data analysis (Eisenhardt 1989; Eisenhardt & Graebner 2007; Yin 2009). In this section, these four stages will be followed to expand on the research design in this research work.

3.3.1 Conducting Constructs

According to Eisenhardt (1989), in the case study design process, a research question and some potentially relevant variables should be formulated with some references to the extant literature at the beginning of the case study, but these variables should not have any specific relationship with the theories. Following Esienhardt's approach, in Chapter 2, based on the research aim and other researchers' work, one conceptual framework, ten R&D department's capabilities, and six contextual factors were used as the constructs for the proposed contributions of this PhD study. These constructs are helpful to shape the initial design of the current research, and they can also be further developed via the four case studies. If these constructs prove indispensable as the study progresses, then this research will have a firmer empirical grounding for emergent theory (Eisenhardt 1989).

3.3.2 Identifying Cases

Before identifying the cases to be studied, the case sites to be researched were considered first. Since the research objects of this study are STOs in both China and the UK, the telecommunications industries in these two countries were scoped to find typical firms.

Table 3.2: Characteristics of the Example Telecommunications Firms in China and the UK[7]

Country	Firms	Reason for Selecting as Potential Research Target
China	**China Telecom**	China Telecom is an integrated information full-services operator and the world's largest wireline telecommunications, CDMA mobile network and broadband Internet services provider, providing basic telecommunications services such as wireline telecommunications services and mobile telecommunications services, and value-added telecommunications services such as Internet access services and information services in China.
	China Mobile	China Mobile is the world's largest mobile network and the world's largest mobile customer base. In 2012, the company was once again selected as one of the "FT Global 500" by the Financial Times and "The World's 2,000 Biggest Public Companies" by Forbes magazine.
	China Unicom	China Unicom is engaged in GSM and WCDMA cellular business, the provision of fixed line voice, broadband and other Internet-related services, information and communications technology services, business and data communications services, and other related telecommunication value-added businesses in China. At the end of October 2014, total subscribers to the company's mobile, local telephone and broadband businesses reached 450 million.
UK	**British Telecom (BT)**	BT is one of the world's leading communications services companies, serving the needs of customers in the UK and more than 170 countries worldwide. BT's main activities are the provision of fixed-line services, broadband, mobile and TV products and services as well as networked IT services.
	Vodafone	Vodafone is a UK-based mobile operator serving more than 400 million customers around the world. Vodafone now operates in more than 30 countries and partners with networks in over 50 more.

In Table 3.2, the potential research targets in China and the UK and their business status are clearly presented. However, since large firms in both the UK and China have strict restrictions, not all of them could be accessed easily. With assistance from supervisors and family members, three of these five firms allowed access:

[7] Source: The Official Website of China Telecom: http://www.chinatelecom-h.com/eng/company/company_overview.htm
The Official Website of China Mobile: http://www.chinamobileltd.com/en/about/overview.php
The Official Website of China Unicom: http://www.chinaunicom.com.hk/en/aboutus/about_profile.html
The Official Website of BT: http://www.btplc.com/thegroup/ourcompany/index.htm
The Official Website of Vodafone: http://www.vodafone.com/content/index/about.html

China Telecom and China Mobile in China, and BT in the UK. All of these three firms became the research objects for this study, and the details of these three case sites are listed as Table 3.3 below.

Table 3.3: Details of the Three Selected Case Sites[8]

Case Site	Region	Main Business Areas	Employees	Annual Profit (£bn)	Number of Subscribers (million)	R&D Expense (£m)
China Mobile	China	• Mobile voice service • Data service • IP telephone service • Multimedia service	197,030	67.5	767	Data not available
China Telecom	China	• Land-line voice service • Mobile voice service • Internet accessing service • Information service	306,545	33.6	442	65.8
British Telecom	UK	• Land-line voice service • Broadband service • Mobile voice service • TV service • Networked IT service	87,900	18.3	Data not available	544

After determining the three research targets, the regime for the comparison cases selection was constructed. Based on the six contextual factors on categorising radical product innovations, as indicated in the previous chapter, the cases selected in this research needed to be distinguished by all of these factors. According to Eisenhardt (1989), choosing cases in comparisons can force researchers to look for subtle similarities and differences between cases, and comparing different cases can lead to more sophisticated understanding. In the current research, selecting cases in this way is helpful to understanding the impact of these six contextual factors on the R&D department’s capabilities in each radical innovation development activity. Therefore, based on the above regime,

[8] Source: The Annual Report of China Mobile 2013 (China Mobile 2014)
The Annual Report of China Telecom 2013 (China Telecom 2014)
The Annual Report of British Telecom 2013 (BT group plc 2013)

and with the goal of choosing cases which are likely to replicate or extend the emergent theory (Eisenhardt 1989), four cases were selected for this research, as shown in Table 3.4:

Table 3.4: The Four Cases Selected from the Chinese and British Telecommunications Industries

Case (Abbreviation)		Telematics (T)	Xi-He (X)	21CN (N)	BT Fusion (F)
Case Site		China Mobile	China Telecom	British Telecom	British Telecom
Contextual Factors on Categorising Radical Innovations	Project Narrative	Radical to the Firm	Radical to the Global Industry	Radical to the Global Industry	Radical to the Global Industry
	Source of Innovation	Watching Others	Regulations Push	Internal Need Pull	External Need Pull
	Project Complexity	Medium	Medium	Large	Medium
	Cultural Context	Chinese Market	Chinese Market	British Market	British Market
	Technology Content	Low	High	High	High
	Market Concentration	New	Existing	Existing	Existing

As shown in Table 3.4, four cases were selected from the target three case sites in this PhD research. All of these four cases are recent projects in the Chinese and British telecommunications industry, and some of them are even going through development processes, which can make it easier to collect fresh data on cases.

Due to the rigorous restrictions on accessing the STOs, and the limited time for the current PhD research, it was difficult to focus on all of the four cases from comprehensive perspectives. Therefore, in this research, the case study on telematics that was conducted first among the four cases was selected as the main case for this study, and more data collection time was spent on it. For the other three cases, with guidelines from the main case study, only perspectives seeming to be different were concentrated on, which can be helpful in reducing data collection time and overcoming the challenge of limited access to the STOs, to a certain extent.

3.3.3 Data Collection

With the case selection regime and the four proposed cases presented in the previous section, in this section the focus will be moved to how various data collection methods are used to implement the research design. Before deciding on which data collection methods were to be used in this study, the criteria for collecting data were considered first. Rather than focusing only on the R&D departments of the STOs, data from other perspectives were also concentrated on in this study. The advantages for collecting data from different perspectives are important from two aspects: firstly, it can enhance the creative potential of the research, since different perspectives can increase opportunities to capitalise on any novel insights which are contained within the data; secondly, it can enhance confidence in findings, since the integration of data from different perspectives can avoid biased data to a certain extent (Eisenhardt 1989). In the current research, besides collecting data from the R&D departments in the telecommunications firms, relevant information was also gathered from other departments within the three case sites. Additionally, the co-operators of the selected telecommunications operators and even their competitors in some specific industry segments were also the sources of data in the research.

On reviewing the literature (Eisenhardt 1989; van de Ven et al. 1990; Yin 2009), in case study research, four data collection methods are usually involved, including archival documents, interviews, direct observations, and participant observation. The comparisons between them are summarised in Table 3.5:

Table 3.5: Four Main Data Collection Methods for Case Study Research: Advantages and Disadvantages (Yin 2009, p.102)

Data Collection Methods	Advantages	Disadvantages
Archival Documents	Stable, unobtrusive, exact, broad coverage, and precise	Retrievability, biased, and difficult to access
Interviews	Focuses directly on case study topics; Provides perceived causal inferences and explanations	Biased, inaccuracies due to poor recall, and reflexivity
Direct Observation	Reality, and contextual	Time-consuming, selectivity, and reflexivity
Participant Observation	Reality, contextual, and insightful into interpersonal behaviour and motives	Time-consuming, selectivity, reflexivity, and biased

Due to the rigorous restrictions on access, it was difficult to undertake archival documents research and direct observation in the selected telecommunications operators. Therefore, interviews and participant observation (PO) become the primary choices for considering data collection in this study.

However, based on Table 3.5, for both interviews and PO, they do have their individual limitations. According to Van de Ven and Huber (1990), to compensate for these potential limitations, a combination of various data collection methods is necessary. Moreover, for overcoming the common weaknesses of interviews and PO, such as biased and reflexive data, the data collection criteria mentioned in the early part of this section can help reduce their negative impact.

3.3.3.1 Interviews

According to Dunsmuir and Williams (1991), interviewing is a data collection method that enables a researcher to gain detailed and descriptive information about the lives of people being studied.

In social research, it captures all manner of information from interviewees and respondents, including the interviewees' own behaviour, their attitudes, norms, beliefs, and values (Bryman 2012); and all this type of information can be treated as describing some external reality and internal experience (Silverman 2010). As Yin (2009) addressed, interviews have two main functions in case study research: firstly, they can follow the researcher's individual line of inquiry, which is specified in the case study protocol designed before; secondly, interviews can help the researcher ask, in an unbiased manner, the actual questions which can serve the needs of his/her line of inquiry.

The classification of interviews can be viewed from three perspectives. To start with, in relation to the number of interviewees, interviews could be divided into one-to-one interviews and group interviews. This research mainly adopts the one-to-one interview approach, and referring to Denscombe (2003), there are four reasons for that: firstly, a one-to-one interview is easy to arrange, as only two people's diaries need to coincide, however, for group interviews, it is much more difficult to arrange, especially for large firms with rigorous restrictions. Secondly, in a one-to-one interview it is fairly straightforward for researchers to identify specific ideas with specific people, since the opinions and views expressed throughout the interview stem only from the interviewee. Thirdly, for research students with no working experience, a one-to-one interview is much easier to control. Fourthly, it is far easier to transcribe a recorded interview when the talk involves just one interviewee. These positive aspects make one-to-one interviews the best type of interview approach for this research.

Subsequently, from the perspective of the content of interview questions, interviews can be further divided into in-depth and survey interviews. In an in-depth interview, the interview questions are about all the facts of a matter as well as the respondents' opinions on it, while for a survey interview, the interview questions are designed to produce quantitative data as part of the case study evidence (Yin 2009). Since as mentioned above, this study mainly collects data in a qualitative form, therefore, from this perspective, the in-depth interview is the main type of interview in this study.

Finally, from the perspective of the structures of interview questions, interviews are categorised into structured interviews, unstructured interviews, and semi-structured interviews. Structured interviews are often adopted in quantitative research, and all the interview questions are designed to maximise reliability and validity for measuring the key concepts (Bryman 2012). In comparison, in an unstructured interview, the interviewer has a general idea about which questions to ask, and the interviewing process largely depends on the conversation (Franklin 2012). A semi-structured interview integrates the advantages of the structured interview and the unstructured interview; it has a clearly defined research objective along with flexible questions (Franklin 2012). Based on the aim of the current research and the existing findings from other researchers, some constructs for conducting this PhD study have already been indicated in Chapter 2, where the interview questions (example: Appendix 1) can be derived. However, along with the research process, the constructs could be changed in both order and content (Eisenhardt 1989), and the interview questions need to be modified to match those changes. Therefore, a semi-structured interview is the better choice in this research from the perspective of the structure of interview questions.

Interviews in the current research were undertaken in all of the three telecommunications operators involved, as well as in some co-operators and even their competitors. Based on the four cases mentioned above, different interview questions were designed for different firms, based on the cases and the nature of the interviewees and firms. Referring to the data collection regime, except for interviewing the staff from the R&D department, interviews at the other departments of telecommunications firms, the co-operators of them, and even their competitors in some specific industry segments, were also conducted to avoid biased data and look into the cases from a more objective perspective. All of the interviews are in the in-depth, face-to-face form, and last one to three hours, and during most of the interviews, with the permission of the interviewees, a tape recorder was used to record the entire conversation. However, due to the confidentiality policy of some telecommunications operators, especially for the R&D department, a tape recorder was forbidden. In this situation, a written record was used instead. Moreover, for confidential reasons, the names of all the interviewees, and some of the institutions visited other than the case sites, remain anonymous, and they are coded as the initial letter of their family names and company names in this research. Additionally, as requested by some interviewees, the final versions of the case description contents based on their interviews were sent for their reviewing and checking before submission.

3.3.3.2 Participant Observation

Participant observation (PO) is the second type of data collection method in this research, which requires the researcher to act in a variety of roles within a case study situation and actually participate in the events to be studied (Yin 2009). Saunders (2007, p.283) defined PO as the approach "where the researcher attempts to participate fully in the lives and activities of subjects and thus becomes a member of their group, organisation or community, and enables researchers to share their experiences by not merely observing what is happening but also feeling it". With the help of PO, the researcher can go deeply into the research area, observe from a member's perspective, and also have an individual impact on what is observed, due to their own participation (Flick 2002). Moreover, PO can also help infiltrate situations, and sometimes it is just like an undercover operation, to understand the culture and processes of the groups being investigated (Denscombe 2003).

In the current research, the main aim of PO is to experience how the R&D department in the STO develops its radical innovation. It can truly help enhance the results of interviews and the literature review, and test whether the data gained from them can be used in the study. PO was from two perspectives in this study: firstly, all the internal and collaboration meetings within the R&D team of an STO were participated in; secondly, as a full-time trainee in the department, some particular roles in the case development process are also played during the PO. Field notes were adopted as the main data recording approach in PO, and whatever impressions occur rather than just what seemed to be important was recorded. Questions such as "what am I learning?" as well as "how does this case differ from the last?" were prominent thinking when taking notes (Eisenhardt 1989, p.539).

When conducting PO in this study, the R&D department staff's activities in each radical innovation development stage were daily observed, and during the PO, all the internal discussions and external meetings were attended, where the communicating, collaborating, learning, and organisational activities of the department can be also observed. Due to privacy issues, the R&D department staff's exact activities on the development of their radical innovation cannot be presented. Instead of that, data gathered from PO in this study were presented in the form of how the R&D department undertook its activities in different radical innovation development stages.

3.3.3.3 Summaries of the Data Collection Work

Based on the research methods analysed above, summaries of the data collection work of the current research are shown in Table 3.6 and Table 3.7 respectively, and as discussed previously, the names of all the interviewees and some of the visited institutions other than the case sites are anonymous.

As addressed previously, among the four cases, telematics was selected as the main case in this research, and more data was collected on it compared to the other three cases. In the case study of telematics, PO was the primary data collection method where all the R&D department's radical innovation development activities were actively engaged and recorded. In addition to the data collected from PO, interviews were also supplementally conducted to the R&D department for overcoming the challenges brought by privacy issues as mentioned above, as well as the partners and competitors of China Mobile on telematics to understand the R&D department's development activities of telematics from different perspectives. For the other three cases in this research, most data was collected from interviews to the R&D staff within the case sites directly, and some supplementary interviews were also undertaken to third-party institutes such as partners and regulators for conducting these three case studies from different perspectives.

Table 3.6: Summary of the Interviews undertaken in the Current Research

Case	Interviews					
	Institution Visited	**Nature of the Institution**	**Interviewee**	**Position**	**Times Visited**	**Interview Duration (Hours)**
T	China Mobile	Case Site	Y_1	Leader of the R&D Team	1	1
			W_1	Deputy Leader of the R&D Team	1	1
			Y_2	R&D Team Member	2	3
			S_1	R&D Team Member	1	1.5
	C_A[9]	Partner	Z_1	Deputy CEO	1	1
	C_N[10]	Competitor	Z_2	Leader of the R&D Team	1	2
			Z_3	Deputy Leader of the R&D Team	1	3
			Z_4	R&D Team Member	1	1
			S	CEO	1	2
	CTA[11]	Industry Association	F_1	Chairman	1	3
	U_B[12]	Academic Institution	W_2	Dean of the Electronic and Electrical Engineering School	1	1.5
	Former Staff	Individual	Z_5	Previous Staff of the R&D Department of China Mobile	2	3
X	China Telecom	Case Site	L_1	Team Leader of the R&D Team & Deputy Chief Engineer of China Telecom	2	4
			B_1	Staff from the Marketing Department of China Telecom	2	2
			F_2	Staff from the Marketing Department of China Telecom	1	1.5
	U_T[13]	Partner	Y_3	Professor	1	1
			L_2	Professor	1	2
	MOST[14]	Regulator	J_1	One of the Organisers and Sponsors of the Xi-He Project	1	2.5
N	British Telecom	Case Site	B_2	Head of Business Engagement and Operations of the R&D Department	2	3
	Former Staff	Individual	Z_5	Previous R&D Team Member of the R&D Department of British Telecom	2	2
F	British Telecom	Case Site	P_1	Vice President of Converged Services and Mobility of the R&D department	1	1
	Former Staff	Individual	Z_5	Previous R&D Team Member of the R&D Department of British Telecom	2	2
Sum					**29**	**44**

9 One of the largest LBS firms in China
10 One of the largest LBS firms in China
11 The Chinese Telematics Association
12 One of the top universities in China located in Beijing
13 One of the top universities in China located in Shanghai
14 *The Ministry of Science and Technology of the People's Republic of China*

Table 3.7: Summary of the PO undertaken in the Current Research

Case	PO				
	Institution Visited	**Nature of the Institution**	**Form of the PO**	**Observed Contents**	**PO Duration (Hours)**
T	China Mobile	Case Site	Full-time Internship	• The R&D team members' daily activities on developing Case T (3 months in total) • 12 weekly internal team meetings attended by all the R&D team members (36 hours in total) • 2 meetings with the top management team attended by the director of the R&D department, the Chief Scientist of the development, and some selected R&D team members (4 hours in total) • 3 meetings with a law agency attended by some patent-filing experts and all the R&D team members (24 hours in total)	360
	C_A	Partner	PO in One Meeting	• One internal meeting on discussing the collaborations with the R&D department of China Mobile attended by all the R&D team members of C_A (6 hours in total)	6
Sum					**366**

3.3.4 Data Analysis

Data analysing is the most important stage when building theory from a case study, however, since the qualitative data derived from PO and interviews usually come with plenty of unstructured textual materials, the analysis of data becomes the most difficult and the least codified part in the research process (Eisenhardt 1989; Yin 2009; Bryman 2012). Unlike statistical analysis with fixed formulas to guide the analysis, in case study research, data analysis mostly depends on the researcher's own style of empirical thinking and evidence, without fixed analysis models (Bryman 2012). However, some guidelines can genuinely help researchers to undertake their qualitative data analysis.

The first guideline is from the perspective of the data analysis strategy. According to Yin (2009), there exist four strategies for analysing data in case study research, including relying on theoretical propositions, developing a case description, using both qualitative and quantitative data, and examining rival explanations. In this research, due to the constructs derived from the literature review, and the qualitative data collected in the data collection phase, this research adopts the strategy of relying on theoretical propositions to guide the data analysis activities. Differently from the other three strategies, analysing the data relying on theoretical propositions can be helpful to ensure concentration on "useful" data whilst ignoring the "useless" data, and it also helps to organise the entire case study and to update the proposed theoretical framework to be employed (Yin 2009, p.130).

The second guideline is from the perspective of data analysis technique. Based on the data analysis strategy, relying on theoretical propositions, pattern matching is the technique adopted in this study. According to Saunders et al. (2007, p.489), pattern matching "involves predicting a pattern of outcomes based on theoretical propositions to explain what you expect to find". When adopting this data analysis technique, based on the constructs developed in the literature review, the data are classified into patterns, and all these empirically-based patterns are compared with other researchers' existing findings (Yin 2009). If the patterns of the data appear to match other research, the result will be helpful in strengthening the internal validity of the case study (Saunders, Lewis et al., 2007).

The third guideline is from the perspective of data analysis methods. This study adopts within-case analysis to deal with the data as the first step. Since the research questions for a case study are usually open-ended, the research usually comes with a massive volume of data, which makes within-case analysis one of the key steps in the research process, to cope with the volume of data. With the help of within-case analysis, this study created familiarity with each case, and accelerated further cross-case comparison (Eisenhardt 1989). The subsequent step in the data analysis work is cross-case analysis. For the data comparison, as previously mentioned in the case selection section, four cases were selected from the three case sites concentrated on in this research. According to Eisenhardt (1989), there are two strategies to undertaking cross-case analysis: firstly, dimensions are selected to look for within-group similarities as well as inter-group differences; secondly, different pairs of cases are chosen, and the similarities and differences between each pair are listed. Following the above data analysis methods, in the current research, the selected R&D department's capabilities as identified in the literature chapter were catalogued into each activity of the conceptual framework for the in-case analysis, and referring to Rohrbeck's research work (2011), all the capabilities were marked from level zero to level three in each case, where the general measurement criteria can be discussed as follows:

- Level 0: The R&D department did not concentrate on the capability for developing its radical innovation.
- Level 1: The R&D department had some concentration on the capability but not much.
- Level 2: The R&D department concentrated on the capability but neglected a few significant perspectives.
- Level 3: The R&D department concentrated on the capability from all the significant perspectives.

Moreover, for the specific measurement criteria of each individual capability, they are further developed in details (see Appendix 2) in the current research for undertaking the cross-case analysis more efficiently.

By undertaking the cross-case analysis comparing the capabilities involved in each activity with the measurement criteria among the four cases, the reasons for the differences between the marking levels of the R&D departments' capabilities can be explained with reference to the six contextual factors in relation to categorising radical innovations, which are helpful to discover which contextual factors played the most significant roles in affecting the R&D departments' capabilities at each stage of the radical innovation development cycle.

The fourth guideline is from the perspective of the data analysis process. Referring to Eisenhardt (1989), this research divides the case study data analysis into two steps. In the first step, the constructs are redefined with the building evidence in each case. In the second step, this study verifies that the emergent relationships between constructs fits with the evidence in each case, and the cases that confirm the emergent relationships can enhance confidence in the validity of the relationship, whilst the cases that weaken the relationships can inspire an opportunity to refine and extend the theory.

The final guideline for data analysis in the case study research is from the perspective of comparing the proposition with the literature. In this study, when the research findings were proposed, the capabilities and contextual factors in each radical innovation developing activity were compared with the literature to find theoretical support from the sources used. According to Eisenhardt (1989), this perspective can be helpful in enhancing the emergent theory from the perspectives of internal validity, generalisability, and the theoretical level of theory building.

3.4 Summary

This chapter focuses on the research design and methodology that are used in this research work in order to answer the research questions of this study. After discussing the research-related philosophical issues underpinning the study and the related qualitative or quantitative considerations, to examine the topic case studies were selected as the main research approach in this research. The case study research design is divided into four stages, consisting of getting started, identifying cases, data collection, and data analysis. Subsequently, the four cases in the three target telecommunications firms were selected, and the data collection and data analysis methods were discussed, which guided the data collection and further data analysis activities in this study. The summaries of the data collection work in this research were also presented in this chapter.

Chapter 4 Case Studies

4.1 Introduction

Chapter 3 presented the research design, methodology, and data collection process, and outlined how data were analysed. In this chapter, the contexts of the four case studies undertaken in this research are presented. After introducing the background of the case sites and the cases themselves, standing in the position of the R&D department and following the conceptual framework as indicated in Figure 2.3, the development processes of the four cases concentrated on are described.

4.2 Case Study of Telematics

4.2.1 Introduction

Telematics, which is an innovative project learned from other leading telecommunications operators in the world, is significantly different from China Mobile's traditional lines of businesses. In this section, the backgrounds of China Mobile and the telematics service are first introduced. Subsequently, standing in the position of the R&D department, the development process of the telematics service within the R&D department of China Mobile is presented from the perspectives of idea generating, project management, and R&D activities. Until the end of the data collection stage, the project on telematics within China Mobile is still in its R&D stage, therefore its R&D department's activities in the launching stage of the conceptual framework are not focused upon in this section.

4.2.2 Background of China Mobile

As the largest mobile network operator in the world, China Mobile's traditional lines of businesses include a mobile voice service, a data service, an IP telephone service, as well as a multimedia service in the domestic market. Up to the end of 2013, China Mobile had 197,030 employees, and the number of its mobile service customers had reached 767 million. Its customer numbers are still increasing at a rate of 8.0% per year[15].

Due to the nature of a state-owned firm in China, compared with domestic privately-owned firms, China Mobile has the following five advantages[16]: Firstly, state-owned firms in China are more attractive to talented people, since their staff receive better salaries and pensions and face less risk of losing their jobs. Secondly, with high street branches in most of the cities and towns in China, China Mobile has the advantage of more sales channels. Thirdly, as a state-owned firm which used to be a part of the government, China Mobile has close links with the government. Fourthly, for some public information published by the government, such as live traffic congestion information, China Mobile can obtain the information more easily than private firms. Finally, as a firm with 197,030 employees, none of the privately-owned firms can compete with the scale of China Mobile, which has brought them the strongest research capability in the domestic telecommunications industry.

[15] Referring to China Mobile Limited 2013 Annual Report (China Mobile 2014)
[16] Referring to the interviews with F_1 and Z_3

4.2.3 Background of the Telematics Services

Telematics, which is a typical application of the Internet of Things technology utilised in the transportation area, can integrate the services of telecommunications, informatics, smart traffic management, intelligent dynamic information, and smart vehicle control into one platform. According to the interview with Y_1, the telematics service can be divided into three layers. The first layer is the perception layer. In this layer, the traffic information will be captured via sensors, including the traffic lights, traffic channelling information, the traffic condition, and the vehicle and human movement information. The second layer is the information interaction layer, where the vehicle will communicate with other vehicles and infrastructures via telecommunications technologies such as DSRC (dedicated short-range communications), Wi-Fi, and mobile Internet. The third layer is the application layer, where the vehicle can utilise the dynamic information service and smart vehicle control with the information they capture for undertaking real-time management, monitoring traffic factors and increasing operational efficiency, driving safety, and energy saving throughout the entire traffic system.

In China, the large cities are suffering significant traffic issues, such as traffic congestion and parking difficulties. According to some marketing reports[17], the economic losses caused by traffic problems have reached 170 billion yuan (17 billion pounds) per year in China, and in the year of 2009, the number of deaths in traffic accidents reached 60,000. Additionally, with its huge number of vehicles, in the top 10 list of the most polluted cities in the world, China ranks seventh. As indicated by F_1, the telematics service is recognised as one of the ideal solutions

[17] Data available on request

for solving global traffic problems, especially in China, which makes both the Chinese government and domestic firms place significant importance on it.

Telematics in China can be divided into the pre-install service and the after-install service. In the current Chinese telematics market, car manufacturers dominate the entire pre-install segment, which leaves less space for new entrants. For the after-install telematics services however, due to huge government support from the perspectives of policy and finance[18], a large number of firms are willing to participate in the market. According to F_1, "although the market (the after-install service) is not clear, the industry has already entered the red-ocean model".

However, since telematics is an emerging industry in China, many challenges exist for new entrants. As indicated by F_1, the largest challenge that telecommunications operators may face is that they want to dominate the entire value chain due to their individual strengths on communications channels, but within the current trend of policy, it is impossible for them to manage the whole telematics industry.

4.2.4 The Development of Telematics within China Mobile

4.2.4.1 Idea Generating Stage

The idea for developing the telematics service within China Mobile was generated in early 2012 by the top management team of the R&D department, inspired by

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[18] From the perspective of policy, according to F_1, the central government reduced the tax in telematics industry from 25 per cent to 15 per cent in China;
From the perspective of finance, since the investments on telematics in China are not only from the central government, but also the local governments in different provinces, the total exact amount of governmental investments is difficult to calculate. However, according to some portal websites of China, the total investments must be over 10 billion RMB (about 1 billion GBP). (Source: http://auto.people.com.cn/n/2014/0214/c153909-24364981.html; http://auto.people.com.cn/n/2014/0214/c153909-24364981.html)

several internal and external considerations, including the market and technology trends at that time, the policies within the industry, and the strengths of China Mobile itself from both the market and technology perspectives, as discussed below.

From the perspective of market trends, since telematics is not a traditional market segment that China Mobile usually concentrates on, they did not have enough experience or data to refer to when entering the market. However, the strong market needs in China and some other world-leading telecommunications operators' R&D directions analysed by the R&D department inspired China Mobile to engage in this totally new industry.

From the perspective of technology trends, the LBS technology, which is closely linked with the telematics service, is much more mature than before. The higher accuracy of positioning, the wider bandwidth of the mobile Internet, and the availability of well-functioning telematics terminals and smart mobile phones, have all made the service possible from a technology perspective.

From the perspective of policy, support from the government for the telematics industry is significant, which has attracted many companies to enter the market, as F_1 indicated,

> *"...support*s *from the government are from policy and finance…the* government have invested huge money on the telematics services, and have a lot of national projects in the telematics industry for companies to appl*y…they also reduce the tax in telematics industry from 25 per cent to 15 per cent..."*

Finally, from the perspective of individual strengths, although it is said "the core competencies apart from the communications capabilities are the main gap between the Chinese and US telecommunications operators"[19], in the Chinese domestic market, the telecommunications operators have the strongest integration capability[20]. Moreover, China Mobile also has individual strengths from the following perspectives on developing telematics:

Talent introducing: as one of the largest state-owned firms in China, China Mobile is much more attractive to talented people. Comparing it with privately-owned firms, China Mobile has advantages on salary, pension, and the stability of the work, which help them recruit the best graduates in China and also 'grab' experienced staff from other competing firms. In the case of telematics, since it is a totally new service to China Mobile, the R&D department did not have enough research capabilities in this area at the beginning. However, after poaching the staff from competitors and recruiting graduates from the best universities in China in the telematics area, their research capabilities are even stronger than some incumbents in the industry.

The communications 'tunnel' technology: according to W_1, communications technology is one of the core technologies in telematics. As the largest mobile telecommunications operator in China, and with its self-developed 3G and 4G mobile communications standards, China Mobile has the inherent advantage in providing 'tunnel' technology for developing its telematics service.

Links with the government: due to the special status of the Chinese state-owned firms in the domestic market, China Mobile has close links with the government.

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[19] According to the interview with Y_1

[20] According to the interview with W_1

With the help of that, they can access more internal information on industrial policies than any other competitors. Moreover, it can be easier for China Mobile to apply for national grants and receive policy and financial support from the government.

4.2.4.2 Project Management Stage

- Constructing the Team

After generating the idea of developing the telematics service within China Mobile, the R&D department's focus moved to the construction of an R&D team for telematics. In the beginning of the development cycle, the R&D department met significant challenges in building a team. Since China Mobile's previous R&D experience was mainly in the area of mobile communications, and the telematics service was totally new to them at that time, they did not have enough human resources for undertaking further R&D work. However, with the individual strengths of the Chinese state-owned firms as mentioned above, the R&D department overcame the challenges and constructed the R&D team in a year. Since the top management team of the R&D department within China Mobile had great enthusiasm about the telematics service, they appointed the chief scientist in the department as the leader of the R&D team for telematics, who also played the role of attracting talented staff to construct the team. At the beginning of 2013, an initial team with 14 members had been constructed, including the team leader already mentioned; five staff from other R&D teams within the department; three members 'grabbed' from competitors, who had rich experience in the R&D work of telematics; four newly-graduated students with Master's or PhD degrees from the top 20 universities in China, and one three-month internship student. Excluding the team leader, the other 13 team members were divided into three sub-teams, as shown in Table 4.1 below:

Table 4.1: Three Sub-Teams within the R&D Team for Telematics

Sub-team Names	**Main Responsibilities**
New Industry Learning Sub-team	• Learning the existing value chains and business models in the industry • Building new value chains and business models • Tracking competitors' activities • Finding potential co-operators
Policy Study Sub-team	• Building links with the relevant departments of the government who are involved in the telematics industry • Learning the existing policies in the industry • Tracking the latest policies
Patents Working Sub-team	• Thinking about patent points • Reviewing existing patents on telematics • Finding law agencies to cooperate with • Applying patents

For most of the telematics development work, the whole R&D team worked together on achieving common targets. However, for some specifics, the three sub-teams had different research concentrations based on their responsibilities. The R&D team had a regular meeting once a week, and the current progress of each member's individual work was assessed and discussed. Moreover, in the regular meetings, the team leader also allocated the work for the following week to individuals, and encouraged the team members to have brainstorming activities about the strategic plan, patents, and applications of their telematics service.

- Policy Tracking

As indicated in Table 4.2, the policy study sub-team was mainly responsible for policy tracking activities on developing telematics. The sub-team members attended conferences held by the relevant departments of the government regularly, from which they could learn the government's attitudes towards the telematics industry, and predict further policy trends on it. Moreover, the sub-team members also tracked the latest policies via the Internet and newspapers every day. One case here is that on the 9th Jan, 2013, the Ministry of Transport published the policy that in nine provinces of China, all business cars would be forced to install the BeiDou Navigation Satellite System (BDS)[21]. On the same day, on learning of this policy, the policy study sub-team helped the team director organise one meeting within the R&D team to discuss how this policy could affect their telematics service, how they could take advantage of it, and which kinds of innovative applications they could provide via this policy trend. In the meeting, the team leader also assigned tasks on thinking about patents and applications in the interlinked areas of telematics and BDS to the team members.

- Identifying Uncertainties

The R&D team's uncertainties-identifying activities for developing its telematics service were mainly from the following two perspectives:

Firstly, the uncertainties which can be brought about by policies were identified by the policy study sub-team, and the process was similar to the policy-tracking activities.

Subsequently, the R&D team identified the uncertainties that were encountered by similar services in the industry worldwide. After analysing the existing products, the team members found that the pre-install telematics market was dominated by the car manufacturers due to their inherent advantages on bundling the service together with the vehicles, especially for some high-end car manufacturers, such as BMW and Mercedes-Benz, which left few market opportunities for China

[21] A Chinese independently- researched and developed navigation system to compete with GPS and GLNOASS

Mobile. Compared with the pre-install market, the team members found that the market segment for the after-install market was still not clear, and it was difficult to predict the winning companies and applications in the industry, which had great market potential for China Mobile to explore. However, uncertainty about the competition in the after-install market, where a large number of companies had the willingness to participate, was neglected by the R&D team[22].

- Developing the Strategic Plan

Before developing its own strategic plan, the R&D team analysed existing plans in the global telematics industry first. Rather than sitting in the office to search on the Internet, team members were sent to attend the latest conferences on telematics, to track the competitors' strategic plans for developing their services, and find its own R&D direction. Two team members were selected to attend the 11th Consumer Telematics Show & Conference held in Las Vegas in 2013. After the conference, they made a two-hour presentation to all the team members on their own findings, from not only the direction that the competitors were researching, but also users' interests in telematics, the innovation points that the team could add into their service, and the challenges that they could meet during the R&D process. According to Y_1:

> *"…the lack of the basic capabilities (on telematics), such as the capability* on building the data service platform for multiple stakeholders and the capabilities on cloud computing and big data*…and the lack of heavyweight partners on telematics services…are the largest challenges that we will meet for our own service…"*

[22] Referring to the Interview with F_1

After tracking existing strategic plans in the global industry, the R&D team discussed its individual plan to develop a telematics service. As indicated by Y_1:

> *"…different from the traditional vehicle manufacturers who provide the vertical structure services…we are aiming to establish a series of* platforms for software development, information components development, sensors on the road, and system positioning, which will constitute our new *concept of telematics services…"*

With the above considerations, the R&D team took advantage of the individual strengths of China Mobile in communications technology, its integrations capability, and its sales channels, and avoided the weaknesses in relation to links with vehicle manufacturers and the lack of mature customer groups. As indicated by Y_1, compared with the traditional OEM (Original Equipment Manufacturer) telematics services which focus on the functions of navigation and vehicle components inspection, the R&D team chose the car insurance and driving safety areas as its concentrated market segments, and provided services with auxiliary information on road weather, route optimisation, dangerous driving detection and warning, and navigation. However, according to the interview with Z_5, in China Mobile's strategic plan for developing the telematics service, the R&D team was lacking consideration of finding profit points and building profit models.

Moreover, since the telematics industry was totally new to China Mobile, they did not have a mature customer group and sales channels. To overcome this challenge, as the largest mobile telecommunications operator in China, and with the largest customer group in telecommunications products, the R&D team developed a strategic plan for combining the service with China Mobile's existing mobile telecommunications products, to achieve wider sales channels.

- Building Innovation Networks

As indicated in the strategic plan for developing the telematics service, the R&D team selected the car insurance and driving safety areas as its concentrated market segments. Based on this consideration, the R&D team designed a closed-loop solution for its telematics service and found stakeholders to be involved in it, which are shown in Figure 4.1:

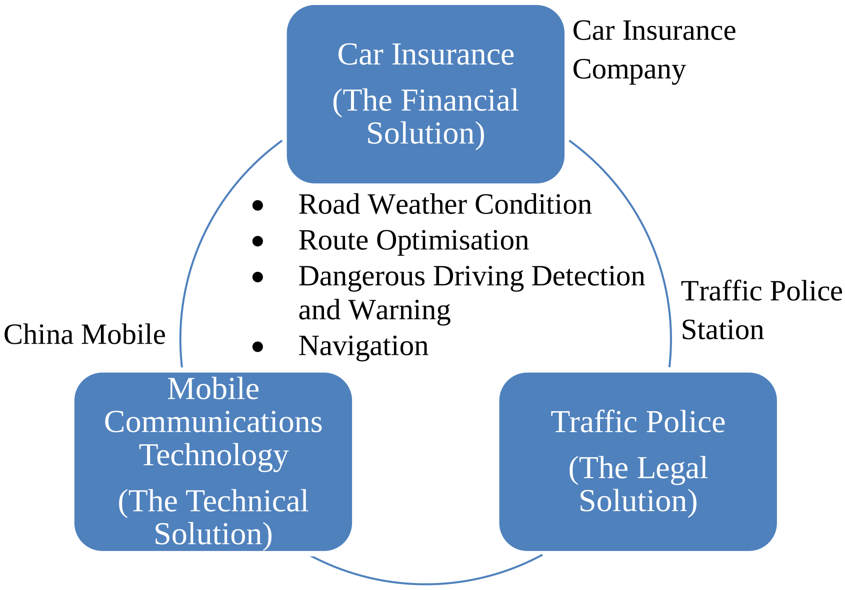

Figure 4.1: The Framework of China Mobile's Closed-Loop Solution for Telematics[23]

As shown in Figure 4.1, China Mobile, the traffic police stations, and the car insurance companies formed the closed loop of the telematics service. Based on China Mobile's technical solutions on realising the proposed telematics service, the R&D team found partners from the insurance companies and the traffic police

[23] Referring to the interview with Y_1

stations that could provide financial solutions and legal solutions respectively for its telematics service, and aimed to achieve a win-win situation.

4.2.4.3 R&D Stage

- Research Activities

Since the key techniques for realising the telematics service were learned from the global industry, the R&D team's research activities for developing telematics were mainly undertaken from the perspectives of co-publishing a white paper with the government and patent applications.

The white paper, co-published with the government, discussed the status of the current domestic automotive market, the issues existing in the areas of road traffic safety, traffic congestion, environmental pollution, and energy security, and proposed some solutions for promoting the Chinese telematics industry from the perspective of policy. Moreover, the telecommunications operators' position in the telematics industry was also addressed in the white paper. According to Y_1,

> *"…in the white paper, we indicated the four stages that the* telecommunications operators would experience in the telematics *industry…the first stage is the 'tunnel' stage, we will provide the 'tunnel' service to each fragmented telematics service…in the se*cond stage, we will provide the unique communications platform and the basic network *capability perpendicular to the telematics value chain…in the third stage,* we will be the providers of the integrated platforms of some telematics value chains, where our number of users will experience a significant *increase… in the last stage, we will become the integrator of the entire industry…"*

Co-publishing the white paper with the government helped the R&D team pave the way to subsequent R&D activities from the following three perspectives:

Firstly, the white paper helped the R&D team find its position in the telematics value chain. Referring to the four stages that the telecommunications operators would experience, as discussed in the white paper, they were only the 'tunnel provider' when they undertook the initial research activities, and with the R&D efforts with its telematics service, they aimed to become the integrator of the entire industry. Finding a position in the value chain was helpful for the R&D team to define its R&D directions, and since the white paper was co-published with the government, this meant the R&D team's proposed value chain positioning was endorsed by the government, which would make it much easier for the team to attain government support on policy and finance.

Secondly, co-publishing a white paper helped the R&D team enhance its position in the telematics industry. Since telematics was totally new to China Mobile, they did not have any influence in the industry, which also made it difficult for them to find co-operators for the R&D activities. However, a white paper usually functions as an official document for an entire industry, therefore publishing it with the government showed the public that China Mobile's understanding of telematics was more official than any other competitors, and had been approved by the government. It could significantly enhance China Mobile's position in the industry, and help the R&D team find its co-operators more easily.

Finally, co-publishing the white paper with the government enhanced the R&D team's links with the government. When collaborating with the government, the R&D team understood the telematics services that the government expected, and with that input, the team could undertake R&D activities more strategically. As explained by Z_3:

> *"...in the Chinese industries...who has the closest links with the* government, is who can *win the game..."*

For patent-applying activities where the intellectual property rights of China Mobile could be protected, the R&D telematics team built close links with law agencies, since they thought that compared with the technical staff within the team, people from law agencies have the following strengths: firstly, the law agencies are more professional when filing patents and more familiar with the patent-applying process; secondly, collaborating with law agencies can save the team members' time when undertaking a patents review and writing patent-filing documents; thirdly, law agencies can help the team expand the range of the patent-protection areas.

Since most of the team members did not have any experience on filing patents, the team leader arranged meetings between the R&D team and one of the cooperating law agencies. All the team members were requested to attend the meetings and present their individual parts of the R&D work to the law agency for them to better understand the telematics technologies. Meanwhile, the law agency also gave their presentations on the current domestic environment of intellectual property protection and the patent-filing process. Moreover, the R&D team leader also allocated the patent-filing work to both sides: the R&D team within China Mobile was responsible for cataloguing the telematics technologies and finding the patent points whilst the law agency was in charge of the patents review work and writing the patent-filing documents. However, as the collaboration proceeded, from the R&D team's side, the first draft of the patents reviewing report sent from the law agency was not satisfactory. The R&D team members had to re-do some of the reviewing work by themselves, and their research progress on patents was delayed by it.

To find patent points, the R&D team looked into some overlapping areas, such as the area between BDS and telematics technologies, and discussed them in the regular meeting each week. Some experts from other R&D teams within the R&D department were also invited to the meetings. One case here is that in the R&D department of China Mobile, the wireless network R&D team applied for the largest number of patents. Therefore, one of their team members was invited to the regular meeting and gave presentations on how they found patent points, as well as the mechanism of the group on filing patents.

The R&D department of China Mobile had significant concentrations on the quantity of patents. Within the telematics R&D team, all team members were assigned the task of filing ten patents per year, and their annual performance awards were closely related to the number of patents they filed. Due to the heavy burden of achieving patent quantity, the team members not only looked into patent points which had close connections with their telematics service, but they also considered patents in some areas that China Mobile had not reached or would never reach. According to Z_5, this concentration on the quantity of patents made the team neglect the importance of the patents' industrialisations:

> *"…in the developed* countries, they designed the applications firstly, and *then applied the patents based on that…but in China, the patents are* considered at the same time as the applications, and even before the

> applications. In this situation, how could the team industrialise the *patents?...the main reason for it is that in China,* compared to applications, the quantity of patents is not only the index for assessing the *team members, but also the team leaders...they need the quantity of* patents for promotions without considering whether the firm really needs *them...that is the reason* why China has a large number of patents, but they still need to pay a huge amount of money to the developed countries for *intellectual properties...*"

All of the research outcomes were written in documents and presented to the team leader for the feasibility assessment, and for some significant R&D outcomes, they were also presented to the top management team of the R&D department of China Mobile. However, the feasibility assessments from the top management team of the R&D department usually took three to six months, which is quite long especially for rapidly-developing industries such as telematics. Moreover, despite the links with the top management team of the R&D department, the R&D telematics team seldom had connections with the headquarters of China Mobile Group. The R&D department usually acts as an individual section within the group, and has its individual decision-making mechanisms and research funding. However, some negative impact can be brought about by the above perspective, as indicated by Z_5, "if one innovation is expected to cross the chasm between *'research' and 'industrialisation', it is important for the R&D department to get* support from the top management team of the group, since the R&D department usually concentrates more on the innovativeness of the technology, while the top management team of the group mostly focuses on the profit of the product, which is one of the most significant components for crossing the chasm to industrialisation".

- Product Development Activities

The R&D team's product development activities on telematics are mainly from the perspective of applications, which are recognised as one of the important components in the innovation development cycle. As indicated by Y_2:

> *"…applications are the UI (user interface) between the technology and customers…it is the place that the users utilise our technology and the platform that we make money from…"*

Before designing applications for telematics, the R&D team reviewed the existing applications in the domestic and global telematics industries respectively, and discussed their strengths and limitations, which improved the R&D team's efficiency in designing its individual applications. Moreover, with the guidelines of the strategic plan, the team narrowed the range of applications down to the driving safety and car insurance areas, and reoriented the directions for its application designs.

As with the research activities, the R&D team had brainstorming activities in the regular meeting each week to discuss the applications, and sometimes some experts in the relevant areas from other R&D teams were also invited to the discussions. The team members looked into some overlapping areas, and linked their potential telematics applications with China Mobile's existing products and even future ones. One case here is that when one team member presented his idea for an application in the overlapping areas of TD-LTE[24] and the telematics service on driving safety at a regular meeting, all the team members discussed its feasibility from the point of view of technical considerations, and after the regular meeting, the idea generator was advised to write down an application proposal for a feasibility assessment by the R&D department leaders. Moreover, all the team members, especially for the patent working sub-team, were encouraged to find the patent points from this application.

However, according to Z_5, applications for telematics should be driven by profit, but not technology, as he said,

> *"…R&*D activity is one of the largest investments of industrial firms, since the group leaders think that they can get huge financial rewards *from it…from the perspectives of the capital, the applications can have value only if their rewards exceed the costs…th*en the group leaders would have the enthusiasm to invest i*n it…"*

Therefore, without adequate considerations of profit models, the applications designed by the R&D team did not have strong evidence to convince the group leaders to invest in them. Additionally, with e-commerce providers entering the telematics market in the past few years, profit channels for the telecommunications operators were narrowed[25]. Therefore, how to find and sustain applications with the appropriate profit models in the telematics market was critical to the R&D team.

[24] Time-Division Long-*Term Evolution, China Mobile's largest investment in the 4G* mobile telecommunications service
[25] Referring to the interview with F_1

4.3 Case Study of Xi-He

4.3.1 Introduction

The Xi-He system, which aimed to realise the first mature seamless positioning solution in both indoor and outdoor environments in the global industry, is an innovation developed and funded by the Chinese government. As a participant, China Telecom successfully applied for the project and acted as the leading company in the indoor positioning part of the project. In this section, following the background introductions for China Telecom and the Xi-He system, standing in the position of the R&D department, the development activities of the Xi-He system within China Telecom are presented from the perspectives of idea generating, project management, R&D, and launching, respectively.

4.3.2 Background of China Telecom

As the largest land-line telecommunications, CDMA mobile networks, and broadband Internet services operator in the world, China Telecom provides basic telecommunications services such as land-line and mobile telecommunications services, Internet accessing services, and information services in the domestic market of China. At the end of 2013, China Telecom had 186 million mobile subscribers, 156 million access lines, and about 100 million broadband subscribers[26].

Similar to China Mobile, China Telecom is also a state-owned firm in China with the strengths of abundant talents, wide sales channels, strong links with the government, rich resources of data, the large scale of the firm, as well as a strong

[26] China Telecom Corporation Limited 2013 Annual Report (China Telecom 2014)

research capability. However, according to the interview with B_1, compared with China Mobile, China Telecom is much more likely to collaborate with partners. One case here is the instant messenger software, for China Mobile, which they developed as their own brand software named Fetion; for China Telecom, they aimed to provide the best customer experience for the users who are using QQ[27] with China Telecom's mobile Internet. Among the three telecommunications operators in China, China Telecom is the first one to introduce the iPhone into the Chinese market. As indicated by B_1:

> *"…we are no longer the largest telecommunications service operator in* China. China Mobile has the largest customer group; China Unicom has *also exceeded us in some certain market segments…what we* should do is to understand our position in the market, and actively explore the *collaborating opportunities…"*

4.3.3 Background of Xi-He

With the advent of the Compass Navigation System, there existed strong demands on the outdoor-indoor seamless real-time positioning technologies in the Chinese LBS market. Based on this consideration, the decision to develop the Xi-He system was made by the Ministry of Science and Technology of China. The Xi-He system, which is named after the goddess of the Sun from the ancient Chinese legend, is an innovative project based on the BDS, utilising a real-time precise positioning system, an indoor navigation system, a holographic map and location information database, as well as a position information-processing platform to

[27] The largest instant messenger software in China

provide smart location services in the areas of transportation, agriculture, land resources, maritime, disaster mitigation, and civil safety.

The R&D work for the Xi-He system has been divided into two parts: the outdoor positioning part as well as the indoor positioning part. When collecting data, the first part of the Xi-He system for outdoor positioning had already been finished, but the second part, for indoor positioning, was still in its development process. The indoor positioning part of the Xi-He system, which is concentrated on in the current research, was published by the government and applied for by nine firms altogether. These nine firms had different responsibilities in the project, and they made an agreement on the interfaces between each firm's individual R&D content. At the end of the development cycle, the entire project is expected to be integrated seamlessly.

4.3.4 The Development of the Xi-He System within China Telecom

4.3.4.1 Idea Generating Stage

Compared with China Mobile's idea about the telematics service which originated from its R&D department, the Xi-He system was a project generated and funded by the government. The R&D department of China Telecom was introduced to the second part of the Xi-He system by one of its co-operators in another project run by the municipal government of Shanghai. This co-operator had close links with China Telecom and participated in the expert group for drafting the proposal for Xi-He for the government. They thought that the existing technology bases of China Telecom on realising indoor positioning with Wi-Fi technology to be one of the ideal solutions for the Xi-He system. Therefore, they encouraged the R&D

department of China Telecom to apply for the project and provided them plenty of useful suggestions.

The decision made by the R&D department of China Telecom on applying for the project was mainly based on the following four considerations:

Firstly, China Telecom had the R&D experience on indoor positioning technology. Before the Xi-He project, the R&D department of China Telecom participated in another project sponsored by the government on indoor positioning around 2011, and they developed their technical prototype. Therefore, when China Telecom was first introduced to the project for the Xi-He system, the R&D department already had a clear direction for its R&D work.

Secondly, the project funding for the Xi-He system was large. The government invested 50 million RMB (about 5 million pounds) for the indoor positioning part of Xi-He[28], and applying for the project could help the R&D department expand its existing prototype on the indoor positioning solution without any financial pressures.

Thirdly, China Telecom had its unique strengths on realising the indoor positioning part of the Xi-He system, which was the wide distribution of the Wi-Fi hotspots within buildings. As indicated by L_1, in Shanghai, China Telecom is the largest Wi-Fi network provider, with 9,000 networks, 50,000 hotspots, as well as 50,000 to 60,000 Wi-Fi access points, and this advantage could help the R&D department realise its indoor positioning solution from a technical perspective.

Finally, the R&D department believed that indoor positioning technology had huge market potential and they could benefit from R&D activities on it. This

[28] Referring to the Interview with L_2

market opportunity was considered from two perspectives: on one hand, the previous R&D experience on the prototype of indoor positioning technology helped the R&D department understand the great market demands for this kind of service; on the other hand, from the perspective of the Internet of Things (IoT), which was one of main trends of the technologies' developing directions, indoor positioning solutions were predicted to be the first large-scale application of it. As indicated by L_1:

> *"…we call it scale application, since when constructing the Internet of* Things, the construction work of the perception layer is the most difficult *one…but the wide distribution of the Wi*-Fi hotspots of China Telecom as well as the increasing number of smartphones with the Wi-Fi technology can fill the gap of the perception layer, and make our indoor positioning *solution be the first scale application of the Internet of Things…"*

4.3.4.2 Project Management Stage

- Constructing the Team

By absorbing the staff from the previous government-sponsored project, the new R&D team for the Xi-He system has more than 20 members. Compared with the telematics service within China Mobile, to reduce the cost on team construction, the R&D team for Xi-He was built in the form of a 'virtual team', which means the team members met only during the regular meeting each week, and after these meetings, they went back to their original divisions and continued their assigned work there. The R&D team members for the Xi-He system were not only from the R&D department of China Telecom, but also the marketing department, for analysing the market and providing suggestions on the project from their perspectives.

- Policy Tracking

Since the Xi-He system was a government-sponsored project, most of the policies for the development activities were transparent to all the participants. Therefore, it was not necessary for the R&D team to track the latest policies all the time. Moreover, if some polices related to the Xi-He system were changed, with the strong links with the government due to the nature of the project, the R&D team within China Telecom would be notified by the government immediately.

- Identifying Uncertainties

According to the interview with L_1, the uncertainties for developing the Xi-He system were assessed by the R&D team from two perspectives: the first type of uncertainties that the R&D team identified was from the market perspective, and since there were no such type of mature indoor positioning product in the market, it was difficult for the R&D team to predict the market and identify the user groups; the second type of uncertainties identified by the R&D team was from the technical perspective on indoor positioning accuracy, and since its existing positioning prototype based on Wi-Fi technology was not fully tested, the R&D team was not sure whether its current algorithm could meet the requirements of the government on indoor positioning accuracy.

- Developing the Strategic Plan

As discussed earlier, the technical prototype of the R&D team's indoor positioning solution had already been developed. Therefore, the strategic plan for developing the Xi-He system was mainly designed from the business model perspective, rather than the technical perspective, by the R&D team. For the Xi-He system, the government had published some guidelines on the business model for it. However, the R&D team within China Telecom did not follow them, as indicated by L_1:

> *"...from my perspective, I* do not expect the guidance of the business model from the government, since the market is quite different from what *they thought…we are the leading firms in the second part of* the Xi-He system, we have a *better view of the project than others…thus, we are building the business model by ourselves…"*

The business model of the Xi-He system designed by the R&D team followed China Telecom's traditional business model on Internet applications. In this model, if users utilise the applications of the Xi-He system via China Telecom's mobile Internet services, they will be charged for the network traffic for accessing the applications, and China Telecom will share the profit from it with the application providers. Additionally, to attract customers and compete with China Mobile and China Unicom with its own R&D product, China Telecom provides the specific mobile numbers for the applications of the Xi-He system. With these specific mobile numbers, users can have a discount on the data traffic tariffs when they utilise the Xi-He applications, which is another channel for China Telecom to make profits from the project.

- Building Innovation Networks

The R&D team's innovation networks on developing the Xi-He system were mainly built based on its value chain. The initial value chain of the Xi-He system was constructed by the government. Based on their understanding of indoor positioning solutions, they divided the second part of the Xi-He system into six sub-subjects. China Telecom was individually responsible for the first sub-subject on realising the indoor positioning from the technical perspective; the second and third sub-subjects were about indoor maps; and the fourth, fifth, and sixth sub-subjects were on the applications development in different areas, as shown in Figure 4.2 below:

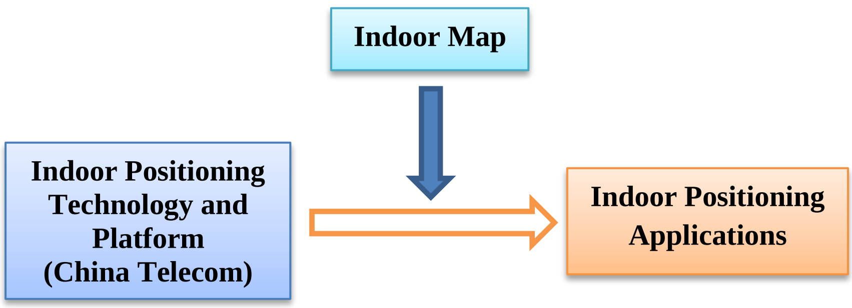

Figure 4.2: The Initial Value Chain of the Xi-He System[29]

In the above value chain, all the participants were appointed by government. Similar to China Telecom, they were also the applicants for the second part of the Xi-He system. However, as L_1 indicated, most of the participants in this value chain only shared the investment from the government but did nothing, which made it difficult for China Telecom to collaborate with them. Corruption is recognised as the main reason for the above issue. According to L_1:

> *"…for* most of the participants in the Xi-He system, they were selected by the government only due to their close links with the government but did nothing in the first two years of the R&*D stage…half of the money the government invested on the project was given to the firms did nothing…*

[29] Referring to the interview with L_1

we can't control that…only the government can control that but they did not…"

Moreover, some other participants also addressed the corruption issues in the application stage of the Xi-He system, as indicated by L_2:

> *"…the only reason some participants successfully applied* for the project and got the investment from the government is that their managers are in the list of the expert group (of the Xi-He system), they had the right to *speak during the application stage…the corruption in the Chinese science* and technology areas are very serious*…"*

For furthering the project, the R&D team within China Telecom personally reformed the value chain and found individual co-operators. Therefore, from the R&D team's perspective, the external collaborations for the project of the Xi-He system had two meanings: firstly, the original collaborations were assigned by the government, who shared the investment and formed the initial value chain; secondly, the co-operators in reality for the indoor positioning solutions were chosen by the R&D team itself, and with these co-operators, the R&D team formed its new value chain. According to L_1,

> *"…in 2013, we are happy to see that our value chain is growing stronger,* a lot of firms approached us for collaborations on the indoor positioning technology and products, such as the equipment providers of Qualcomm *and Motorola…another thing* that needs to be emphasised here is that in 2013, two applications providers emerged and approached us *initiatively…these two firms are the O2O (online to offline) service*

providers, and they will utilise our indoor positioning data for business information pushing…"

Referring to the interview with L_1, the new value chain was formed as shown in Figure 4.3:

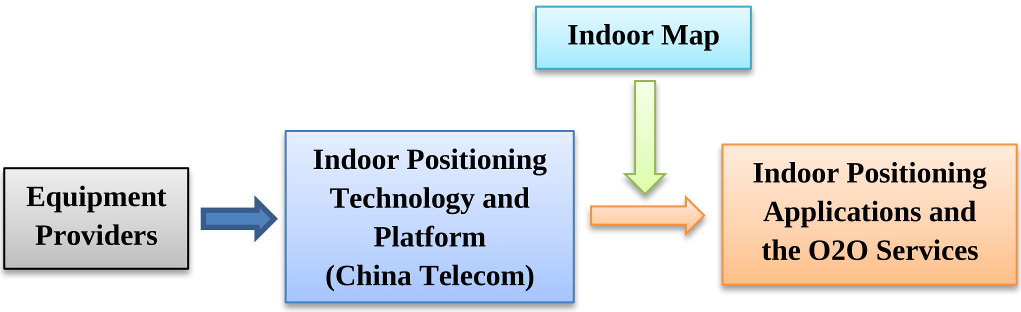

Figure 4.3: The New Value Chain of the Xi-He System[30]

However, from the perspective of the co-operators in the initial value chain, they thought that the internal issues of China Telecom made collaboration difficult, as indicated by Y_3:

> *"…China Telecom is a relatively closed firm, and it is difficult for us to collaborate with them…they think they are the giants in the market, and they will never listen to others…we don't have any proper* communications with China Telecom on the R&D activities of the Xi-He *system, and they do not want to have any connections with us…they are doing their individual things…China Telecom is a leading firm on the* indoor positioning part of the Xi-He system, but they never arrange one meeting for all the *participants of the project …"*

[30] Referring to the Interview with L_1

4.3.4.3 R&D Stage

- Research Activities

The research activities that the R&D team focused on when developing the Xi-He system were mainly distributed in the areas of the indoor positioning algorithm and intellectual property protections.

For the algorithm, since the positioning accuracy is one of the largest challenges for realising the second part of the Xi-He system, the R&D team within China Telecom placed significant emphasis on it. Based on China Telecom's existing prototype of Wi-Fi positioning solutions, some new technologies were added into the algorithm when undertaking the research activities, such as the indoor map fingerprints technology.

For the intellectual property protection, compared with China Mobile's telematics service, where all the team members were encouraged to file patents, in the Xi-He system, only two team members with good writing skills concentrated on the patents filing work within China Telecom. Similar to the case study of telematics, the R&D team for the Xi-He system collaborated with a law agency for applying for patents. Although it was not necessary for the R&D team members to present their research activities to the top management team of China Telecom, they were requested to send all the documents on patents to the headquarters for central assessing. The whole process for central assessing can take up to one year. Due to the fact that the Xi-He system is a government-sponsored project, the R&D team for the Xi-He system can take advantage of the green channel. However, it still took them 10 months waiting time for the central assessments.

For all of the above research developments, the R&D team reported them regularly to the government. The team members not only presented their research outcomes in the annual meeting of the Xi-He system held by the government and the expert group of the project, but also went through inspection activities from the government each year.

- Product Development activities

The product development activities of the Xi-He system were mainly undertaken by the co-operators of China Telecom in the value chain. These co-operators had mature customer groups and were more familiar with the customers' demands for products. With this consideration, the R&D team focused on its external links with the co-operators and left the product development activities to them.

4.3.4.4 Launching Stage

- Testing

The testing activities for the Xi-He system were undertaken in 2014, and 15 areas in the Pudong district of Shanghai were selected as the testing areas. From the perspective of the government, the technical indexes published for the project of the Xi-He system were the criteria to assess the participants' development outcomes in the testing stage, where the R&D team within China Telecom was requested to concentrate on the availability of the service, the interfaces between the co-operators, and the accuracy of its indoor positioning solution for the Xi-He system project.[31] However, from China Telecom's perspective, among the three testing indexes published by the government, the largest challenge that the R&D team faced was on the interfaces between the co-operators, as L_1 indicated:

[31] Referring to the interview with J_1

"…I cannot identify our links with the co-operators from the initial value *chain as close or not close…such as the sub*-subject on traffic safety, I *don't even understand how it can contribute to the project…for some other* sub-subjects, such as the indoor mapping, we built some links with the co-*operators, but I don't know in which form they will join us…it is difficult* for us t*o build the interfaces with them…"*

Therefore, for the testing activities of the Xi-He system, on the one hand, the R&D team collaborated with its 'practical' co-operators to realise its end to end[32] indoor positioning solution, to meet the indexes published by the government. On the other hand, the R&D team developed open interfaces based on its individual understanding of the project and provided them to the 'literal' co-operators from the initial value chain.

- Fully Exploiting

In comparison with the testing activities, the government had less influence on the R&D team fully exploiting the activities of the Xi-He system. According to J_1:

"…our role in the development cycle of the Xi-He system is as raising a *child…when a child is born, we will pro*vide him/her the life necessities, the education from the kindergarten to the high school, as well as the *direction for his/her life…however, when the child is 18 years old, he/she needs go to the university or work…we will leave him/her to stand in the* society by themselves...for the Xi-He system, the process is the same, we will give it life, raise it up, build the value chain for it, and monitor it until

[32] User terminal end to the platform end

it is mature enough… after the testing stage, we will leave the fully exploiting work to the particip*ating firms …"*

Similar to the government's role in the development process of the Xi-He system, when undertaking fully exploiting activities, the R&D team handed over the project to the operating department of the group. However, as indicated by L_1, when the project was finished, it was not expected that all the R&D challenges could be solved, and the R&D team would undertake continuous development work and update its services during the entire life cycle of the project.

4.4 Case Study of 21CN

4.4.1 Introduction

Following the above two Chinese cases, the concentration of this research moves to the British telecommunications market. In this section, after introducing the background of the case sites and the case itself, standing in the position of the R&D department, the development activities of the first British case on 21CN within BT are presented from the perspectives of idea generating, project management, R&D, and launching, respectively.

4.4.2 Background on British Telecom

British Telecom (BT), which is the largest communications solutions and services operator in the UK and one of the oldest communications firms worldwide, is fulfilling customer needs for telecommunications in the UK and more than 170 countries in the world. It provides landline services, broadband, mobile and TV products and services, and networked IT services to individual customers, small and medium-sized enterprises, and the public sector. Additionally, BT also sells its wholesale products and services to domestic and worldwide telecommunications providers and multinational corporations, as well as to national and local government organisations[33].

To serve these different types of customers, BT is organised into six individual divisions. The four customer-facing business divisions are BT Global Services, BT Retail, BT Wholesale and Openreach, supported by two internal non-profit services units, BT Innovation & Design (BTID) and BT Operate. Among all of the six individual divisions, BTID is responsible for the R&D activities of the entire group, and it can be recognised as the R&D department that is focused on by this research.

Compared with the Chinese telecommunications firms with their strengths of abundant talent, wide sales channels, strong links with the government, rich resources of data, the large scale of the firm, and strong research capability, BT has only the advantages of talent introducing, the scale of the firm, and research capabilities. For its sales channels, after demerging the mobile part which became O2 later, BT is a landline network operator only, without any mobile solutions and high street branches[34], which brought them many challenges for exploiting their new services. As for links with the government and resources of data, due to the different market environments in the UK and China, it is difficult for BT to get financial and policy support from the government, and it is also impossible for them to get any unfair advantages on resources. Therefore, it is not necessary for BT to focus on links with the government for new product development.

[33] The official website of BT, http://www.btplc.com/Thegroup/Ourcompany/index.htm
[34] Referring to the interview with P_1

4.4.3 Background of 21CN

21CN[35], which is BT's largest investment in the past ten years, is the next generation network which can integrate BT's traditional lines of business on the networks of PSTN (public switched telephone network), broadband, and TV services into one platform. According to Reeve et al. (2005), compared with the legacy services operating on different platforms, 21CN can deliver an improved customer experience and faster service provision, and significantly reduce the overall operating costs of BT.

Based on the above statements, it can be inferred that cost, technology, and service are the three main drivers for BT to develop its 21CN. For the cost driver, since 21CN can integrate the legacy network functions into one platform and bring higher utilisations of the network resources, it can help BT reduce its operating costs significantly; for the technology driver, based on the new network architecture of 21CN, BT can manage its networks and add new functions more easily; and finally, for the service driver, the open interface of 21CN allows third-party applications to enter the network, which can encourage more application providers to put work into 21CN.

4.4.4 The Development of 21CN within BT

4.4.4.1 Idea Generating Stage

Differently from the projects of telematics and the Xi-He system, the idea generating and decision making activities on the development of 21CN were mainly undertaken by the board members of BT Group. However, during this

[35] The 21st Century Network in full

process, the group of strategy people, which can be treated as part of BTID currently, did provide their comments and analysis from the technical perspectives.

As discussed in the previous section, cost reduction, advanced network architecture, and open interfaces are the three main drivers for BT to make the decision to develop 21CN, and among these three drivers, the perspective of cost reduction was significantly emphasised by BT. Due to the intensive competition in the UK telecommunications industry, BT's lines of business became more challenging and entered a bottleneck period. Therefore, BT had to find ways to adjust the cost structure of its business, and deliver services that could be attractive to customers. According to I_1, compared with BT's legacy services that operate the TV, broadband, and landline telephone networks separately, that were increasingly difficult and costly to maintain, 21CN could significantly reduce its operating costs and enable it to deliver new services, which can help BT overcome the current bottleneck and bring them new opportunities in the future.

4.4.4.2 Project Management Stage

- Constructing the Team

Similar to China Telecom's team construction activities for the Xi-He system project, the R&D team for 21CN within BT was also constructed in the form of a virtual team, where the team members were located in different places and undertook individual R&D work in their original divisions.

According to I_1, when constructing the R&D team for 21CN, the existing experience of related technical areas was significantly important. As an R&D

department with 21,200 staff[36], there existed enough R&D capacities for BTID to undertake the development activities for 21CN. Therefore, when constructing the R&D team for 21CN, most of the team members were selected from the existing staff within the institution, and for some particular gaps on realising 21CN a few specialists were also hired by BTID to cross the technical chasms.

- Identifying Uncertainties

When developing 21CN, the uncertainties identified by the R&D team were mainly from the technical perspective of whether all the proposed functionalities could be delivered by the end of the development cycle. As introduced by I_1, there always existed issues related to some individual functionality that the R&D team thought, or the co-operators promised they could deliver in an early stage, but in the end they could not manage it.

To identify the above challenges, the R&D team analysed them from the viewpoint of its individual capabilities and the co-operators' capabilities respectively for realising the functionalities of 21CN. On the one hand, the team members did early tests for the feasibility assessment of its individual R&D work; on the other hand, the R&D team needed to understand what the co-operators could deliver, and have tests in its individual labs for verifying the co-operators' promises on 21CN. According to I_1:

> *"... (For the uncertainties) we need to understand what (the co*-operators) can actually deliver, what they promise us, and how we can deal with the uncer*tainties in the lab…the research lab can prove these things feasible,* quite possible, and underestimated*…"*

[36] Source: BT Annual Report 2013 (BT group plc 2013)

- Developing the Strategic Plan

The strategic plan on the development of 21CN was strongly driven by the R&D team within BTID from the technical perspectives. As indicated by I_1, since 21CN merged a pool of unconnected knowledge into one platform, designing the network architecture for integrating the legacy networks was the first and the most significant component that the R&D team identified in its proposed strategic plan. Except for the network architecture, the team members focused on the assignment of the R&D work, not only to themselves in the labs, but also to the co-operators, and undertook the assessment report on the timeline to completion of each individual part of the R&D work. Additionally, in the strategic plan, the R&D team also identified the issues of how to transfer the existing users from its legacy network to 21CN in the further launching stage.

Apart from the above technical considerations, the R&D team also built the business model of 21CN in its strategic plan development activities. In the business model, the team members addressed the technologies that 21CN could deliver, the price of the services, and even whether the functionalities of 21CN could meet the expectations of the marketing people.

For all the above contents developed in the strategic plan, the R&D team reported them to the board members of the group for feasibility assessment. Moreover, the team members also collaborated with other departments within BT to learn their expectations of 21CN and the customers' demands in the market.

- Building Innovation Networks

When building innovation networks for the development of 21CN, the R&D team found some large telecommunications equipment and solutions providers to collaborate with, such as Cisco, Ericsson, and Huawei, and the collaborations were mainly from the perspectives of the R&D activities and public relations.

From the perspective of the R&D activities, before developing the innovation networks, the R&D team had already built mature links with these equipment providers. For the 21CN project, rather than approaching these co-operators on their own initiative, these equipment providers came to the R&D team and enthusiastically responded to requests for information and tendering exercises to undertake the parts of the R&D work that interested them. Since BT was the first telecommunications operator to provide such integrated services in the global telecommunications industry, undertaking an individual part of the R&D work for a world-leading technology could significantly improve the co-operators' reputations, and due to the co-operators' great enthusiasm for 21CN, the R&D team had opportunities to bargain with them on both the price and the functionalities that they could deliver in their individual part of the R&D work. Moreover, the R&D team also built links with some world-leading universities on the research activities. In the case of MIT (Massachusetts Institute of Technology), some of the world-leading network experts from this academic institution worked with the R&D team for 15 years, and these experts' R&D contributions were successfully transferred to some functions of 21CN.

From the perspective of the public relationships, the R&D team did some press releases together with the co-operators from the technical perspectives on what they had achieved during the development process. One case here is the collaboration with Ciena on delivering very fast communications over fibre networks in 21CN, which was the first real solution in the world, and having finished the research work, the R&D team published a joint press release together with Ciena for their joint benefits[37].

4.4.4.3 R&D Stage

- Research Activities

As presented by I_1, the research activities for developing 21CN were about everything related to delivering the functionalities of the integrated services. During the project management stage, as mentioned in the previous section, the R&D team had already divided the entire research work on 21CN into different parts and selected its co-operators for undertaking the research contents. Therefore, in the research stage, the R&D team within BT not only did its individual part of the research in the lab, but also did tests on the co-operators' research outcomes and integrated them together.

Similar to the Chinese telecommunications operators, the R&D team of 21CN concentrated on protecting their intellectual properties significantly. For the 21CN project, hundreds of patents were filed in the relevant technical areas during its development process[38].

Within the R&D team, all the team members were encouraged to file patents. Moreover, there also existed a group of intellectual property lawyers situated within the team for assisting these research staff on patent-filing activities.

[37] Referring to the interview with I_1
[38] Referring to the interview with I_1

According to I1, the R&D team had incentive systems for the members on filing patents: on the one hand, the research staff were financially rewarded for each patent they filed; on the other hand, if the patent was successfully granted, the relevant team members would receive a further reward.

Compared with the Chinese telecommunications operators that concentrated on the number of patents they applied for, the R&D team within BT filed only the patents that were predicted to be feasible and implementable. However, in relation to the potential business value of the patents, the team members did not focus on this initially. As indicated by I_1:

> *"…The problem is that actually you don't know it (the business value) at the time you are doing it…clearly, some of the patents will have no value at all, since you never go on to develop it…but you are making an investment…"*

When undertaking the above research activities, except for the external collaboration with the co-operators, the R&D team also built internal links with the board members and other departments within the BT Group.

For the internal links with the board, the R&D team was requested to report to the BT board members regularly. According to I_1:

> *"…For most of the projects within BTID, it is not necessary for us to report to the BT board regularly…however, for 21CN, since it was so* major for BT and several billion pounds were invested i*n it… they (the* board) want to be confident, they want to have the sum of the details, time-*skills, and functionalities (of the new services)…"*

Moreover, the board of BT also did many separate feasibility assessments on each individual part of 21CN, as indicated by I_1:

> *"…The board would also have analysis on that, analysing the progress on* what was going on, probably every month at *least, if not every week…I am* pretty sure that these things are reviewed on a regular basis; I am sure *21CN was presented many many times to the board…"*

Like the Chinese cases, the internal communication with the board members on the research activities also took a long time. The R&D team needed to present each of the R&D activities to them and secure their approval before moving on to the next stage. Additionally, since 21CN represented a huge investment, the team members had to request authorisation from the board to spend money at each stage, and give the board confidence, and then there would be money invested in the next stage. Therefore, referring to I_1, the internal communications between the R&D team and the BT board took many years for the whole process.

As for the links with the other departments within BT group, due to the strict regulations of Ofcom on Openreach, the R&D team met significant challenges on collaborating with them, since they had to treat the Openreach department separately from other departments, such as BT Retail[39]. To overcome this challenge, only certain identified team members from the R&D team can work with Openreach, and they were well trained to acknowledge that they understood

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[39] BT Openreach and BT Retail have different customer groups. BT Retail serves the individual users of their broadband, telephone, and TV services; whilst for Openreach, it serves telecommunications operators such as Virgin Media, Vodafone, O2, Sky TV, TalkTalk, and BT Retail as well. Due to the regulation of Ofcom, BT Openreach is requested to treat all telecommunications providers equally, and BT Retail cannot receive any unfair advantages from Openreach, although they are in the same group. Therefore, the R&D team was not allowed to share all the information on 21CN with both BT Retail and Openreach.

their privileged positions and that they understood that they could not share information gained from their Openreach interactions with other BT units unless that information was also available to all communication providers.

- Product Development Activities

The target of BT on undertaking product development activities is to transplant all the existing applications from the legacy networks to 21CN and develop some new applications that cannot be realised on the traditional networks. Since the applications in the legacy networks were driven by the marketing people, the applications of 21CN were also considered mainly by these marketing staff rather than the R&D team within BT. However, the R&D team did play a significant role in the process.

Within the R&D team, one specific sub-team was designated for tracking the latest applications all over the world. They focused on what the start-up companies were doing, who are usually the origins of the most innovative applications, and they also focused on the applications developed by the large telecommunications firms in the global telecommunications industry. Subsequently, the sub-team members brought the knowledge back to the group, particularly to the department of BT Retail, for their reference, and with the above knowledge, the Retail people went to the tracked companies, and carried out their own feasibility assessments on these applications.

4.4.4.4 Launching Stage

- Testing

The testing activities for the development of 21CN were mainly undertaken from two perspectives within the R&D team of BT: on the one hand, the team members tested all the individual components of 21CN; on the other hand, they tested all these components together as an integrated solution.

Since the R&D work on 21CN involved many co-operators' individual research activities, in the testing stage, the R&D team for 21CN also requested these co-operators to have tests done on their R&D outcomes. Subsequently, the R&D team returned to some of the testing results, and re-tested them in some integrated experiments, since large projects such as 21CN can always encounter issues with interfaces and integrations, and "it would be very expensive to construct a network that cannot work", as I_1 said.

Due to the massive testing workload of 21CN and the timeline to completion of all the testing activities, the R&D team collaborated with some research centres in other countries for remote testing. Moreover, for all the testing outcomes, the R&D team reported them to the board members of BT regularly for them to better understand the testing progress. Additionally, the impact of the testing results on applications was discussed with the marketing people from the other departments within BT.

- Fully Exploiting

When undertaking the fully exploiting activities of 21CN, there can still exist some operational issues in the service, since a new technology cannot be as reliable as traditional ones which have been tested and implemented for years. Moreover, marketing people can also ask for more functionality, or the R&D team can find something new to be implemented. Therefore, in this stage, the R&D team needed to undertake continuous R&D work on the new integrated networks, fixing issues or adding new things.

For continuous development, the R&D team had links with the co-operators for technical upgrades of the network. The team members also collaborated with other departments within BT to improve their services, such as the marketing people from the Retail department for learning about customers' behaviours and their demands for 21CN.

4.5 Case Study of BT Fusion

4.5.1 Introduction

BT Fusion is the second case concentrated on within BT in the current research, and since both 21CN and Fusion were developed by the R&D teams in the same research institution (BTID), most of their development activities on these two cases were similar. However, due to the different contextual factors involved in the two projects, compared with the case study of 21CN, some different activities of the R&D team did exist in the development process of BT Fusion. In this section, following the background introduction, the R&D team's development activities on its Fusion service which are different from 21CN are concentrated on, and these activities are mainly presented from the perspectives of idea generating, external collaborations and internal collaborations during the development cycle.

4.5.2 Background to BT Fusion

BT Fusion, which allows customers to use the mobile telecommunications network outdoors and Wi-Fi technologies at home to make phone calls with the same handsets for a better rate, is an innovative product launched by BT in 2003. However, in 2009, BT withdrew its Fusion service, and according to the interview with P_1, the reasons for the withdrawal were from the following four perspectives: firstly, the limited handset range of Fusion gave customers few choices on mobile terminals; secondly, after the demerged Cellnet, which later became O2, separated from BT, BT did not have any mobile networks, therefore, for the mobile solution of Fusion, the R&D team had to completely integrate with the mobile telecommunications operators, which brought difficulties when adding new functionalities into the service; thirdly, from a marketing perspective, since the price gap between the mobile telecommunications services and the landline ones is decreasing rapidly and can even be ignored in recent years, without the Fusion service, users can also have cheap voice calls outdoors; and finally, the lack of high street shops does not allow BT to promote its Fusion service widely.

4.5.3 The Development of Fusion within BT

4.5.3.1 The Idea Generating Activities

Similarly to 21CN, the decision for developing the Fusion service was also made by the board members of the BT Group. However, during this process, the R&D department did provide suggestions from the following three perspectives:

From the perspective of overcoming individual weaknesses, as mentioned above, after demerging Cellnet from BT in 2002, BT became a landline network operator without any mobile solutions. However, most of the telecommunications operators in the UK at that time provided landline and mobile operations. Therefore, BT became concerned with the fact that they would not be a mobile operator any more. In this situation, based on the largest domestic broadband distributions within the UK, the strategic people from BTID came up with the idea of providing mobile communications solutions at home and in offices via broadband access.

Subsequently, from the perspective of market trends, according to P_1, when developing the Fusion service the strategic people noticed that compared to phone calls made outdoors, 70 per cent of voice calls were made at the office and at home. Moreover, during that period, the price gap between the landline and mobile telecommunications methods was significant. Therefore, the strategic people within BTID indicated that a cheaper solution for mobile communications within buildings could be strongly demanded by customers.

Finally, from technical considerations, it was perceived that for voice communications at that time it was important for the R&D department to have seamless communications services between indoor and outdoor environments where phone call signals would not drop, and this functionality could be realised by the proposed Fusion service.

4.5.3.2 The External Collaborations Activities

Since the external collaborations activities in the whole Fusion development cycle are significantly different from the case of 21CN, in this section, instead of discussing the external links built in each development stage respectively, the R&D team's external collaborations activities in the entire development cycle are discussed together, for better understanding of the differences between the two UK cases from this perspective. During the development process of Fusion, the external links built by the R&D team were mainly with mobile communications operators and handset providers, as discussed in the remaining parts of this section.

- The External Links with the Mobile Communications Operators

As mentioned above, the technical solution of Fusion is providing seamless communications services between indoor and outdoor environments. With mature solutions for landline telecommunications at the office and at home, BTID was lacking mobile communications capabilities for releasing the functionalities of the Fusion service. Therefore, rather than investing significant money on building new capabilities on the mobile telecommunications networks, the R&D team chose to collaborate with Vodafone, which is one of the largest mobile operators in the UK, to provide the outdoor communications solution.

To deliver an excellent customer experience for seamless communications, the R&D team within BTID built close links with Vodafone. However, from a strategic perspective, providing services largely relying on its co-operators means that the team had to have a very close relationship with the mobile operator, both at the commercial level and the technical level, which left less bargaining room for the R&D team members, as addressed by P_1:

> *"…Since your solution is h*ighly integrated into their networks, (if you want to change the mobile operator), you have to withdraw that and start *again, and do the same things with another mobile operator…we don't want it to happen…"*

- The External Links with the Handset Providers

For BT Fusion, Wi-Fi technology was a regular and one of the most important components for delivering the functionalities of the service. For mobile handsets today, it is not a challenge, since currently all smartphones have been supplied with Wi-Fi chips. However, when BT Fusion was first launched in 2003, Wi-Fi technology was not a standard configuration of mobile devices. To overcome this challenge, the R&D team built links with Motorola, and provided four models of handsets to meet the technical requirements of the Fusion service. However, according to P_1, as Steve Jobs noticed in 2007, from a marketing perspective, devices played a key role in the telecommunications market but not the mobile network providers. Therefore, compared with hundreds of mobile phone models on the market, the very limited handset range of the Fusion service did bring significant challenges for exploiting the project.

4.5.3.3 The Internal Collaborations Activities

The internal collaborations between the R&D team and the other divisions within BT Group were mainly from two perspectives, which are the communications with the board members and collaborations with the division of BT Retail respectively.

In comparison with the 21CN project where 10 billion pounds was invested, BT Fusion is a relatively small project within the BT Group. Therefore, for the Fusion service, the interest from the board members was much less than 21CN. According to P_1, there did exist some communications between the R&D team and the board members on the development activities of the Fusion service. But compared with 21CN, where all the activities in the development cycle were requested to be presented regularly, the R&D team of Fusion presented only the key components of the development activities, such as the strategic plan, the technical architecture, and the key R&D outcomes. Moreover, the feasibility assessments from the board on Fusion were much fewer than for the 21CN project.

As mentioned in the case study of 21CN, to undertake the development activities, the R&D team built internal links with all the departments of the BT Group. However, for the Fusion service project, since it was a project facing only to individual customers, the major internal links that the R&D team built were with the department of BT Retail. The marketing people from the Retail department provided information about the market analysis, customer behaviour, technical bugs, and the demands of customers from the Fusion service to the R&D team, whilst the R&D team provided technical support and technical solutions for customer services to the Retail department. However, according to P_1, after demerging Cellnet from the BT Group, the Retail division did not have high street shops any more at that time. Therefore, the BT Fusion product cannot be presented to customers on site, which has become a significant challenge for exploiting the Fusion service.

4.6 Summary

In this chapter, based on the data collected from 29 interviews and a three-month internship, the four case studies concentrated on in this PhD research work were described, including the telematics services within China Mobile, the Xi-He system within China Telecom, and 21CN and BT Fusion within British Telecom. In each case study, the background of the firm and the cases were introduced first, and the development activities were described objectively from the four radical innovation development stages indicated in the conceptual framework, which are: the idea generating stage, the project management stage, the R&D stage, and the launching stage respectively. In the next chapter, the data presented in Chapter 4 will be analysed from the perspectives of the R&D department's capabilities and the contextual factors affecting the R&D team's uses of these capabilities in different radical innovation development activities.

Chapter 5 Data Analysis

5.1 Introduction

Building upon the conceptual framework developed in Chapter 2 and standing in the position of the R&D department, Chapter 4 presented the development processes of the four selected cases in the current research. Following the initial data analysis results included within Appendix 3, where the R&D department's capabilities involved in each activity of the radical innovation development cycle were marked from level zero to level three, in this chapter, the data presented in the previous chapter will be cross-analysed for the four cases, and the main reasons for their different uses in each case are described in relation to the contextual factors identified in Chapter 2.

5.2 Data Analysis

5.2.1 Idea Generating Stage

- **Developing the Innovative Idea and Making Decisions**

Based on the data presented in the previous chapter, the R&D departments of the four telecommunications operators focused on had six capabilities within their idea generating and decision making activities, as described in Table 5.1 below[40]:

[40] As identified in Chapter 3, the letter T stands for the telematics service within China Mobile, X for the Xi-He system developed by China Telecom, and the letter N and F stand *for BT's projects on 21CN and Fusion respectively.*

Table 5.1: Creating the Innovative Idea and Making Decisions

Activity	Capabilities	T	X	N	F
Creating the Innovative Idea and Making Decisions	Creativity	1	1	1	1
	Technology Capability	1	3	3	3
	Opportunities & Threats Sensing Capability	2	2	2	3
	Internal Collaborations Capability	1	1	1	1
	External Collaborations	2	2	0	0
	Knowledge Identifying Capability	3	2	0	0

By comparing the R&D departments' capabilities for undertaking the idea generating and decision-making activities of the four cases as shown in Table 5.1, there are certain issues regarding the similarities and differences between the four R&D departments, as analysed below:

Firstly, all the four cases selected for this research did not concentrate on their creativity capabilities in the idea generating stage. For the telecommunications operators in China, since both of the ideas were not generated by the R&D departments themselves, their creativity capabilities were only involved in activities when generating the specific definition of the service and designing solutions for meeting the technical requirements of the government on the project. For the British telecommunications operators, the ideas for the two cases were generated by the board members of the group. However, the R&D department did provide its recommendations and analysis from a technical perspective. Therefore, it can be summarised that the R&D department within the STO did not concentrate on its creativity capability in the idea generating stage, and the contextual factors did not have any impact on this capability when generating innovation ideas.

Secondly, for the four case sites selected, their R&D departments' technology capabilities in the idea generating stage were different. In the case study of telematics, the R&D department of China Mobile had few technical considerations when generating the idea and making a decision. However, for the other three case studies in this research work, their R&D departments had fully technical considerations at this stage. The main reason for the above difference was attributed to the contextual factor of technology content. For telematics, since the technologies involved in the project were learned from other firms in the industry, the technology content of the innovation was relatively low, and there existed a pool of external knowledge on technologies for the R&D department to refer to. Based on this consideration, it was not necessary for them to build a strong technology capability to generate the innovative idea. In comparison, the technology content in the other three cases was high, and there was no existing technical knowledge in the market for their R&D departments to refer to. Therefore, the R&D departments in these three cases built up strong technology capabilities to evaluate all the technical uncertainties and opportunities in the market as well as the technical strengths and weaknesses of the firms themselves. Based on the analysis above, the R&D departments' technology capability was affected by the contextual factor of technology content, and the higher the technology content involved in the innovation, the stronger the technology capability the R&D department built up in their idea generating activities, and vice versa.

Subsequently, for the opportunities and threats sensing capability, all the four R&D departments concentrated on this when undertaking idea generating and decision-making activities, especially for the BT Fusion project. The Chinese telecommunications operators focused on their internal strengths and external opportunities when making decisions, whilst neglecting negative perspectives. In contrast, the UK telecommunications operators emphasised their internal weaknesses and external threats, but neglected their positive aspects. The reason for the above difference was attributed to the contextual factor of cultural context. In China, competition in the telecommunications market is low since the state-owned firms such as China Mobile and China Telecom dominate the market, and the government have huge support for the industry from both finance and policy perspectives (Lu & Wong 2003). Therefore, it is not necessary for Chinese telecommunications operators to focus on weaknesses or threats because they have less pressure on their survival. However, the UK telecommunications market is one of the most competitive markets in the world. The telecommunications operators need to concentrate on their profit and provide cost-reduction solutions all the time, since they need to survive (Bromwich & Hong 2000). According to this consideration, it is important for them to identify the threats and weaknesses which can bring challenges to them even in the beginning stage of the innovation development process. Based on the analysis above, it can be summarised that when creating the idea and making the decision to develop a radical innovation, the R&D department had strong opportunities and threats sensing capability. Due to the cultural contexts of the cases, the R&D department within UK telecommunications operators concentrated more on their threats and weaknesses in this stage; whilst in China, the R&D department focused on the opportunities and strengths to help them make the decision on the development of its innovation.

Fourthly, when creating innovative ideas, the internal collaborations capabilities of the four selected R&D departments were not strong. During the idea generating stage, the R&D departments built links only with the top management teams of the firm for feasibility assessments and resources allocation, but did not place emphasis on internal links with other departments. Based on the analysis above, it can be summarised that when generating innovative ideas, the only internal links that the R&D department built was with the top management team of the group. Therefore, it was not necessary for them to build up a strong internal collaboration capability in this stage.

Fifthly, in the idea generating and decision making stage, the two Chinese R&D departments collaborated with the government and external partners for their innovations, whilst for the two UK cases, the R&D departments did not have any external collaboration activities in this stage. The reason for the above difference was due to the contextual factor of cultural contexts. In China, since the government had strong support for the industries both from the policy and the finance perspectives, it was important for the telecommunications operators to build close links with them. In the case study of telematics, the R&D department collaborated closely with the government in making the decision to develop their innovative service. In the case study of the Xi-He system, despite the fact that the R&D department of China Telecom did not collaborate with the government directly in this stage, collaborations with partners who participated in the government-linked project previously helped the department build indirect links with the government. For the two UK cases, since the UK telecommunications industry is more market-oriented, it was not necessary for the R&D departments to build links with the government for creating their ideas and making decisions. Based on the analysis above, it can be summarised that in the idea generating stage, the R&D department's external collaborations capability was related to the contextual factor of cultural contexts. In China, the R&D department collaborated closely with the government for their decision-making activities, whilst in the UK it was not necessary for the R&D department to build any external links in this stage.

Finally, for the knowledge identifying capability, the R&D departments in the case studies of telematics, Xi-He, and Fusion concentrated on this when generating their ideas and making decisions, whilst for the case study of 21CN, its R&D department did not identify any external knowledge in this stage. The reason for the above difference lay in the contextual factor of source of innovation. For the two Chinese cases and the Fusion service, since their sources of innovation were external knowledge such as similar products in the industry, regulations, and market demands, it was important for the R&D department to identify these external sources during the idea generating stage. In comparison, in the case study of 21CN, the idea of 21CN was generated from the perspective of the internal need pull, and there was no external knowledge involved for the R&D department with which to identify. Based on the analysis above, the contextual factor of source of innovation affected the R&D department's knowledge identifying capability when undertaking the idea generating activities. If the innovation source was from external knowledge, the R&D department built a strong knowledge identifying capability for generating its innovative idea, and when the innovation sources were from the internal perspective, it was not necessary for the R&D department to concentrate on its knowledge identifying capability in that stage.

5.2.2 Project Management Stage

- **Constructing the Team**

Referring to the data presented in the previous chapter, two capabilities were involved in the R&D department's activities on constructing the team, which were organisational capability and internal collaborations capability, as shown in Table 5.2, and in this sub-section, the similarities and differences among the four R&D departments' uses of these two capabilities are discussed in detail.

Table 5.2: Constructing the Team

Activity	Capabilities	T	X	N	F
Constructing the Team	Organisational Capability	3	3	3	3
	Internal Collaborations Capability	0	1	1	1

When constructing the teams for developing radical innovations, organisational capabilities were focused on by all of the R&D departments in the four case studies. Large firms such as the STOs concentrated on in this research all had mature team management skills (Rogers 2004), and the organisational capabilities already existed in the R&D departments. Besides, the constructed R&D teams in the four cases were in different forms and the physical distances between the team members were various. However, the R&D departments' organisational capabilities were not affected by this. Based on the analysis above, it can be summarised that when constructing the team for the development of a radical innovation, the R&D department built up a strong organisational capability, and the form of the R&D team did not have any impact on its organisational capability.

For the internal collaborations capability, all the R&D departments did not build up close links with other departments within their case sites when constructing the

R&D team. Due to existing R&D experience and organisational capabilities, most of the required capabilities for developing the cases already existed in the departments. Therefore, it was not necessary for them to hire new staff from other departments to construct the team. However, in the cases of 21CN and BT Fusion, since their innovations were closely related to other departments' lines of business, when constructing the R&D teams, a few project management experts from these departments did participate in the development processes of the cases. Additionally, in all of the four cases, the R&D departments did not have any links with the board members of the groups. Based on the analysis above, the R&D department did not have the strong internal collaborations capability to build its team, but if the innovation was closely related to other departments' lines of business, some specific internal links with these departments also helped the R&D department with its team construction activities.

- **Policy Tracking**

Based on the data presented, four capabilities were utilised by the R&D teams on tracking the latest policies for the development of their radical innovations, including the opportunities and threats sensing capability, the external collaborations capability, the knowledge identifying capability, and the knowledge learning capability.

Table 5.3: Policy Tracking

Activity	Capabilities	T	X	N	F
Policy Tracking	Opportunities & Threats Sensing Capability	3	0	0	0
	External Collaborations Capability	1	2	0	0
	Knowledge Identifying Capability	2	0	0	0
	Knowledge Learning Capability	3	1	0	0

As shown in Table 5.3 above, due to the contextual factor of cultural contexts, the R&D teams in the UK cases did not have any activities on tracking policies from the regulators. For the Chinese cases, with different sources of innovation, the R&D teams' capabilities on the policy tracking activities were differently used, as stated below:

Firstly, for the opportunities and threats sensing capability, the R&D team for telematics concentrated on this when tracking policies. One member of the non-technical staff within the team identified the opportunities and threats that could be produced by the latest policies and reported to the other team members for discussion. However, in the case study of the Xi-He system, the R&D team within China Telecom did not build up any opportunities and threats sensing capability in this stage.

Secondly, for the external collaborations capability, the R&D team for telematics built links only with the Ministry of Industry and Information of China when undertaking policy tracking activities. But for the other related departments of the government on telematics, such as the Ministry of Transport of China, the R&D team did not have any collaborating activities with them in this stage, since transportation was an unfamiliar industry to China Mobile and they did not have any existing links with this department of the government. Moreover, the R&D team for telematics did not collaborate with any other companies for tracking polices. In comparison, in the case study of the Xi-He system, the R&D team had strong external collaborations capabilities in this stage. As a participant in the project, they had close links with the government and learned the policies much more easily than the non-participants. Additionally, similar to the case of telematics, the R&D team for the Xi-He system did not build any links with other firms on tracking policies.

Thirdly, for the knowledge identifying capability, in the case study of telematics, one non-technical member of staff within the R&D team was responsible for tracking the latest policies, and with a pool of external knowledge on policies, this team member identified the ones that could have an impact on their telematics service and reported this to the team leader. In contrast, in the case study of the Xi-He system, since most of the newly published policies were supplementary to the initial project plan proposed by the government, and few of them were disruptive ones, it was not necessary for the R&D team to concentrate on its knowledge identifying capability in this stage.

Finally, for the knowledge learning capability within the R&D team for telematics, they first tracked significant policies, then the staff responsible for policy tracking analysis had discussions with other team members to identify the opportunities and threats that could be produced by these policies. However, since the policy tracking staff did not have a strong technical background, they could not relate all the policies to the development activities of telematics from a technical perspective. In the case study of the Xi-He system, since most of the policies had a clear and direct impact during the development process of the Xi-He system, it was not vital for the R&D team within China Telecom to build up a strong knowledge learning capability at this stage.

Based on the discussions above, the reasons for the above differences among the capabilities in the four cases contained factors of cultural contexts and source of innovations. For the factor of cultural contexts, as mentioned in the beginning of this sub-section, it was important for the R&D departments in China to concentrate on their policy tracking activities, whilst in the UK it was not necessary for the telecommunications operators to do so, and none of the four capabilities for tracking policies were identified by them at this stage. For the factor of source of innovation in the Chinese cases, in telematics, since its main source of innovation was other firms in the global industry but not the policies published by the government, it was important for the R&D team to identify whether a similar innovative service could be implemented in the domestic policy trend at that time. Additionally, since the idea of telematics was not learned from the government directly, the R&D team did not build close links with the government. Therefore, it was also necessary for them to identify and learn the policies published by the government in the related areas of telematics. By contrast, the Xi-He system was a project published by the government, and as a participant in the project, the R&D team within China Telecom built close links with the government on tracking policies. Thus, it was not necessary for the R&D team to have strong opportunities and threats sensing capability for tracking policies. Moreover, with the advantage of a government-sponsored project, most of the policies published in the related areas of the Xi-He system had a direct and clear impact on the development process. Based on this consideration, the R&D team did not have the strong capability to identify and learn the latest policies.

To sum up this sub-section on policy tracking, the R&D departments of the UK telecommunications operators did not concentrate on any capabilities at that stage. For the Chinese telecommunications operators, if the source of the radical innovation was regulation, the R&D department had strong external collaborations capability, but weak opportunities and threat sensing capability, knowledge identifying capability, and knowledge learning capability for tracking policies. If the source of innovation was not regulation, the R&D team concentrated on its opportunities and threat-sensing capability, knowledge identifying capability, and knowledge learning capability, but placed less emphasis on the external collaborations capability for this activity.

- **Identifying Uncertainties**

According to Leifer et al. (2000), uncertainties cataloguing should be undertaken at the very beginning of the radical innovation development cycle, and it could provide a foundation for the team to identify alternative paths to finding solutions to uncertainties. Based on the data presented in Chapter 4, four capabilities were involved in the R&D teams' uncertainties identifying activities, as listed in Table 5.4:

Table 5.4: Identifying Uncertainties

Activity	Capabilities	T	X	N	F
Identifying Uncertainties	Opportunities & Threats Sensing Capability	2	2	2	2
	Knowledge Identifying Capability	3	0	0	0
	Knowledge Learning Capability	3	0	0	0
	Technology Capability	0	3	3	3

As shown in Table 5.4, the R&D teams in different cases had different capabilities in their uncertainties identifying activities, and the similarities and differences among the R&D teams on these four capabilities can be analysed as follows:

When undertaking activities on identifying uncertainties, the R&D teams in the four cases all concentrated on the opportunities and threats sensing capabilities for the development of their radical innovations. In the Chinese cases, they mainly identified uncertainties that could be produced by external opportunities and threats in the domestic industry, and placed less emphasis on the uncertainties that arose through their internal strengths and weaknesses. For the UK cases, the R&D teams within BT identified the uncertainties produced by their individual weaknesses and external threats, but focused less on the positive perspectives, such as their internal strengths and external opportunities. The main reason for the above difference was attributed to the contextual factor of cultural contexts. In China, since competition in the telecommunications market was not strong and the government had huge support in the domestic industry for boosting technology developments, the R&D teams faced less pressure on the survival of their innovative projects. Therefore, at this stage, it was vital for the R&D teams to focus on the uncertainties that could be produced by external sources such as policies, whilst it was less important for them to identify the uncertainties that arose from internal strengths and weaknesses. In contrast, in the UK, competition in the telecommunications industry was strong and the government provided less support for the market, so the R&D teams' pressures on the survival of their projects were much larger than in the Chinese cases. Therefore, at the beginning of the development cycles of their innovations, the R&D team needed to identify the worst situations that they could meet during the development of the projects, which could be brought about by the uncertainties of their internal weaknesses and external threats, but not their individual strengths and external opportunities. Based on the analysis above, it can be summarised that the R&D teams needed to have strong opportunities and threats sensing capabilities for identifying the uncertainties related to the development of radical innovations. Due to the contextual factor of cultural contexts, the R&D teams in the Chinese cases mainly concentrated on the uncertainties that could be brought about by external opportunities and threats. In the UK, the R&D teams usually focused on the uncertainties that arose through their individual weaknesses and external threats.

For the knowledge identifying and knowledge learning capabilities, only the R&D team within China Mobile focused on these for identifying uncertainties on the development of telematics, but for the other three cases in this research, they did not concentrate on these two capabilities in their uncertainties identifying activities. The contextual factor of project narrative was the main reason for the above difference. Differently from the other three cases, telematics was a project that was radical only to the firm but not to the global industry. Therefore, at the beginning of the development cycle, there existed a pool of external knowledge on the uncertainties that other firms had met in the development of their telematics services. The R&D team within China Mobile identified them and was concerned whether they could also occur in its individual service. However, since the other three cases concentrating on in this research were radical to the global industry, there was little external knowledge of uncertainties for the R&D teams to refer to. Based on this consideration, it was not necessary for them to build up strong knowledge identifying and knowledge learning capabilities in this stage. To sum up, the R&D team's knowledge identifying and knowledge learning capabilities for identifying uncertainties could be affected by the contextual factor of project narrative. If the innovation was radical only to the firm, it was important for the R&D team to concentrate on its knowledge identifying and knowledge learning capabilities in this activity. By contrast, if the innovation was radical to the global industry, the R&D team did not need to build up strong knowledge identifying and knowledge learning capabilities for identifying uncertainties during the development process of its radical innovation.

According to Leifer et al. (2000), among different kinds of uncertainties, technical challenges are the only part of a puzzle that must be resolved. Therefore, technology capability can play a significant role in uncertainties identifying activities. In the four case studies concentrated on in the current research, the R&D teams of Xi-He, 21CN, and BT Fusion placed significant emphasis on their technology capabilities when identifying uncertainties. However, in the case study of telematics, the capability was not concentrated on by the R&D team within China Mobile in this activity. The main reason for the above difference lay in the contextual factor of technology content. Since the technologies for filling the technical gaps and realising the telematics service were learned from other firms in the industry, the technology content of this innovation was relatively low. Therefore, the significant technical uncertainties had already been identified by other firms, and it was not necessary for the R&D team within China Mobile to have strong technology capability in this situation. For the other three cases in this research, the technologies involved in the innovations were self-developed by the R&D teams, and the technology content of these projects was high. Based on this consideration, there were no mature technologies and identified technical uncertainties for the R&D teams to refer to, which required them to build up strong technology capabilities for identifying all the technical uncertainties related to their innovations. Therefore, it can be summarised that when identifying the uncertainties that exist in the radical innovation development process, the R&D team's technology capability could be affected by the contextual factor of technology content, and the higher the technology content involved in the innovation, the stronger the technology capability the R&D department built up in its uncertainties identifying activities, and vice versa.

- **Developing a Strategic Plan**

According to previous research, the strategic plan can guide the firm's resource allocations, value delivery, and competitive advantage for their radical innovation (Dodgson et al. 2008), and it plays an important role in the radical innovation development process (Tidd & Bessant 2009). Referring to the four cases presented in the previous chapter, the R&D teams' capabilities involved in the strategic plan development activities can be shown as Table 5.5 below.

Table 5.5: Developing a Strategic Plan

Activity	Capabilities	T	X	N	F
Developing a Strategic Plan	Opportunities & Threats Sensing Capability	2	2	2	2
	Creativity	2	1	1	1
	Technology Capability	1	1	3	3
	Internal Collaborations Capability	0	0	3	1
	Knowledge Identifying Capability	3	0	0	0

As shown in Table 5.5, the R&D teams' capabilities on developing their strategic plans included the opportunities and threats sensing capability, the creativity capability, the technology capability, the internal collaborations capability, and the knowledge identifying capability. Their similarities and differences for developing a strategic plan is analysed below:

For the opportunities and threats sensing capability, when developing strategic plans for their radical innovations, the R&D teams in the four cases identified various technical opportunities and threats, both from internal and external perspectives at this stage. However, according to Zott et al. (2011), strategic plans in innovations are not only related to technologies, but also to value creation, competitive advantage, and relationship infrastructure from the business and marketing perspectives, which were less focused on by the R&D teams in the four cases. Based on the analysis above, it can be summarised that when developing strategic plans, most of the technical opportunities and threats from the internal and external perspectives were concentrated on by the R&D teams within the telecommunications operators, but less focus was identified in relation to business and marketing considerations in this stage.

When building strategic plans for developing radical innovations, the R&D teams in the four cases had different creativity capabilities as follows: in the case study of telematics, despite referring to some existing products in the global industry, the strategic plan for telematics was developed by the R&D team itself, whilst in the other three cases, the R&D teams had fewer creativity activities in this stage since they followed the traditional strategic plans for their existing products. The reason for the above difference lay in the contextual factor of market concentration. Since the R&D team for telematics faced a totally new market on developing their radical innovation, it was difficult for them to refer to any internal experience of existing telecommunications products in this stage. Therefore, the strategic plan for telematics was specifically designed by the R&D team and involved significant creative activities in this process. However, since the other three cases in this research distributed in the same markets as their existing products, in this stage, the R&D teams referred to their strategic plans for the existing products and designed new ones. Based on the analysis above, the contextual factor of market concentration had an impact on the R&D team's creativity capability when building the strategic plan. If the project was in a totally new market compared with its existing products, the R&D team needed to concentrate on its creativity capability in this stage. If the project distributed in the same market as its existing products, it was not necessary for the R&D team to have strong creative capability for developing its strategic plan.

For the technology capability, when developing the strategic plan, the R&D teams in the four cases had different concentrations on it for developing their radical innovations. In the case study of telematics and Xi-He, despite the technical considerations on identifying opportunities and threats from internal and external perspectives, in this stage the R&D teams did not have detailed plans for realising the relevant technologies of the projects. By contrast, in the case study of 21CN and BT Fusion, the strategic plans were developed mainly with technical considerations such as the functionalities that their innovations required and how they could achieve these technologies. Therefore, comparing the four cases, the UK telecommunications operators had stronger technology capabilities for developing their strategic plan than the Chinese telecommunications operators. The contextual factor of cultural contexts was the main reason for the above difference. In China, due to the significant support from the government and the relative low competition in the telecommunications industry, the tolerances of the firms to failure are high. Therefore, for the technological innovations, the Chinese telecommunications operators concentrated on the 'concept' of innovations rather than the actualising of them[41]. Based on this consideration, it was not necessary for their R&D teams to build up strong technology capabilities in this process. In the UK, competition in the telecommunications sector is high and operators such as BT face huge pressures for survival. Therefore, it was important for their R&D teams to build up strong technology capabilities at this stage, which can be helpful when designing detailed technical plans for realising their services and passing them to board members for feasibility assessments. Based on the analysis above, the R&D team's technology capability on developing a strategic plan was affected

[41] Referring to the interview with W_1

by the factor of cultural contexts. In the Chinese cases, the R&D teams did not concentrate on their technology capabilities in this stage, whilst in the UK, it was important for their R&D teams to build strong technology capabilities for developing their strategic plans.

In the strategic plan designing activities, only the R&D team of 21CN built strong internal collaborations capability on developing its innovation, but for the other three cases in this research, the R&D teams did not concentrate on their internal links during this stage. The factor of project size was the main reason for the above difference. For the 21CN project, since it was BT's largest investment in ten years and £10 billion was invested in it, the board members and even the whole group had significant interest in this project. Therefore, during this process, the R&D team needed to build close links with the board members and other departments, and present its strategic plan to them again and again for their feasibility assessments. However, for the other three cases, their project sizes were relatively small, and the attention from the board members was much less compared with 21CN. In this situation, it was not necessary for them to build strong internal collaboration capabilities when developing their strategic plans. Based on the analysis above, the R&D teams' internal collaborations capability when designing a strategic plan could be affected by the factor of project size, and the larger the project was, the stronger the internal collaborations capability the R&D team built, and vice versa.

For the knowledge identifying capability when developing the strategic plan, among the four cases in this research, only the R&D team for telematics had a concentration on this capability, and for the other three cases, they did not identify any external knowledge during this stage. The reason for the above difference lay in the contextual factor of project narrative. In the case study of telematics, since it was a project that was radical only to China Mobile itself but not to the global industry, there existed a pool of external knowledge on the strategic plans of mature telematics products. After identifying the strengths and weaknesses of these external strategic plans, the R&D team within China Mobile avoided the pre-installed market segment that was dominated by vehicle manufacturers, and found their new one. In the other three case studies that were radical to the global industry, there was no external knowledge on strategic plans that could be identified by their R&D teams. Therefore, in this stage, it was not necessary for them to build strong knowledge identifying capabilities for developing their strategic plans. Based on the analysis above, it can be concluded that during the strategic plan development process, the R&D team's knowledge identifying capability could be affected by the factor of project narrative. If the project was radical only to the firm itself, the R&D team needed to build up strong knowledge identifying capability in this stage. However, if the project was radical to the global industry, it was not necessary for the R&D team to concentrate on its knowledge identifying capability for developing the strategic plan for its innovation.

- **Building An Innovation Network**

Since technologies are becoming more complicated in modern industries, the innovation development process cannot be a solo act but must be a group of activities (Dodgson et al. 2008; Tidd & Bessant 2009). Therefore, it is important for technical firms, especially their R&D departments, to concentrate on external links and construct networks for developing their innovations (Freeman 1991). Based on the data presented in the previous chapter, after developing strategic plans, the R&D teams built up two capabilities for constructing their innovation networks, including the external collaborations capability and the technology capability, and the similarities and differences of these capabilities among the four cases are analysed in this sub-section.

Table 5.6: Building an Innovation Network

Activity	Capabilities	T	X	N	F
Building An Innovation Network	External Collaborations Capability	2	2	2	2
	Technology Capability	1	1	3	3

As can be seen in Table 5.6, when constructing innovation networks, the R&D teams in the four selected cases all had strong external collaborations capabilities. In the case studies of telematics and the Xi-He system, the R&D teams mainly built their external links with content and service providers for their innovations, and these links were newly built in this stage. But for the links with technical partners on research activities, the R&D seldom concentrated on that. By contrast, in the case studies of 21CN and BT Fusion, their R&D teams mainly found partners for developing technical solutions in this stage, and these partners were selected from some world-leading firms that had long-term and mature relationships with BT. But for the links with application and content providers, the R&D teams within BT did not focus on that. The reason for the above difference was complex; however, it can mainly be described in relation to the contextual factors of source of innovation and market concentration. For telematics, since its source of innovation was watching others, and the technology solutions for releasing the service were mature in the industry, it was not necessary for the R&D team to consider technical partners in this stage. However, with mature technical solutions, the bottleneck for the development of telematics became the application of it, which made the R&D team move its concentration to partners from this perspective. Xi-He was a project proposed by the government, and they assigned the responsibilities for the development process to different participants. China Telecom was responsible for the technical part of it, and their R&D team had comprehensive solutions for realising the technologies, so they did not concentrate on building external links from technical perspectives. However, for the partners appointed by the government on applications, the R&D team within China Telecom did not collaborate with them very well, since they thought that these partners did nothing in the development process of Xi-He. Therefore, the R&D team found new partners for applications by themselves and built close links with them. For the projects of 21CN and BT Fusion, their sources of innovations were internal need pull and external need pull respectively when filling BT's technical gaps. Based on these considerations, they found partners to help them fill these gaps and built close links with them. But for the links for applications, due to the contextual factor of market concentration, the lines of business for 21CN and BT Fusion were similar to BT's existing services, and most of the applications could be migrated from the legacy networks to the innovative ones. Therefore, it was not necessary for their R&D teams to concentrate on their external links with applications providers in this stage. Based on the analysis above, it can be concluded that when building innovation networks, all of the R&D teams built up strong external collaborations capabilities. However, their concentrations were different due to the factors of source of innovation and market concentration. If the sources of innovation were not related to technologies, such as watching others and regulations, it was important for the R&D team to build close links with applications providers; if the source of innovation were the internal and external needs for filling the technical gaps, and the lines of business were similar to their existing products, the R&D team needed to concentrate on building external links from the perspective of technology development, but not applications.

For the technology capability, the four R&D teams had different concentrations on it when undertaking their innovation network building activities. In the case studies of telematics and Xi-He, since their co-operators during the innovation development processes were mainly from the perspectives of service content and applications, it was not necessary for the R&D teams to have strong technology capabilities for selecting their partners. For the case studies of 21CN and BT Fusion, the R&D teams built their external links mainly for technologies development. Therefore, when finding partners, they had significant concentration on their technology capabilities. The reason for the difference was the contextual factor of source of innovation as specified in the external collaborations capability in this stage. Based on the analysis of it, it can be concluded that if the innovations source was related to technologies such as the need for filling technical gaps, the R&D team needed to have strong technology capability for building their innovations networks, whilst if the innovation source was not related to technologies, it was not necessary for them to build up strong technology capability in this stage.

5.2.3 R&D Stage

According to Dodgson et al. (2008), R&D activities can provide an important contribution to radical innovation since it is the major source of rejuvenation and growth for companies. In this section, the R&D teams' R&D activities for developing radical innovations are analysed from the perspectives of research and product development respectively.

- **Research Activities**

As Arnold et al. (1992) indicate, research activities for developing radical innovations include actions such as generating new knowledge, understanding theory, and absorbing external knowledge. In this study, based on the data presented in the previous chapter, eight capabilities were involved in the R&D teams' research activities as shown in Table 5.7 below. In this sub-section, the similarities and differences of these capabilities between the four cases are also discussed.

Table 5.7: Research Activities

Activity	Capabilities	T	X	N	F
Research Activities	External Collaborations Capability	1	1	3	3
	Internal Collaborations Capability	1	1	1	1
	Technology Capability	3	2	3	3
	Creativity	1	2	3	3
	Knowledge Identifying Capability	3	1	1	1
	Knowledge Learning Capability	2	0	0	0
	Knowledge Reframing Capability	3	0	0	0
	Organisational Capability	2	2	3	3

When undertaking research activities, the R&D teams in the four cases had different concentrations on their external collaborations capabilities. In the case studies of telematics and Xi-He, the R&D teams focused on external links with government for co-publishing the white paper or reporting their research progress, in addition to links with the law agencies for filing their patents. However, for technologies development, these two R&D teams did all the technical research activities themselves and did not collaborate with any other firms in this stage. In the case study of 21CN, the R&D team within BT had strong links with their external co-operators on developing technical solutions, producing technical releases, and improving public relations. In the case study of BT Fusion, the external collaborations were mainly from the perspective of filling the technical gaps, and its R&D team built strong links with the mobile solution provider when undertaking the research activities. Except for the factor of source of innovations as mentioned in the innovation networks-building activities in the previous section, the reason for the above difference was also laid in the contextual factor of cultural contexts. For the case studies of telematics and Xi-He, since both of China Mobile and China Telecom are state-owned firms and monopolies in the domestic telecommunications industry, they face less pressures in the market and "do not have the willingness to collaborate with others" [42]. In the research stage, they concentrated on their links with the government, and when they met some technical gaps, they preferred to build up new capabilities rather than collaborating with other firms. However, for the UK cases, since BT is a public company facing one of the most competitive markets in the world, they faced significant pressures on survival. Therefore, when meeting technical gaps, the R&D teams evaluated the cost of the decisions of building up new capabilities, collaborating with others, and making acquisitions on capabilities (de Man & Duysters 2005), and then reported to the board members for their feasibility assessments. For the cases of 21CN and BT Fusion, since the technical gaps in the research stage were significant, it was difficult and expensive for the R&D teams to build up all the capabilities individually. Based on this consideration, they chose the partners that had mature relationships with for filling the technical gaps. To sum up, when undertaking research activities, except for the contextual factor

[42] Referring to the interview with F_1

of source of innovation, the R&D team's external collaborations capability was also affected by the contextual factor of cultural contexts: if the firms were state-owned firms and had monopolies in the domestic market, such as China Mobile and China Telecom, their R&D teams concentrated on the external links with the government, but seldom collaborated with technical partners. However, if the firms were public ones and faced significant competition in the industry, the R&D teams built up strong external links with the technical partners on developing their services.

For the internal collaborations capability, when undertaking the research activities for developing radical innovations, the R&D teams in the four cases concentrated on only built internal links with the board members of the firms for central assessing. However, for the links with other departments, the R&D teams did not concentrate on them in this stage. Therefore, it can be concluded that during the research stage of the radical innovation development cycle, it was not necessary for the R&D team to have the strong internal collaborations capability, and the only internal link it needed to build was with the board members. Moreover, none of the contextual factors on affecting the R&D department's uses of capabilities could have impact on the team's internal collaborations capability in this stage.

When developing radical innovations, despite in the case study of Xi-He where its R&D team was criticised by the partners on the technology capability for filling the technical gaps, the four focused R&D teams in this research, including the Xi-He team, all concentrated on building up their technology capabilities for undertaking research activities in this stage. Based on the analysis above, it can be summarised that in the research stage for developing a radical innovation, it was important for the R&D team to have strong technology capability on their research activities, and for the contextual factors that could have impacts on the R&D department's uses of capabilities, none of them had impact on the R&D team's technology capability in this stage.

For the creativity capability when undertaking the research activities, the R&D teams in the four cases had different concentrations on it. In the case study of telematics, the R&D team within China Mobile only had their creativity on applying patents in this stage; for Xi-He, despite the idea on realising the indoor positioning solution with the Wi-Fi technology that was referred to some research and academic institutes for the algorithm of it, it was self-developed and tested by the R&D team in this stage. Moreover, the R&D team also had their creativity on applying patents, whilst for the 21CN project and BT Fusion, the R&D teams within BT designed all of their research activities by themselves and undertook them together with the co-operators, which involved a lot of creativity in this stage. The reason for the above difference was based on the factor of technology content. For telematics, as mentioned previously, the technology content involved in the project was relative low, and when undertaking the research activities, there existed some mature research experience to which the R&D team could refer. Therefore, it was not necessary for them to build up strong creativity capability in this stage. For the other three cases in the current research, since the technology content involved in their innovations was high, there was no existing experience of the research activities for these three R&D teams to which to refer. Based on this consideration, the R&D teams needed to have strong creativity capabilities for undertaking the research activities on their radical innovations. To sum up, the R&D teams' creativity capability in the research activities was affected by the factor of technology content, and the higher the technology content involved in the innovation, the stronger the creativity capability the R&D department built up in their research activities, and vice versa.

When undertaking the research activities for developing radical innovations, the four R&D teams had different knowledge identifying capabilities in this stage. In the case study of telematics, the R&D team within China Mobile had significant concentrations on identifying the external knowledge in the industry, from not only the perspective of technologies, but also patents reviewing. In contrast, for the other three cases in this research, they did not build up strong knowledge identifying capabilities for undertaking research activities, and the only external knowledge they identified in this stage was a patents review for the new aspects of their individual innovations. The factor of technology content was also the reason for the above difference. In the case study of telematics, since the technology content involved in the project was relatively low, most of the technical solutions for realising the telematics service were learned from other firms in the industry. Therefore, when undertaking the research activities for telematics, there existed a pool of external knowledge on the existing products for the R&D team to refer to, and this external knowledge did help the R&D team find their research direction and avoid the experience of failure of other companies' research. In contrast, the technology content involved in the other three cases was high, and there was no related external knowledge on the technologies for their R&D teams to refer to. Based on this consideration, the R&D teams did not build up strong knowledge identifying capabilities in their research stages. Therefore, it can be summarised that when undertaking research activities for developing radical innovations, the R&D team's knowledge identifying capability was affected by the contextual factor of technology content, and the higher the technology content involved in the innovation, the stronger the knowledge identifying capability the R&D department built up in their research activities, and vice versa.

For the R&D teams' knowledge learning and knowledge reframing capabilities in the research stage, they were closely related to the knowledge identifying capability and could also be affected by the contextual factor of technology content. If the R&D team concentrated on identifying external knowledge in this stage, they would have the resources to learn and reframe it subsequently for their research activities, and build up strong knowledge learning and knowledge reframing capabilities. However, if the R&D team did not identify significant external knowledge, when undertaking research activities there would not be enough resources for them to do so. In this situation, it was not necessary for them to concentrate on their knowledge learning and knowledge reframing capabilities in this stage. Based on the analysis above, it can be summarised that the factor of technology content also had an impact on the R&D team's knowledge learning and knowledge reframing capabilities, and the higher the technology content involved in the innovation, the stronger the knowledge learning and reframing capabilities the R&D department built up in their research activities, and vice versa.

When undertaking research activities, the R&D teams in the four selected cases all built up strong organisational capabilities for developing their radical innovations. As three of the largest telecommunications operators in the world, with mature models for managing research activities, strong organisational capabilities could have already existed within the R&D teams before the research stage (Alvarez & Barney 2001). In addition, these R&D teams also had mature incentive systems for individuals in their research achievements. However, in relation to concentration on these incentive systems for research achievements, they were quite different between the cases. In the case studies of telematics and Xi-He, when undertaking research activities, their R&D teams focused on the quantity of their research achievements rather than the quality of them. Within these two R&D teams, members were rewarded for each patent they filed, and for the R&D telematics team, the team leader also assigned the objective of publishing ten patents per year to each team member. But for the implementation of their research achievements, they did not concentrate on these. In contrast, in the case studies of 21CN and BT Fusion, team members were rewarded only for their research achievements, after they could prove that the research was feasible and implementable. Based on this consideration, it can be summarised that the R&D teams within BT focused on the quality of their research achievements rather than the quantity of them. The reasons for the above difference can be ascribed to the contextual factor of cultural contexts. As Z_5 said,

> *"…in China, they (the R&D team) concentra*ted on the quantity of research achievements since it is a significant index for the promotion of *the team members and even the team leaders…(moreover) mobility of staff* and leaders between different teams, departments, and even different state-owned firms is so frequent (in China), which made them only concentrate on the current research progress which can be measured by the quantity of research achievements for their promotions, but never on the long-term benefits of the research, which can be measured by the quality of research achievements (since during that stage, they may not work in the same institution any *more)…".*

However, in the UK, since telecommunications operators such as BT faced significant market competition, and their lines of business became more challenging, they did not have enough funding to undertake all the research activities. Therefore, they encouraged research that could be predicted to have further business value only, which could help them significantly reduce the research costs. Based on the analysis above, it can be concluded that when undertaking research activities on developing radical innovations, all of the R&D teams in this research had strong organisational capabilities. However, their concentration on incentive systems was affected by the factor of cultural contexts. In China, the R&D teams focused on the quantity of research achievements rather than the quality of them, whilst in the UK, the quality of the research was emphasised by their R&D teams during the research stage.

- **Product Development activities**

During the development stage of the four radical innovations, the R&D teams for telematics, 21CN, and BT Fusion had different capabilities for undertaking their product development activities. However, in the case study of Xi-He, since the co-operators played a key role in the product development stage but not the R&D team within China Telecom, the R&D team members built only external links with these co-operators but did not put emphasis on any other capabilities. Therefore, except for the external collaborations capabilities, its R&D team's other capabilities were not focused on in this sub-section.

Table 5.8: Product Development Activities

Activity	Capabilities	T	X	N	F
Development activities	External Collaborations Capability	2	2	0	0
	Internal Collaborations Capability	0	0	3	1
	Technology Capability	3	0	1	1
	Creativity	3	0	0	0
	Knowledge Identifying Capability	3	0	3	3
	Knowledge Learning Capability	3	0	0	0
	Knowledge Transferring Capability	2	0	0	0
	Organisational Capability	3	0	3	3
	Opportunities & Threats Sensing Capability	2	0	0	0

As can be seen in Table 5.8 above, nine capabilities were involved in the R&D teams' product development activities, and the similarities and differences between the four cases are analysed in the following part of this sub-section.

When undertaking product development activities, the R&D teams within the four cases had different concentrations on their external links. In the case study of telematics, the R&D team built close links with its co-operators from the value chain on developing applications. For the project of the Xi-He system, their external links in this stage can be analysed from two perspectives: firstly, for the official partners appointed by the government, the R&D team within China Telecom did not build close links with them, since most of these co-operators did nothing during the product development stage; secondly, for the real co-operators that the R&D team found by themselves, the team members collaborated with them closely. However, in terms of external links with the government on the above two cases, the R&D teams did not concentrate on these in this stage. By comparison, in the case studies of 21CN and BT Fusion, the R&D teams did not collaborate with their co-operators. The reason for the above differences lay in the contextual factors of source of innovation and market concentration, as mentioned in the innovation networks building activities, where if the source of innovation was not related to technologies, such as watching others and regulations, the R&D team needed to collaborate with the content and applications providers for fulfilling its value chain in the product development stage. If the source of innovation was internal and external needs for filling the technical gaps, and the lines of businesses of the innovative product were similar to its existing products, it was not necessary for the R&D team to concentrate on their external collaborations capabilities for undertaking product development activities.

During the development stage of radical innovations, only the R&D team of 21CN built close internal links with the board members of BT Group and other departments for undertaking its product development activities. However, in the other three case studies, their R&D teams did not concentrate on internal collaborations capabilities in this stage. The contextual factor of project size was the main reason for the above difference. As BT's largest investment for ten years, the entire group had significant concentration on the project. Therefore, during the development stage, the R&D team needed to collaborate with the marketing people from different departments on applications and build close links with the board members on the feasibility assessment of its product development activities. But in the other three case studies, their project sizes were relatively small and the concentration from the board members was much less compared with 21CN. Based on this consideration, the R&D teams needed to build only internal links with some specific operating departments from the perspective of applications, but it was not necessary for them to report to the board members regularly on their product development activities. Based on the analysis above, the R&D teams' internal collaborations capability in the development stage was affected by the factor of project size, and the larger the project was, the stronger the internal collaborations capability the R&D team had for its product development activities, and vice versa.

When undertaking product development activities, the R&D telematics team built up strong technology and creativity capabilities when considering its applications and providing technical solutions to their co-operators. But in the case studies of 21CN and BT Fusion, since the applications in these two cases were considered mainly by the marketing people within different operating departments, the R&D teams needed only to provide technical suggestions to these people on the product development activities, and it was not necessary for them to build up strong technology and creativity capabilities in this stage. The reason for the above difference lay in the contextual factor of source of innovation. In the case study of telematics, since it was a project learned from other companies, the R&D team did not built up strong technology and creativity capabilities for its research activities. However, for the product development activities, the R&D team needed to assess the new aspects of their applications from the technical perspective to compete with other companies in the industry. In contrast, in the case study of 21CN and BT Fusion, since their sources of innovations were needs pull on new technologies which were mainly learned by the marketing people within BT Group, it was the responsibility of those marketing people to consider the development activities of their radical innovations. For the R&D teams, they only provided their technical suggestions to the marketing people on applications in this stage. Based on the analysis above, when undertaking product development activities, the R&D team's technology and creativity capabilities were affected by the contextual factor of source of innovation. If the innovation was learned from other companies, the R&D team built up strong technology and creativity capabilities for its product development activities, whilst if the innovations were inspired by needs pull identified by marketing people, it was not necessary for the R&D team to concentrate on these two capabilities in this stage.

For each of the cases on telematics, 21CN, and BT Fusion, when undertaking product development activities, there existed a pool of external knowledge of applications for the R&D team to refer to. With strong knowledge identifying capabilities, these three R&D teams identified the knowledge effectively, but subsequently, for the knowledge learning capabilities on analysing the identified knowledge, these were quite different between cases. In the case study of telematics, with the identified external knowledge on applications, the R&D team within China Mobile indicated their strengths and weaknesses, and found the different market segments when developing their individual applications. In the case study of 21CN and BT Fusion, the R&D teams did not analyse the external knowledge they identified; instead of that, they brought the knowledge back to the marketing people, and these marketing people were responsible for undertaking the learning activities. The reason for the above difference in the knowledge learning capability was due to the contextual factor of source of innovation, where for telematics, it was mainly the responsibility of the R&D team to consider their applications, so it was important for them to learn the external knowledge themselves; whilst for the cases of 21CN and BT Fusion, the marketing people were responsible for developing applications, and it was important for them, but not the R&D people, to analyse the external knowledge to undertake their product development activities.

Moreover, for the knowledge transferring capability, similar to the knowledge learning capability, only the R&D telematics team built this up during its product development activities. However, it was a criticism that in the case study of telematics, the R&D team did not give adequate consideration to their profit model when transferring the knowledge into applications, which could bring them plenty of difficulties in the subsequent exploiting stage. Therefore, it can be concluded that due to the contextual factor of source of innovation, the R&D team for telematics had significant emphasis on their knowledge transferring capability when undertaking product development activities. However, due to their individual limitations, they did not build up the strongest capability for transferring knowledge in this stage.

For the organisational capability when undertaking product development activities, as mentioned in the research stage, as two of the largest telecommunications operators in the world with mature models of R&D management, the R&D teams in the case studies of telematics, 21CN, and BT Fusion all built up strong organisational capabilities during their product development stage. Moreover, these R&D teams also had mature incentive systems for individuals and their developing achievements. Therefore, it can be summarised that when undertaking product development activities, it was important for the R&D team to build up strong organisational capability, and the organisational capability cannot be affected by any contextual factors.

Lastly, among the three cases, only the R&D team for telematics built up its opportunities and threats sensing capability when undertaking product development activities. However, most of the opportunities and threats identified by the team were in relation to technical considerations, whilst fewer marketing and business perspectives were emphasised during the product development process. In the case study of 21CN and BT Fusion, since most of the activities for identifying opportunities and threats were undertaken by the marketing people, it was not necessary for their R&D teams to build up strong capabilities for undertaking product development activities in this stage. The reason for the above difference was also due to the contextual factor of the source of innovation, as mentioned above, and it can be concluded that if the innovation was learned from other companies, the R&D team built up strong opportunities and threats sensing capability for their development activities. If the innovation was inspired by needs pull identified by the marketing people however, it was not necessary for the R&D team to concentrate on its opportunities and threats sensing capability in this stage.

5.2.4 Launching Stage

When the data collection work of the current research was finished, the case study of telematics was still in its development process and the launching activities had not started at that time. Therefore, their R&D team's capabilities in the launching and continuous development stage were not included in this section. For the other three cases in this research, the R&D team’s capabilities in this launching stage were discussed and cross-analysed from the perspectives of testing and fully exploiting.

- **Testing**

According to Cooper (2001), testing activities are compulsory for an R&D team to develop their radical innovation, since having the innovative product work in the lab or development department is not enough, the R&D team also needs to make the product work properly when the customer uses and abuses it. Based on the data presented in Chapter 4, when undertaking testing activities, three capabilities were involved in the R&D teams' testing activities, as shown in Table 5.9 below:

Table 5.9: Testing Activities

Activity	Capabilities	X	N	F
Testing Activities	Technology Capability	3	3	3
	External Collaborations Capability	3	3	3
	Internal Collaborations Capability	1	3	0

When undertaking testing activities for developing radical innovations, all of the three selected R&D teams built up strong technology capabilities in this stage. They had technical considerations for all of their activities, and having met with technical issues when testing, the R&D teams solved them immediately with their technology capabilities. Therefore, it can be summarised that when undertaking testing activities, it was important for the R&D team to build up strong technology capability, and none of the contextual factors can have an impact on this capability during the testing process.

During the testing stage for developing radical innovations, the chosen R&D teams in this research all had strong external collaborations capabilities. In the case study of Xi-He, the R&D team built close external links not only with their partners when realising the end-to-end indoor position solutions, but also with the government on their inspections activities. In the case study of 21CN and BT Fusion, the R&D team collaborated closely with their partners on troubleshooting the problems of their new services in this stage. Based on the analysis above, it can be summarised that during the testing activities of the radical innovation development process, the R&D team built up a strong external collaborations capability, and this capability could not be affected by any contextual factors concentrated on in this research.

For the internal collaborations capability when undertaking testing activities, only the R&D team for 21CN built close links with other internal departments within BT. Since the testing workload for 21CN was massive and the R&D team was requested to complete it within a specific time, the R&D team collaborated with the research centres of BT in other countries for remote testing. Moreover, during the testing process, the R&D team also built close links with board members and other operating departments for their assessing activities. But for the other two R&D teams, they did not concentrate on their internal collaborations capabilities in this stage. The reason for the above difference lay in the factor of project size. Since 21CN was BT's largest investment for ten years, the entire group had significant concentration on the project. Therefore, during the testing stage, the R&D team within BT needed to build close links with them. But in the other two cases, since their project sizes were relatively small and the attention from the board members was much less compared with 21CN, it was not necessary for them to build up strong internal collaborations capabilities in this stage. Based on the analysis above, it can be summarised that during the testing process, the R&D team's internal collaborations capability was affected by the contextual factor of project size, and the larger the project was, the stronger the internal collaborations capability the R&D team had for their testing activities, and vice versa.

- **Fully Exploiting**

During the fully exploiting activities, the three R&D teams handed over the projects to their operating departments. However, it was not expected that all the

R&D challenges could be solved when the projects were finished. The R&D teams also undertook continuous development activities for their radical innovations. Based on the data presented in Chapter 4, in the fully exploiting stage, as indicated in Table 5.10 below, three capabilities were involved in the R&D team's fully exploiting activities, including the technology capability, the external collaborations capability, and the internal collaborations capability, and the similarities and differences among the three R&D teams on these capabilities are also analysed in this sub-section.

Table 5.10: Fully Exploiting

Activity	Capabilities	X	N	F
Fully Exploiting	Technology Capability	3	3	3
	External Collaborations Capability	2	3	3
	Internal Collaborations Capability	2	3	2

When undertaking the fully exploiting activities for developing radical innovations, all the selected R&D teams in this section built up strong technology capabilities, and they not only solved technical issues with the new services, but also considered new applications proposed by the marketing people or co-operators with their technical considerations. Moreover, the R&D teams also built up roll-back capabilities in case of the failure of updates to the services. Based on the analysis above, it can be summarised that during the fully exploiting activities, it was important for the R&D team to build up a strong technology capability, and the R&D team’s technology capability was not affected by any contextual factors.

In the fully exploiting activities, the R&D teams retained their external links with co-operators for developing their radical innovations. In this stage, they collaborated with their co-operators for the continuous development of their services. Therefore, similarly to the testing activities, the R&D team in the fully exploiting stage also built close external links with its co-operators, and none of the contextual factors had an impact on its external collaborations capability.

For the internal collaborations capability during the fully exploiting stage, the three R&D teams collaborated with the operating departments within their groups on the technical issues of the innovations as well as new ideas for applications to be added into the services. However, due to the contextual factor of project size as mentioned in the testing stage, the board members had different levels of concentration on innovative projects. Therefore, in this stage, only the R&D team for 21CN built close links with the board members for central assessing activities, and in the case studies of Xi-He and BT Fusion, their R&D teams did not concentrate on that. Based on the analysis above, it can be concluded that during the fully exploiting activities, it was important for the R&D team to build close links with the operating departments. But internal links with board members could be affected by the contextual factor of project size, and the larger the project was, the stronger the internal collaborations capability the R&D team built for its links with board members, and vice versa.

5.3 Summary

Following the initial data analysis results included within Appendix 3, where the R&D department's capabilities involved in each activity of the radical innovation development cycle were marked from level 0 to level 3, Chapter 5 cross-analysed the data from the four cases. The main reasons for the R&D departments' different uses of the capabilities were described in relation to the contextual factors identified in Chapter 2. The next chapter will discuss the findings of this data analysis chapter in relation to each of the research questions in turn.

Chapter 6 Discussion

6.1 Introduction

The following chapter reviews the findings of the data analysis presented in Chapter 5. These will be discussed in relation to each of the research questions in turn on identifying the R&D departments' capabilities involved in each stage of the radical innovation development cycle, and the contextual factors that played the most significant roles in affecting these capabilities in all of the radical innovation development stages within the STOs.

6.2 Addressing Research Question 1

As analysed in Chapter 5, standing in the position of an R&D department, ten capabilities were identified in relation to activities for developing radical innovations in the telecommunications industry. Table 6.1 below provides an overview of the capabilities involved in each of the R&D departments' radical innovation development activities, and when one capability was addressed by any R&D department in that specific activity, it is ticked in the relevant box of the table. In addition, at the bottom of the table, the numbers of times each capability was addressed can be advantageous in indicating the importance of each capability in the entire radical innovation development cycle. Based on the contents shown in Table 6.1, in this section, to answer the research question on what capability the R&D department of an STO uses for each separate activity of its radical innovation development process, the ten capabilities are further discussed and compared with the previous literature.

Table 6.1: Addressing the R&D Department's Capabilities in the Radical Innovation Development Cycle

Stage	Activities	Creativity Capability	Technology Capability	Opportunities & Threats Sensing Capability	Internal Collaborations Capability	External Collaborations Capability	Organisational Capability	Knowledge Identifying Capability	Knowledge Learning Capability	Knowledge Reframing Capability	Knowledge Transferring Capability
Idea Generating	Creating an Innovative Idea	√	√	√	√	√		√			
Project Management	Constructing the Team				√		√				
	Tracking Policies			√		√		√	√		
	Identifying Uncertainties		√	√				√	√		
	Developing the Strategic Plan	√	√	√	√			√			
	Building Innovation Networks		√			√					
R&D	Research Activities	√	√		√	√	√	√	√	√	
	Development activities	√	√	√	√	√	√	√	√		√
Launching	Testing		√		√	√					
	Fully Exploiting		√		√	√					
Sum		4	8	5	7	7	3	6	4	1	1

Creativity Capability

For the creativity capability during the radical innovation development cycle that can be conceptualised as the process for generating new ideas (Rhodes 1961), the R&D departments within the telecommunications operators in this research not only used this capability for generating an innovation idea from a technical perspective, which was identified by most of the literature (Rhodes 1961; Godoe 2000; Alves et al. 2007; Azadegan et al. 2008), but also for ideas for the strategic plan in the project management stage (Lawson & Samson 2001; Zott & Amit 2008), and for ideas for patents and applications in the R&D stage (Alves et al. 2007; de Rassenfosse & van Pottelsberghe de la Potterie 2009). Based on the above analysis, the creativity capability can be involved in four activities of the R&D department's radical innovation development process, including generating the innovation idea, developing the strategic plan, and the research and development activities, respectively, as shown in Figure 6.1 below:

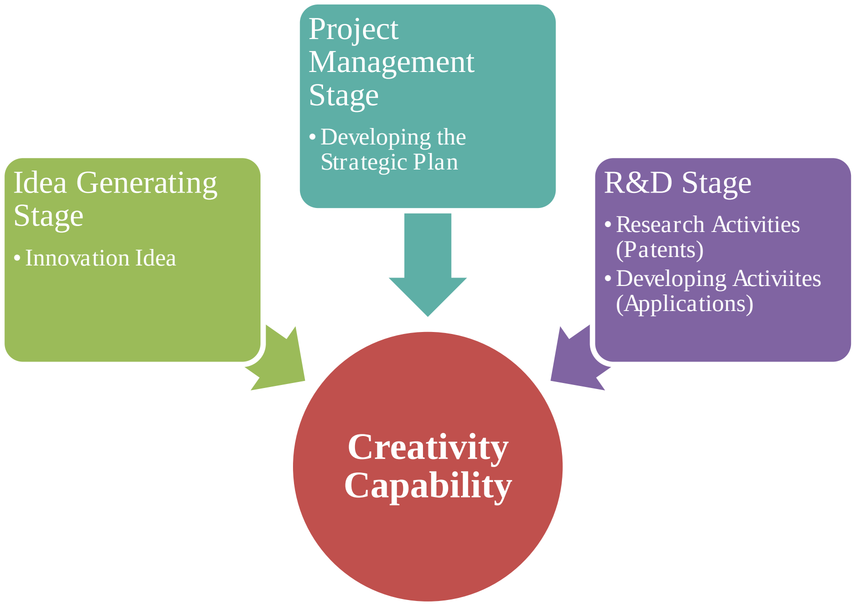

Figure 6.1: The Creativity Capability in the Radical Innovation Development Cycle

Technology Capability

In this research, the technology capability not only relates to the R&D department's activities on formulating and developing new products, but also involves technical considerations in related activities of the radical innovation development cycle (Moorman & Slotegraaf 1999) from the perspective of idea generating (Gatignon & Xuereb 1997), uncertainties identifying (Song et al. 2007), strategic plan developing (Montoya-Weiss & Calantone 1994) and innovation networks building (Song et al. 2007) in the idea generating and project management stages, from the perspectives of researching, product development, testing, and fully exploiting (Song et al. 2007) in the R&D and launching stages, which is the most frequent capability addressed by R&D departments (eight times), from the beginning of their radical innovation development cycles to the end. Therefore, during the radical innovation development cycle, the technology capability was built in by the R&D department within the STO for most of the activities derived from the conceptual model for developing radical innovation, except for activities on team construction and policy tracking, as shown in Figure 6.2 below:

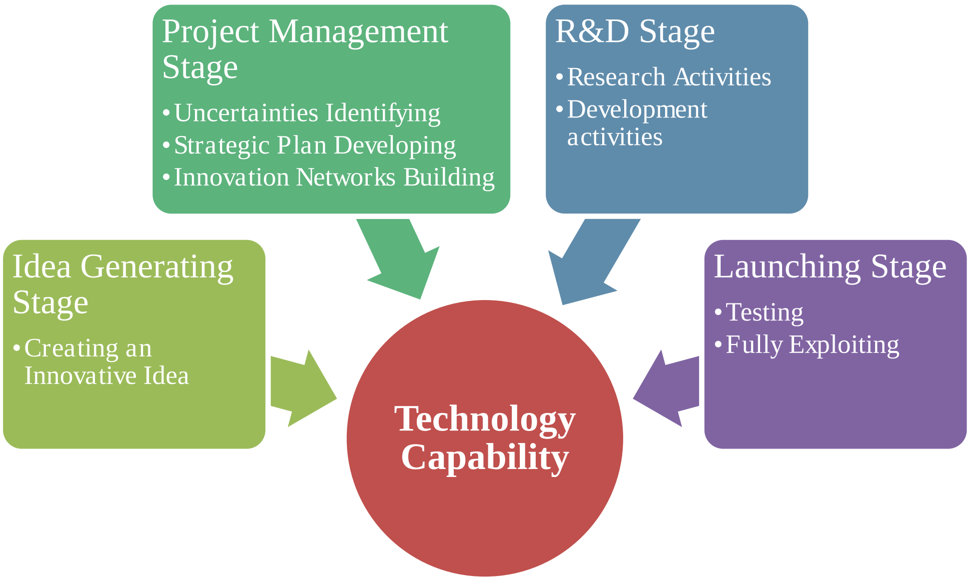

Figure 6.2: The Technology Capability in the Radical Innovation Development Cycle

Opportunities & Threats Sensing Capability

For achieving competitive advantages in the telecommunications industry (Teece 2000; Teece 2007; Barreto 2009), the opportunities and threats sensing capability concentrated on in this research stands for the R&D department's capability for identifying internal strengths and weaknesses (including activities on idea generating, strategic plan developing and product development) as well as external opportunities and threats (including activities on idea generating, policy tracking, uncertainties identifying, strategic plan developing and product development) for developing radical innovation, which is consistent with Gilbert's (2006) and Teece's (2007) research work. Moreover, based on the analysed data presented in Chapter 5, it can also be proposed that most of the activities that the opportunities and threats sensing capability was involved in were distributed in the earlier two stages of the radical innovation development cycle, and in the latter two stages, the R&D department had only the capability for product development activities. Based on the above discussions, when developing radical innovations, the opportunities and threats sensing capability was mainly addressed by the R&D department for its activities in the idea generating and project management stages, including activities on generating the innovation idea, tracking policies, identifying uncertainties and developing a strategic plan, whilst for the later R&D and launching stages in the radical innovation development cycle, this capability was only emphasised by the R&D department for its product development activities, as shown in Figure 6.3 below:

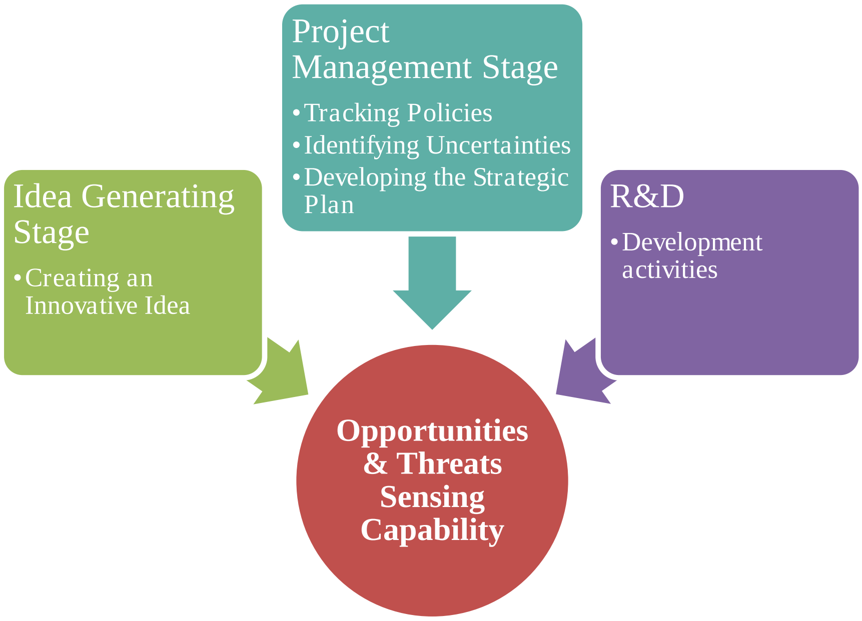

Figure 6.3: The Opportunities & Threats Sensing Capability in the Radical Innovation Development Cycle

Internal Collaborations Capability

When developing radical innovations, the R&D departments concentrated on in this research used their internal collaborations capabilities mainly for building internal links with the marketing people of the operating departments, on learning the market, customer behaviours and customer reactions to their products, as well as with the board members of the groups on the feasibility assessments for developing their radical innovations. Referring to the conceptual model developed in Chapter 2 and the analysed data presented in Chapter 5, the internal collaborations capability was addressed the second most frequently (seven times) by the R&D department among the ten capabilities for developing radical innovations, including all the activities in the stages of idea generating, R&D and launching and continuous development, as well as the activities on team constructing and strategic plan developing in the project management stage, which is consistent with other researchers' work on the integration of the R&D work for developing innovations with marketing and senior management members of the group (Saghafi et al. 1990; Olson et al. 1995; Bremser & Barsky 2004). Therefore, it can be concluded that during the radical innovation development cycle, it was important for the R&D department to use the internal collaborations capability for building links with the marketing people and the board members within the STO, and this capability was involved in the R&D department's activities in creating the innovative idea, in the idea generating stage, constructing the team and developing the strategic plan in the project management stage, research and developing in the R&D stage, as well as testing and fully exploiting in the launching stage, as shown in Figure 6.4 below:

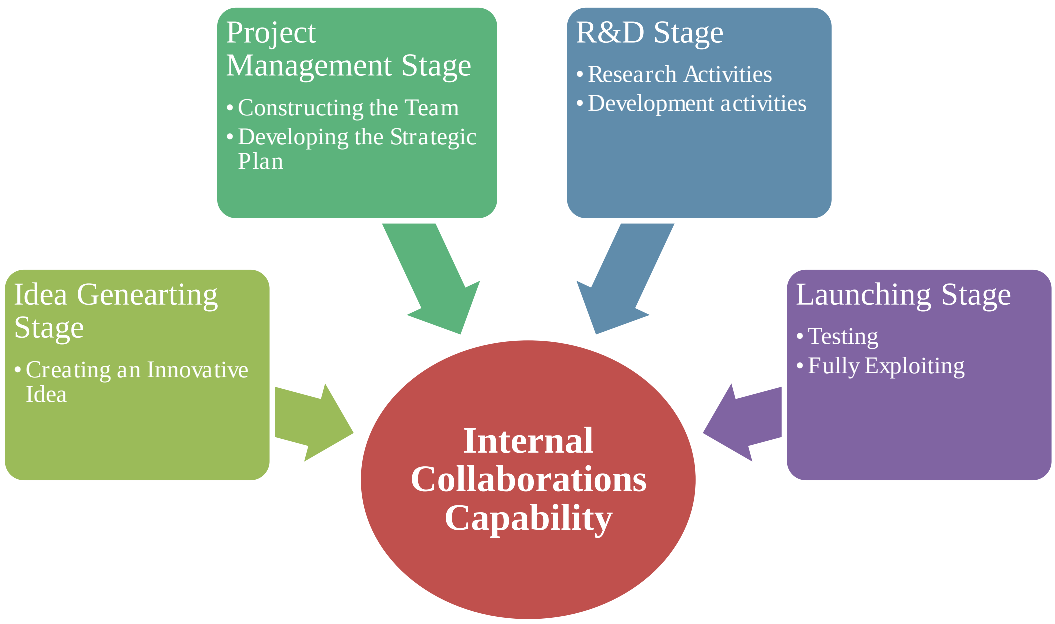

Figure 6.4: The Internal Collaborations Capability in the Radical Innovation Development Cycle

External Collaborations Capability

In this research, the R&D departments' external collaborations capability for developing radical innovations mainly focused on building links with partners from the value chain and the relevant departments of the government, and it was addressed by the R&D departments in most of their activities during the radical innovation development cycle (except the activities on constructing the team, tracking policies, identifying uncertainties and building innovation networks in the project management stage). For the links with partners, as indicated by other researchers, a collaboration alliance can help the R&D department gain great learning opportunities and access to rare resources (Feller et al. 2005; Walter et al. 2014), integrate with external marketing people (Saghafi et al. 1990), build the innovation network (Tripsas 1997), develop the strategic plan (Bremser & Barsky 2004) and transfer the technology into the product (Tripsas 1997), which were all addressed in the case studies of this research. However, in relation to external links with the government, these were less emphasised by other researchers. Based on the case studies in this research, especially in the two Chinese cases, it was important for the R&D departments within the STOs to focus on these external links during their radical innovation development process, since the government could offer significant support to innovations in the industry from both the perspectives of finance and policy. Based on the above discussions, it can be summarised that when developing radical innovations, the R&D department's external collaborations capability for building links with the partners and the government was addressed in most of the activities developed in the conceptual model, including activities on generating the idea, tracking policies, building innovation networks, research, product development, testing and fully exploiting.

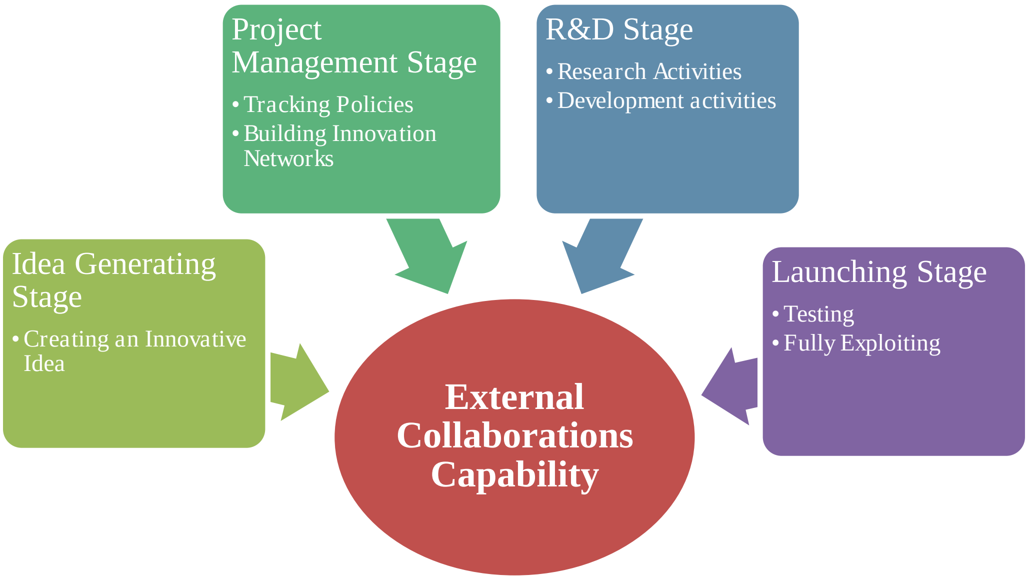

Figure 6.5: The External Collaborations Capability in the Radical Innovation Development Cycle

Organisational Capability

Organisational capability when developing radical innovations was addressed three times by the R&D departments in the case studies of this research, including activities on team construction in the project management stage, as well as research and product development in the R&D stage. These activities are consistent with other research, where organisational capability can help the R&D department manage its human resources, transfer knowledge into new products and undertake the R&D product and process development for developing its radical innovations (Grant 1996; Lawson & Samson 2001). Therefore, it can be concluded that when developing a radical innovation, the organisational capability was mainly addressed by the R&D department within the telecommunications operator for its team construction activities, research activities and product development activities, respectively, as shown in Figure 6.6 below:

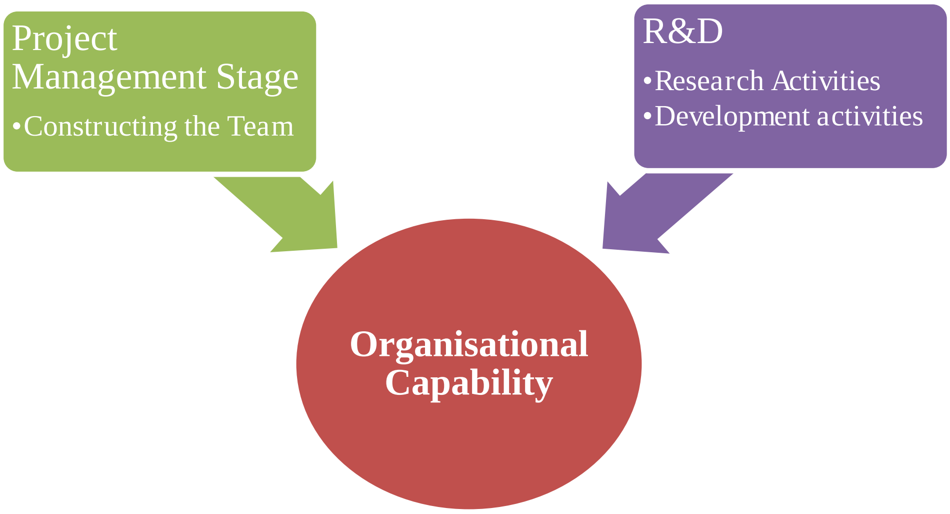

Figure 6.6: The Organisational Collaborations Capability in the Radical Innovation Development Cycle

Knowledge Identifying Capability

The knowledge identifying capability, which refers to "*a firm's capability on* identifying and acquiring externally generated knowledge which is critical to its operations" (Zahra & George 2002, p.189), helped the R&D departments concentrated on in this research identify external knowledge which was mature in the industry or could not be realised within their firms, from not only the perspective of technology, but also the perspectives of marketing and policy. In this research, the knowledge identifying capability was addressed six times by the R&D departments for developing their radical innovation, which was the fourth most frequently among the ten capabilities, and the activities that involved the knowledge identifying capability in the radical innovation development cycle were addressed by other researchers, including idea generating activities (Cohen & Levinthal 1990; Escribano et al. 2009), industrial policy learning activities (Cohen & Levinthal 1990; Lane et al. 2006), technological opportunities and challenges identifying activities (Tidd & Bessant 2009), strategic resources assessing activities (Tsai 2001), as well as research and development activities (Cohen & Levinthal 1990; Lane et al. 2006; Tidd & Bessant 2009), respectively. Referring the above activities to the conceptual framework developed in Chapter 2, it can be concluded that during the radical innovation development cycle, the knowledge identifying capability was addressed by the R&D departments within the STOs in their activities of idea generating, policy tracking, uncertainties identifying, strategic plan developing, as well as research and product development, as shown in Figure 6.7 below:

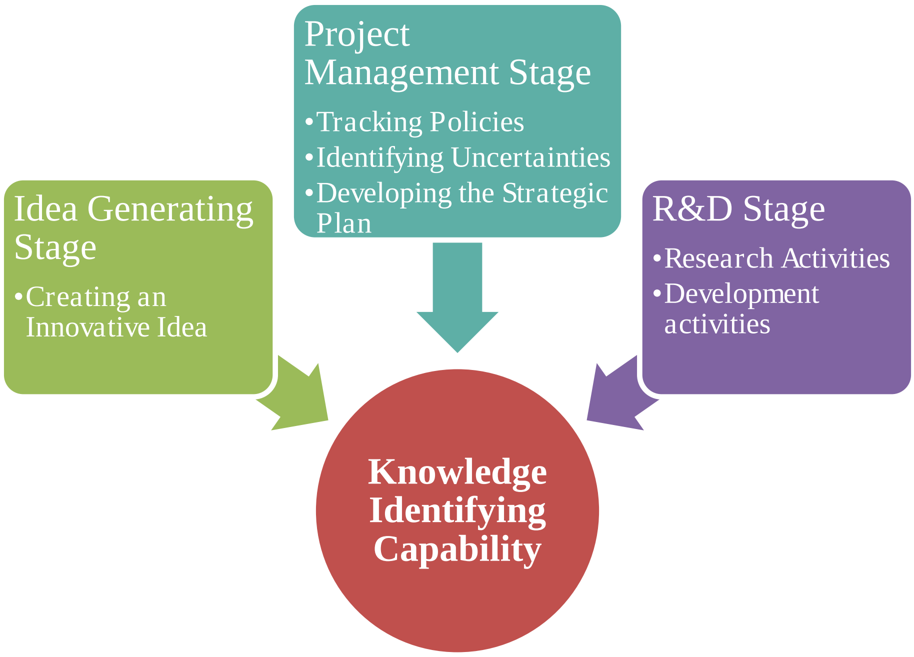

Figure 6.7: The Knowledge Identifying Capability in the Radical Innovation Development Cycle

Knowledge Learning Capability

Based on the externally generated knowledge identified with the knowledge identifying capability, the R&D departments in this research used the knowledge learning capability for analysing, processing, interpreting and understanding the above external knowledge (Zahra & George 2002). Based on the data analysed in the previous chapter, not all of the identified knowledge was learned by the R&D departments when developing their radical innovations, and compared with the knowledge identifying capability, which was addressed the fourth most frequently by the R&D departments among the ten capabilities, knowledge learning capabilities were involved only in policy-tracking activities, uncertainties identifying activities and research and development activities, in the radical innovations development cycles. In the activities of decision making and strategic plan developing, the R&D departments identified external knowledge only for the new aspects of their ideas on innovation and strategic plans, thus it was not necessary for them to understand and analyse these external ideas in detail for developing their radical innovations. Therefore, it can be concluded that regarding knowledge learning capabilities when developing radical innovation, the R&D department within the STO concentrated on it for its policy tracking activities and uncertainties identifying activities in the project management stage, as well as research activities and product development activities in the R&D stage, as shown in Figure 6.8 below:

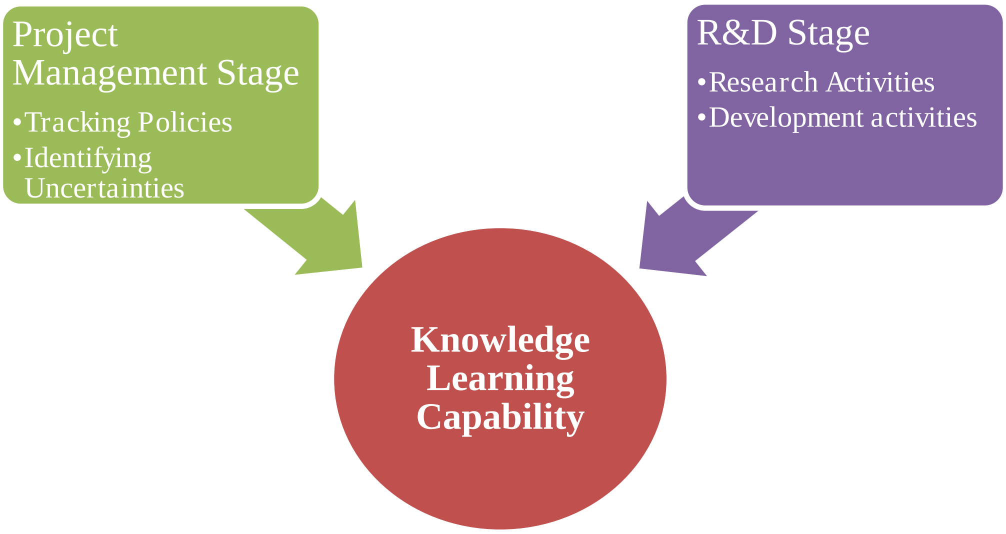

Figure 6.8: The Knowledge Learning Capability in the Radical Innovation Development Cycle

Knowledge Reframing Capability & Knowledge Transferring Capability

For the knowledge reframing capability and knowledge transferring capability, which can be helpful to "develop and refine the routines that facilitate combining existing knowledge and the newly acquired and assimilated knowledge" and transform external knowledge into its operations and create new competencies (Zahra & George 2002, p.189), they were addressed only once respectively in the R&D stage of the radical innovations development cycle by the R&D departments in this research. For external knowledge learned from the policy tracking and uncertainties identifying activities, which were not focused on in these two capabilities, since they had impact only on the radical innovation development processes but could not be reframed and transferred into technologies directly, it was not necessary for the R&D departments to use them in these situations. Based on the above points, it can be summarised that during the radical innovation development cycle, the knowledge reframing capability and the knowledge transferring capability were addressed only once by the R&D department within the STO in its research activities and product development activities, as shown in Figure 6.9 below:

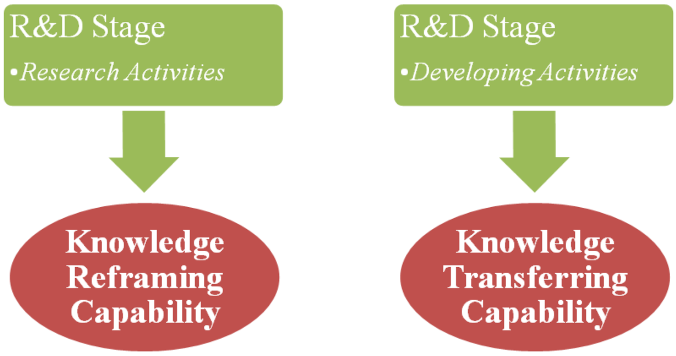

Figure 6.9: The Knowledge Reframing and Knowledge Transferring Capabilities in the Radical Innovation Development Cycle

6.3 Addressing Research Question 2

As analysed in Chapter 5, the R&D department's use of capabilities for developing radical innovations were affected by six contextual factors: project narrative, source of innovation, project size, cultural context, technology content, and market concentration. Table 6.2 below illustrates the number of times the R&D department's capabilities were affected by each contextual factor for developing its radical innovation, and at the bottom of the table, the line sums up the number of times these contextual factors were addressed in the entire radical innovation development cycle, which can be helpful to indicate the importance of each contextual factor in affecting the R&D department's use of these capabilities. Based on the content of Table 6.2, in this section, to answer the second research question of this PhD study, on which contextual factors explain the differential usage of an R&D department’s capabilities within the radical innovation development process of an STO, the six contextual factors above are further discussed and compared with the previous literature.

Table 6.2: Addressing the Contextual Factors in the R&D Department’s Radical Innovation Development Capabilities[43]

Radial Innovation Development capabilities	**Times of Addressing**	**Contextual factors for Describing Radical Innovation**						
		None	**Project Narrative**	**Source of Innovation**	**Project Complexity**	**Cultural Contexts**	**Technology Content**	**Market Concentration**
Creativity Capability	4	1		1			1	1
Technology Capability	8	3		2		1	2	
Opportunities & Threats Sensing Capability	5	1		2		3		
Internal Collaborations Capability	7	3			4			
External Collaborations Capability	7	2		4		3		2
Organisational Capability	3	2				1		
Knowledge Identifying Capability	6	1	2	2		1	1	
Knowledge Learning Capability	4		1	2		1	1	
Knowledge Reframing Capability	1						1	
Knowledge Transferring Capability	1			1				
Sum	46	13	3	14	4	10	6	3

Project Narrative

For the contextual factor of project narrative, this divided the radical innovations concentrated on in this research into two different types: innovation radical to the global telecommunications industry, where technological uncertainties can be greater, and innovation radical to the telecommunications operators themselves where they can meet a chasm when commercialising the knowledge that they have (Green et al. 1995). Referring to the conceptual framework developed in Chapter 2, several key words exist in the above statements: knowledge, technological uncertainties and commercialising, which are consistent with the

[43] In Table 6.2, the contextual factor of ‘None’ means none of the contextual factors discussed in this research had an *impact on the R&D department’s current capability*

empirical findings of this research, that during the radical innovation development cycle, the contextual factor of project narrative affected the R&D department's knowledge identifying capability and knowledge learning capability from the perspectives of technological uncertainties identifying and strategic plan developing. Furthermore, based on the case studies in this research, it can also be proposed that during the above two activities in the radical innovation development cycle, when the innovation was radical to the firm itself (i.e. Case T), the R&D department had stronger knowledge identifying and knowledge learning capabilities than in the other situations (i.e. Case X, Case N, and Case F). To sum up, within the STOs, the contextual factor of project narrative when describing the radicalness of the innovation had an impact on the R&D department's knowledge identifying capability and knowledge learning capability in the activities of uncertainties identifying and strategic plan developing. During the radical innovation development cycle, an R&D department developing an innovation that was radical to the operator itself had stronger knowledge identifying and knowledge learning capabilities than an R&D department that developed an innovation which was radical to the whole global telecommunications industry, as indicated in Table 6.3 below:

Table 6.3: The Impact of the Contextual Factor of Project Narrative on an R&D Department's Radical Innovation Development Capabilities

Stage	**Activity**	**Capability**	**Project Narrative**	
			Radical to the Firm	Radical to the Industry
Project Management Stage	Identifying Uncertainties	Knowledge Identifying Capability	Stronger	Weaker
		Knowledge Learning Capability	Stronger	Weaker
	Developing the Strategic Plan	Knowledge Identifying Capability	Stronger	Weaker

Source of Innovation

As shown in Table 6.2, standing in the position of the R&D department, the contextual factor of source of innovation affects 14 capabilities during the radical innovation development cycle, which is the highest occurrence within the six contextual factors when describing radical innovation. In this research, referring to Tidd and Bessant's (2009) research work, the sources of the innovations concentrated on in the four case studies are watching others, regulations push, internal need pull and external need pull, respectively, and to understand their impact on the R&D department's capabilities in the radical innovation development process, these four sources of innovation are differentiated from three perspectives, as shown in Table 6.4 below:

Table 6.4: Analysis of the Contextual Factor of Source of Innovation

Source of Innovation	**Watching Others** (Case T)	**Regulations Push** (Case X)	**Internal Need Pull** (Case N)	**External Need Pull** (Case F)
Knowledge Push or Need Pull	Knowledge Push	Knowledge Push	Need Pull	Need Pull
Internal or External Source	External	External	Internal	External
Regulations Related	No	Yes	No	No

From the perspective of knowledge push or need pull, the sources of the innovations concentrated on in this research are divided into knowledge push (i.e. Case T and Case X), which involves the technical knowledge gained as the result of original research activity, and need pull (i.e. Case N and Case F), which involves internal or external needs for a new product or process (Freeman & Soete 1997). In this research, the R&D department's radical innovation development capabilities affected by the contextual factor of source of innovation from the perspective of knowledge push or need pull are mainly distributed in the innovation networks building activities (including the external collaborations capability and the technology capability) in the project management stage, as well as in the research activities (including the external collaborations capability) and development activities (including the external collaborations capability, the technology capability, the creativity capability, the knowledge learning capability, the knowledge transferring capability and the opportunities and threats sensing capability) in the R&D stage. Based on the data analysed in Chapter 5, it can be suggested that when developing a radical innovation, if the source of the innovation was from the perspective of knowledge push, the R&D department within the STO concentrated on its external links with the applications and content providers, and has a stronger external collaborations capability, technology capability, creativity capability, knowledge learning capability, knowledge transferring capability and opportunities and threats sensing capability in the development activities, whilst if the source of the innovation was from the perspective of need pull, the R&D department focused on its external links in its research activities and had stronger technology capability when building innovation networks, as indicated in Table 6.5 below:

Table 6.5: The Impacts of the Contextual Factor of Source of Innovation on the R&D Department's Radical Innovation Development Capabilities (1)

Stage	**Activity**	**Capability**	**Source of Innovation**	
			Knowledge Push	Need Pull
Project Management Stage	Building Innovation Networks	External Collaborations Capability	Focused on building links for applications and content	Focused on building links for research activities
		Technology Capability	Weaker	Stronger
R&D	Research Activities	External Collaborations Capability	Weaker	Stronger
	Development activities	External Collaborations Capability	Stronger	Weaker
		Technology Capability	Stronger	Weaker
		Creativity Capability	Stronger	Weaker
		Knowledge Learning Capability	Stronger	Weaker
		Knowledge Transferring Capability	Stronger	Weaker
		Opportunities & Threats Sensing Capability	Stronger	Weaker

From the perspective of internal or external source, the sources of the innovations in this research are divided into internal sources (e.g. Case T, Case X, and Case F) and external sources (e.g. Case N), and this distinction affected the R&D department's knowledge identifying capability in the idea generating activities of the radical innovation development cycle, which is consistent with Tidd and Bessant's (2009) statement that when the idea of innovation is from an external source, external knowledge of similar products in the industry, regulations, and user behaviours need to be identified. Therefore, it can be concluded that during the radical innovation development cycle, the R&D department's knowledge identifying capability in the idea generating activities was the only capability that could be affected by the perspective of internal or external source, and if the source of innovation was an external one, the R&D department within the STO used a stronger knowledge identifying capability for generating the innovative idea, and vice versa, as indicated in Table 6.6 below:

Table 6.6: The Impact of the Contextual Factor of Source of Innovation on the R&D Department's Radical Innovation Development Capabilities (2)

Stage	Activity	Capability	Source of Innovation	
			Internal Source	External Source
Idea Generating	Creating an Innovative Idea	Knowledge Identifying Capability	Weaker	Stronger

From the perspective of regulations related factors, the sources of the four innovations concentrated on in this research were divided into sources related to regulations (i.e. Case X) and sources unrelated to regulations (i.e. Case T, Case N, and Case F). As indicated by the empirical data, the impact of this perspective was mainly on the R&D department's capabilities in policy tracking activities. For the relationships between the perspective and the R&D department's radical innovation development capabilities, it can be suggested that for the innovation whose source was regulations related, links with the government had already been built by the R&D department when applying for the project, and with the help of these existing links, in the policy tracking activities, the latest policies were learned directly from the government. Therefore, the R&D department only needed to use a stronger external collaborations capability for enhancing its existing links with the government in this situation. In contrast, for an innovation where the source was not related to regulations, there were no existing links between the R&D department and the government for undertaking policy tracking activities, and new links in this situation were also difficult for it to establish. To overcome this challenge, it used a stronger opportunities and threats sensing capability, knowledge identifying capability and knowledge learning capability in policy tracking activities for developing its radical innovation. Based on the above discussions, it can be summarised that for the perspective of regulations related to the contextual factor of source of innovation, this affected the R&D department's opportunities and threats sensing capability, external collaborations capability, knowledge identifying capability and knowledge learning capability in policy tracking activities. Within the STO, if the radical innovation originated from regulations, the R&D department used a stronger external collaborations capability for tracking the latest policies, whilst if the source of innovation was not regulations related, a stronger opportunities and threats sensing capability, knowledge identifying capability and knowledge learning capability were used by the R&D department for its policy tracking activities, as shown in Table 6.7 below:

Table 6.7: The Impacts of the Contextual Factor of Source of Innovation on the R&D Department's Radical Innovation Development Capabilities (3)

Stage	Activity	Capability	**Source of Innovation**	
			Regulations Related	Regulations Unrelated
Project Management Stage	Tracking Policies	Opportunities & Threats Sensing Capability	Weaker	Stronger
		External Collaborations Capability	Stronger	Weaker
		Knowledge Identifying Capability	Weaker	Stronger
		Knowledge Learning Capability	Weaker	Stronger

Project Complexity

For the contextual factor of project complexity, this divided the radical innovations concentrated on in the case studies into highly complex innovation (i.e. Case N) and moderately complex innovation (i.e. Case T, Case X, and Case F). In this research, based on the above distinction, the contextual factor of project complexity was mainly addressed in the R&D department's internal collaborations capabilities for building internal links between different parts of the radical innovation developing work, including the strategic plan development activities in the project management stage, the product development activities in the R&D stage, and the testing and fully exploiting activities in the project launching stage, which are consistent with Tatikonda and Rosenthal's (Tatikonda & Rosenthal 2000) statements that the interactions among different sub-tasks of a project can be recognised as significant criteria for identifying the contextual factor of project complexity. In addition, for the relationships between the contextual factors and the R&D department's capabilities, based on the analysed data presented in Chapter 5, it can be proposed that in the above radical innovation development activities, the more complex the project was, the stronger the internal collaborations capability built by the R&D department, and vice versa, as shown in Table 6.8 below:

Table 6.8: The Impact of the Contextual Factor of Project Complexity on the R&D Department's Radical Innovation Development Capabilities

Stage	**Activity**	**Capability**	**Project Complexity**	
			High Complexity	Medium Complexity
Project Management Stage	Developing the Strategic Plan	Internal Collaborations Capability	Stronger	Weaker
R&D Stage	Development activities	Internal Collaborations Capability	Stronger	Weaker
Launching Stage	Testing	Internal Collaborations Capability	Stronger	Weaker
	Fully Exploiting	Internal Collaborations Capability	Stronger	Weaker

Cultural Contexts

In this research, the contextual factor of cultural contexts was reflected from two perspectives: competition in the market (Bromwich & Hong 2000; Lu & Wong

2003) and government interventions in the telecommunications industries (Bourreau & Doğan 2001). Based on the above two perspectives, the radical innovations concentrated on in the case studies were divided into innovation in the Chinese telecommunications industry, where an R&D department faces less competition and the government mainly plays an ex-post regulatory interventions role (i.e. Case T and Case X), and innovation in the British telecommunications industry, where competition is extremely high and the regulator mainly plays an ex-ante regulatory interventions role (i.e. Case N and Case F). As shown in Table 6.2, due to the contextual factor of cultural contexts, the selected R&D departments in this research used different opportunities and threats sensing capabilities, external collaborations capabilities, knowledge identifying capabilities, knowledge learning capabilities, technology capabilities and organisational capabilities in different activities of their radical innovations development cycles.

When undertaking idea generating activities, due to the different competition and regulations environments, the R&D departments within the Chinese and British telecommunications operators used different opportunities and threats sensing capabilities and external collaborations capabilities for developing their radical innovations, which are consistent with other research (Eisenhardt & Bourgeois 1988; Bourreau & Doğan 2001; Ganotakis & Love 2012; Wan et al. 2014). For the impact of this contextual factor on the R&D department's idea generating activities, based on the analysed data, it can be suggested that in the Chinese telecommunications industry, where competition in the industry is low and the government mainly plays an ex-post regulatory interventions role, the R&D department in this research focused on positive perspectives such as its individual strengths and external opportunities, and built closer links with the government for generating an innovation idea. In the UK telecommunications market, however, where competition is extremely high and the government mainly plays an ex-ante regulatory interventions role, negative perspectives such as individual weaknesses and external threats were focused on, and the R&D department did not build external links with the government in its idea generating activities.

During the policy tracking activities, referring to Bourreau and Doğan's (2001) statements, the Chinese and the UK governments in this research had different incentive effects on the incumbents' innovation development processes, due to the different regulatory interventions roles played by them in the telecommunications market. Based on this consideration, it was important for the R&D department within a Chinese telecommunications operator to track the latest policies published by the government, which can have incentive effects for them, whilst in the UK telecommunications market, the R&D department did not concentrate on any capabilities when undertaking its policy tracking activities. Therefore, it can be concluded that for the contextual factor of cultural contexts, this affected the R&D department's radical innovation development activities in policy tracking activities. In the Chinese telecommunications market, where the government mainly plays an ex-post regulatory intervention role, the R&D department within the STO used the opportunities and threats sensing capability, the external collaborations capability, the knowledge identifying capability and knowledge learning capability for tracking the latest policies, whilst in the UK telecommunications market, where the government plays an ex-ante regulatory interventions role, none of the above capabilities was addressed by the R&D department.

When undertaking uncertainties identifying activities, the contextual factor of cultural contexts had an impact on the R&D department's opportunities and threats sensing capability in this research, which is consistent with Hofstede's (1984; 2001) and Bourreau and Doğan's (2001) research work. Based on the analysed data presented in Chapter 5, it can be proposed that during uncertainties identifying activities, the R&D department within a Chinese telecommunications operator focused on external uncertainties that could be caused by external opportunities and threats, whilst in the UK telecommunications industry, the R&D department within the STO emphasised the uncertainties that can be brought about by negative perspectives, such as internal weaknesses and external threats on developing its radical innovation.

During strategic plan development activities, referring to Riordan's (1992) research work, an R&D department's technology capability was affected by the contextual factor of cultural contexts. As indicated by the analysed data, in the Chinese telecommunications market, the R&D department did not concentrate on its technology capability when developing a strategic plan, which is in accordance with the interviews with W_2 and Z_5, as follows:

> *"...in the Chinese high*-tech industries, the firms concentrate on proposing *the 'concept'* rather than the actualising of it*...such as the Internet of* Things and the Cloud Computing technologies, we heard the concepts of them many years ago, and all of the firms have their strategies on *developing them…but till now, who (no one) has the mature tec*hnical *solutions on that..." (*W_2)

> *"…in China, everyone is proposing new ideas…but no one* is concerned about the technologies in them *(on how to actualise the ideas)…" (*Z_5).

In the UK telecommunications market, where competition is extremely high, an operator such as BT faces huge pressure to survive. Therefore, as addressed by Lal, et al. (2004), when developing a strategic plan, the R&D department used a strong technology capability for designing detailed technical plans for realising its innovative services.

Finally, when undertaking the research activities, in accordance with other researchers (Bourreau & Doğan 2001; Garrett et al. 2006), the contextual factor of cultural contexts affected the R&D department's external collaborations capability and organisational capability for developing a radical innovation. Based on the analysed data, it can be proposed that the British R&D department had a stronger external collaborations capability than the Chinese one for its research activities. When meeting technical gaps, the R&D department in China chose to build up new capabilities rather than collaborating with others, which is consistent with the statement by Mr F (the president of the Chinese telematics association) that Chinese telecommunications operators "do not have the willingness to collaborate with others", whilst in the UK, due to the huge competition in the telecommunications industry, the R&D department found that it was cost-effective for them to collaborate with others on filling research gaps and they had the willingness to use a stronger external collaborations capability, which is consistent with Ettlie's (2000) and de Man and Duyster's (2005) research work. For the organisational capability, due to the different cultural contexts between China and the UK, the R&D departments' concentrations on research activities were different. Based on the analysed data in this study, it is found that compared to the British R&D departments, the R&D department in the Chinese telecommunications industry focused on its quantity of research achievements. This finding is in accordance with the data from World Intellectual Property Organisation, where as shown in Table 6.9 below, in 2013, the number of patents filed in China was approximate thirty-six times more than the UK, and the growth of it was also dramatically faster in China (from 2012 to 2013).

Table 6.9: The Numbers of Patents Filed in China and the UK in 2013 and Their Growth Rates[44]

Country	**China**	**UK**
Number of Patents Filed in 2013	825,136	22,938
Growth (%): 2012-13	26.4	-1.3

In addition, it was also found that for the quality of research achievements when developing a radical innovation, the R&D department in a British STO addressed it much more than a Chinese one, and this statement is consistent with the interview with Z_5, as follows:

> *"…in the developed countries, they design the applications first, and then apply the patents based on that…bu*t in China, the patents are considered at the same time as the applications, and even before the applications. In *this situation, how could the team industrialise the patents?…the main* reason for it is that in China, compared with applications, the quantity of patents is not only the index for assessing the team members, but also the *team leaders…they need the quantity of patents for promotions without considering whether the firm really needs them…that is the reason China* has a large number of patents, but they still need to pay huge amount of *money to the developed countries for the intellectual properties…" (*Z_5)

[44] Source: World Intellectual Property Organisation: http://www.wipo.int/ipstats/en/wipi/

Based on the above discussions, the impact of the contextual factor of cultural contexts on the R&D department's radical innovation development capabilities can be summarised as shown in Table 6.10 below:

Table 6.10: The Impact of the Contextual Factor of Cultural Contexts on the R&D Department's Radical Innovation Development Capabilities

Stage	**Activity**	**Capability**	**Cultural Contexts**	
			China	UK
Idea Generating Stage	Creating an Innovative Idea	Opportunities & Threats Sensing Capability	Focused on Individual Strengths and External Opportunities	Focused on Individual Weaknesses and External Threats
		External Collaborations Capability	Strong	Less Emphasised
Project Management Stage	Tracking Policies	Opportunities & Threats Sensing Capability	Strong	Less Emphasised
		Knowledge Identifying Capability	Strong	Less Emphasised
		Knowledge Learning Capability	Strong	Less Emphasised
		Technology Capability	Strong	Less Emphasised
	Identifying Uncertainties	Opportunities & Threats Sensing Capability	Focused on External Opportunities and Threats	Focused on Individual Weaknesses and External Threats
	Developing the Strategic Plan	Technology Capability	Less Emphasised	Strong
R&D	Research Activities	External Collaborations Capability	Weaker	Stronger
		Organisational Capability	Focused on the quantity of research achievements	Focused on the quality of research achievements

Technology Content

As indicated by Tatikonda and Rosenthal (2000), the technology content of a radical innovation relates to the novelty of the technologies employed in the product development effort, and based on this definition, the contextual factor of technology content divided the radical innovations concentrated on in this research into innovation with high technology content (i.e. Case X, Case N, and Case F) and innovation where technology content was relatively low (i.e. Case T). In this research, based on the analysed data presented in Chapter 5, the contextual factor of technology content affected the R&D department's capabilities six times, including the technology capabilities in the idea generating and uncertainties identifying activities, respectively, as well as the creativity capability, the knowledge identifying capability, the knowledge learning capability and the knowledge reframing capability in the research activities. For the R&D department's technology capabilities in the idea generating activities and uncertainties tracking activities, and the creativity capability in the research activities, the relationships between the above capabilities and the contextual factor of technology content were positive, where the more technology novelty was involved in the radical innovation, the stronger the capabilities that the R&D department used from the above three perspectives, for developing its radical innovation. In contrast, for the knowledge identifying capability, the knowledge learning capability and the knowledge reframing capability in the research activities, when the technology novelty of the project was high, it was less important for the R&D department to use these capabilities. The above findings are consistent with Balachandra and Friar's (1997) statements, that in the high-tech field, the R&D department's capabilities related to technologies can be much more important than in the low-tech field (where stronger technology capability and creativity capability can exist), whilst in the low-tech field, the R&D department has to refer to existing standards and practices and provide an advantage in its individual products (where stronger knowledge identifying capability, knowledge learning capability and knowledge reframing capability in the research activities can exist). Based on the above discussions, the impact of the contextual factor of technology content on the R&D department's radical innovation development capabilities can be summarised as shown in Table 6.11 below:

Table 6.11: The Impact of the Contextual Factor of Technology Content on the R&D Department's Radical Innovation Development Capabilities

Stage	**Activity**	**Capability**	**Technology Content**	
			High	Low
Idea Generating Stage	Creating an Innovative Idea	Technology Capability	Stronger	Weaker
Project Management Stage	Identifying Uncertainties	Technology Capability	Stronger	Weaker
R&D Stage	Research Activities	Creativity Capability	Stronger	Weaker
		Knowledge Identifying Capability	Weaker	Stronger
		Knowledge Learning Capability	Weaker	Stronger
		Knowledge Reframing Capability	Weaker	Stronger

Market Concentration

Based on the analysed data in Chapter 5, the contextual factor of market concentration, which is defined as the nature of the market (existing or new) that a new product is entering (Balachandra & Friar 1997), can divide radical innovations in this research into innovation facing an existing market of mature products (i.e. Case X, Case N, and Case F) and innovation facing a completely new market (i.e. Case T). As indicated in Table 6.2, the contextual factor of market concentration affected the R&D department's capabilities three times during the radical innovation development cycle, including the creativity capability in the strategic plan development activities and the external collaborations capabilities in the innovation networks building activities and development activities. The relationships between the contextual factors and the above capabilities can be discussed from two perspectives. Firstly, in comparison with innovation which faced an existing market of its previous products, when developing a radical innovation that entered a new market, the R&D department of the STO used a stronger creativity capability for its strategic plan, which is consistent with Maidique's and Zirger's (1985) research work which states that the strategic plan in an existing market should come from proactive approaches (in which more creativity should be involved), but in a new market, the strategic plan can be derived from passive understanding of the existing products and user needs. Secondly, for the external collaborations capability, in comparison with a product in an existing market where applications can be transplanted into a new product directly, when the product entered a new market, the R&D department emphasised its external links with the applications providers when building its innovation networks and undertaking product development activities. Based on the above discussions, the impact of the contextual factor of market concentration on the R&D department's radical innovation development capabilities can be summarised as in Table 6.12 below:

Table 6.12: The Impact of the Contextual Factor of Market Concentration on the R&D Department's Radical Innovation Development Capabilities

Stage	**Activity**	**Capability**	**Market Concentration**	
			Existing	New
Project Management Stage	Developing the Strategic Plan	Creativity Capability	Weaker	Stronger
	Building Innovation Networks	External Collaborations Capability	Did not Focus on Links with the Applications Providers	Focused on Links with the Applications Providers
R&D Stage	Development activities	External Collaborations Capability	Weaker	Stronger

6.4 Summary

This chapter presented how each of the two research questions was addressed by drawing on the previous data analysis chapter, to identify the capabilities that the R&D department used in each stage of the radical innovation development cycle, and how these capabilities were affected by different contextual factors. The next chapter will conclude this thesis by presenting the research contributions, the limitations of the current research, areas for further research and concluding remarks.

Chapter 7 Conclusions

Following on from how the two research questions were addressed in relation to the contemporary literature, as discussed in Chapter 6, this chapter presents the research contributions of this work from the theoretical and practical perspectives respectively, and explores the limitations of the research for the purpose of addressing them in further research. Moreover, the chapter also concludes the entire research work by stating how its research aims were addressed.

7.1 Theoretical Research Contributions

Rather than attempting to build a theory about the whole radical innovation development process, this research stood in the position of the R&D department and specifically concentrated on radical innovation in the telecommunications industry, in order to develop a better understanding of the research topic. After addressing the two research questions, based on the conceptual framework developed in Chapter 2, the main contributions of this research are analysed from two perspectives in this section: firstly, which capabilities the R&D department of the STO used in each stage of its radical innovation development cycle; secondly, among the six contextual factors in describing a radical innovation, which contextual factors play a more significant role in affecting the R&D department's capabilities in each radical innovation development stage.

7.1.1 Radical Innovation Development Capabilities

During the radical innovation development cycle, all the capabilities that the R&D department used in different radical innovation development stages were addressed by different researchers. However, the majority of their research work analysed these capabilities from the perspective of an R&D department's general capabilities in developing new products from a resource-based view, considering dynamic capabilities as well as absorptive capability, and few of them specified these capabilities in relation to an R&D department's different stages, and even different activities, when developing its radical innovation within STOs. Therefore, in this research, the capabilities that the R&D department used for developing its radical innovation were systematically discussed, and the capabilities involved in each stage of the R&D department's radical innovation development cycle are recognised as one of the key findings of this PhD research, demonstrated in the four propositions as shown below. All the research findings from this perspective are summarised in Figure 7.1, which is presented at the end of this sub-section.

Proposition 1a: When generating the idea of a radical innovation, the R&D department within an STO uses the creativity capability, the technology capability, the opportunities and threats sensing capability, the internal collaborations capability, the external collaborations capability and the knowledge identifying capability for developing its radical innovation.

Proposition 1b: During the project management stage, most of the R&D department's capabilities for developing a radical innovation are focused on by an STO, except the knowledge reframing capability and the knowledge transferring capability.

Proposition 1c: Within an STO, the R&D department uses all of its radical innovation development capabilities during the R&D stage of the radical innovation development cycle.

Proposition 1d: During the launching stage of the radical innovation development cycle, the R&D department within an STO uses the technology capability, the external collaborations capability and the internal collaborations capability for developing its radical innovation.

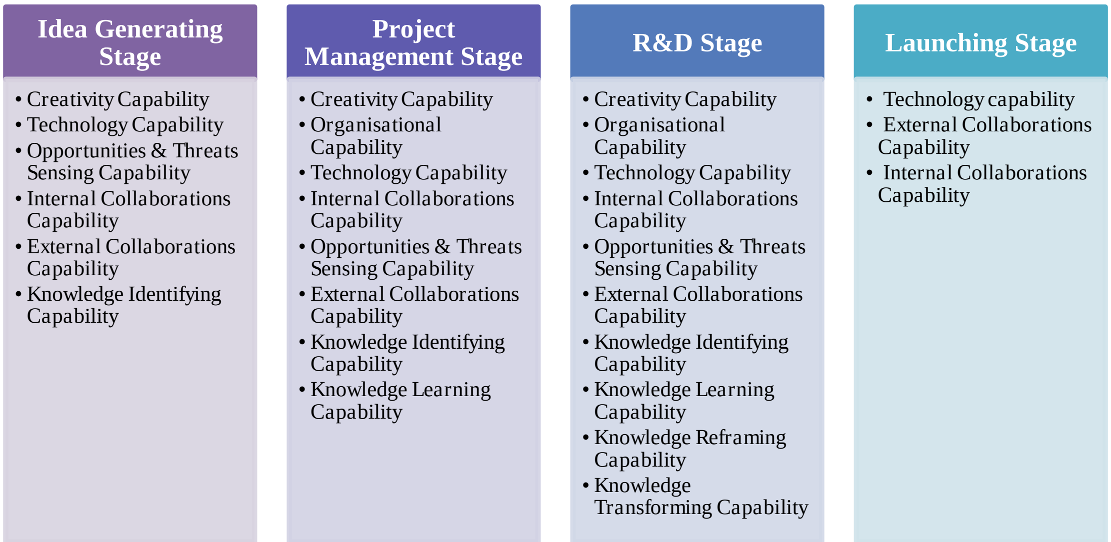

Figure 7.1: Summary of the R&D Department's Capabilities Involved in Each Radical Innovation Development Stage

7.1.2 The Impact of Contextual Factors on an R&D Department's Capabilities in Each Radical Innovation Development Stage

As indicated in Section 6.3, an R&D department's capabilities in developing a radical innovation can be affected by six contextual factors: project narrative, source of innovation, project complexity, cultural contexts, technology content and market concentration. In comparison with other researchers, the key research findings from this perspective disseminate which contextual factors play a more significant role in affecting an R&D department's capabilities (affecting the capabilities the highest number of times) in each radical innovation development stage, as discussed below:

- **Idea Generating Stage**

During the idea generating stage, referring to other research (Leifer et al. 2000; Tidd & Bessant 2009), the contextual factor of source of innovation is critical for a large company to generate and search for its innovative ideas. However, in this research, it was found that the contextual factor of source of innovation only affected the R&D department's radical innovation development activities once in the idea generating stage, the same as the contextual factor of technology content. In contrast, the contextual factor of cultural contexts, which was addressed in the R&D department's opportunities and threats sensing capability and external collaborations capabilities in the idea generating stage, plays a more important role in affecting an R&D department's capabilities for generating an innovative idea. Therefore, the key research finding from this perspective can be discussed as follows:

> **Proposition 2a**: During the idea generating stage of the radical innovation development cycle, the different cultural contexts in different countries are the main contextual factors that affected the R&D department's use of radical innovation development capabilities within the STO.

- **Project Management Stage**

In relation to an R&D department's capabilities in the project management stage, as indicated by Leifer et al. (2000), the complexity of the uncertainties involved in the innovation, which can be derived from the contextual factor of project complexity addressed in this research, can significantly affect a large firm's use of radical innovation management tools. In other research, it has been suggested that the contextual factors of source of innovation (Tidd & Bessant 2009) and cultural contexts (Ettlie 2000) could also have an impact on an R&D department's radical innovation development capabilities. In this research, based on the empirical data analysed in Chapter 5, it was determined that an R&D department's radical innovation development capabilities were affected mainly by the contextual factors of source of innovation (addressed six times) and cultural contexts (addressed six times) in the project management stage. However, for the contextual factor of project complexity, this did not affect any R&D department's capabilities for managing its radically innovative project within the STO. Based on the above analysis, the key research finding from this perspective can be analysed as per the proposition stated below:

> **Proposition 2b**: During the project management stage, the R&D department's use of radical innovation development capabilities is mainly affected by the contextual factors of source of innovation and cultural contexts within the STO.

- **R&D Stage**

During the R&D stage of the radical innovation development cycle, previous research addressed the importance of the contextual factors of cultural contexts

(Ettlie 2000), technology content (Balachandra & Friar 1997; Tidd & Bessant 2009) and market concentration (Tidd & Bessant 2009) in affecting the R&D department's radical innovation development capabilities. However, based on the empirical data analysed in this research, it was found that compared with the contextual factors indicated by other researchers, the contextual factor of source of innovation affected the most capabilities in the R&D stage (addressed seven times), especially in product development activities. Based on the above analysis, the key research finding from this perspective can be discussed as per Proposition 2c below:

> **Proposition 2c**: During the R&D stage of the radical innovation development cycle, the R&D department's use of radical innovation development capabilities is mainly affected by the contextual factor of source of innovation within the STO.

- **Launching Stage**

For the R&D department's capabilities in the launching stage, referring to Tidd and Bessant's (2009) research work, the contextual factor of project complexity is critical for the R&D department to use its capabilities for launching a radically innovative product. In this research, the findings from the analysed data confirmed Tidd and Bessant's statement that the contextual factor of project complexity plays the main role in the launching stage of an R&D department's radical innovation development cycle. Therefore, the key research finding from this perspective can be discussed as follows:

> **Proposition 2d**: During the launching stage of the radical innovation development cycle, the R&D department's use of radical innovation

development capabilities is mainly affected by the contextual factor of project complexity.

Based on the above discussions, the summaries of the four propositions presented in this sub-section, in relation to which contextual factors play a more significant role in affecting an R&D department's use of the capabilities in each radical innovation development stage are shown in Figure 7.2 below:

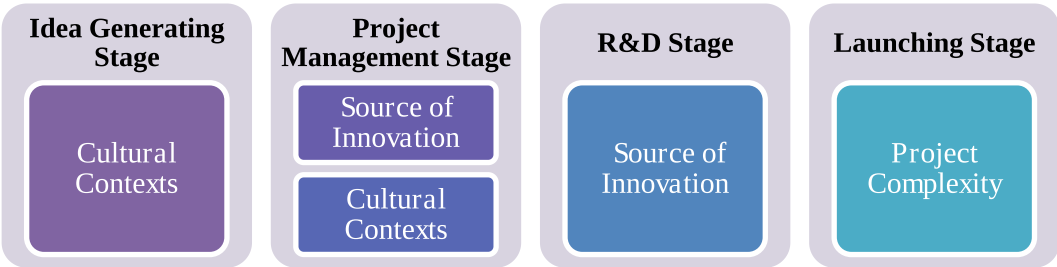

Figure 7.2: Summary of the Contextual Factors that play the Most Significant Role in Affecting the R&D Department's Use of Radical Innovation Development Capabilities

7.2 Practical Contributions

In addition to the theoretical contributions as discussed above, practically, the findings of this study could also guide R&D managers and strategy people within an STO on how to use different capabilities to develop different types of radical innovations, using the prior experience of the four case studies.

Among the six contextual factors which were identified when categorising radical innovations in this research, the findings on the factor of cultural contexts raised the greatest interest from a practical perspective. Due to the nature of a cross-cultural study, this research focused on how the R&D departments of Chinese and British STOs developed radical innovations with different concentrations on their developed capabilities. As discussed in Chapter 6, taking into account the different types of competition and government interventions in the two telecommunications industries focused on, the R&D departments of the Chinese and British STOs demonstrated different uses of capabilities when undertaking activities for developing an innovative idea, tracking policies, identifying uncertainties, developing a strategic plan and research, in their radical innovation development cycles.

To address the findings of this research from the perspective of cultural contexts, five guidelines can be derived on how the four case sites addressed the contextual factor of cultural contexts with different emphases within their radical innovation development activities. These guidelines could be referred to by R&D managers and strategy people in other Chinese and British STOs, to predict the impacts that different cultural contexts would have in their radical innovation development cycles, and to help them develop a project plan on the uses of capabilities, to address this contextual factor.

- To address the contextual factor of cultural contexts when engaging in a radical innovation, the R&D department in the Chinese STO mainly identified the external opportunities in the market, as well as their individual strengths, to help them make a decision about developing the innovation and to assess the external opportunities and threats when developing the strategic plan; in comparison, in the British STO, the R&D department mainly focused on its internal weaknesses and external threats when undertaking activities from the two perspectives above.
- Due to the different cultural contexts in China and in the UK, during the radical innovation development cycle the R&D department in the Chinese

STO tracked the latest policies related to its radical innovation development activities; however, the R&D department in the British STO did not carry out any activities from this perspective.

- To address the different cultural contexts in China and in the UK when engaging in a radical innovation, the R&D department in the Chinese STO developed its strategic plan mainly in relation to marketing and policy considerations; in comparison, in the British STO the R&D department's strategic plan for developing its radical innovation was mainly discussed in relation to technical considerations.
- Due to the different cultural contexts in China and in the UK, when engaging in a radical innovation the R&D department in the Chinese STO sought external collaborations for its idea-generating activities; however they neglected some of these external links when undertaking research activities; in comparison, in the British STO the R&D department collaborated only with some internal departments and self-developed the innovative idea within the group, but for its subsequent research activities during the radical innovation development cycle they largely relied on the vendor's capabilities.
- To address the different cultural contexts in China and in the UK when undertaking research activities for the development of a radical innovation, the R&D department in the Chinese STO focused on the quantity of its research achievements, but neglected the implementation of them; in comparison, in the British STO the R&D department concentrated on the implementation of all its research achievements, but did not address the quantity of them.

7.3 Limitations and Areas for Further Research

Despite the above theoretical and practical contributions, limitations still exist in the current research that have not yet been fully addressed, and more research effort is required. This section summarises these limitations and also includes suggestions for future research.

The primary limitation of the current research, commonly raised in relation to qualitative case study research design, is from the perspective of generalising and expanding the research findings (Flyvbjerg 2006). In this research, although the findings are drawn from comprehensive data collection processes, the limited access to large telecommunications firms means that three sites represent STOs in the entire British and Chinese telecommunications industries, which could raise the question of the reliability and validity of the research findings.

In addition to the above limitation, the impacts of different cultural contexts in the R&D departments' radical innovation development activities raised great interest within the current research. This study selected two telecommunications industries with different competition environments and government intervention roles for the research. However, due to limited time, some other typical telecommunications industries in the world, with different cultural contexts, were not focused on, and questions could be raised about the feasibility of expanding the research findings to other telecommunications industries globally.

Moreover, when conducting cross-case analysis, in the current research the concentration on data collection work in the four case studies was different. Among the four cases, due to limited research time and access to STOs, telematics was selected as the key case, and most of the interviews and POs were conducted on this. However, in this case the data on the R&D department's exploiting stage during the exploiting cycle was missing, since the project was still in development when the data collection work for this study ended. In the other three cases, this research concentrated only on the radical innovation development activities that were different from the key case, and fewer interviews were undertaken with these others. Despite some researchers conducting research with the same data collection portal (Rohrbeck 2010), questions could be raised about neglecting some significant perspectives in this study.

To overcome the above limitations and to enhance the findings of this study, three areas for further research are suggested, as follows:

Firstly, some case sites for this study could be revisited for interview. When revisiting these case sites, referring to the findings of this research, some specific interview questions could be designed which focus on the missing data from the four cases. Taking the case study of telematics as an example, as a former trainee in the department, retaining close links with some R&D team members, revisiting the case sites would be feasible and the missing data in the exploiting stage of telematics could be collected via further one-to-one interviews with these team members. The newly-collected data could be compared with the findings of this study, and then verified.

Subsequently, in further research, the R&D departments of some other Chinese and British telecommunications industries could be visited to conduct more case studies to enhance the findings of this study, such as China Unicom in China and Vodafone and O2 in the UK. The findings of this research could be taken to the proposed case sites in order to open their doors for access, and some qualitative data collection methods, such as interviews, could be undertaken within these R&D departments. If the data from these proposed case studies proves consistent with what has been found in this study, the findings of this research would be enhanced. If the data in these further studies cannot match what has been found, the reasons for the differences could be analysed and the findings of the current study would then be extended.

Finally, to test the practical contributions of this study and to expand the research findings from the perspective of cultural contexts to more countries, some further survey-based quantitative research could be conducted according to what has been found in this study. Referring to Tidd and Bessant's innovation audit tool (2009, p.601), an initial survey-research protocol could be designed, as shown in Appendix 4. The questionnaire for the proposed survey research could be sent to the R&D managers of STOs in some other counties with different cultural contexts, such as India, the US, Germany, and Brazil, and the sample of this further quantitative research would be expected to reach 20.

7.3 Summary of the Thesis

In conclusion, based on the three research conversations, which are the radical innovation development process, the R&D department's capabilities, and the contextual factors that affect an R&D department's use of capabilities, respectively, this research determined when the R&D department of an STO engaged in radical innovation, which capabilities they used, and how the use of these capabilities could be affected by different contextual factors in each stage of the radical innovation development cycle. By comparing the aim of the current research with other researchers' findings on relevant topics, three gaps were identified, and for filling these research gaps, two research questions were raised in this research as follows:

- RQ1: What capabilities do the R&D department of an STO use for each separate activity during its radical innovation development process?
- RQ2: Within the radical innovation development process of an STO, which contextual factors explain the differential use of an R&D department's capabilities?

Following the above two research questions, and based on the philosophical views of interpretivism and social constructivism, this PhD study chose a qualitative research strategy and a case study research approach to guide the research design. Based on the data collected from 29 interviews, plus a three-month and full-time PO, four case studies were conducted in this research, which were the telematics service within China Mobile, the Xi-He system within China Telecom, and 21CN and BT Fusion within BT. By comparing the four cases, the R&D department's uses of capabilities in each separate activity of its radical innovation development cycle were identified, and the reasons for the different uses of these capabilities were described in relation to the six contextual factors, as introduced in Chapter 2, which addressed the two research questions of this study.

At the end of this research, based on the four case studies and the data analysis, from the perspective of the R&D department eight theoretical propositions were put forward for an STO to develop its radical innovation. The propositions concerned the capabilities involved at each stage of the R&D department's radical innovation development cycle, as well as the contextual factors that played the most significant roles in affecting these capabilities at all of the radical innovation development stages. In addition to the eight theoretical propositions, practically, five guidelines were also proposed in this study, which contributes to the understanding of the R&D managers and strategy people of other Chinese and British STOs, in terms of the impacts that the contextual factor of cultural contexts would have on their radical innovation development activities.

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Appendix 1 Example of Interview Questions (Interview with I_1 on the Case Study of 21CN)

1. May I ask how did BT make the decision to develop 21CN?
2. What was the role of BTID during the development process of 21CN?
3. How did BTID build the R&D team for the development of 21CN? Have you met any challenges when building the R&D team? How did you overcome these challenges?
4. Did the R&D team have any policy tracking activities during the development process of 21CN?
5. When developing 21CN, which kinds of uncertainties did the R&D team predict would be met during the development process? How did you identify these uncertainties? Have you met any challenges when identifying the uncertainties? And how did you overcome these challenges?
6. From the strategic perspective, how did BT produce the development plan for 21CN? What role did the R&D team play in this process? Did you meet any challenges when developing the strategic plan? And how did you overcome these challenges?
7. Did the R&D team have any technical acquisitions for the development of 21CN?
8. How did the R&D team build the innovation networks for 21CN (finding co-operators)? Have you met any challenges during this process and how did you overcome them?
9. Which kinds of research activities did the R&D team undertake for the development of 21CN? Have you filed any patents for the research outcomes of 21CN? Did you meet any challenges when undertaking the research activities? And how did you overcome these challenges?
10. Which kinds of product development activities did the R&D team undertake for the development of 21CN? Did you meet any challenges during this process and how did you overcome them?
11. May I ask when developing 21CN, how you collaborated with the board team members and other operating divisions of BT respectively? Did you

meet any challenges when building these internal links? And how did you overcome them?

12. How did you collaborate with partners during the development process of 21CN? Which kinds of challenges did you meet? And how were these challenges overcome by the R&D team?
13. May I ask which role did the R&D team play when undertaking testing activities for 21CN? Were there any challenges during this process? And how did you overcome them?
14. May I ask what the role of the R&D team was during the fully exploiting activities of 21CN? Did you meet any challenges during this process and how did you overcome them?
15. In addition to the above interview questions, may I ask is there anything else you want to mention that either helped or hindered the project during the development process of 21CN?

Appendix 2 The Measurement Criteria of the R&D Department's Radical Innovation Development Capabilities

Referring to Rohrbeck's research work (2010), the measurement criteria of the R&D department's radical innovation development capabilities can be discussed as follows:

Creativity Capability

- Level 0: The R&D department did not have any creativity activities during the process, and all the knowledge was learnt from external sources.
- Level 1: The R&D department had some creativity activities during the process, but most of the knowledge was learnt from external sources.
- Level 2: The R&D department placed significant emphases on its creativity during the process, but some certain pieces of knowledge were learnt from external sources.
- Level 3: The R&D department had the creativity activities from all the significant perspectives.

Organisational Capability

- Level 0: The R&D department did not have any activities on managing its human resources during the process.
- Level 1: The R&D department undertook a few activities on managing its human resources during the process, but not many.
- Level 2: The R&D department concentrated on its human resources-management activities during the process but neglected a few significant perspectives.
- Level 3: The R&D department placed significant emphases on its human resource-management activities from all the significant perspectives during the process.

Technology Capability

- Level 0: The R&D department did not have any technical considerations during the process.
- Level 1: The R&D department had a few technical considerations during the process, but not many.
- Level 2: Most of the activities during the process were undertaken with technical considerations, but a few significant perspectives were neglected by the R&D department.
- Level 3: All the activities during the process were undertaken with technical considerations.

Internal Collaborations Capability

- Level 0: The R&D department never collaborate with the board team members and other departments within the company during the process.
- Level 1: The R&D department built some certain internal links with the board team members and other departments during the process but not many.
- Level 2: The R&D department closely collaborated with the board team members and other departments during the process but neglected a few significant internal links.
- Level 3: The R&D department built all the important internal links with the board team members and other departments during the process.

External Collaborations Capability

- Level 0: The R&D department never collaborated with any co-operators or government during the process.
- Level 1: The R&D department built some certain external links with its co-operators and the government but not many.
- Level 2: The R&D department closely collaborated with its co-operators and the government during the process but neglected a few significant external links.
- Level 3: The R&D department built all the significant external links with its co-operators and the government during the process.

Opportunities and Threats Sensing Capability

- Level 0: The R&D department never focused on any opportunities and threats during the process.
- Level 1: The R&D department identified some certain opportunities and threats that can have impacts on its radical innovation development activities during the current process but not many.
- Level 2: The R&D department identified most of the important opportunities and threats from both the internal and external perspectives during the process but neglected a few significant ones.
- Level 3: All the significant opportunities and threats from both the internal and external perspectives were identified by the R&D department during the process.

Knowledge Identifying Capability

- Level 0: The R&D department did not identify any external knowledge during the process.
- Level 1: The R&D department identified some certain pieces of external knowledge during the process but not many.
- Level 2: The R&D department identified most of the significant pieces of external knowledge during the process but neglected a few important ones.
- Level 3: The R&D department identified all the significant pieces of external knowledge during the process.

Knowledge Learning Capability

- Level 0: The R&D department did not learn any pieces of external knowledge during the process.
- Level 1: The R&D department learnt some certain pieces of external knowledge during the process but not many.
- Level 2: The R&D department learnt most of the significant pieces of external knowledge during the process but neglected a few important ones.
- Level 3: The R&D department learnt all the significant pieces of external knowledge during the process.

Knowledge Reframing Capability

- Level 0: The R&D department did not reframe any pieces of external knowledge into its individual research activities during the process.
- Level 1: The R&D department reframed some certain pieces of external knowledge into its individual research activities but not many.
- Level 2: The R&D department reframed most of the significant pieces of external knowledge into its individual research activities but neglected a few important ones.
- Level 3: The R&D department reframed all the significant pieces of external knowledge into its individual research activities during the process.

Knowledge Transforming Capability

- Level 0: The R&D department did not transform any pieces of external knowledge into its individual products during the process.
- Level 1: The R&D department transformed some certain pieces of external knowledge into its individual products but not many.
- Level 2: The R&D department transformed most of the significant pieces of external knowledge into its individual products but neglected a few important ones.
- Level 3: The R&D department transformed all the significant pieces of external knowledge into its individual products during the process.

Appendix 3: Initial Data Analysis

Based on the specific measurement criteria of each capability developed in this research (Appendix 2), the initial in-case data analysis of the current research is presented in Appendix 3, where the R&D department's radical innovation development capabilities are marked from level zero to level three in each case, and the reasons for the marks are also discussed in this appendix.

Stage One: Idea Generating Stage

Case Study of Telematics

Developing the Innovative Idea

- Creativity Capability

Since the idea for the telematics service was not originated by the R&D department of China Mobile but learned from others, such as some car manufacturers and telecommunications operators in the developed countries, it was not necessary for the staff to build up strong creativity capability to generate the idea. However, with consideration of the individual strengths, the R&D department had its new definition of the telematics service which concentrated on communications technology. Therefore, the R&D department's creativity capability in the idea generating stage is marked with level 1.

- Technology Capability

During the idea generating stage for telematics, the R&D department of China Mobile did not build up a strong technology capability. However, referring to its technical understanding of the industry, the R&D department noticed that the LBS technology, the mobile Internet technology, and the functional telematics terminals, which are the key components in the telematics service, were more mature than before. Therefore, in the idea generating stage of telematics, the R&D department's technology capability is marked with level 1, since despite the few technology considerations on generating the idea, the technical understanding of the telematics industry did help the department make the decision to develop its telematics service.

- Opportunities and Threats Sensing Capability

The R&D department's decision to develop the telematics service was made with some internal and external considerations, such as the current market and technology trends, policies in the industry, and the strengths of China Mobile from the marketing and technical perspectives. Based on these considerations, the R&D department addressed most of the significant opportunities in the industry, however, it ignored a few vital threats, which results in its opportunities and threats sensing capability being marked with level 2 in the idea generating stage.

- Internal Collaboration Capability

In the idea generating stage, the R&D department did not have many internal collaborating activities with the other departments of China Mobile. However, the R&D department built some links with the top management team of the Group for their feasibility assessment of the project. Therefore, the internal collaborating capability during the idea generating stage is marked with level 1.

- External Collaborations Capability

During the idea generating stage of the telematics service, the R&D department of China Mobile built close links with the government. When the idea of developing telematics emerged, with the help of the links with the government, the R&D department learned that if they entered the telematics industry, they could be supported by the government, which was one of the main reasons for the department to make the decision to develop telematics. However, except for the links with the government, the R&D department did not build any other external links in this stage. Therefore, the R&D department's external collaborations capability for undertaking idea generating activities is marked with level 2.

- Knowledge Identifying Capability

As indicated previously, the idea of telematics did not initially originate from the R&D department of China Mobile itself. It was based on similar products developed by other world-leading car manufacturing and telecommunications firms. Therefore, when making the decision to develop telematics, there existed a pool of knowledge for China Mobile to adopt. The R&D department identified these different products, such as the telematics services of Verizon and Sprint, which did help them make the decision on telematics. Based on the analysis above, the R&D department's knowledge identifying capability in the idea generating stage is marked with level 3.

Case Study of Xi-He

Developing the Innovative Idea

- Creativity Capability

Since the idea of the Xi-He system was not generated by China Telecom but directly learned from the Chinese government, the R&D department did not have any creativity in its idea generating stage. However, before the Xi-He project, the R&D department of China Telecom already had its initial technical solution for realising indoor positioning with Wi-Fi technology in another project, and this solution was expected to be expanded in the Xi-He project. The R&D department's creativity in that project helped them make the decision to apply for Xi-He from the government. Therefore, the R&D department's creativity capability in the idea generating stage is marked with level 1.

- Technology Capability

When making the decision to develop Xi-He, the R&D department fully used technical considerations in relation to global technology trends and its own technical strengths, which did help them make the decision to apply for the project from the government. Therefore, the R&D department's creativity capability in the idea generating stage of Xi-He is marked with level 3.

- Opportunities and Threats Sensing Capability

During the idea generating stage, the R&D department within China Telecom identified most of the opportunities in the industry (such as government support, market needs, and technical trends) and its individual strengths (such as its existing technical base for realising the indoor positioning solution), however, few market threats or individual weaknesses were focused on by them. Therefore, the R&D department's opportunities and threats sensing capability is marked with level 2.

- Internal Collaborations Capability

Similar to the case study of telematics, the R&D department for Xi-He had few links with other departments of China Telecom, and the only internal link the R&D department built in this stage was with the board members of the group for their feasibility assessment and resource allocations. Based on the analysis above, the R&D department's internal collaborations capability for making the decision to apply for Xi-He is marked with level 1.

- External Collaborations Capability

When making the decision to develop Xi-He, the R&D department of China Telecom built close links with its co-operators. China Telecom was introduced to the Xi-He project by one of its co-operators, and this co-operator also provided the R&D department with some useful suggestions on the project-applying process. However, in relation to links with the government, since China Telecom joined the project in the second part of Xi-He, they did not build close links with the government when making the decision to apply for the project. Based on the analysis above, the R&D department's external collaborations capability in the idea generating stage is marked with level 2.

- Knowledge Identifying Capability

Since the idea for the Xi-He project arose from the government, the R&D department of China Telecom followed the guidelines published by the government directly for its idea generating activities. This process did not involve much external knowledge for the department to identify. However, when considering solutions for realising indoor positioning, the R&D department identified external knowledge from some academic institutions, and chose Wi-Fi technology as its individual technical solution. Based on the analysis above, the knowledge identifying capability in the idea generating stage is marked with level 2.

Case Study of 21CN

Developing the Innovative Idea

- Creativity Capability

Despite the idea of 21CN being first proposed by BT Group in the global industry, the R&D department did not play a key role in the idea generating activities. However, at this stage, the department did provide its recommendations and analysis from the technical perspective to the idea generators. Therefore, the R&D department's creativity capability in the idea generating stage is marked with level 1.

- Technology Capability

When the BT board members made the decision to develop 21CN, the R&D department provided them with mature technical solutions to convince them. Moreover, to integrate the three legacy networks into one platform, from the technical perspective, the R&D department also designed the new architecture of 21CN in this stage. Therefore, it can be concluded that the R&D department had fully technical considerations when helping the board members generate the idea of 21CN, which means its technology capability can be marked with level 3 in the idea generating stage.

- Opportunities and Threats Sensing Capability

During the idea generating stage of 21CN, the R&D department of BT assisted the board members to understand the main weaknesses of BT's existing lines of business and the threats in the domestic market. However, in terms of opportunities in the industry and its individual strengths for delivering 21CN, the R&D department did not focus on these. Based on the discussion above, the R&D department's opportunities and threats sensing capability in the idea generating stage is marked with level 2.

- Internal Collaboration Capability

When generating the idea of 21CN, the R&D department built internal links with the board members for providing its technical analysis and recommendations.

However, for internal links with other departments within BT, the R&D department seldom collaborated with them in this stage. Therefore the R&D department's internal collaborations capability in the idea generating stage is marked with level 1.

- External Collaborations Capability

The R&D department of BT did not have any external links with the government or other firms during the idea generating stage of 21CN, so the external collaborations capability in this stage is marked with level 0.

- Knowledge Identifying Capability

Since in the global telecommunications industry, BT was the first telecommunications operator that proposed the idea of integrated networks, there was no external knowledge for the R&D department of BT to refer to. Based on this consideration, the R&D department's knowledge identifying capability in this stage is marked with level 0.

Stage Two: Project Management Stage

Case Study of Telematics

Constructing the Team

- Organisational Capability

The R&D department's organisational capability on constructing the team can be considered from three perspectives. Firstly, the top management team of the R&D department assigned the chief scientist of the department as the team leader for the project; this person had a wealth of experience in team management. Secondly, compared with some privately-owned firms, China Mobile can offer higher salary and pension benefits to attract the best experts and post-graduate students in related technical areas. Thirdly, as an R&D department with nearly 1,000 staff, the existing R&D and project management experience could help the department build the new team efficiently. Based on the above three perspectives, it can be proposed that the R&D department of China Mobile had a strong organisational capability in building the new team, so this capability can be marked with level 3 for team constructing activity.

- Internal Collaborations Capability

When constructing the new team, the R&D department did not have any internal links with other departments of China Mobile. Moreover, as a relatively independent R&D institution with different staff-recruiting channels, it was not necessary for the R&D department to report to the board members of the group and request permission for recruiting new staff. Therefore the R&D department's internal collaborations capability on constructing the new team is marked with level 0.

Policy tracking

- Opportunities and Threats Sensing Capability

Within the R&D telematics team, one non-technical member of staff was mainly responsible for tracking the latest policies published by the government. This team member tracked all the policies in the telematics industry, not only from the internet every day, but also by attending conferences held by the government. Therefore the R&D team's opportunities and threats sensing capability in the policy tracking activity is marked with level 3.

- External Collaborations Capability

The telematics industry in China is mainly regulated by the Ministry of Transport and the Ministry of Industry and Information, which are two departments of the Chinese government. When tracking policies for developing telematics, the R&D team built links only with the Ministry of Industry and Information, but not with the Ministry of Transport. The R&D department did not build any links with other firms on tracking policies. Based on the analysis above, the R&D team's external collaborations capability in the policy tracking activity is marked with level 1.

- Knowledge Identifying Capability & Knowledge Learning Capability

As indicated above, within the R&D team, one team member was responsible for tracking the latest policies in the telematics industry. However, since this team member was non-technical, he/she could not relate all the external knowledge on policies to the R&D activities from a technical perspective. Therefore the R&D team's knowledge identifying capability on tracking policies is marked with level 2.

After identifying external knowledge on policies, the policy-tracking staff arranged meetings for the whole team to learn these policies together. In the meetings, the technical and business opportunities and threats that could be brought about by the policies were discussed. Based on the analysis above, the R&D team's knowledge learning capability on tracking policies is marked with level 3.

Identifying Uncertainties

- Opportunities and Threats Sensing Capability

When identifying uncertainties, the R&D team addressed the external opportunities and threats in the domestic industry. However, the uncertainties that arose from its internal strengths and weaknesses were less focused on by the R&D team. Based on this consideration, the R&D team's opportunities and threats sensing capability in the uncertainties identifying activity is marked with level 2.

- Knowledge Identifying Capability & Knowledge Learning Capability

When undertaking uncertainties identifying activity, the R&D team identified and learned external knowledge on the uncertainties that other firms met when developing their telematics services, and analysed whether these uncertainties could also occur in the Chinese telematics industry. Therefore the R&D team's knowledge identifying capability and knowledge learning capability in the uncertainty-identifying activity are both marked with level 3.

- Technology Capability

Most of the uncertainties that the R&D team identified for developing its telematics service were from the business and marketing perspectives, however, few uncertainties were related to technical considerations. Based on the analysis above, the R&D team's technology capability for identifying uncertainties is marked with level 0.

Developing the Strategic Plan

- Opportunities and Threats Sensing Capability

When developing the strategic plan for telematics, the R&D team identified most of the internal and external opportunities and threats. However, it was a criticism that the R&D team did not focus on the profit model for the telematics service in the strategic plan developing activity. Based on the analysis above, the R&D team's opportunities and threats sensing capability when developing the strategic plan is marked with level 2.

- Creativity Capability

During the development cycle of telematics, despite referring to some existing products in the global industry, the R&D team developed its strategic plan by itself. Differently from other products, the market segment of car insurance was focused upon, which involved a great deal of creativity. Based on the discussion above, the R&D team's creativity capability in its strategic plan developing activity is marked with level 2.

- Technology Capability

When developing the strategic plan for telematics, the R&D team took into account technical considerations, such as China Mobile's existing technical strengths for delivering the service. However, in this activity, the R&D team did not develop a detailed plan on how to realise the technologies involved in its proposed telematics service. Therefore the R&D team's technology capability in the strategic plan developing activity is marked with level 1.

- Internal Collaborations Capability

When developing the telematics service, the R&D team did not build any internal links with the board members of the group and other departments of China Mobile for developing its strategic plan, which means that its internal collaborations capability can be marked with level 0 for this activity.

- Knowledge Identifying Capability

Before developing the strategic plan, the R&D team of China Mobile identified some typical telematics products in the global industry. In this activity, the R&D team focused on external knowledge of the strategic plans for these products, and found a new market segment for providing its own service. Based on the discussion above, the R&D team's knowledge identifying capability for developing the strategic plan is marked with level 3.

Building Innovation Networks

- External Collaborations Capability

Referring to the strategic plan for the telematics service, the R&D team within China Mobile built links with some insurance companies and the traffic police stations for the content of its telematics service. However, in terms of links with technical partners on further research activities, the R&D team seldom concentrated on these. Therefore the R&D team's external collaborations capability when building its innovation networks is marked with level 2.

- Technology Capability

When building innovation networks, the R&D team presented its technical solution for attracting the co-operators. However, similar to the strategic plan-developing activity, the technical solution was not mature enough, since the R&D activities had not then started. Based on this consideration, the R&D team's technology capability for building its innovation networks is marked with level 1.

Case Study of Xi-He

Constructing the Team

- Organisational Capability

When constructing the team for developing Xi-He, the R&D department's organisational capability can be analysed from three perspectives. Firstly, the vice chief engineer of China Telecom (Shanghai) was appointed as the team leader for the R&D work of Xi-He; this person had a wealth of experience in project management and led the previous municipal indoor positioning project. Secondly, similarly to China Mobile, with the features of state-owned firms, China Telecom could offer a higher salary and pension to attract talented staff from other firms. Thirdly, the existing R&D experience and staff from the previous municipal indoor positioning project were able to help the department construct the new team efficiently. Based on the above three considerations, the R&D department's organisational capability on constructing the new team is marked with level 3.

- Internal Collaborations Capability

Since the R&D Xi-He team was in the form of a 'virtual team', the R&D department needed to build links with other departments to request permission for hiring their staff to work on the project. But apart from these links, when building the new team, the R&D department did not have any other internal links within China Telecom. Therefore the R&D department's internal collaborations capability on constructing the new team for Xi-He is marked with level 1.

Policy Tracking

- Opportunities and Threats Sensing Capability

Since Xi-He was a project published by the government, as a participant in the project, all the latest policies can be tracked directly from the government. Therefore, the R&D team within China Telecom was not sensitive about the opportunities and threats which could be brought about by the policies, which means that its opportunities and threats sensing capability can be marked with level 0 for the policy tracking activity.

- External Collaborations Capability

As a participant in the project, when tracking policies the R&D team within China Telecom built close links with the government. However, in terms of external links with the co-operators, the R&D team did not focus on these. Based on this consideration, the R&D team's external collaborations capability for tracking policies is marked with level 2.

- Knowledge Identifying Capability & Knowledge Learning Capability

With the nature of the government-oriented project, all the policies published by the government had a direct impact on the R&D team's development process for Xi-He, which made it not necessary for the team members to identify these policies. Moreover, having tracked the latest policies from the government, the R&D team would undertake learning activities in the regular meeting each week. However, most of these newly-published policies were supplementary to the initial project plan proposed by the government, and few of them were disruptive ones, which significantly reduced the difficulties for the R&D team in understanding them. Therefore, the R&D Xi-He team did not focus on learning activities for the latest policies. Based on the analysis above, the R&D team's knowledge identifying capability and knowledge learning capability on tracking policies are marked with level 0 and level 1 respectively.

Identifying Uncertainties

- Opportunities and Threats Sensing Capability

When identifying uncertainties for developing Xi-He, the R&D team identified the uncertainties of external opportunities and threats. However, in relation to uncertainties brought about by China Telecom's individual strengths and weaknesses, these were less concentrated on by the team members. Based on the analysis above, the R&D team's opportunities and threats sensing capability when identifying uncertainties is marked with level 2.

- Knowledge Identifying Capability & Knowledge Learning Capability

In the global industry, since there was no mature indoor-positioning solution for China Telecom to refer to at that time, it was difficult for its R&D team to identify and learn the uncertainties that other firms met when developing their products. Based on this consideration, the R&D Xi-He team did not focus on its knowledge identifying capability and knowledge learning capability for identifying uncertainties, which means that these two capabilities are marked with level 0 in this activity.

- Technology Capability

On delivering the indoor-positioning solution for the Xi-He system, the R&D team within China Telecom built up a strong technology capability for identifying uncertainties. Positioning accuracy, for example, which was recognised as one of the most significant bottlenecks in the Xi-He project, was identified by the R&D team from a technical consideration. Therefore the R&D team's technology capability on identifying uncertainties is marked with level 3.

Developing the Strategic Plan

- Opportunities and Threats Sensing Capability

When developing the strategic plan for Xi-He, the R&D team identified its internal strengths and weaknesses for developing the project. However, despite specific emphasis being placed on designing the business model of the indoor-positioning part of the Xi-He system, during this activity, the R&D team within China Telecom did not find the profit point of its service. Based on the analysis above, the R&D team's opportunities and threats sensing capability for developing the strategic plan is marked with level 2.

- Creativity Capability

When undertaking the strategic plan developing activity, rather than creating something new, the R&D team combined its indoor-positioning solution with China Telecom's mobile Internet services and followed the company's traditional strategic plan for Internet applications. This process did not involve much creativity, which means that the R&D team's creativity capability for developing the strategic plan can be marked with level 1.

- Technology Capability

When developing the strategic plan, the R&D team had technical considerations on the accuracy of its indoor-positioning solution and the distribution of the Wi-Fi hotspots inside buildings. However, a detailed technical plan for delivering the solution was not developed by the R&D team during this process. Based on the analysis above, the R&D team's technology capability for developing the strategic plan is marked with level 1.

- Internal Collaborations Capability

For the strategic plan for Xi-He, the R&D team developed this individually and did not have any internal links with the board team members and other departments of China Telecom, which means that its internal collaborations capability can be marked with level 0 in this process.

- Knowledge Identifying Capability

Despite some guidelines on the strategic plan for Xi-He that were published by the government, the R&D team did not refer to them in this process. Moreover, since there was no mature indoor-positioning solution in the global industry, the R&D team did not have any existing strategic plan to follow. With the considerations above, the R&D team did not identify any external knowledge for developing the strategic plan, which means that its knowledge identifying capability can be marked with level 0 in this activity.

Building Innovation Networks

- External Collaborations Capability

For the initial co-operators appointed by the government for the Xi-He project, the R&D team did not collaborate with these very well. However, for delivering its individual indoor-positioning solution, the R&D team within China Telecom found some new co-operators by itself and built close links with them. Based on the analysis above, the R&D team's external collaborations capability on building innovation networks is marked with level 2.

- Technology Capability

When finding new co-operators, the R&D team had certain technical considerations when fulfilling the value chain of its individual indoor-positioning solution. However, in relation to the initial co-operators appointed by the government, the R&D team did not share all the technical information with them. Therefore the R&D team's technology capability on building innovation networks is marked with level 1.

Case Study of 21CN

Constructing the Team

- Organisational Capability

As a large R&D institution with more than 21,200 people, the R&D department of BT had a wealth of experience of related technical areas of 21CN, and when constructing the R&D team, the vast majority of team members came from thousands of skilled people within the institution which had been built up for years. Based on the consideration above, it can be concluded that during the team construction process, a strong organisational capability was built by the R&D department, which means that this capability can be marked with level 3 in the current activity.

- Internal Collaborations Capability

When constructing the team for 21CN, the R&D department did not build many links with other operating departments within BT. However, for some specific parts of the project, a few staff from these operating departments joined the R&D team and provided their recommendations. Based on this consideration, the R&D department's organisational capability when constructing the team is marked with level 1.

Policy Tracking

When developing 21CN, the R&D team did not place any emphasis on the policies published by the government. Therefore all the four capabilities involved in the R&D team's policy tracking activity are marked with level 0.

Identifying Uncertainties

- Opportunities and Threats Sensing Capability

When identifying uncertainties for developing 21CN, the R&D team mainly evaluated its internal weaknesses and external threats. However, in relation to its internal strengths and external opportunities on developing the project, the R&D team seldom identified these in this activity. Based on this consideration, the R&D team's opportunities and threats sensing capability for identifying uncertainties is marked with level 2.

- Knowledge Identifying Capability & Knowledge Learning Capability

In the global telecommunications industry, since BT was the first operator to deliver this kind of integrated network, when identifying uncertainties, there was no existing experience in the industry for the R&D team to refer to. Therefore, the R&D team did not place any emphasis on its knowledge identifying capability and knowledge learning capability for identifying uncertainties, which means that these two capabilities can be marked with level 0 in the current activity.

- Technology Capability

When identifying uncertainties for developing 21CN, the technology capability helped the R&D team identify internal technical uncertainty on the feasibility of delivering an integrated solution. To reduce technical uncertainty from this perspective, the R&D team fully understood the technical architecture of 21CN, and carried out individual research in the lab to identify the problems. Based on the discussion above, the R&D team's technology capability for identifying uncertainties is marked with level 3.

Developing the Strategic Plan

- Opportunities and Threats Sensing Capability

When developing the strategic plan, the R&D team identified most of the technical opportunities and threats in the industry, as well as its individual strengths and weaknesses for delivering 21CN from a technical perspective. However, for the opportunities and threats from a marketing perspective, these were less focused on by the R&D team in its strategic plan. Therefore, during the strategic plan development process, the R&D team's opportunities and threats sensing capability is marked with level 2.

- Creativity Capability

The R&D team's strategic plan for developing 21CN was mainly relevant to BT's traditional lines of business, which were integrated into 21CN, and therefore did not involve much creativity in this process. However, for the new functionalities to be added into 21CN, the R&D addressed these in the strategic plan with creativity. Based on the discussion above, the R&D team's creativity capability for developing its strategic plan is marked with level 1.

- Technology Capability

When developing the strategic plan for 21CN, the R&D team within BT built up a strong technology capability for determining the new functionalities that 21CN could deliver and how technical challenges could be overcome when integrating the legacy networks. In this process, all the technical perspectives in the strategic plan were considered by the R&D team, which means that its technology capability can be marked with level 3 in the strategic plan developing activity.

- Internal Collaborations Capability

For developing the strategic plan of 21CN, the R&D team built up a strong internal collaborations capability, and its internal links in this activity were not only with the board team members of BT for their feasibility assessment, but also with the other operating departments for meeting their technical expectations for the new service. Based on the analysis above, the R&D team's internal collaborations capability for developing the strategic plan is marked with level 3.

- Knowledge Identifying Capability

Since 21CN was the first platform to integrate the legacy networks in the global telecommunications industry, there was no external knowledge on the strategic plan for the R&D team to refer to. Therefore, it was not necessary for the team to build up a knowledge identifying capability to develop its individual strategic plan for 21CN, which means that the capability can be marked with level 0 in the current activity.

Building Innovation Networks

- External Collaborations Capability

When building innovation networks for 21CN, the R&D team built external links not only with the technical co-operators for delivering its service, but also with some academic institution for cutting-edge technologies to be added into 21CN. However, the external links above were all from the technical perspective. In relation to links on the applications for 21CN, the R&D team did not place any emphasis on these. Therefore the R&D team's external collaborations capability is marked with level 2 for building its innovation networks.

- Technology Capability

As discussed in the previous capability, when building innovation networks for 21CN, the R&D team within BT found most of its co-operators in relation to technical considerations, which means that its technology capability is marked with level 3 in the current activity.

Case Study of BT Fusion

Since 21CN and BT Fusion were developed by the R&D teams in the same department of BT, most of these two teams' capabilities in the product management stage were similar, except for the internal collaborations capability in the strategic plan developing activity.

When developing the strategic plan, the R&D team mainly built its internal links with the board team members and the marketing people from the Retail department for their feasibility assessments. However, compared with 21CN, BT

Fusion was a relatively small project, and the emphasis placed by the board team members and other operating departments on the strategic plan was much less than in the case study of 21CN. Therefore, it was not necessary for the R&D team to build close internal links within BT to develop the strategic plan, which means that its internal collaborations capability can be marked with level 1 in this activity.

Stage Three: R&D Stage

Case Study of Telematics

Research Activities

- External Collaborations Capability

When undertaking research activities for telematics, the R&D team mainly built its external links with the government on co-publishing the white paper, as well as with some law agencies on filing patents. However, except for the two perspectives discussed above, the R&D team did not collaborate with any other firms for its research work on telematics. Based on the analysis above, the R&D team's external collaborations capability in its research activities is marked with level 1.

- Internal Collaborations Capability

For the research activities on telematics, the only internal links that the R&D team built was with the top management team of the R&D department, where its research process and progress on telematics were presented to the top management team members regularly for their feasibility assessment. However, except for the above links, the R&D telematics team did not collaborate with any other departments of China Mobile for the research work on telematics, so its internal collaborations capability can be marked with level 1 in the current activities.

- Technology Capability

When undertaking its research activities, the R&D team of China Mobile built up a strong technology capability to fill the research gaps for delivering its telematics service. As well as co-publishing a white paper together with the government, the R&D team placed significant emphasis on the marketing perspective for the other activities in the research work for telematics, and they were all undertaken with technical considerations. Based on the analysis above, when undertaking research activities for telematics, the R&D team's technology capability is marked with level 3.

- Creativity Capability

When developing telematics, most of the R&D team's research activities were related to other firms' existing experience on delivering similar products, and the only creativity involved in the R&D team's research work was from the perspective of patents filing. Therefore the R&D team's creativity capability when undertaking research activities for telematics is marked with level 1.

- Knowledge Identifying Capability

As mentioned in the previous capability, when undertaking research activities for telematics, the R&D team within China Mobile reviewed other firms' research work on similar products. Moreover, in the current activities, the R&D team also identified external knowledge on patents review with the help of law agencies. Based on the analysis above, it can be proposed that during the research activities on telematics, the R&D team identified most of the significant external knowledge, which means that its knowledge identifying capability can be marked with level 3 for research activities.

- Knowledge Learning Capability

For most of the identified external knowledge, the R&D team analysed their strengths and limitations from a technical perspective, and avoided the failure experience that other firms suffered. However, when filing patents, the R&D team members discovered all the patent points by themselves without any externally-learned knowledge. Based on the discussions above, the knowledge learning capability on undertaking research activities is marked with level 2.

- Knowledge Reframing Capability

With the knowledge learned from external sources, when undertaking research activities, the R&D team reframed them into its individual research work and added its own innovative functionalities into the service. Therefore, the R&D team's knowledge reframing capability in research activities is marked with level 3.

- Organisational Capability

When undertaking research activities, the R&D team within China Mobile had an incentive system for its team members' research achievements. For the telematics project, each team member was assigned a target of filing ten patents per year. Both of the above two perspectives did have stimulating effects on the R&D team's research activities. However, a criticism is that the current incentive system of China Mobile makes team members focused on the quantity of its research outcomes rather than the quality of them, which can bring certain challenges to the R&D team in its subsequent exploiting stage. Based on the analysis above, the R&D team's organisational capability is marked with level 2 in the current activities.

Product Development Activities

- External Collaborations Capability

When undertaking product development activities for telematics, the R&D team built links with car manufacturers, vehicle terminal providers, and GIS map providers for developing its applications. Moreover, referring to the strategic plan built into the previous stage, the R&D team also collaborated with insurance companies and police stations for fulfilling the value chain of its telematics service. However, in relation to external links with the government, the R&D team did not place significant emphasis on these. Based on the discussions above, the R&D team's external collaborations capability in the product development activities is marked with level 2.

- Internal Collaborations Capability

During the product development activities, the R&D telematics team did not build any internal links with other departments of China Mobile, which means that its internal collaborations capability can be marked with level 0 in the current activity.

- Technology Capability

When undertaking development activities for telematics, the R&D team's technology capability can be analysed from two perspectives. Firstly, for the applications for telematics, the R&D team considered these from technical perspectives, such as integrating its service with the Compass Navigation system, or utilising the TD-LTE technology as its communications solution. Secondly, when collaborating with the partners on product development activities, the R&D team within China Mobile provided technical solutions for delivering the new applications, where a strong technology capability was needed. Therefore the R&D team's technology capability when undertaking product development activities is marked with level 3.

- Creativity Capability

Based on the strong technology capability involved in the R&D team's product development process, the team members also built up a strong creativity capability in their current activities, which reflected on the R&D team's innovative ideas on applications for its telematics service. Based on the discussion above, the R&D team's creativity capability in product development activities is marked with level 3.

- Knowledge Identifying Capability & Knowledge Learning Capability

When undertaking product development activities for telematics, the R&D team reviewed the external knowledge on existing applications in the domestic and global telematics industries first, and then analysed their strengths and limitations for finding their own direction on applications. Therefore, it can be concluded that during the product development activities, the R&D team build up a strong knowledge identifying capability and knowledge learning capability, which means that these two capabilities can both be marked with level 3 in the current activities.

- Knowledge Transferring Capability

Referring to identified and learned knowledge, the R&D team developed its own individual applications for the telematics service. In the product development process, the R&D team avoided the weaknesses of existing applications in the industry and adopted their strengths. However, in the current activities, it was a criticism that the R&D team within China Mobile did not have adequate consideration of its profit model when transferring the external knowledge into its applications, which can bring plenty of difficulties into the further exploiting stage of its telematics service. Based on the analysis above, the R&D team's knowledge transferring capability is marked with level 2 for the product development activities of telematics.

- Organisational Capability

As a research institution with nearly 1,000 staff, the R&D department of China Mobile had a mature management model for its product development activities. Moreover, similarly to the research activities for telematics, the R&D team also had an incentive system for its team members on their product developing achievements. Based on the analysis above, the R&D team's organisational capability is marked with level 3 when undertaking its product development activities.

- Opportunities and Threats Sensing Capability

When undertaking product development activities for telematics, the R&D team within China Mobile identified most of the internal and external opportunities and threats from a technical perspective, however, less emphasis was placed by the R&D team on the marketing and business perspectives in this process, which means that the R&D team's opportunities and threats sensing capability can be marked with level 2 in its product development activities.

Case Study of Xi-He

Research Activities

- External Collaborations Capability

When undertaking research activities for Xi-He, the R&D team built external links with the government for the feasibility assessment and with law agencies for filing its patents. However, except for the above links, the R&D team did not place any emphasis on building links with the co-operators from the value chain when undertaking research activities. Based on the analysis above, the R&D team's external collaborations capability in research activities is marked with level 1.

- Internal Collaborations Capability

During the research activities of Xi-He, the only internal links that the R&D team built were with the headquarters of China Telecom for centrally assessing its patents filing work. However, except for the patents reviewing work, the R&D team did not place any emphasis on building internal links with the other departments of China Telecom. Therefore the R&D team's internal collaborations capability in the research activities of Xi-He is marked with level 1.

- Technology Capability & Creativity Capability

When undertaking research work for Xi-He, the R&D team had technical considerations for most of its research activities, from the indoor-positioning algorithm design, to the patents filing work, which also involved a great deal of creativity in this process. However, from the co-operators' perspective, they thought that the technology capability and the creativity capability of the R&D team for Xi-He was far below their expectations due to its own unique solution on delivering the indoor positioning technology. Based on the analysis above, the R&D team's technology capability and creativity capability when undertaking research work on Xi-He are both marked with level 2.

- Knowledge Identifying Capability

During the research activities for Xi-He, the R&D team did not place significant emphasis on its knowledge identifying capability, and the only external knowledge they identified in the current activities was on patents review for the novelties of their individual patents. Therefore, it can be proposed that when undertaking research activities for Xi-He, the R&D team's knowledge identifying capability should be marked with level 1.

- Knowledge Learning Capability & Knowledge Reframing Capability

As mentioned in the previous capability, the only external knowledge identified by the R&D team in its research activities for Xi-He was on the novelties of its own patents. However, in relation to the knowledge identified from this perspective, the R&D team did not learn and reframe it, which means that its knowledge learning capability and knowledge reframing capability can both be marked with level 0 in the current activities.

- Organisational Capability

During the research process for Xi-He, the R&D team within China Telecom had mature models for managing research activities as well as an incentive system for its team members' research achievements. However, similarly to the case study of telematics, the incentive system of China Telecom also made team members focus on the quantity of its research outcomes rather than the quality of them. Based on the analysis above, the R&D team's organisational capability is marked with level 2 when undertaking research activities for Xi-He.

Product Development Activities

In the Xi-He project, the R&D team within China Telecom was responsible only for delivering the indoor-positioning solutions. However, in relation to its product development activities, these were not considered by the R&D team but by the co-operators in the value chain. Therefore, during the product development activities for Xi-He, the only capability that the R&D team concentrated on was the external collaborations capability (as discussed below), and in terms of the other capabilities in the current process, the team members did not focus on these (be marked with level 0).

- External Collaborations Capability

When undertaking product development activities for Xi-He, the R&D team built close links with the co-operators it found by itself. However, in relation to the co-operators appointed by the government, the R&D team did not place significant emphasis on collaborating with these. Based on the discussions above, the R&D team's external collaborations capability is marked with level 2 for its product development activities.

Case Study of 21CN

Research Activities

- External Collaborations Capability

During the research work for 21CN, the R&D team built up a strong external collaborations capability, and the external links the team members built in the current activities were not only with the vendors on the research work, standards, and public relations, but also with some academic institutions for the cutting-edge technologies to be added into 21CN. Therefore the R&D team's external collaborations capability is marked with level 3 for its research activities.

- Internal Collaborations Capability

When undertaking the research activities for 21CN, the R&D team within BT built internal links with the board team members of the Group. Since 21CN was BT's largest investment for ten years, the board team members monitored all the R&D team's research activities and progress. However, except for the internal links with board team members, the R&D team did not build any links with other departments of BT. Therefore, the R&D team's internal collaborations capability in its research activities is marked with level 1.

- Technology Capability & Creativity Capability

For the research activities for 21CN, the R&D team within BT built up a strong technology capability and creativity capability during the entire research process, from the network architecture design at the beginning, to the integration of all the individual research parts in the end. Based on the considerations above, the R&D team's technology capability and creativity capability in its research activities are both marked with level 3.

- Knowledge Identifying Capability

Similarly to the case study of Xi-He, when undertaking research activities for 21CN, the R&D team identified external knowledge only on the existing patents in the industries in relation to the novelties of their own patents. For other pieces of external knowledge relating to the research activities for 21CN, the R&D team did not place any emphasis on this. Therefore the R&D team's knowledge identifying capability in its research activities is marked with level 1.

- Knowledge Learning Capability and Knowledge Reframing Capability

Without strong knowledge identifying capability, the R&D team did not learn and reframe any external knowledge during the research process for 21CN, which means that its knowledge learning capability and knowledge reframing capability can both be marked with level 0 in the current activities.

- Organisational Capability

For the research activities of 21CN, the R&D team within BT had an incentive system for individuals on their research achievements. By comparing the cases of telematics and Xi-He, in the case study of 21CN, the R&D team focused on the quality of its research activities rather than the quantity of them. Based on the analysis above, the R&D team's organisational capability is marked with level 3 for its research activities.

Product Development Activities

- External Collaborations Capability

When undertaking product development activities for 21CN, the R&D team within BT seldom collaborated with its co-operators. Moreover, since the applications of 21CN were mainly considered by the marketing people, for the content providers of these applications, it was the responsibility of the marketing people to build links, but not the R&D team. Therefore it can be concluded that the R&D team's external collaborations capability in its product development activities should be marked with level 0.

- Internal Collaborations Capability

The applications for 21CN were mainly considered by the marketing people of BT. However, the R&D team did play a significant role in this. When undertaking product development activities, the R&D team built close links with the marketing people from different departments, such as BT Retail, BT Wholesale, and BT Openreach. Additionally, in the current product development activities, the R&D team also built close links with the board members of BT Group for their feasibility assessment. Based on the analysis above, the R&D team built up strong internal collaborations capability in its product development activities, so is marked with level 3.

- Technology Capability

When undertaking development activities for 21CN, the R&D team had technical considerations on how to transplant the existing applications from the legacy networks to the integrated one, and how to develop the platform for the new applications required by the marketing people, which could not be delivered in the traditional networks. However, except for the perspectives above, the R&D team did not have any other technical considerations in the current activities, which suggests that its technology capability in the product development activities should be marked with level 1.

- Creativity Capability

The product development activities for 21CN, as mentioned above, were mainly considered by the marketing people from different departments of BT. Therefore, this did not involve any R&D creativity in this process. Based on this consideration, the R&D team's creativity capability in its product development activities is marked with level 0.

- Knowledge Identifying Capability, Knowledge Learning Capability & Knowledge Transferring Capability

During the product development process of 21CN, the R&D team identified the latest applications from other telecommunications firms all over the world. However, when they identified external knowledge, rather than analysing it themselves, the R&D team brought it to the other departments of BT, and the marketing people in these departments undertook the knowledge analysis and transferring work. Therefore, when undertaking product development activities for 21CN, the R&D team's knowledge identifying capability is marked with level 3, whilst its knowledge learning and knowledge transferring capability are both marked with level 0 in the current activities.

- Organisational Capability

Due to the strict restrictions of Ofcom on BT's lines of business, the R&D team trained some special staff to collaborate with the department of Openreach in its product development activities. However, except for the perspective above, the R&D team did not take any other action relating to organisational capability in the current activities. Therefore the R&D team's organisational capability when undertaking product development activities is marked with level 1.

- Opportunities and Threats Sensing Capability

When undertaking product development activities for 21CN, internal and external opportunities and threats were mainly identified by the marketing people but not the R&D team, which means that the R&D team's opportunities and threats sensing capability can be marked with level 0 for its product development activities.

Case Study of BT Fusion

Compared with the 21CN project, when undertaking research and product development activities for Fusion, the only different capability that the R&D team of Fusion built up was the internal collaborations capability in its product development process.

During the product development activities for BT Fusion, the R&D team built its internal links only with the Retail department. However, for the other departments of BT Group, the R&D team seldom built links with these. Based on the discussion above, when the R&D team undertook product development activities, its internal collaborations capability is marked with level 1.

Stage Four: Exploiting Stage

Case Study of Xi-He

Testing

- Technology Capability

When undertaking testing activities for Xi-He, based on the technical index published by the government, the R&D team concentrated on the availability of the service, the interface between the co-operators, and the accuracy of its indoor-positioning solution from the technical perspective. Moreover, once technical issues in the testing process were found, the R&D team within China Telecom solved them immediately with its technology capability. Based on the analysis above, for the R&D team's technology capability during its testing activities, it is marked with level 3.

- External Collaborations Capability

During the testing process for Xi-He, the R&D team built close links with its co-operators to find issues in their collaborative end-to-end indoor-positioning solution. In addition, the R&D team also built links with the government on their inspections activities. The above two perspectives mean that the R&D team's external collaborations capability can be marked with level 3 in the current activities.

- Internal Collaborations Capability

In the testing activities for Xi-He, the R&D team did not build many internal direct links with other departments of China Telecom. However, since the team was in the form of a 'virtual team' and the team members were from various departments, this did involve some hidden internal links in this stage. Therefore, in relation to the R&D team's internal links when undertaking testing activities, this is marked with level 1.

Fully Exploiting

During the fully exploiting activities for Xi-He, the R&D team handed over the project to the operating department of China Telecom. However, it was not expected that all the R&D challenges could be solved when the project was finished. The R&D team undertook continuous development activities for its indoor-positioning solution, where its technology capability, external collaborations capability, and internal collaborations capability were involved in this process, and their marks were discussed as below:

- Technology Capability

When undertaking fully exploiting activities, the R&D team solved the technical issues of Xi-He reported by the operating departments of China Telecom. Moreover, when they found some issues on the algorithm of its indoor-positioning solution, the R&D team tracked back to its R&D activities and undertook some of them again. Based on the two perspectives discussed above, the R&D team's technology capability in its fully exploiting activities is marked with level 3.

- External Collaborations Capability

During the fully exploiting activities, the R&D team retained its external links with the partners they collaborated with in the testing process. However, for the links with the government, since the Ministry of Science and Technology had less influence on the R&D team's activities in the current process, it was not necessary for the team members to focus on building links with them. Therefore the R&D

team’s external collaborations capability when undertaking fully exploiting activities is marked with level 2.

- Internal Collaborations Capability

As discussed previously, the operating department of China Telecom was mainly responsible for the fully exploiting activities of Xi-He. During the current stage, the R&D team built close links with them for solving the technical issues of the service. Moreover, based on the customer demands learned by the operating departments, the R&D team also added new functionalities into its service. However, in terms of internal links with the board team members of China Telecom, the R&D team did not place significant emphasis on these. Based on the discussions above, the R&D team’s internal collaborations capability for undertaking fully exploiting activities is marked with level 2.

Case Study of 21CN

Testing

- Technology Capability

During the testing process for 21CN, the R&D team had technical considerations for all of its activities, which means that its technology capability can be marked with level 3 in the current process.

- External Collaborations Capability

Since the R&D work of 21CN involved many co-operators’ individual activities, in the test activities, the R&D team built close links with these and required the co-operators to carry out individual tests on their own parts of the R&D outcomes. All the test results were sent to the R&D team for integration, and when the team members met with some technical issues during the integrating process, they identified the parts of the R&D work with problems and returned the work to the co-operators who were responsible for them. Based on the considerations above, the R&D team's external collaborations capability for undertaking the test activities of 21CN is marked with level 3.

- Internal Collaborations Capability

Since the testing workload of 21CN was massive and the R&D team was requested to complete testing within a specified time, the team members built internal links with the research centres of BT in other countries for remote testing. Moreover, the R&D team also built close links with the board members and the operating departments of BT to present its testing results regularly. Based on the analysis above, the R&D team's internal collaborations capability when undertaking the testing activities is marked with level 3.

Fully Exploiting

- Technology Capability

When undertaking fully exploiting activities for 21CN, the R&D team built up a strong technology capability on solving the technical issues of the new service, delivering the new functionalities required by the marketing people, and testing the upgraded content, which means that its technology capability can be marked with level 3 in the fully exploiting activities of 21CN.

- External Collaborations Capability

Since 21CN was a project that relied on the co-operators' capabilities, during the fully exploiting activities the R&D team retained its external links from the previous stage, and undertook continuous development activities for 21CN together with its co-operators. Therefore the R&D team's external collaborations capability on fully exploiting 21CN is marked with level 3.

- Internal Collaborations Capability

When undertaking the fully exploiting activities for 21CN, the R&D team built close links with the marketing people from the operating departments to indicate technical issues involved in the new service as well as new functionalities that could be added into 21CN. In addition, the R&D team also built internal links with the board team members of BT to present its fully exploiting activities for their inspections. Based on the analysis above, the R&D team's internal collaborations capability in the current process is marked with level 3.

Case Study of BT Fusion

In comparison with 21CN, the different capabilities that the R&D team of BT Fusion built up during the launching stage were its internal collaborations capabilities when undertaking activities on testing and fully exploiting respectively.

In the testing process for BT Fusion, the R&D team did not build any internal links with the operating departments of BT. Moreover, since Fusion was a relatively small project that was less emphasised by the board team members, the R&D team did not build close links with them. Therefore the R&D team's internal collaborations capability when undertaking the testing activities for Fusion is marked with level 0.

During the fully exploiting activities, compared with 21CN where all the internal links were concentrated on, in the case study of BT Fusion, the R&D team collaborated with the marketing people from the department of BT Retail to identify the technical issues involved in its new service, as well as the board team members when presenting its fully exploiting results. However, except for the internal links above, the R&D team did not collaborate with other operating departments of BT in the current process, which means that its external collaborations capability should be marked with level 2 for the fully exploiting activities.

Appendix 4: An Initial Survey-Research Protocol from the Perspective of Cultural Contexts for Further Research

For the undertaking of further research based on the practical findings of this study, an initial survey-research protocol has been designed which focuses on how R&D departments addressed the contextual factor of cultural contexts in their radical innovation development cycles. When conducting further surveys, a questionnaire with fourteen statements, as below, could be sent to the R&D managers in the STOs of some other countries, and they would be requested to put a score from 0 (= not true at all) to 3 (very true) for each statement referring to their radical innovation developing activities.

No.	Statements	Score (0 = not true at all to 3 = very true)
1	When making decisions on developing radical innovations, the R&D department identified all of its individual strengths for developing them.	
2	When making decisions on developing radical innovations, the R&D department identified all of its individual weaknesses for developing them.	
3	When making decisions on developing radical innovations, the R&D department identified all the external opportunities in the industry for developing them.	
4	When making decisions on developing radical innovations, the R&D department identified all the external threats in the industry for developing them.	
5	When engaging in radical innovations, the R&D department built close links with its partners for generating the innovative idea and making decisions on developing these radical innovations.	
6	When engaging in radical innovations, the R&D department	

	built close links with the government for generating the innovative idea and making decisions on developing these radical innovations.
7	The R&D department tracked all the relevant policies in the industry for developing its radical innovations.
8	When identifying uncertainties for developing radical innovations, the R&D department identified all of its individual strengths.
9	When identifying uncertainties for developing radical innovations, the R&D department identified all of its individual weaknesses.
10	When identifying uncertainties for developing radical innovations, the R&D department identified all the external opportunities in the industry.
11	When identifying uncertainties for developing radical innovations, the R&D department identified all the external threats in the industry.
12	When developing the strategic plan for developing radical innovations, the R&D department had fully technical considerations.
13	When undertaking the research activities for developing radical innovations, the R&D department built close links with its partners.
14	When undertaking research activities for developing radical innovations, the R&D department concentrated on the quantity of its research achievements.
15	When undertaking research activities for developing radical innovations, the R&D department concentrated on the quality of its research achievements.