Bridge Managers in Global R&D Projects: Relationship between Project Difficulties and Manager's Competencies for Facilitating the Projects

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Doctoral Dissertation

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Abstract

Research and development (R&D) is an important activity of the organization to gain a competitive advantage as it leads to the production of new and innovative products and services for customers. In the globally connected world, innovation becomes more and more dependent on the collaboration among people from different backgrounds who exchange and combine their own knowledge and expertise to create innovative outcomes. Literature has long shown that diversity of knowledge increases the creativity and innovation of teams and corporations. Multinational corporations (MNCs) expand their R&D function abroad and take advantage of global knowledge resources. However, there are challenges to overcome ranging from organizational level such as international R&D strategies, global R&D team cooperation to individual level issues such as R&D manager assignment, researcher relocation, and expatriate adjustment. During the early days of R&D internationalization around the 1980s, prior studies in R&D internationalization focused on the organizational level, how firms organize their international R&D operations. Therefore, issues such as international R&D strategies and global R&D team cooperation were better developed and well established. As the business environment has always been changing and the world has become more connected, although the organization management needs to adapt to the changing environment, it is also necessary to pay attention to the individual level issues to enhance the global R&D operations.

Facilitating research collaboration between teams located in different countries and have members of diverse backgrounds is a challenging task for managers. Organizations operate global R&D projects all over the world to gain access to diverse knowledge resources. Global R&D projects involve both internal and external stakeholders who are from different countries and having diverse backgrounds. Although global R&D project members can interact with each other using technology support tools, the effectiveness of interaction is limited by the communication channels such as email, phone, etc. Cultural differences which are the different values, beliefs, behaviors, languages, and practices play an important role in global R&D project collaboration. Organizations employ managers, who we call “R&D bridge managers (BMs)”, to facilitate research collaboration in global R&D projects. They are facilitators in charge of bridging research activities between teams in the home country of the company and foreign R&D teams. There is a limited number of studies of BMs who help the organizations to put in place a smooth operation of global R&D projects.

Individual managers require particular competencies to perform their tasks effectively. The concept of competency has been used to improve the task performance of individuals. A number of prior studies focused on leadership competencies and defined competency to includes skills, knowledge, abilities, and characteristics that lead to superior results. Competency development frameworks were identified for different professions such as project managers and medical workers. In the case of global R&D projects, the research found that manager's sophisticated people skills and leadership to deal with the human aspect influence performance of dispersed R&D teams. Extant studies have shown that the leadership competencies of managers are an important factor for successful cross-cultural collaboration. The competency concept is used in this dissertation to improve the global R&D project facilitation. The competencies of managers who facilitate research collaboration between headquarters and foreign R&D laboratories in global R&D projects have not been identified.

This dissertation aims to identify crucial competencies of BMs for the facilitation of global R&D projects of MNCs in the information technology industry and to investigate the relationship between difficulties of facilitating global R&D projects and competencies of BMs. Particularly, this dissertation attempts to address the major research question: *How are the difficulties and competencies of managers in global R&D projects related?* This dissertation employed multimethodology, including semi-structured interviews and questionnaire surveys as data collection methods. Thematic coding was used to analyze interview data of BMs to identify difficulties in facilitating global R&D projects. A list of competencies was derived from existing literature on leadership competency to develop measurement items of the questionnaire survey. Relevance ratio and qualitative comparative analysis were conducted to explore the relationships between difficulties and competencies. Findings reveal four difficulties that the BMs face when they facilitate global R&D projects, including quality control, research approach guidance, requirement clarification, and team communication. In addition, the results show relatively more important competencies of BMs for solving difficulties in global R&D projects. To the best of our knowledge, there are no competencies specifically identify for BMs concerning difficulties they faced, especially in the context of global R&D projects. It is plausible to conclude that there are crucial competencies for BMs to overcome particular difficulties in global R&D projects. BMs may develop and possess those competencies hence they could improve global R&D project facilitation. In addition, organizations may utilize crucial competencies of BMs in their human resource management practices, including new manager recruitment, manager assignment, and manager's training program development.

Keywords: Global R&D project, R&D bridge manager, Project difficulty, Manager competency, Global team collaboration

Dedication

For my father, mother, brother, and sister who encouraged me to pursue my dreams.

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"Ph.D. is not an individual accomplishment, but a collection of invisible support."

Anonymous

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Chapter 1 Introduction

This chapter provides an overview of this dissertation, including relevant background information, problem statement, research gaps, research objectives with corresponding research questions, and a brief detail of research methodology. The background section introduces related topics of this research. Then, problem statements and research gaps are identified. The objective section lists what are the research objectives which will be achieved by mean of research methodology. The research question section identifies a major research question and subsidiary research questions. Lastly, this chapter ends with a dissertation structure that briefly explains information in each chapter of this dissertation.

1.1 Background of the study

The research and development (R&D) internationalization is not a new phenomenon. The United Nations produced the world investment report in 2005 focusing on R&D (UNCTAD, 2005). Firms adapt their technologies locally to successfully sell products in host countries. Multinational companies (MNCs) are setting up foreign R&D facilities outside developed countries. They target both local markets and global markets and embed themselves into the global R&D networks. MNCs expect to increase their production and operate efficiently in developing countries. The investment for global R&D has been increasing and distributing around the world and Asia is the largest R&D investing region as shown in Figure 1.1 (Heney, 2020). Global R&D needs a high level of skills, knowledge, and support which traditionally is not easy to find in developing countries. R&D also requires dense knowledge exchange between customers and producers. In the early days, a small number of firms participated in R&D internationalization because it required a lot of resources and enormous efforts. However, some locations have become more and more attractive for MNCs to operate their R&D function abroad. More countries develop the capability to connect themselves to the global R&D systems.

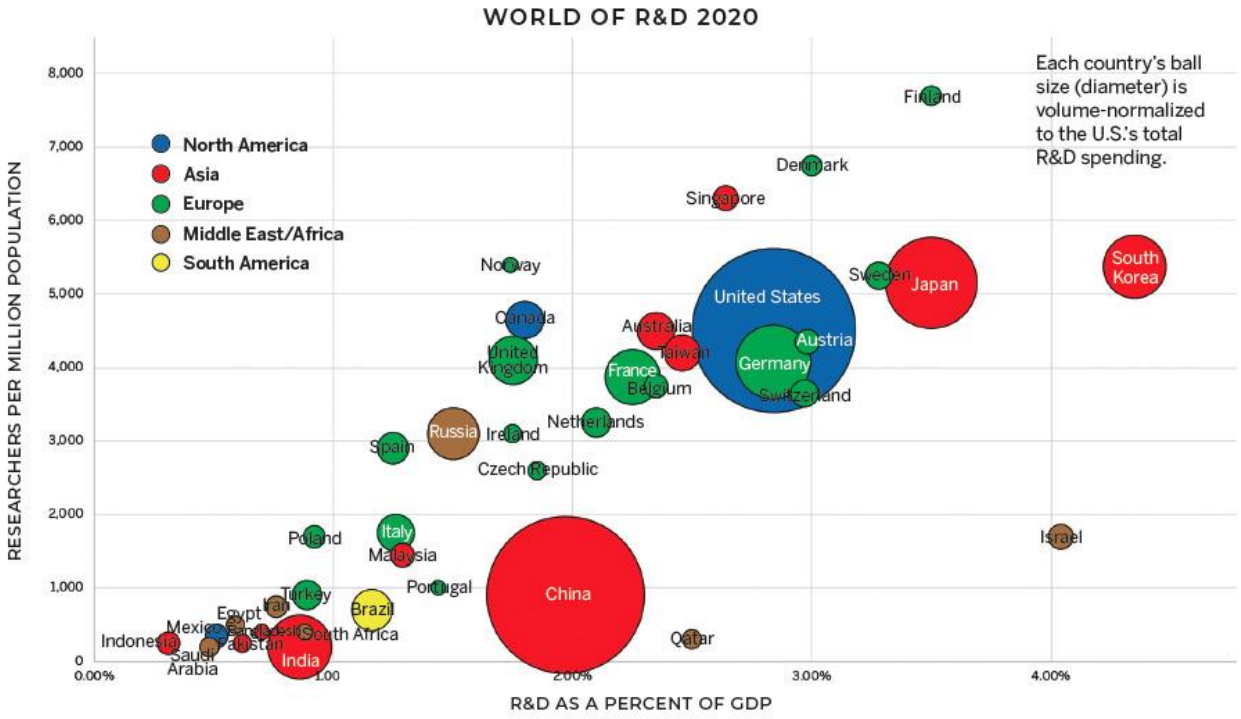
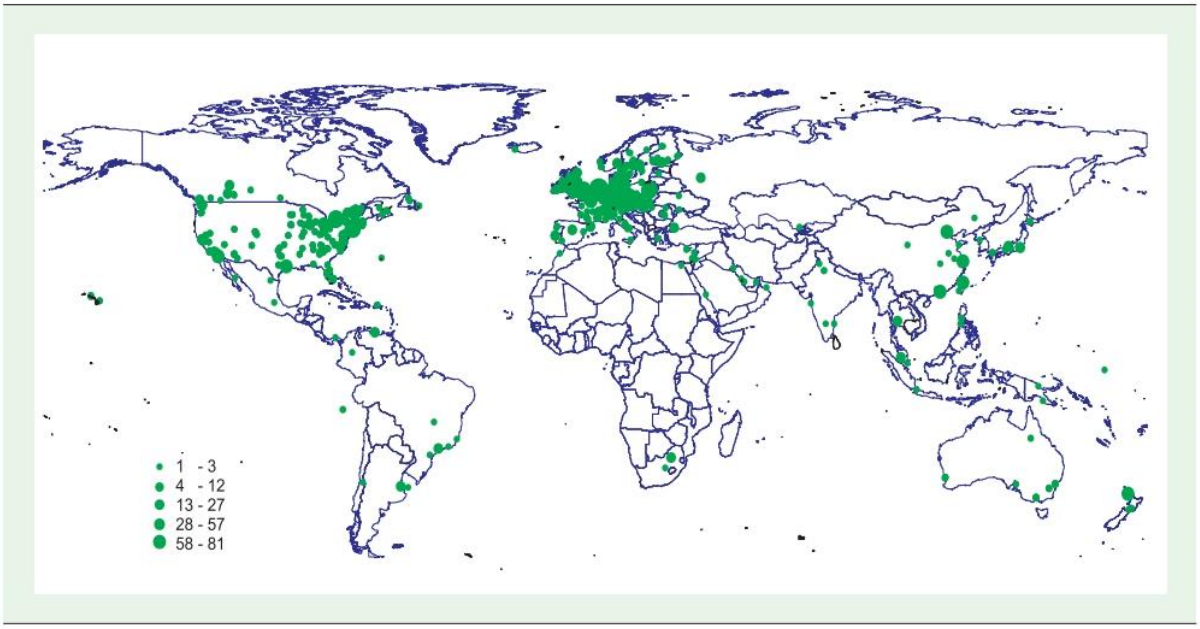


Figure 1.1: Global R&D investment (Heney, 2020)

It is understood in the industry that global R&D is a vital function for business growth. The first foreign R&D lab of Motorola was established in China and has around 700 R&D units in the country (UNCTAD, 2005). General Electric employ 2,400 people in India to perform R&D activities in diverse areas such as aircraft engines, consumer durables, and medical equipment (UNCTAD, 2005). New R&D facilities increase in developing countries reflects the spread of R&D activities outside their home countries as shown in Figure 1.2 (UNCTAD, 2005). In academics as well, international R&D is a topic of interest of many researchers since the beginning of this phenomenon in the industry. Allen (1971) investigated the international transfer of technological information, which focuses on the operation of communication channels, and introduced the technological gatekeepers who connect internal users with external information sources. Ronstadt (1977) identified four types of global R&D laboratories including transfer technology units, indigenous technology units, global technology units, and corporate technology units. Further, De Meyer and Mizushima (1989) explored global R&D management trying to develop a framework for effective use of dispersed R&D laboratories. The topic of international R&D or global R&D gains increasing attention.



Source: UNCTAD, based on the *Who Owns Whom* database (Dun & Bradstreet).
Note: On the basis of 2,603 majority-owned foreign affiliates engaged in R&D.

Figure 1.2: Locations of majority-owned foreign affiliates engaged in R&D, 2004 (UNCTAD, 2005)

The international R&D operations become more complex and involve more locations, both in developed countries and developing countries (UNCTAD, 2005). Since 1980's when many studies mostly focused on why and how firms internationalize their R&D, Cheng and Bolon (1993) grouped research findings into five categories: 1) site selection for foreign R&D subsidiaries, 2) local autonomy granted to subsidiaries, 3) international coordination of multinational R&D, 4) organizational structure for foreign R&D activities and 5) human resource management in multinational R&D. Specifically for the human resource management in multinational R&D, only the work of De Meyer and Mizushima (1989) pointed out that very little consideration was given to the ability of individual managers to manage researchers from different cultures. This highlighted a concern, at that time, on a new direction of international R&D research at the micro-level (individual-level).

R&D managers play important roles in the success of R&D internationalization such as connecting corporate strategy to R&D strategy, choosing appropriate R&D sites, and integrating activities of different foreign R&D sites (Gammeltoft, 2005). The increasingly connected world and more diverse R&D staff post new challenges for R&D managers in terms of human resource management (De Boer et al., 1998). Thamhain (2009b) argued that leaders of global R&D teams must understand not only the work process

and collaborative technology but also the organization infrastructure and handle complex social issues which determine value system and culture of multinational enterprises. Focusing on the relationship between headquarters and foreign R&D subsidiaries, Asakawa (2001a) argued that there should be an active broker's role that support transfer of information using a few liaison persons. This broker's role mechanism helps foreign R&D laboratories to attain semi-connected freedom which means the laboratories try to increase information connection with headquarters while at the same time trying to keep as much autonomy as possible (Asakawa, 2001a). Uchihira et al. (2017) characterized the R&D bridge managers (BMs) role by comparing them with bridge system engineers (BSEs) of offshore software development projects. BMs require management skills to improve research collaboration between headquarters and foreign R&D subsidiaries, control dynamically changing situations, communicate properly with project members, and raise the motivation of local researchers (Uchihira et al., 2017). There is an increasing interest in the topics related to skills, traits, and behaviors of R&D project managers who influence the delivery of projects (Ram & Ronggui, 2018).

Skills, abilities, and knowledge are the components included in the concept of competency. The concept of competency has long been developed for a few decades since McClelland (1973) reviewed the performance measurement of individuals using traditional intelligence tests and proposed competencies as a better alternative solution considering knowledge, skills, self-concepts, traits, and motives. Since then, competency became well known for researchers and practitioners who are interested in individual performance management. Identification of professional competencies for performing particular tasks has received attention from researchers and practitioners (Albetkova et al., 2019; Gowie et al., 2020; Mansfield, 1996). By its evolving definition, competency includes knowledge, skills, abilities, attitudes, and characteristics that help individuals to perform their tasks effectively (Athey & Orth, 1999; Fotis & Gregoris, 2006; Lustri et al., 2007; Teodorescu, 2006). There are well-established competency development frameworks that indicate abilities, skills, and knowledge necessary for particular professions. For example, laboratory leaders, human resource professionals, and clinical research staff (Albetkova et al., 2019; Gowie et al., 2020; Mansfield, 1996). In the case of project managers, they have project manager competency development framework (PMI, 2017). Podgórska and Pichlak (2019) argued that leadership competencies influence project success, and the degree of influence depends on the types of projects. Researchers also found that the competencies of managers have a relationship with project success (Cheng et al., 2005; Elkins & Keller, 2003; Geoghegan & Dulewicz, 2008; Yalaho & Nahar, 2010).

1.2 Problem statement and research gaps

R&D internationalization receives more attention from both academic and industry as it is an important activity for the firms to harness technological capabilities, improve innovation performance, and gain competitive advantage (Bowonder et al., 2000; Castellani & Pieri, 2013; Cheng & Bolon, 1993; De Meyer & Mizushima, 1989; Hsu et al., 2015; Persaud et al., 2002). Scholars have explored firm's R&D internationalization to answer why and how firms pursue particular approaches (Bartlett & Ghosbal, 1987; Ronstadt, 1977). There are concerns and challenges of how firms manage dispersed R&D operations. Five types of R&D organizations in MNCs were identified using R&D activities dispersion and the degree of cooperation between R&D units (Gassmann & von Zedtwitz, 1999). Six fundamental dilemmas were identified; they make it difficult for firms to benefit from the full potential of global innovation (von Zedtwitz et al., 2004). The majority of prior studies in internationalization of R&D focused on the organizational level, how firms organize their international R&D operations. Research during the early days of the international R&D phenomenon focused on organization strategies to expand R&D function. As business situations keep changing, more research is interested in individuals working in global R&D units. Although strategies and coordination mechanisms of global R&D are well established, some managers and researchers in global R&D projects fail to achieve the expected performance level.

At the micro-level, individual members of global R&D projects collaborate with each other to deliver innovative outcomes. Global R&D management requires special attention to the communication network among laboratories to effectively utilize globally dispersed R&D laboratories (De Meyer & Mizushima, 1989). The effectiveness of in-person communication, including managers, scientists, and engineers, between the headquarters and subsidiary laboratories influences the firm's innovation capability (Persaud et al., 2002). Intrafirm mobility of middle managers between headquarters and distant R&D locations has a positive relation to the innovation outcomes of the firm (Choudhury, 2017). Prior studies focused on the outputs such as project outcomes, and innovation capability that is delivered by individual managers but did not identify the challenges they faced. The role of managers who facilitate research collaboration between headquarters and foreign R&D subsidiaries is important to improve the effectiveness of the global R&D operation of the firm. Hence, this dissertation focuses on the individual managers in global R&D projects to identify challenges they have faced in facilitating global R&D projects. Further, this dissertation also focuses on the competencies of managers that they possess to help them overcome the challenges of project facilitation. Three research gaps have been identified as follows.

There is a research gap concerning the supporting role of individual global R&D project managers. There are various issues related to the role of managers. The global R&D managers have high responsibility and influence for the delivery of the projects (Ram & Ronggui, 2018). The managers responsible for the integration of corporate strategy and R&D strategy, choosing appropriate locations for R&D sites, assignment of the right people to R&D laboratories, managing sites during start-up, and consolidating tasks of multiple foreign R&D sites (Gammeltoft, 2005; Lian et al., 2020). Meanwhile, geographical distance creates mental pressure on the project managers because they have frequent business trips across different locations of R&D sites (Liu et al., 2019). Further, the increasing business competition creates more challenges and increased complexity in global R&D operations (Belderbos et al., 2020). It can be seen that prior studies focused on the roles and responsibilities of global R&D managers to lead and deliver projects. Even so, there are roles of facilitators to support the smooth operation of global R&D projects. Skilled and competent facilitators are important for groups and teams to produce effective outcomes (Nelson & McFadzean, 1998). Studies on the facilitator role in global R&D projects are limited. For instance, Asakawa (2001a) introduced an influencer role to facilitate active information exchange between headquarters and foreign R&D laboratories, thus foreign R&D laboratories can attain desired degree of autonomy. Jang (2017) defined cultural brokerage as the facilitation of actor's interaction across cultural boundaries to elicit knowledge from different cultures, hence the creative performance of multicultural teams can be enhanced. To date, this kind of supporting role in global R&D projects receives more attention as they can add value to increasingly complex projects. Existing studies investigated the roles of influencers and cultural brokers how they enhance team performance. Effective collaboration in multicultural teams like global R&D teams is also one of the crucial parts to enhance team performance, but the role of managers in charge of this collaboration receives limited attention. This dissertation addresses this research gap; the lack of exploration into facilitator role in global R&D projects who enhance research collaboration between headquarters and foreign R&D subsidiaries.

Another research gap focuses on how the managers in global R&D projects perform their tasks effectively. A number of prior studies focused on leadership competencies which include skills, knowledge, abilities, and characteristics that lead to superior results (Geoghegan & Dulewicz, 2008; Gray, 2007). Elkins and Keller (2003) reviewed the literature on leadership and found that skills and roles of leaders in R&D organizations have a relationship with R&D project success. Thamhain (2009a) argued that managers need sophisticated people skills and leadership to deal with the human aspect which influences the performance of dispersed R&D teams. Competent managers play a crucial role in R&D projects and technology-intensive teams. In a global context, overseas R&D is expected to improve firm's capability to develop more innovations by acquiring a diverse knowledge base, and capable workforce (Rahko, 2021). This gives a higher demand for the facilitators in global R&D projects to pay closer attention to the collaboration

between R&D professionals in the projects. Prior studies have shown that the leadership competencies of managers are an important factor for successful cross-cultural collaboration (Jensen, 2020; Lisak & Erez, 2015; Podgórska & Pichlak, 2019; Thamhain, 2012), but these studies did not focus on the identification of competencies that are crucial for global R&D project facilitation. We do not know yet which competency is crucial with regard to global R&D project facilitation. Thus, the crucial competencies of managers who facilitate research collaboration between headquarters and foreign R&D laboratories in global R&D projects need to be identified.

Furthermore, studies have shown that different competencies are required in order to perform effectively in different contexts (Dulewicz & Higgs, 2005; Hoffmann, 1999; Tiina, 2005; Yu et al., 2012). This last research gap pays attention to the relationship between the crucial competencies of managers for effective facilitation and difficulties the managers face in the context of global R&D projects. Effective performance of individual managers may be assessed by measuring the achievement of objectives or appropriate process execution (Boyatzis, 1982). For some jobs, it is clearly possible to measure performance because performance measures and goals are available such as output per month. There are jobs that performance measures are not easily accessible such as R&D managers. It is suitable to measure their performance by assessing whether they follow certain processes or not. The interpersonal sensitivity competency, cross-cultural positive regards, and management skills can differentiate high performers from average performers (McClelland, 1973). Competencies for particular jobs have been identified for effective performance such as laboratory leaders (Albetkova et al., 2019), human resource professionals (Mansfield, 1996), and clinical research staff (Gowie et al., 2020). Literature review informed that competencies for particular jobs are identified concerning job responsibilities and requirements (Fotis & Gregoris, 2006). The competencies of managers are usually identified based on their tasks and behaviors (Alvarenga Jeferson et al., 2019; Asumeng, 2014). In the case of global R&D team leaders, for instance, Thamhain (2003) argued that leaders of global R&D teams need sophisticated people skills to make sure of effective transfer of technology; his method concerned environment of the workplace, leadership and performance of the teams of high-technology product or service developments. However, there is no study to identify the competencies of managers who facilitate research collaboration concerning their difficulties in global R&D projects. In addition, there is a long list of competencies for managers to choose from, but it is impractical and difficult for managers to develop all competencies. Therefore, the relationship between manager competencies and global R&D project difficulties needs to be clarified to highlight crucial competencies that correspond to the right difficulty. The three research gaps are summarized and depicted in Figure 1.3.

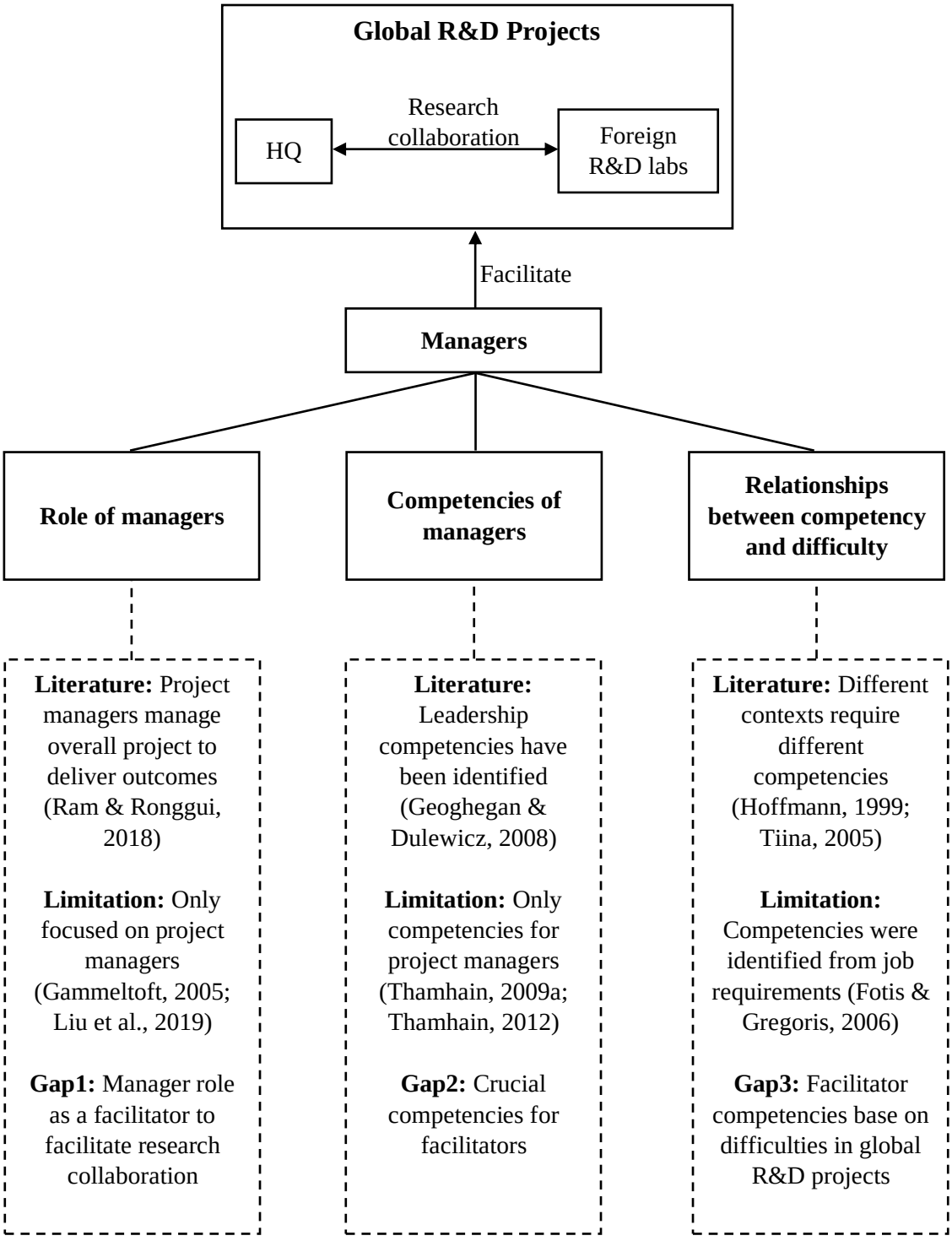


Figure 1.3: Research gaps

1.3 Research objectives

Base on the higher demand on global R&D projects to deliver competitive innovative outcomes, the managers in charge of research collaboration between teams in different countries need to possess competencies that help to improve collaboration and overcome difficulties in global R&D projects. This dissertation aims to identify crucial competencies of the managers by considering the difficulties they face when facilitating global R&D projects. This aim could be achieved by fulfilling three overarching objectives as follows.

1) To identify global R&D project difficulties that the managers face when facilitating research collaboration between teams in different countries

2) To identify crucial competencies of managers for facilitating research collaboration in global R&D projects

3) To examine the relationships between global R&D project difficulties and manager's competencies for facilitating global R&D projects

1.4 Research questions

To accomplish objectives of the research, this dissertation attempts to address research questions including a major research question (MRQ) and three subsidiary research questions (SRQs) as shown in Figure 1.4. In order to improve collaboration in global R&D projects, manager's competencies are indispensable. Through a review of the existing research, the following research questions have been informed by literature and will be investigated:

MRQ: How are the difficulties and competencies of managers in global R&D projects related?

SRQ1: What are the difficulties faced by managers when they facilitate research collaboration between teams in different countries of global R&D projects?

SRQ2: What are the crucial manager's competencies for facilitating global R&D projects?

SRQ3: How the managers possess the competencies to solve difficulties in global R&D projects?

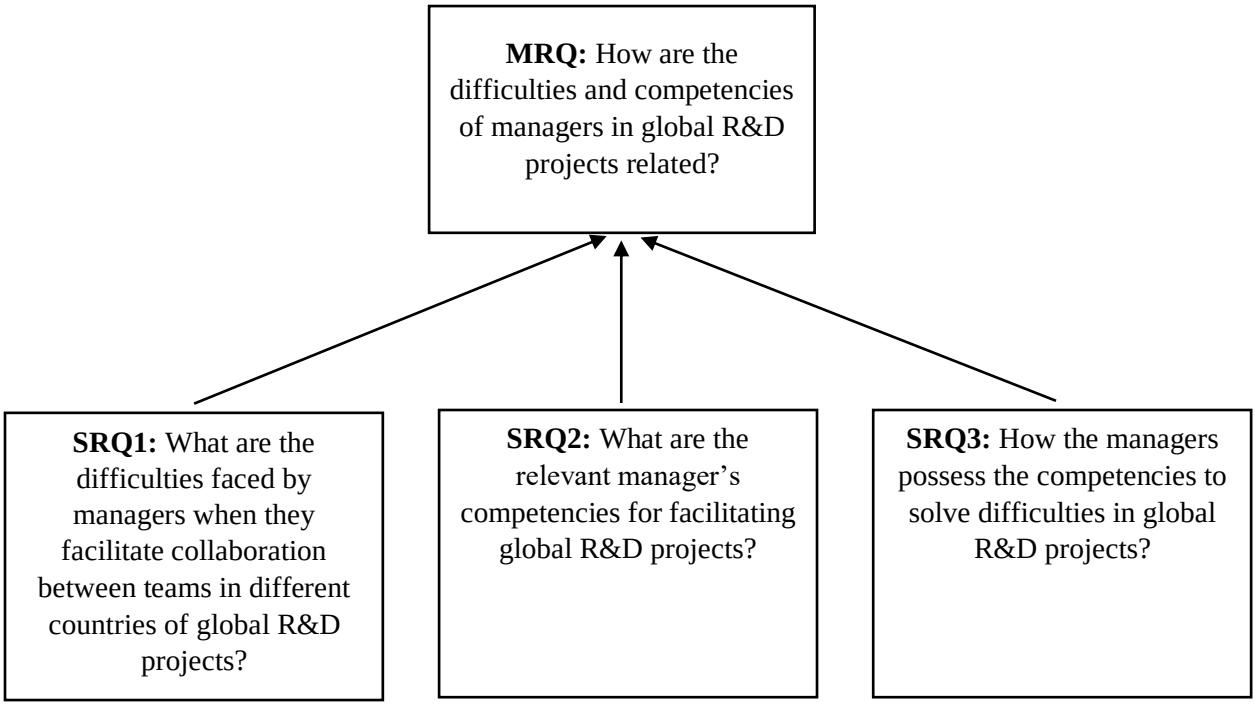


Figure 1.4: Research questions

1.5 Dissertation structure

This dissertation aims to improve global R&D projects by identifying crucial competencies of managers who facilitate research collaboration in the projects. It is presented in this dissertation which consists of six chapters. This chapter, Chapter 1 introduces the research by explaining the research background, research problem, and research objectives. Chapter 2, theoretical backgrounds, provides information on relevant literature. Chapter 3, research methodology, shows the overall research design of the two subsidiary studies. Chapter 4, subsidiary study 1 is about difficulties in global R&D projects. Chapter 5, subsidiary study 2 is about the competencies of managers. Lastly, Chapter 6, conclusion, implication, and limitations.

Chapter 1: Introduction

This chapter presents to the readers with research background overview, research gaps, research objectives, and research questions. A brief research design and dissertation structure are also included.

Chapter 2: Literature review

In this chapter the researcher studies existing literature and reviews what the other researchers have found about international R&D, cross-cultural collaboration, knowledge transfer, human resource management, and competency concept. The existing literature is summarized and analyzed to inform literature gaps and provide a foundation for this research.

Chapter 3: Research methodology

This chapter shows the procedure of how the research was carried out, the research design, data collection method, and data analysis process. This dissertation includes two subsidiary studies whose results were integrated. The sampling process and the measurement of the quantitative study were also explained in this chapter.

Chapter 4: Difficulties in facilitating global R&D projects

One of the subsidiary studies was explained in this chapter. It is a qualitative study using the semi-structured interview as a data collection method. This chapter explains the interview questions and the analysis of interview data. The results showed four common difficulties the managers faced when they facilitate global R&D projects.

Chapter 5: Competencies of R&D bridge managers

Another subsidiary study was explained. It is a quantitative study including a questionnaire survey as a data collection method and using relevance ratio and qualitative comparative analysis to examine the relationships between the competencies of managers and the difficulties in global R&D projects. Crucial manager's competencies were identified.

Chapter 6: Conclusion, implications, and limitations

In this chapter, findings are summarized and discussed in relation to the existing literature to highlight the key contributions of this dissertation. The theoretical contributions and practical implications are indicated. Several limitations of this dissertation are indicated along with possible future research directions to address those limitations and further exploration into the topic. Finally, the relevant recommendations are presented for practitioners and organizations.

Chapter 2 Theoretical background

This chapter reviews relevant literature, important concepts, and terminologies used in this dissertation. It is separated into several subsections, including introduction, research and development, open innovation, international R&D management, cross-cultural collaboration, knowledge transfer, human resource in global projects, competency, and summary which includes literature analysis. A broad general theme of this dissertation is R&D management. The literature review highlights the increasing importance of global R&D projects along with the more pressing challenges for the companies to effectively operate international R&D operations. International R&D involves the operations of R&D laboratories in different countries. It strengthens the company's R&D capability and gains a competitive advantage.

In this chapter, R&D management is presented first and then follows by the concepts of open innovation which accelerates the R&D process, international R&D management which broadens R&D boundary, cross-cultural collaboration as a mechanism for effective collaboration, knowledge transfer which is highly important in the R&D context, global project human resources who play important roles, and competency which is the main concept for investigation in this dissertation. International R&D management is the management of R&D activities in laboratories located in different countries (De Meyer & Mizushima, 1989). However, there are many constraints that hinder the full potential of global R&D resources. Lastly, the significance of competency is described in the context of global R&D projects, specifically, the competency of managers.

2.1 Research and development

Since the industrial revolution in 1760, the manufacturing processes have changed dramatically. The production line using human power was changed to machines and other tools. The machines and steam engines have been widely used which extremely helped to improve the efficiency and productivity of the industry. That was an important time in history when people's life had changed like never been before.

Later, research and development (R&D) has been introduced for the industry competitiveness and plays a vital role since then. The R&D can be different from institute to institute. Accordingly, the industry R&D is described in this section. Research is an activity to identify ideas exemplary for more study, look into what is known, put forward what is unknown, and try out the assumption using experiments to manifest the theories; development is an activity of using and advancing an idea until it turns to be a practicable outcomes (Wingate, 2015). According to OECD (1981), R&D is an inventive work based on a well-organized procedure to enlarge body of knowledge, which includes human knowledge, cultural and societal aspects, and knowledge utilization to come up with new applications. There are three activities in R&D which are summarized in Table 2.1.

	Definition
Basic research	"Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view."[a]
Applied research	"An original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective."[a]
Experimental development	"Systematic work, drawing on existing knowledge gained from research and practical experience, that is directed to producing new materials, products, and devices; to install new processes, systems and services; or to improve substantially those already produced or installed."[a]

[a]OECD (1981, p. 13)

Table 2.1: Three activities of R&D

Having R&D in the industry provides advanced knowledge and product development which is a strategic advantage over the competitors. Therefore, R&D is important for the industry. First, R&D helps the industry to have a long-term strategy and to maintain competitiveness. Second, R&D leads industry toward the innovation which is indispensable for today's business. R&D and the innovation process have a close relationship with the initial step to discover new insight which is useful for the industry. Chesbrough (2003) introduced more theoretical information about a new paradigm for the advancement of traditional R&D and innovation, which is called "Open Innovation".

2.2 Open innovation

Traditionally, research projects of a company are conducted to satisfy the company's goals, by the company's researchers, and using the company's internal knowledge. Open innovation was defined as the usage of incoming and outgoing knowledge to increase speed of innovation inside the company, and enlarge markets for innovation outside the company (Chesbrough et al., 2006). In open innovation, the company uses both internal and external knowledge to improve the innovation of the company, internally. In addition, open innovation also expands the markets and promotes the external use of innovation. The ideas inside the company can be transferred to the market via external channels. R&D would be an open system in the open innovation paradigm. The useful ideas are from both inside and outside of the company.

Chesbrough et al. (2006) explained that the innovation paradigm was changed from a closed to open model. This open innovation concept has a great contribution to the globalization era and shows the potential of R&D function to be outsourced which is similar to the outsourcing of manufacturing function many years ago. The following figures illustrate the two different paradigms, "closed innovation model" (Figure 2.1) and "open innovation model" (Figure 2.2).

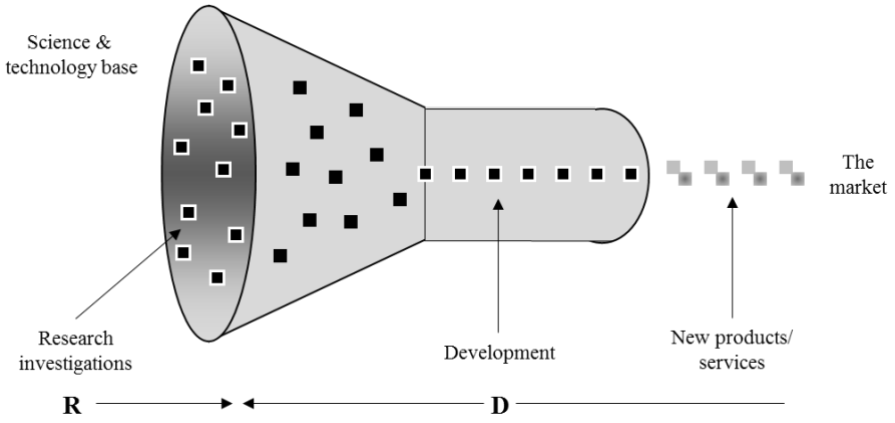


Figure 2.1: Closed innovation model (Chesbrough et al., 2006)

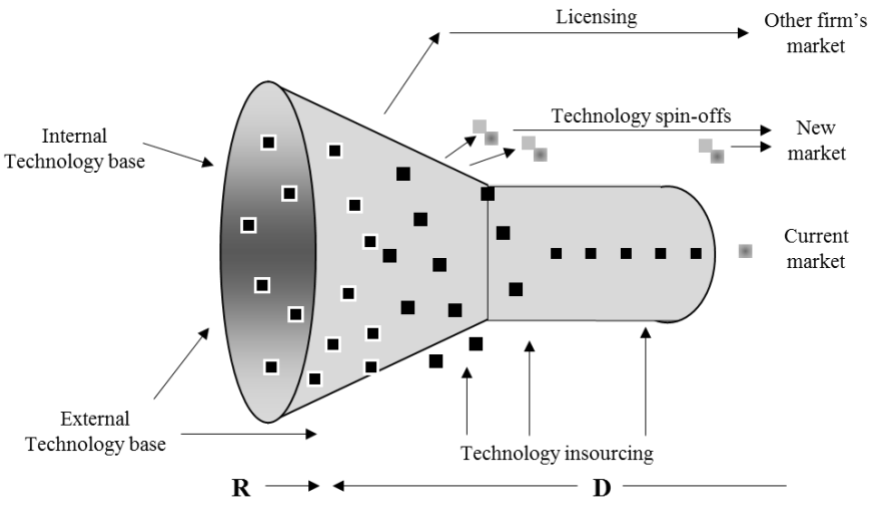


Figure 2.2: Open innovation model (Chesbrough et al., 2006)

Open innovation has eight different points compared to the traditional innovation approach, closed innovation. According to the literature, each different point is explained as follows (Chesbrough et al., 2006).

1) External knowledge and internal knowledge are equally important.

2) Novel outputs are not limited to present business models but can go into markets in several ways.

3) Type I and type II errors when evaluating R&D projects within the firm.

4) The purpose of knowledge outbound flow, the technology can find ways to go to the market externally. These channels need to be managed properly.

5) The underlying knowledge landscape, important knowledge should be widely distributed with high quality.

6) The provident role of intellectual property management. The intellectual property could be cross-licensed and becomes a critical element of innovation.

7) The innovation intermediary advancement because the innovation process changes to be more open. Other parties can transact at any stage during the innovation process.

8) The new measurement systems to assess firm's innovation capability and firm performance.

Since open innovation was introduced, it has influenced the R&D management in organizations. The companies apply this meaningful concept to their own business and gain better competitiveness. However, because of the dynamic of the markets and social construct, several challenges of open innovation in R&D activity have changed and need to be handled properly. Gassmann and Enkel (2004) argued that the solid boundaries of companies transformed into a semi-permeable membrane which means innovation can easily move between the environment inside and outside of the innovation process of the company; three core innovation processes were identified as shown in Figure 2.3. Gassmann et al. (2010) identified research trends of open innovation such as penetration of industry, intensity of R&D, open innovation processes, and open innovation context, for further investigation on the topic. Many companies are moving to the open innovation mode by acquiring knowledge from knowledge hubs around the world, and internationalizing their R&D operations around the world (Patra & Krishna, 2015).

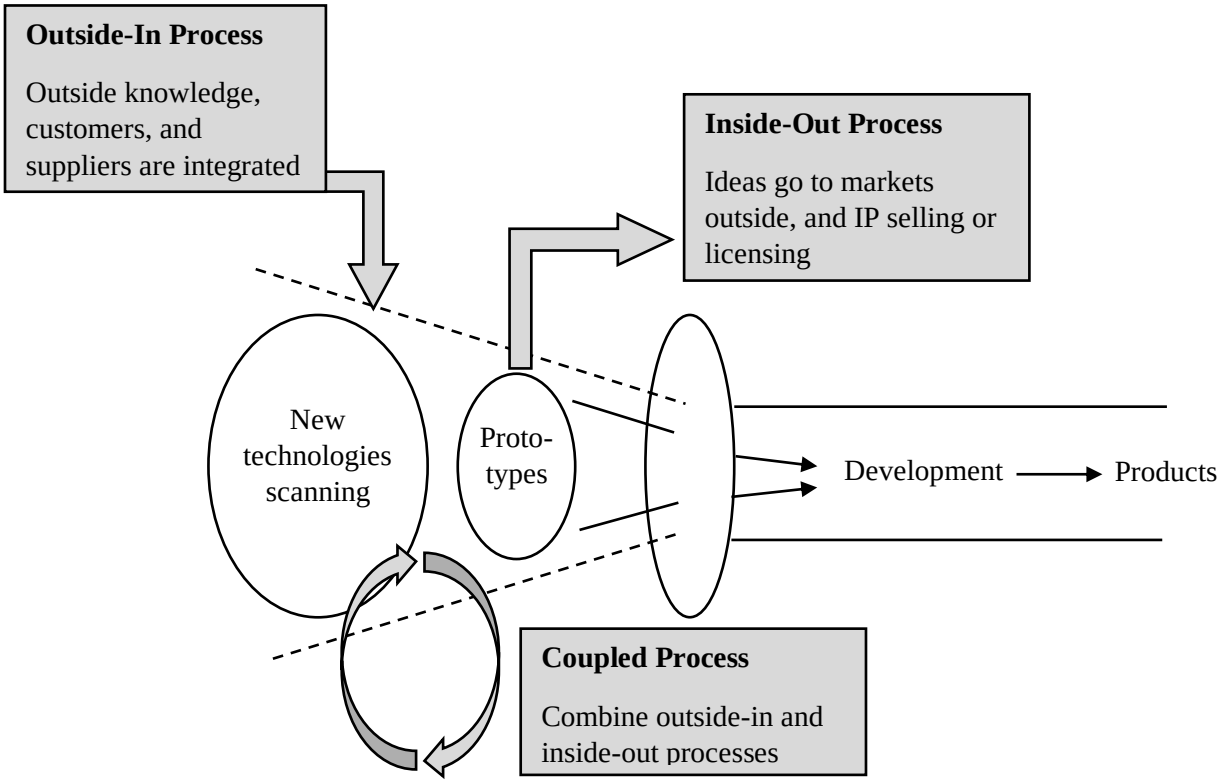


Figure 2.3: Three archetypes of open innovation processes (Gassmann & Enkel, 2004)

2.3 International R&D management

It is getting more competitive when doing business in global markets where competitors are not only from the domestic markets but also from the international markets, firms need to get into the market as quickly as possible with quality products or services. Agile innovation accelerates and transforms the process of moving from ideas to prototypes (Morris et al., 2014) as the time to market is important for global R&D projects. However, implementing agile in the project might be very challenging because this requires frequent changes from all parties involved. In addition, a global innovation landscape has shifted to India and China as emerging economies where there are more investments on R&D from multinational companies (MNCs) (Li & Kozhikode, 2009). Li and Kozhikode (2009) discussed the challenges of MNCs in this innovation landscape where firms may face delicate intellectual property rights, reckless knowledge spillovers to local firms, and the creation of potential competitors. International R&D management research becomes more important as the open innovation broaden boundary across countries, increases the speed of R&D processes, and open new innovation landscape. New management approaches for international R&D management become more relevant.

R&D has changed rapidly in the globalization era. Several years ago, R&D has changed from a supporting role to a critical strategy of the company's R&D networks. It becomes more on a global scale in which firms establish international R&D cooperation. Although there are advantages, global R&D brings more challenges as well. Organizational-level approaches to overcome challenges were introduced. For example, identification of phases to initiate R&D sites abroad and information flow between headquarters and R&D sites (Kuemmerle, 1997), management of virtual R&D teams (Gassmann & von Zedtwitz, 2003), and the knowledge flow and R&D activities in a multinational company (MNC) (Kurokawa et al., 2007).

R&D plays important role in helping the company to promote technology adoption and to support innovation (Griffith, 2000). In the past few decades, team members worked for one single organization and all of them were in the same location (Binder, 2007). Thereafter, internationalization has changed the structure and process of the workplace environment. The objective of internationalization of business is to look for additional markets, cheap labor, product localization, and fully R&D development (Boutellier et al., 2008). Gammeltoft (2005) conducted literature review on the R&D internationalization and argued that the managerial ability has become more important to manage and coordinate dispersed R&D units.

2.3.1 Typology of international R&D

The globalization of R&D projects comes with challenges that organizations need to overcome. Scholars explored international R&D in different perspectives that suggest future research directions on this topic. For example, identification of factors that influence R&D structure (Chiesa, 1996), identification of phases to initiate R&D sites and information flow between headquarter and R&D sites (Kuemmerle, 1997), coordination patterns of foreign R&D teams (Reger, 1999), virtual R&D team management (von Zedtwitz et al., 2004), and the knowledge flow and R&D activities in a multinational company (MNC) (Kurokawa et al., 2007). Gassmann and von Zedtwitz (2003) classified four types of virtual R&D team organization as shown in Table 2.2 and Figure 2.4.

Types of virtual R&D team organization	**Characteristics**
Decentralized self-coordination	No strong central management and authority. This type of virtual R&D team is suitable for producing highly independent products. Those products have a standard interface between the products and the whole product system. Moreover, the standard interface should be well known by other R&D sites.
System integrator as coordinator	A kind of coordinator who facilitates the R&D activities. This type of virtual R&D team eliminates the interface problem in the decentralized team. The coordinator facilitates and supports cooperation among different R&D sites.
Core team as system architect	The core team works together closely. In the case that team members from all teams cannot work together in the same location, then the core team is established. The core team including team leaders from several decentralized teams.
Centralized venture team	the center responsible only for the strategic and very important decision-making for both technical and business perspectives. The venture should be in the same location, having a strong relationship among team members to achieve team objectives effectively.

Table 2.2: Four types of virtual R&D team organization (Gassmann & von Zedtwitz, 2003)

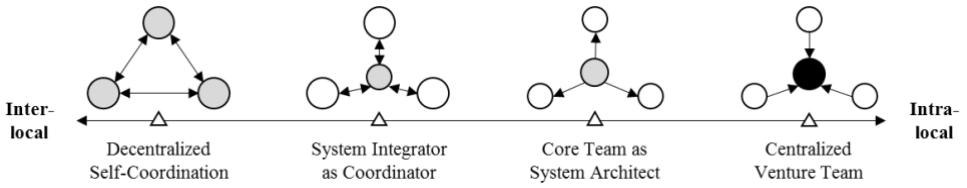


Figure 2.4: Four types of virtual project organization (Gassmann & von Zedtwitz, 2003)

Nobel and Birkinshaw (1998) examined communication patterns and international R&D project control, and then categorized foreign R&D units into three types, including local adaptor, international adaptor, international creator as shown in Table 2.3. They found that each type can be managed using different modes of control. Although managing global R&D projects is always difficult, requires the integration of many activities, supports organizations, partners and stakeholders, many companies go global by operating global R&D projects (Thamhain & Asgary, 2013).

Foreign R&D unit types	**Description**
Local adaptor	The existing technology will be utilized for supporting local production. The local adaptor helps to transfer technology from headquarter to subsidiaries in a foreign country to introduce a new product into the local market. However, this type of R&D unit becomes rare because the foreign subsidiaries improve their technological innovation and expand the scope to international.
International adaptor	This unit is focusing on new product development for international markets. Because of globalization, the support laboratories have a responsibility toward regional or global. Moreover, the local laboratory could provide technological enhancement for the firms, which mean subsidiary can have a leading role in product innovation.
International creator	The important characteristic of this unit type is not only providing improvement and adaptation but also research and development. This unit could be a leader in a specific area, located with a particular market. It is expected to have more linkages to other R&D units and some business units as well.

Table 2.3: Three types of foreign R&D unit (Nobel & Birkinshaw, 1998)

2.4 Cross-cultural collaboration

The dramatic changes in economics, politics, and technology alter the way business is managed. What happens with business in one part of the world can influence the business in another part of the world which far away geographically. One of the most important and difficult topics in international business management is culture. It can be seen in all aspects of international business.

2.4.1 Cultural dimensions

Culture has been defined as mutual reasoning process that distinguishes the members of one group of people from other groups (Hofstede, 2011). Culture plays a significant role to influence our way of feeling, thinking, and acting. People experience culture in their family, community, and organization. Hofstede and Hofstede (2005) classified cultural dimensions to explain cultural differences between nations. These dimensions help us to understand why people from different countries may have conflicts or misunderstandings. A description of the five dimensions is summarized in Table 2.4.

Cultural dimension	**Description**
Power Distance	It is the different levels of power distributed in the organization structure. Large power distance group prone to agree to more hierarchical structures. For the small power distance people, they look for the equality of power.
Collectivism vs. Individualism	Individualism relates to societies with weak relationship between people. People should take care of themself and their immediate family. Collectivism relates to societies with people having strong bond, which throughout their life continue to take care of them in exchange for loyalty.
Femininity vs. Masculinity	It is the different approaches toward preferences. Masculinity pays attention to achievement and material success. On the other hand, femininity focuses on bonds and quality of life.
Uncertainty Avoidance	It is the uncomfortable feeling of uncertainty. Strong uncertainty avoidance people tend to keep maintaining their

	beliefs and behavior and contrast with weak uncertainty avoidance people who are more flexible.
Long- vs. Short-Term Orientation	Long-term orientation is the promoting of morality of future rewards, persistence, and providence. Short-term orientation is the promoting of morality to the past and present, tradition respect, "face" preservation, and satisfying social obligations.

Table 2.4: Cultural dimensions (Hofstede & Hofstede, 2005)

The four dimensions provide a framework for considering the cultural difference effects on organization management. This framework elaborates the differences between cultures base on those mentioned values. For example, North America and Europe are more individualistic while Asia, Africa, and Latin America are collectivist. This could cause conflicts or misunderstandings in collaboration between people who are from different countries.

The cross-cultural-related issue can be managed at different levels, including individual, team, and organizational levels. In multinational corporations, strategies for cultural diversity are required so that employees from different nations can work together smoothly. Global managers are desired to possess competencies to cope with business challenges and the global manager competency becomes an important issue (Wu & Lee, 2007). Traditionally, international managers refer to experienced expatriate managers who have rich experience working in several countries. However, with the expansion of international business, international managers are collecting more global mindsets when they are managing the projects. They are not only working in different physical locations but also managing across cultural boundaries.

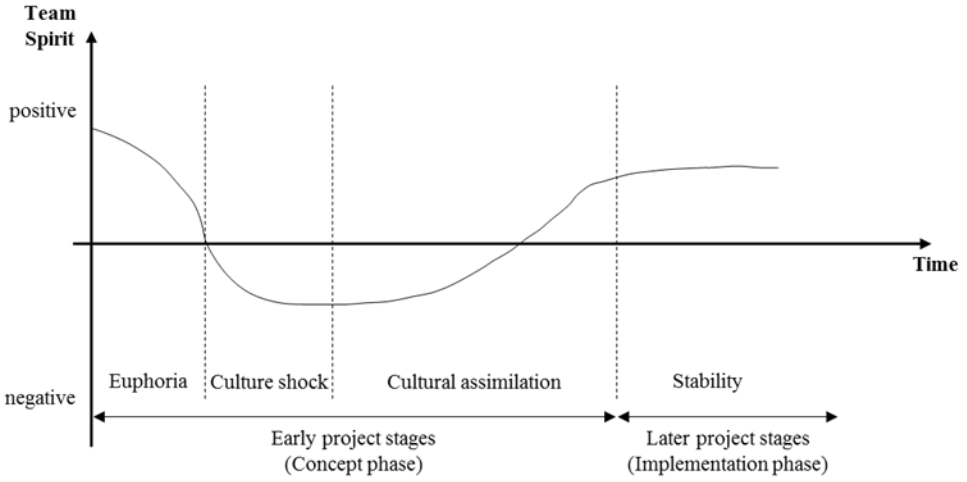


Figure 2.5: Project leaders manage culture shock at an early stage (Boutellier et al., 2008)

It is important for managers to keep in mind that the cultural difference should be managed as early as possible after starting the project, or early project stages as shown in Figure 2.5. Building trust among project members is important for the team. Several techniques such as intercultural training or seminar can be implemented to improve team spirit (Boutellier et al., 2008). Team leaders need to find ways to enhance and maintain team morale level. Thus, the high level of team morale would turn out to be a positive driving force for innovation.

2.4.2 Multicultural team

Once the organization operates internationally, there are teams with members from diverse cultural backgrounds. Multicultural team is a team having members from diverse cultures performing tasks together on activities that cross national boundaries (Lisak & Erez, 2015). The differences among team members could create serious obstacles. Managers are under pressure when having members from different nations, different backgrounds, and have conflict. Brett et al. (2006) classified four categories of challenges when managing multicultural teams as shown in Table 2.5.

Challenges	**Description**
Direct and indirect communication	In Western cultures, communication is direct and explicit. The meaning is obvious, the listeners do not have to understand much about the context, or the speakers interpret it. For other cultures, meaning is attached to how messages are conveyed. This challenge creates hurdles for teamwork effectiveness by turning down information sharing and/or creating interpersonal conflict.
Trouble with accents and fluency	Although English is a language of international business, misunderstandings may occur because of the accents of non-native speakers, fluency of speaking, or translation or usage problems. Team members who are non-fluent may be the most expert on the team, but problem in communication to transfer knowledge makes it difficult for the team to understand their expertise.

Different attitudes about hierarchy and authority	Typically, multicultural teams have flat structure. Team members from some cultures are uncomfortable on flat teams because in their cultures people are treated differently based on their status in an organization.
Conflicting norms for decision making	Cultures greatly varies in decision-making, especially, how fast the decisions should be made and how much analysis is needed beforehand.

Table 2.5: Challenges in managing multicultural teams (Brett et al., 2006)

2.4.3 Culture in international management research

The increasing interconnected economies and organizations influence organization management such as downsizing and team-based management. The business situation in one country may have impacts on the change of business in another country more easily. For example, a company has to layoffs some employees due to the cheaper labor in other countries. Another example is mergers and acquisitions to remain competitive. According to Thomas and Peterson (2015), international management research can be carried out in several forms for different purposes and characteristics. There are six different types of study as shown in Table 2.6. Culture in international management influences how managers should perform in their work. Dealing with cultural differences is one of the challenging tasks for international managers.

Category	**Description**	**Cultural Assumptions**	**Research Questions**
Domestic	Single country	Not consider culture or assume a universal theory	"How can we explain and predict the behavior of people in organizations?"[a]
Replication	Repeated in another country	Question to universality	"Does the theory that applies in culture A also apply in culture B?"[a]
Indigenous	Individual studies executed in one or many cultures	Explain behavior is explained by an indigenous theory	"How can we explain and predict the behavior of people in organizations in country X?"[a]
Comparative	Conducted in two or more countries	May or may not be a theory for the effect of culture	"What similarities and differences exist in the behavior of people in

			organizations? Is this theory universal?"[a]
International	Multinational organizations	Culture is ignored	"How do organizations that operate in multiple countries function?"[a]
Intercultural	Intercultural interactions in organizations	Having specific aspects of culture	"How this theory is influenced by cultural differences, and how is it universal?"[a]

[a]Thomas and Peterson (2015)

Table 2.6: Six types of cross-cultural management research

2.5 Knowledge transfer

The corporate asset has been changed from tangible assets to intangible assets such as information and knowledge (Dunning, 2002). Knowledge becomes an important resource for organizations (Grant, 1996). This kind of intellectual capital is not easy for organizations to manage. In many cases, knowledge management in the organization plays an important role and it is included in the organization management discipline (Nonaka & Takeuchi, 1995). In order to create and maintain knowledge in organizations, knowledge transfer techniques are used. Scholars proposed knowledge transfer models and tools (Hislop et al., 2018; Uchihira, 2014; Uchihira et al., 2012). In global R&D projects, companies utilize global knowledge resources as Uchihira et al. (2016) classified global knowledge resources into three categories, including 1) global knowledge resources (technologies and human resources) are globally acquired, 2) global manufacturing resources for making products and services are globally utilized, and 3) global deployment resources to deploy products and services into a global market.

2.5.1 Information stickiness

Information and problem-solving capability are two important factors to solve problems. Information itself is not easy to acquire and use, especially, when applying them to different locations from origin. "Sticky" is coined by Von Hippel (1994) and this term influences problem-solving of innovation-related. The "sticky information" is the information that is used for solving technical problem; it is costly to obtain, relocate, and utilize in new locations (Von Hippel, 1994). The stickiness of information is the increasing cost required

to relocate information to new locations and use by information seekers. There are three reasons why information is sticky, including the nature of the information, the amount of information, and the attributes of seekers and providers. The nature of information deals with differences between tacit and explicit information. Polanyi (2015) explained that human skills and expertise are often tacit, which can be perceived by observation. It can be transferred by showing an example from master to novice.

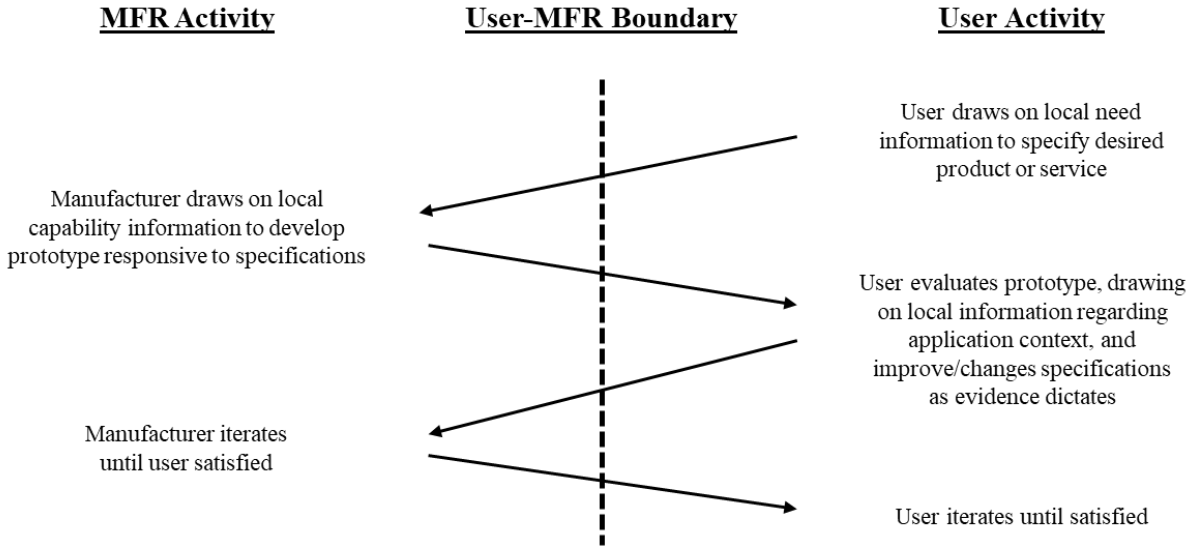


Figure 2.6: Iterative problem-solving pattern in new product and service development (Von Hippel, 1994)

For the innovation-related problem-solving activity of the user and manufacturer (MFR) (Figure 2.6) that needs access to multiple locations of sticky information, there are partitioned tasks. Each task uses only one location of sticky information. In the case of the high cost to transfer sticky information, efforts are needed to reduce the information stickiness which is held at some locations. Tacit knowledge, experience, and technical expertise are converted into explicit forms, which are easier to transfer.

2.5.2 Barrier of knowledge transfer

Szulanski (1996) analyzed the knowledge transfer stickiness within the organization and found important barriers of internal knowledge transfer which are factors related to knowledge such as the absorptive capacity of the recipients, ambiguity of causes, and sources and recipients of knowledge relationship. Transfer of best practice is considered one of the important issues in business management. The

performance of different units within the firm indicated that knowledge utilization needs to be improved. Practices that are transferred within a firm have unambiguous meaning for practitioners. Practice means the routine usage of knowledge by organizations, including a tacit component, embedding in individual skills, and collaborating with social argument. The transfer is to show the movement of knowledge in the organization. Thus, the transfer of best practice is a dynamic exchange of knowledge between source and recipient units in the organization.

There is a cost of knowledge transfer according to the concept of sticky information (Von Hippel, 1994). The difficulty of knowledge transfer could reflect as the cost of transferring information. Szulanski (1996) investigated the origins of internal stickiness and summarized four groups of factors that influence the knowledge transfer difficulty as shown in Table 2.7.

Characteristics of the knowledge transferred	**Description**
Causal ambiguity	It happens because the factors of production and the interaction among them during production are not clear. There is an undefinable part of knowledge that is embodied in tacit human skills (Polanyi, 1962). The unclear understanding of the feature in a new context where the knowledge is used could cause causal ambiguity as well.
Unprovenness	The knowledge without a proven record makes it problematic to induce the perspective recipients to participate in the transfer. The proven record is helpful when selecting knowledge to be transferred.
Characteristics of the source of knowledge	
Lack of motivation	Knowledge sources may not want to distribute important knowledge because they think they will lose possession, advantage, or superiority.
Not perceived as reliable	The sources should be reliable so that they can influence the behavior of the recipient. It is difficult to initiate the transfer from unreliable sources and the knowledge transferred from that source could be challenged and resisted.

Characteristics of the recipient of knowledge	
Lack of motivation	The “not invent here syndrome” makes the recipient reluctant to receive knowledge from outside. The recipient may reject the knowledge during the implementation.
Lack of absorptive capacity	Lacking the preexisting stock of knowledge may cause the recipient unable to assess and use new knowledge successfully.
Lack of retentive capacity	It is difficult to integrate the received knowledge if the recipient does not have the retentive capacity. The integration process cannot continue and then return to the previous status.
Characteristics of the context	
Barren organizational context	The organizational context may influence the transfer of best practices. Knowledge could be effective in one context but ineffective in another context. Previous studies show that structure and system formality, coordination and expertise sources, and attributes of behavior-framing of the organizational context influence amount of attempts to transfer knowledge and the outcomes.
Arduous relationship	Transferring tacit elements of knowledge may require many exchanges between individuals. The exchange success depends on the simplicity of communication and the closeness of the source unit and recipient unit relationship.

Table 2.7: Characteristics of the knowledge transferred (Szulanski, 1996)

2.5.3 Knowledge management, SECI model

According to Nonaka and Takeuchi (1995), knowledge has two types. The first one is called “explicit knowledge” which can be codified and transferred using media such as documents, processes, computer systems, etc. The second one is called “tacit knowledge”. This kind of knowledge is unable to codify, articulate, and not easy to transfer. The knowledge can be created and transferred as explains by SECI Model, which separates knowledge management into four different phases as shown in Figure 2.7. The whole process keeps cycling and accumulating new knowledge like a spiral.

1) Socialization

Tacit knowledge is exchanged between people through participation in social activities. The social gathering such as meeting, or brainstorming is important for team members in different R&D sites.

2) Externalization

Tacit knowledge is transformed into explicit knowledge by using symbols, analogies, or models. The project procedures and knowledge from all R&D sites can be shared during intensive communication.

3) Combination

Explicit knowledge from several sources is merged into a knowledge system. The combination of concepts, specifications formulate prototypes of R&D projects.

4) Internalization

Combined knowledge from the previous phase is internalized into individuals from explicit knowledge to tacit knowledge through learning-by-doing. The explicit knowledge in the form of documents and manuals becomes a part of project cultures which is tacit knowledge.

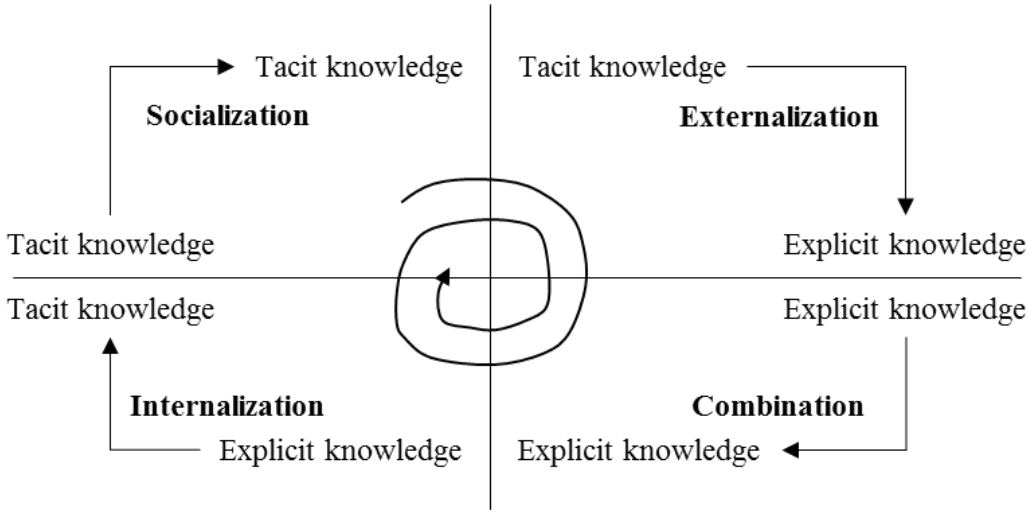


Figure 2.7: SECI Model (Nonaka & Takeuchi, 1995)

Boutellier et al. (2008) discussed knowledge management in global R&D projects. There are four perspectives to be considered. First, creating links between islands of knowledge. The collaboration among all stakeholders could drive the projects to gain more knowledge and innovation. Second, knowledge

creation and project management, sharing knowledge and information can promote new knowledge creation, especially, tacit knowledge (Nonaka & Takeuchi, 1995). Third, in managing cultural diversity, cultural diversity provides advantages for innovation even though it has some disadvantages such as language barriers and misunderstanding. The higher level of cultural diversity, the more challenges in global project management. Fourth, concepts in management are nearly impossible to transfer. The international R&D project managers have frequent business trips and lots of meetings with team members. Knowledge and practices to manage international R&D projects are embedded in the managers themselves.

2.6 Human resource in global projects

2.6.1 Expatriate manager

Expatriate management has received attention in the international human resource management field based on the fact that expatriates play an important role in the global operations of MNCs (Tahir, 2018). An expatriate manager was defined as a manager in a leadership position, involves international assignments, and relocates overseas (Harvey & Moeller, 2009; Pucik & Saba, 1998). Scholars have studied several relevant topics of expatriate managers, including selection criteria and process, training, significant skills, and performance (Forster, 2000; Graf, 2004; Lauring et al., 2019; Michael & Milorad, 2001). Expatriate managers involve in knowledge transfer between headquarters and subsidiaries.

Chang et al. (2012) argued that knowledge transfer competency of expatriate influences the performance of subsidiaries through the knowledge received by the subsidiaries. They found that three dimensions of expatriate competencies in knowledge transfer were all positively related to knowledge received by subsidiaries. The first dimension is the ability to transfer knowledge to a subsidiary such as the ability to solve transfer process difficulty. The second dimension is the motivation to transfer knowledge to a subsidiary such as the motivation to solve transfer process difficulty. The third dimension is the opportunity searching for knowledge transfer to a subsidiary such as searching and utilizing resources and opportunities through social ties to overcome difficulties in the transfer process. It is important for MNCs to employ expatriates who have competencies to overcome the knowledge transfer process difficulty, and thus subsidiary's performance can be improved.

Harvey and Moeller (2009) discussed problems associated with the human resource management process for expatriate managers. One of the problems concerned with expatriate manager selection which related to important traits of successful expatriates, including empathy, respect, local culture attentiveness, adaptability, toleration, technical skills, inventiveness, open-mindedness, sociability, and a positive self-

image. Which trait is more important, how to examine these traits, for which foreign environment are among the questions in the selection process. If the organizations cannot select expatriate managers appropriately, unsuccessful expatriate managers could suffer large direct cost such as training, relocation, and repatriation, and indirect/implicit costs such as reduced service to customers, and strained relations with home country networks. The organizations need a rigorous process for expatriate manager selection so they can assign managers to fit current global market demands.

2.6.2 Bridge system engineer

A bridge system engineer (BSE) is a kind of facilitator who moderates and improves client and service provider relationship in software development projects (Nguyen et al., 2014). In offshore outsourcing projects, cultural difference is one of the factors that slow down the knowledge transfer process. BSEs utilize their experience and knowledge to provide advice for service provider teams. As well as using communication skills to control information flow between two sides. Nguyen et al. (2014) investigated the roles of BSEs who enhance the relationship between clients and service providers, create values, improve collaboration, bridging knowledge gaps, and decreasing cultural differences. The four working stages of BSEs were identified.

1) Planning with client and offshore project

In this phase, BSEs work with both sides starting from listening to client team leaders about overview requirements. Then more detail of the project is provided by designers, programmers. BSEs also receive training for business domain knowledge for a deeper understanding of client business. Then, BSEs interact with offshore teams and project managers to explain the development process. At that time, BSEs estimate the mindset and attitude of offshore teams.

2) Breaking down requirements; design plan and transfer

BSEs use their skills, knowledge, and network they have to arrange knowledge and information before transferring them from client to offshore team. The objective of this step is to minimize gaps between the two sides. Some techniques are used such as developing charts or graphics of the requirements and development plan, using tools like video, images simulation, mind map and memo function in MS-Excel, as well as learning from books, group discussion with the client team, and using familiar examples with offshore teams.

3) Problem solving, review, fix, final quality assurance, and deliver the product

There are several steps in a software development project that BSEs get involve in, both client-side and offshore team side. For the client-side, BSEs help to design the requirement, review products, and evaluate product quality. For the offshore team side, BSEs help project managers to develop a plan and help the development team for reviewing bug fixing, and quality assurance. Those activities required a high level of technical skills, so it is difficult for BSEs, and they have to work together with the project manager. At the same time, BSEs need to maintain a good relationship with the client and the social network with client's groups is more important than other required skills.

4) After delivery: externalizing and sharing experience

After the project, BSEs accumulate knowledge, skills, know-how throughout the project and externalize them in the form of documents, manuals, guidelines for future use. Knowledge from the client-side such as business process and domain are created in the form of requirements. Knowledge from an offshore team, such as team capacity and limitations, is created in the form of reports for evaluation meetings.

Toyoda et al. (2007) proposed a training support tool for improving project management skills and problem-solving skills of bridge software-engineers. The tool is a web-based training system and consists of nine topics of common knowledge from the international project management standard, including project integration management, project scope management, project time management, project cost management, project quality management, project human resource management, project communication management, project risk management, project procurement management (PMBOK, 2004), and five integrated project management processes as shown in Figure 2.8.

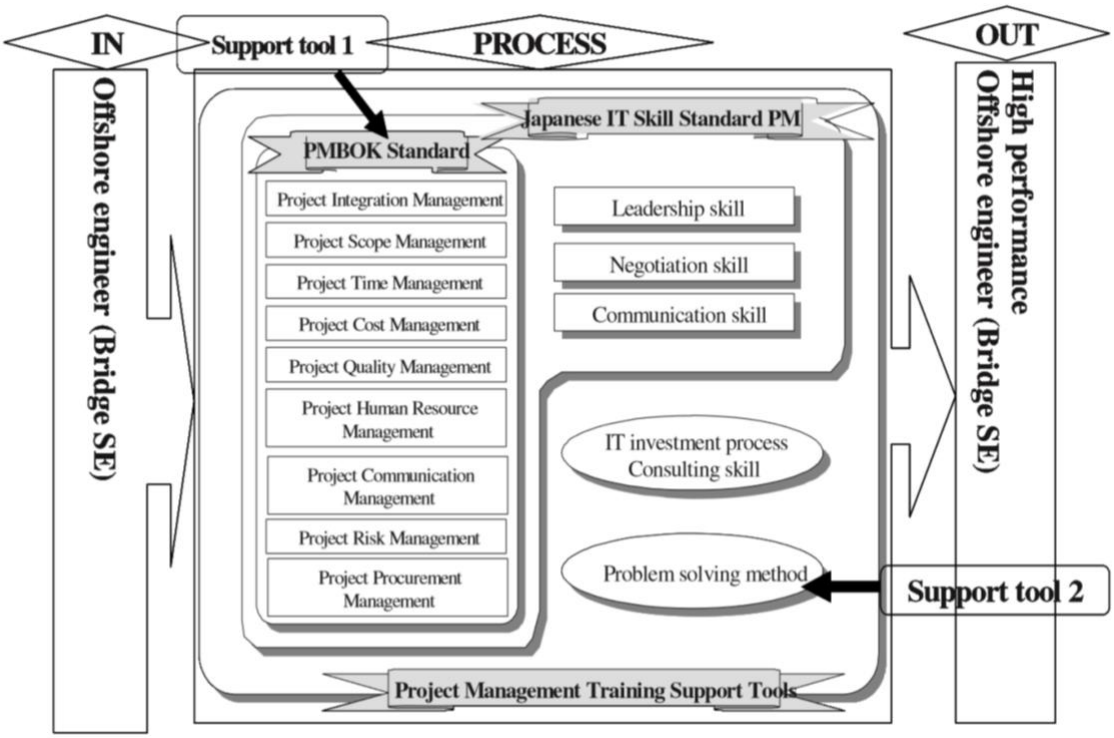


Figure 2.8: Project-management training support systems (Toyoda et al., 2007)

The results showed that a case study of using tools for project-management training-support for offshore development engineers is effective to increase project management knowledge of bridge software-engineers. It is useful for bridge software-engineers to gain more knowledge about the de facto standard of international project management in addition to their existing knowledge about project management for offshore software development. Attending lectures help bridge software-engineers to improve their understanding of problem-solving methods, analytical concept, and solution-action approach, but the problem-solving skills did not improve after using the training-support tools.

2.6.3 R&D bridge manager

Vrontis and Christofi (2019) reviewed the literature on R&D internationalization and found only two works explicitly involved individual-level analysis. One of them is the work of Choudhury (2017) who found that mobility within the firm using short-duration business trips between a distant R&D location and headquarters is positively related to following patenting at the individual level. Asakawa (2001a) introduced the broker's role as an influencer who participates in information transfer via a few liaison persons. The

broker's role helps foreign R&D subsidiaries to maintain semi-connected freedom status which is the optimal position of typical overseas laboratories, particularly conducting basic research, when they attempt to enhance information connectivity with headquarters and trying to maintain autonomy as much as possible (Asakawa, 2001a). Individual members make significant contributions in international R&D operations.

Collaboration between teams in different countries requires intensive facilitation. Uchihira et al. (2017) characterized the roles of BMs by comparison between BSEs and BMs. BMs work in global R&D projects for the purpose to develop high-quality R&D results efficiently and rapidly that contribute to the home organization R&D. They receive high-level R&D requirements as their input for the projects and then deliver outputs as technologies to solve the given R&D requirements. BMs also plays several roles in global R&D projects, including requirement decomposition, requirement assignment to R&D project members of local organization, and result evaluation. Especially, they clarify gaps in communication between the home organization and the local organization about the R&D result quality.

2.7 Competency

The concept of competence has been receiving attention from both academics and industry for decades and was accelerated during the industrial revolution to study the work and skills required to do the jobs effectively. Horton (2000) introduced the competency movement where the Roosevelt administration in the USA identified knowledge and skills for different occupations, trying to set skills standards. They also explored successful managers, and distinguished their attributes and features (Horton, 2000). Boyatzis (1982) concluded that there are factors that differentiate between successful and less successful managers and described competency as characteristics of an individual that is related to effective or superior performance in a job.

The meaning of competency has been evolving and still has no widely accepted single definition (Hoffmann, 1999; Jubb & Robotham, 1997; Strebler, 1997). After the influential work of McClelland (1973), the concept is used extensively. Scholars proposed definitions of competence and competency, and the terms are used interchangeably. In Oxford English Dictionary, competence is having the qualifications required by law to do some particular works (Davies & Ellison, 1997). A very broad definition is that the performance components which associated with life outcomes (McClelland, 1973). Athey and Orth (1999) defined competency as dimensions of observable performance, including knowledge, skills, attitudes, behaviors, team process, and organizational capabilities, that related to high performance and provide a

sustainable competitive advantage to organizations. Hoffmann (1999) discussed the development of competency definition and found one common factor among many studies; it was to improve human performance at work. The competencies predict effectiveness in managerial performance in organizations (Asumeng, 2014; Boyatzis & Boyatzis, 2008).

The development of the term competency definition is still in progress. The general purpose is to improve the performance of individuals when performing particular tasks in diverse contexts. In other words, competent individuals perform their tasks effectively by having particular characteristics, and possessing particular abilities and knowledge in different situations properly.

2.7.1 Leadership competency

The leadership theories have been developed by focusing on individual leaders and their traits concerning the context of leadership situations, observable behaviors, exchange of intellect, and interpersonal relationships (Müller & Turner, 2010). Dulewicz and Higgs (2005) conducted an extensive review of existing leadership theories and identified 15 leadership competencies under three dimensions, including intellectual dimensions (IQ), managerial dimensions (MQ), and emotional dimensions (EQ) as shown in Table 2.8.

Intellectual dimensions (DQ)	**Definition**
Critical analysis and judgment	"A critical faculty that probes the facts, identifies advantages and disadvantages, and discerns the shortcomings of ideas and proposals. Makes sound judgments and decisions based on reasonable assumptions and factual information, aware of the impact of any assumptions made."[a]
Vision and imagination	"Imaginative and innovative in all aspects of one's work. Establishes sound priorities for future work. Clear vision of the future direction of the organization to meet business imperatives. Foresees the impact of changes on one's vision that reflects implementation issues and business realities."[a]
Strategic perspective	"Sees the wider issues and broader implications. Explores a wide range of relationships, balances short- and long-term considerations. Sensitive to the impact of one's actions and decisions across the

	organization. Identifies opportunities and threats. Sensitive to stakeholders' needs and the implications of external factors on decisions and actions."[a]
Managerial dimensions (MQ)	
Resource management	"Plans ahead, organizes all resources, and coordinates them efficiently and effectively. Establishes clear objectives. Converts long-term goals into action plans. Monitors and evaluates staff's work regularly and effectively, gives sensitive honest feedback."[a]
Engaging communication	"A lively and enthusiastic communicator engages others and wins support. Clearly communicates instructions and vision to staff. Communications are tailored to the audience's interests and focused. Communication style inspires staff and audiences, conveys approachability and accessibility."[a]
Empowering	"Gives staff autonomy, encourages them to take on personally challenging demanding tasks. Encourages them to solve problems, produce innovative ideas and proposals and develop their vision and a broader vision. Encourages a critical faculty and a broad perspective, and encourages the challenging of existing practices, assumptions and policies."[a]
Developing	"Believes others have the potential to take on ever more demanding tasks and roles, encourages them to do so. Ensures direct reports have adequate support. Develops their competencies and invests time and effort in coaching them so they contribute effectively and develop themselves. Identifies new tasks and roles to develop others. Believes that critical feedback and challenges are important."[a]
Achieving	"Willing to make decisions involving significant risk to gain an advantage. Decisions are based on core business issues and their likely impact on success. Selects and exploits activities that result in the greatest benefits to the organization and its performance. Unwavering determination to achieve objectives and implement decisions."[a]

Emotional and social dimensions (EQ)	
Self-awareness	"Awareness of one's own feelings and the capability to recognize and manage these in a way that one feels that one can control. A degree of self-belief in one's capability to manage one's emotions and to control their impact in a work environment."[a]
Emotional resilience	"Performs consistently in a range of situations under pressure and adapts behavior appropriately. Balances the needs of the situation and task with the needs and concerns of the individuals involved. Retains focus on a course of action or need for results in the face of personal challenge or criticism."[a]
Intuitiveness	"Arrives at clear decisions and drives their implementation when presented with incomplete or ambiguous information using both rational and "emotional" or intuitive perceptions of key issues and implications."[a]
Interpersonal sensitivity	"Is aware of, and takes account of, the needs and perceptions of others in arriving at decisions and proposing solutions to problems and challenges. Builds from this awareness and achieves the commitment of others to decisions and action. A willingness to keep open one's thoughts on possible solutions to problems and to actively listen to, and reflect on, the reactions and inputs from others."[a]
Influence	"Persuades others to change views based on an understanding of their position and a recognition of the need to listen to this perspective and provide a rationale for change."[a]
Motivation	"Drive and energy to achieve clear results and make an impact. Balances short- and long-term goals with a capability to pursue demanding goals in the face of rejection or questioning."[a]
Conscientiousness	"Displays clear commitment to a course of action in the face of challenge and to match "words and deeds" in encouraging others to support the chosen direction. Shows personal commitment to pursuing an ethical solution to a difficult business issue or problem."[a]

[a]Dulewicz and Higgs (2005, p. 111)

Table 2.8: Leadership dimensions

Müller and Turner (2010) extended the work of Dulewicz and Higgs (2005) to identify different leadership competencies for different project types. They found that Project managers in most successful information and telecommunication technology projects are competent in all competencies, except vision, intellectual competence (Müller & Turner, 2010). Their findings have implications for practitioners when assigning project managers by considering their competencies to fit with different project types.

2.7.2 Project manager competency

There is a growing concern about the relationship between performance and managers' competencies (Cheng et al., 2005). Project managers can decide how successful the project will be by playing important roles, including setting tone and project environment, obtaining commitments from stakeholders and staff, recruiting team members, and helping organizations to understand the benefits of the project (Wingate, 2015). Geoghegan and Dulewicz (2008) used the leadership dimensions questionnaire (LDQ) developed by Dulewicz and Higgs (2004) with project managers (mainly IT-related job function) and found that project success has significant positive relationships with eight competencies, including critical analysis, self-awareness, sensitivity, influencing, motivation, manage resources, empowering, and developing.

Although many other factors contribute to project success, project managers play important roles to facilitate varied project success factors that ultimately contribute to the project performance. Anantatmula (2010) reviewed the literature on project management and developed a summary of seven significant project performance factors related to people as shown in Table 2.9.

People-related project performance factors	**Description**
Create clarity in communication	"Defining project goals and likely project outcomes clearly and early in the project is critical, and failure to do so would lead to identifying some of the project requirements at a later stage. This would cause changes to the project plan resulting in time and cost overruns."[a]
Define roles and responsibilities	"At the outset, defining the roles and responsibilities of project team members without ambiguity is imperative for improving performance and managing conflicts. This practice will lead to

	effective use of the project team members and help functional departments extend their support."[a]
Communicate expectations	"Defining project outcomes and establishing what is expected from all the stakeholders will eventually eliminate perceived and actual incidences of not delivering expected results. This is specifically true with stakeholders within and outside the project who are not routinely involved with projects."[a]
Employ consistent processes	"Developing and deploying consistent and formal project management processes assist in improving operational efficiency, managing risk, and reducing ambiguity. Ultimately, these processes would lead to project management maturity."[a]
Establish trust	"An environment of trust is influenced by the organizational culture which promotes transparency and openness in their communications. Trust among the project team members to work cohesively would lead to knowledge sharing and collaboration."[a]
Facilitate support	"Top management support translates into the willingness of everyone in the organization to support the project. Obtaining support is a challenge in traditional organizations where functional managers control resources."[a]
Manage outcomes	"Clearly defined project mission and objectives would help us develop a formal evaluation of project outcomes to determine project success. It promotes performance, motivation, recognition, and synergy in teams."[a]

[a]Anantatmula (2010, p. 16)

Table 2.9: People-related project performance factors

Projects are full of uncertainties and unknowns. Leadership is of great importance to deal with changes and make some efforts to convince project members about the need to change, guide them to new directions, and motivate people to work together effectively in a demanding work environment (Anantatmula, 2010). Project managers play leadership roles, possess the competencies to manage a diverse group of people in the project.

2.8 Summary

This chapter reviews and summarizes relevant literature, including R&D, open innovation, international R&D management, cross-cultural collaboration, knowledge transfer, human resources in global projects, and competency. The existing literature review informed literature gaps for this dissertation. In the past few decades, the industry has been focusing on the new product development process in order to make the process more effective. Innovation plays an important role in business competition to introduce new products or services to customers. Innovation requires multidisciplinary knowledge, which the traditional innovation process cannot serve. Open innovation suggests utilizing both internal ideas and knowledge and external ideas and knowledge for the benefit of new product development. The internal ideas can turn to be end products within the organization or they can go outside and turn to be end products in other organizations. On the other hand, the ideas from outside the organization can get into the organization and turn to be end products as well.

Companies implement open innovation concepts by seeking external knowledge from global resources. They establish subsidiaries in foreign countries to access larger markets and to exchange knowledge with local knowledge resources around the world. Scholars examine the global R&D management, previously, focused on the organization structure and coordination when the companies established new R&D sites abroad during the early days of R&D internationalization. There are challenges in managing global R&D projects. Scholars discussed global R&D projects from the organization management perspective (Asakawa, 2001b; Boutellier et al., 2008; Reger, 1999; von Zedtwitz et al., 2004). For example, ten challenges and six dilemmas in organizing global R&D were identified by von Zedtwitz et al. (2004). Nowadays, scholars pay closer attention to international R&D operations. However, there are limited studies focus on an individual level, how individual members contribute to the global R&D projects.

In global R&D projects, where intensive communication takes place, cross-cultural management plays an important role in project success because researchers and engineers have to collaborate closely to exchange their professional knowledge and innovative ideas. Communication could be done in several ways such as face-to-face meetings, teleconference, telephone calls, e-mail, etc. Information could be elaborated using text, voice, figure. However, the meanings of the messages cannot be clearly delivered once senders and receivers are from different cultures. Language difference is one of the barriers in cross-cultural

communication. In many cases, there are misunderstandings between people who could speak the same language but do not share the same culture (Haghirian, 2010).

It becomes more challenging when the knowledge must be transferred across different geographical locations and between people who are from different cultures. In global R&D projects, team members are not working in the same location. Kurokawa et al. (2007) mentioned three factors that affect the level of knowledge flow between headquarter and subsidiaries including, 1) trustful and democratic environment, 2) autonomous, and 3) network link. These factors influence the level of knowledge accumulation in a subsidiary and then influence the working performance. Uchihira et al. (2012) discussed the knowledge transfer in R&D project management and introduced a knowledge transfer model to overcome barriers using boundary objects and project case database. Scholars introduced roles of managers in multicultural teams such as influencers (Asakawa, 2001a), and knowledge brokers (Jang, 2017) to mitigate difficulties in the teams. However, in the case of global R&D teams, only a few studies focused on the roles to facilitate research collaboration between teams in different countries.

It is an increasing demand for project managers who in charge of global R&D projects. The more complex needs of customers also give more pressure to the companies to produce new products or services, and consequently, more pressure to the R&D teams. The global R&D teams have to accelerate their R&D process, strengthen research collaboration, and deliver high-quality outcomes. Scholars studied the performance of R&D projects by considering several factors (Adomako et al., 2019; Belderbos et al., 2020; Hsu et al., 2015; Keller, 1994; Kunttu et al., 2019; Persaud et al., 2002; Sbragia, 1984). In particular, some studies focused on the manager roles concerning the project performance of global R&D projects. Sbragia (1984) found that the clarity about responsibilities of managers has a significant relationship with the technical performance of multidisciplinary projects. Geoghegan and Dulewicz (2008) investigated project success in relation to the leadership competencies of project managers and they found significant relationships between competencies and performance. The majority of prior studies focused on project managers. However, other project members also contribute to the global R&D projects. Limited studies paid attention to the competencies of other project members, especially, the facilitators who in charge of research collaboration between teams in different countries of global R&D projects.

Chapter 3 Research methodology

This chapter describes the research methodology addressed by research questions to achieve research objectives. First, an overview of the research design is explained including how this dissertation is organized and structured in order to answer subsidiary research questions which lead to the answer for the major research question. After that, the methodological sequence follows to explain the detail of the research procedure. This dissertation consists of two subsidiary studies which are explained briefly in this chapter and more detail in a dedicated chapter for each of them, Chapter 4 and Chapter 5.

3.1 Research design

As seen from Chapter 1 and Chapter 2, the problem statement, research gaps, and literature review highlight the importance of international R&D, global team collaboration, and contribution of R&D managers in improving innovative performance and success of global R&D projects. Future studies are needed to advance our understanding of manager's competencies that help to solve difficulties in global R&D projects and influence project delivery. The major research question of this dissertation was developed "How are the difficulties and competencies of managers in global R&D projects related?". This dissertation is separated into two subsidiary studies, including 1) identification of difficulties in global R&D projects using qualitative analysis of interview data of experienced managers, and 2) identification of important competencies of managers concerning difficulties in global R&D projects using relevance ratio and qualitative comparative analysis to analyze questionnaire data. Figure 3.1 shows the research design of this dissertation.

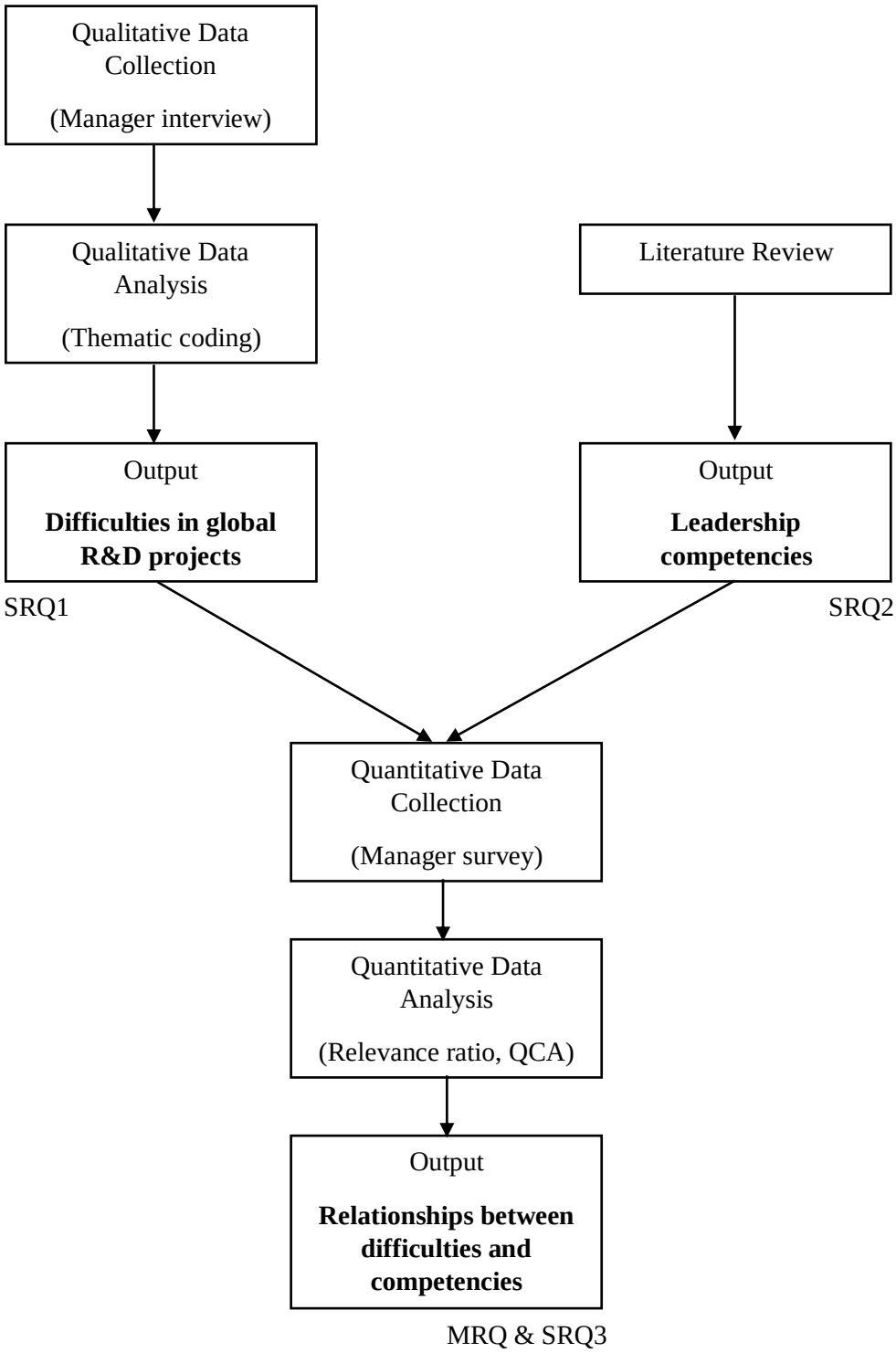


Figure 3.1: Research design

The foremost step is to understand how BMs work in global R&D projects. The analysis starts with exploring the working process of the managers characterized by a similar work process of BSEs in offshore software development projects. The work process is important in that it reveals activities and stakeholders which the managers have to work and deal with. The interview data of nine experienced managers is empirically analyzed to identify difficulties using the thematic coding method. Thematic analysis is a qualitative analysis method that identifies common messages or ideas, assigns codes to them, and then categorizes text into categories (Bryman, 2016). This method provides a flexible approach that can be modified to suit the objectives of the studies (Nowell et al., 2017). This first subsidiary study aims to answer the first subsidiary research question, "What are the difficulties faced by managers when they facilitate research collaboration between teams in different countries of global R&D projects?". Findings suggested categories of difficulties face by BMs throughout the research process in global R&D projects.

Following the first subsidiary study is the quantitative analysis which aims to identify important competencies of BMs to solve difficulties in global R&D projects. This second subsidiary study aims to answer the second and third subsidiary research questions "What are the relevant manager's competencies for facilitating global R&D projects?" and "How the managers possess the competencies to solve difficulties in global R&D projects?". Findings of this subsidiary study show relationships between difficulties in global R&D projects and competencies of BMs and elaborate how the managers solve the difficulties by possessing specific competencies.

Findings from the first and second subsidiary study complement each other and the integration of them leads to the answer to the major research question "How are the difficulties and competencies of managers in global R&D projects related?". The findings of this dissertation are supported by both qualitative and quantitative data analysis of the two subsidiary studies.

3.2 Methodological sequences

This section describes the methodological sequences as shown in Figure 3.2, to provide an overall picture as well as a step-by-step procedure in this dissertation to achieve all research objectives by answering each research question. There are six major steps in this dissertation, including 1) problem identification, 2) research design, 3) subsidiary study 1: identify difficulties in global R&D projects, 4) subsidiary study 2: identify competencies of managers in relation to the difficulties, 5) integrate findings of two subsidiary studies and discussion, and 6) summary.

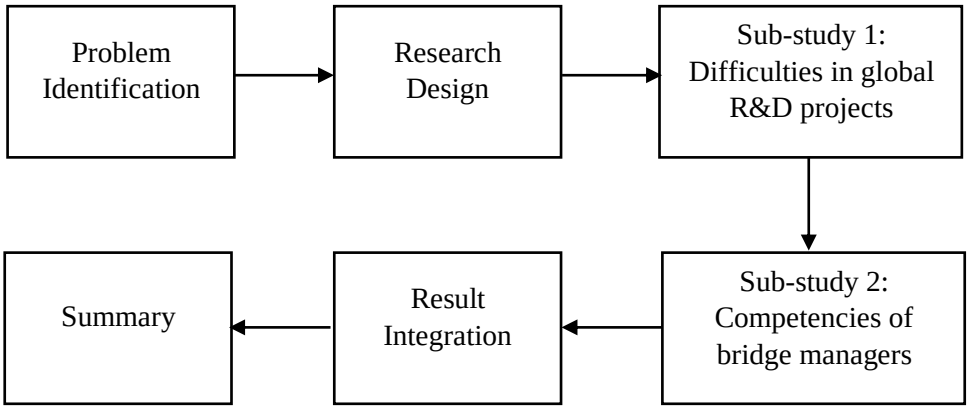


Figure 3.2: Methodological sequences

3.2.1 Problem identification

The problem statement was identified based on the literature review. The problem statement declares and briefly explains problems that have not been investigated and need to be addressed in this dissertation. There are research gaps derived from the problem statement. Closing these gaps bridges existing knowledge and desired outcomes of this dissertation. The research objectives were identified concerning problem statement, research gaps, and expected outcomes considering both academic aspect and practical aspect. The research questions were identified to provide a research direction and facilitate the research process. There are one major research question and three subsidiary research questions.

3.2.2 Research design

Research design identified strategy, research methods, and techniques that are used to integrate all components in this dissertation in a logical manner. It provides an effective and efficient way to answer each research question. It also includes the collection, measurement, and analysis of data. This dissertation divided the research design into two subsidiary studies.

3.2.3 Sub-study 1: Difficulties in global R&D projects

This dissertation focuses on the role of managers to facilitate research collaboration between teams in different countries. This role is characterized based on the role of BSEs in offshore software development projects where the BSEs bridge the gaps between teams in the headquarters of the company and teams of developers in foreign countries. The scope of this subsidiary study is limited to the roles of BMs in global R&D projects and the difficulties they face when facilitating research collaboration.

The target sample of this subsidiary study was the managers who have experience in facilitating global R&D projects. There is an inclusion criterion for selecting the sample. First, the selected managers had to have experience working in global R&D projects. Second, their projects had to involve R&D teams in different countries, not only domestic R&D projects. Third, the selected managers had to involve with activities to facilitate research collaboration between teams in the home country of the company and R&D teams in foreign countries.

This subsidiary study employed a semi-structured interview method to collect data from the sample group. Invitation e-mails were sent to the selected managers who met the inclusion criteria. In addition, some managers were invited by their colleagues to participate. A total of 9 managers participated in this subsidiary study between February 2017 to February 2018. These managers work in the major Japanese IT companies that have R&D subsidiaries in foreign countries. They were CEOs, directors, and leaders who were considered as having adequate knowledge of the global R&D operations, particularly, global R&D project facilitation. This data collection method was designed to address subsidiary research questions and to achieve research objectives.

The interview guide was developed based on the literature review. It provided a guideline for asking questions to the interviewees and ensured to cover all relevant topics. There were 19 initial questions that covered three main topics, including 1) R&D collaboration, cross-cultural setting, 2) knowledge transfer, and 3) BM who facilitates R&D collaboration (skills, behaviors, activities). The interview data from 9 managers were analyzed using thematic analysis which is a method of analyzing qualitative data (Bryman, 2016). The set of interview transcripts were examined to identify common themes, topics, and ideas that came out repeatedly. The interview transcripts passed through the thematic analysis to synthesize difficulties in global R&D projects and work processes informed by BMs. Lastly, the findings were discussed based on the existing knowledge from literature being the work process of BSEs, and challenges in offshore software development projects. This discussion section also involves answers to the research questions.

3.2.4 Sub-study 2: Competencies of R&D bridge managers

This second subsidiary study focuses on the competencies of BMs concerning the global R&D project difficulties which were identified in subsidiary study 1. First, a list of relevant competencies was gathered from literature on leadership competencies and competency development frameworks. The target sample of subsidiary study 2 was as same as in subsidiary study 1. They were managers who have experience in facilitating global R&D projects. The same inclusion criteria were also applied in this subsidiary study 2.

This subsidiary study employed a questionnaire survey as a data collection method. An online questionnaire was developed using the difficulties from subsidiary study 1 and the relevant competencies from the literature. It was distributed by e-mail to the selected managers and also asked them to forward the questionnaire to their colleagues who they think as having adequate knowledge of the topic. This questionnaire aims to collect the opinion of managers on the relationships between difficulties in global R&D projects and the competencies to solve difficulties. The inclusion criteria were identified to include managers who have the experience to facilitate research collaboration between teams in different countries of global R&D projects. The questionnaire opened to get responses between June 2019 to April 2020 and 73 data records were received. The respondents were project managers, project members, and project supporters. The relevance ratio and qualitative comparative analysis were applied to the questionnaire data to analyze the relationships between difficulties in global R&D projects and the competencies of the managers. These relationships demonstrate the important competencies of managers to solve difficulties when they facilitate research collaboration between R&D teams in different countries. Findings were interpreted and discussed on how these findings answered the second and third subsidiary research questions. Findings of subsidiary study 2 also complement the findings of subsidiary study 1 in which the relationships between difficulties and competencies address the importance of specific competencies of BMs to solve difficulties in global R&D projects.

3.2.5 Result integration

Findings from both subsidiary study 1 and subsidiary study 2 are integrated to clarify how the two subsidiary studies complement each other. Global R&D project difficulties from subsidiary study 1 addressed the necessity for the competencies in subsidiary study 2. On the other hand, difficulties and competencies relationships highlight the common challenges faced by BMs when they facilitate global R&D projects. Lastly, the discussion in Chapter 6 discussed overall findings to address the major research question.

3.2.6 Summary

It summarized this dissertation and elaborated on academic contributions and practical implications of the overall findings. The significance and originality of this dissertation are highlighted. This section also included limitations, how to interpret research findings within a limited boundary. Further, this suggested directions for future research on the topic.

Chapter 4 Difficulty in facilitating global R&D projects

This chapter explains subsidiary study 1 which identified difficulties of BMs in global R&D projects. In recent years, technology firms have been facing a highly competitive environment on a global scale. Firms are accelerating to establish R&D sites abroad to access global knowledge resources. In this context, global R&D projects have become more complex and BMs, who facilitate global research collaboration, play a pivotal role. This study aims to investigate the difficulties that BMs are facing and to explore the roles of BMs in global R&D projects. We interviewed nine BMs who have facilitated global R&D projects and propose a model depicting four common and critical difficulties present in facilitating research collaboration between home country teams and foreign R&D teams. The unique contribution of this subsidiary study focuses on the individual managerial level, while most previous studies on global R&D mainly focused on the organizational level.

4.1 Research background

Firms expand their R&D units outside their home countries as international R&D units play an important role in globalization, helping firms improve their innovative performance (Hsu et al., 2015; Hurtado-Torres et al., 2018). The companies gain advantages from foreign R&D subsidiaries by acquiring knowledge from local researchers, as well as an opportunity in commercializing products to those markets, as they build R&D capability abroad and utilize overseas knowledge (Ernst & Kim, 2002; Kuemmerle, 1997; Patra & Krishna, 2015). The global virtual teams often experience difficulties related to knowledge sharing (Eisenberg & Mattarelli, 2017). Global R&D difficulties have become more challenging with the increased complexity of the business environment. Prior studies have identified the challenges of managing global R&D and innovation. Ten challenges for managing global R&D operations were identified based on in-depth interviews (Gammeltoft, 2005; von Zedtwitz et al., 2004). Researchers did not only identify

challenges of managing innovation but also proposed factors that could help firms improve their innovative performance. Hsu et al. (2015) found that firm's experiences in foreign expansion have a positive impact on the R&D internationalization and innovative performance relationship. Prior studies that focused on an organizational level of analysis are well recognized, including the works of Berry (2015); Hurtado-Torres et al. (2018); Moenaert et al. (2000); Sosa et al. (2002), but studies focusing on the individual level of analysis are limited as Vrontis and Christofi (2019) mentioned in their survey paper. The result of the individual-level analysis is different from the analysis at an organizational level. The integration of individual outcomes forms the foundation for higher levels of analysis. There is an underexplored mechanism at the individual level that possibly influences innovation outcomes (Choudhury, 2017).

R&D internationalization consists of knowledge from several subfields, including leadership studies that employ an individual level of analysis. Choudhury (2017) found that the intrafirm mobility of innovators is positively related to the higher level of innovative outcomes of a distributed organization. The intrafirm mobility allows innovators to have face-to-face meetings with product managers and exchange tacit knowledge. In global R&D projects, the managers facilitate research collaboration between headquarters and foreign R&D subsidiaries. Although the roles of managers in global R&D projects have been discussed, the difficulties they face while working on the projects are yet to be identified. The managers in charge of global R&D projects may find it difficult to develop solutions, without a clear understanding of the difficulties of the projects. The researchers may find it useful to understand the difficulties from the manager's viewpoint and to have a more comprehensive view to manage global R&D projects. Choudhury (2017) found that the innovators' intrafirm mobility positively relates to innovative outcomes without indicating challenges in the R&D process. This study further investigates to identify difficulties of facilitating global R&D projects from the manager's perspective.

This chapter is organized as follows. First, research objectives are introduced. There is literature to explain the roles of BMs in global R&D projects. The next section shows the research method and follows by a section to describe research results which are four difficulties BMs face. The next section describes how BMs overcome difficulties and presents a model for identifying and handling difficulties in global R&D projects. The last section summarizes this subsidiary study.

4.2 Research objectives

The purpose of this study is to identify difficulties of global R&D project facilitation perceived by individual managers who are called R&D bridge managers (BMs) (Uchihira et al., 2017). Difficulty refers to the state or condition of being difficult, a thing that is hard to deal with, while challenge refers to a task or situation that tests someone's abilities (Pearsall, 1998). Individual managers encounter situations that are hard to deal with in global R&D projects. BM works in a global R&D project to facilitate research collaboration between teams in different countries. On the one hand, BMs work with teams at the headquarters of the company to understand the requirements and directions of the company. They also work with research teams in foreign R&D subsidiaries of the company to synchronize research work with headquarters. The objectives of this study are to understand individual manager's activities for facilitating global R&D projects by analyzing interview data using thematic analysis and to extend our understanding of difficulties the individual managers face during these projects. The qualitative method was employed to understand the meaning of interactions between BMs and project members. We conducted interviews with nine BMs and found that quality control, team communication, research approach guidance, and requirement clarifications are the four difficulties they face. This subsidiary study discusses the roles of BMs concerning global R&D projects and solutions to overcome those difficulties. Knowledge and understanding derived from this study will benefit the managers in charge of research collaboration between teams in different countries. The managers would acknowledge the difficulties of R&D project facilitation and could prepare effective solutions. Findings from this study shed light on the difficulties that have been previously overlooked in the interactions between managers and members of global R&D projects. Researchers can build on our findings to analyze the managerial roles and investigate the effects of difficulties on the outcomes of global R&D projects. The unique contribution of this subsidiary study focuses on an individual manager level, while most previous studies on global R&D mainly focused on the organizational level.

4.3 Global R&D projects and roles of R&D bridge managers

Globalization of R&D creates challenging tasks that need to be overcome. Objectives of business internationalization are to seek out additional markets, find cheap labor, localize existing products, and form global R&D networks (Boutellier et al., 2008). Firms utilize global knowledge resources to strengthen

the core resources of a company (Uchihira et al., 2017). Once the companies start operating cross-border R&D activities, researchers explore global R&D management to identify relevant factors that affect international R&D operations. von Zedtwitz et al. (2004) conducted interviews with more than 150 R&D directors and chief technology officers of more than 60 companies and identified 10 challenges of managing global innovation. Among them, one of the challenges explains the change of R&D from a function in the company to projects due to the need for transparency and productivity. It is challenging for companies to allocate resources to innovation projects. The project managers become more important, responsible for project success or failure, and team performance. Persaud et al. (2002) applied regression analysis with data collected through questionnaires from R&D executives and found that the innovative performance of global R&D labs can be explained by three factors including the autonomy level of the labs, the degree of socialization, and the effectiveness of in-person communication between headquarters and subsidiaries. To better understand how R&D internationalization affects the innovative performance of multinational firms, Hurtado-Torres et al. (2018) analyzed data from 118 firms in energy industries and found that collaboration among R&D units reduces the impact of R&D internationalization on innovative performance. Collaboration between members in different R&D units means that team members can share and coordinate innovative input and output. There is a relationship between the contribution of individual members and the performance of global R&D projects.

Knowledge on R&D internationalization belongs to a wide variety of business subfields such as international business, innovation, and strategy. Vrontis and Christofi (2019) reviewed the literature on R&D internationalization and found only one study that explicitly focuses on an individual level of analysis. Choudhury (2017) found that mobility within the firm is positively related to patenting of individuals and might affect the innovation outcomes of a distributed organization. The author explained that intrafirm mobility, in which the distant R&D unit members traveling for a temporary short-duration trip to headquarters, provides an opportunity for the innovators to have face-to-face interactions with responsible people, thus helping the innovators gain access to resources. One of the mechanisms is that face-to-face enables the diffusion of tacit knowledge among employees of an organization. The difficulty to deal with tacit knowledge has been well recognized (Szulanski, 1996; Von Hippel, 1994). In the case of global R&D projects, Uchihira et al. (2017) had first attempted to clarify the roles of R&D BMs, who move between headquarters and foreign R&D subsidiaries to promote the utilization of global knowledge resources by playing roles of a gatekeeper and boundary spanner. Given the mechanism to improve innovation outcomes and roles of BMs, the primary research question of this subsidiary study is “what are the difficulties of global R&D projects for BMs to facilitate research collaboration?”

The BM is considered different from the global project manager. Global project managers engage with managerial activities, including obtaining commitments from stakeholders, recruit team members, and drive the projects to achieve organizational goals (Bartlett & Ghoshal, 1992; Wingate, 2015). For the BMs, they facilitate research collaboration between members, decompose requirements, resolve communication gaps of quality, and promote the utilization of global knowledge resources in global R&D projects (Uchihira et al., 2017). The global project managers responsible for the overall operation of the project, while BMs responsible for the relationship between project members to conduct R&D activities. Thus, the global project managers encounter difficulties mostly at the project and organizational levels. The BMs face difficulties mainly in the collaboration between individual members. In this subsidiary study, BM is identified as the liaison who facilitates research collaborations in global R&D projects between home country teams and foreign R&D teams of the firm. Uchihira et al. (2017) clarified the roles of BMs, to be a gatekeeper and boundary spanner. They work with teams at the headquarters of the company. For example, they refine customer requirements and contact external partners. They also work with research teams in foreign R&D subsidiaries and synchronize research work with headquarters.

Based on the literature on cross-cultural management, the global R&D projects are impossible to remain untouched by the challenges posed by cultural differences among project members. Although having multicultural innovation teams leads to more innovative work behavior (Tian et al., 2020), it comes with challenges including direct versus indirect communication and conflicting decision-making norms (Brett et al., 2006). Culture has been investigated in many international business studies and many of them have been influenced by the work of Hofstede (1984). Hofstede's model has six national culture dimensions, including power distance, uncertainty avoidance, individualism or collectivism, masculinity or femininity, long- or short-term orientation, and indulgence or restraint (Hofstede, 2011). In global R&D projects, researchers from different countries who use diverse research approaches reveal the existence of cultural differences in the projects. Cross-cultural training is used to increase the knowledge and skills of employees to live and work effectively in unfamiliar cultures (Schuler et al., 2015). The managers may find it difficult to bridge cultural gaps. This subsidiary study explores what these difficulties are. Knowledge about the difficulties is a foundation for the development of proper and effective solutions that contribute to the improvement of global R&D projects.

As mentioned in the previous section, the globalization of R&D helps firms access global knowledge resources (Patra & Krishna, 2015). Members of the global R&D projects exchange their knowledge for the development of innovative outcomes. Choudhury (2017) argued that mobility within the firm enhances outcomes of innovation by stimulating tacit knowledge diffusion and knowledge recombination. In that

study, the innovators from R&D centers have temporary short business trips to headquarters to speak to the product managers. For this subsidiary study, the BMs travel between foreign R&D subsidiaries and headquarters to deal with knowledge transfer while facilitating research collaboration. It is possible that, in global R&D projects, the BMs face difficulties with knowledge transfer activities.

4.4 Research methodology

This subsidiary study adopted a semi-structured interview as a data collection method. This kind of interview allows interviewees to flexibly emphasize important information in their explanations (Bryman, 2016). The interview questions were developed based on prior studies of Thamhain (2013); Thamhain (2009b) and Nguyen et al. (2014). These studies have a similar context to this study. Thamhain (2009b) interviewed managers, directors, and executives to gain insight into the challenges of cross-functional integration in dispersed R&D teams. Thamhain (2013) interviewed more than 100 managers to investigate risk management practices for large complex projects. Nguyen et al. (2014) investigated the knowledge-creating process in software offshoring projects by interviewing team leaders and project managers. These studies and the current subsidiary study have a commonality in that they investigated complex projects, specifically, the interaction between members in the complex projects. They gathered data by interviewing managers to elicit their opinions when working on the projects. The interview questions of this study adapted some elements from these previous studies. However, the works of Thamhain (2013); Thamhain (2009b) and Nguyen et al. (2014) did not focus on the difficulties of individual managers when they facilitate the projects. In this study, we aim at investigating the difficulties that BMs face and exploring the roles of BMs in global R&D projects. An interview guide was developed containing high-level questions that covered the topics under investigation as suggested in Bryman (2016).

We prepared interview questions related to the professional background of interviewees, global R&D projects, difficulties in global R&D projects, and solutions to resolve complications. Table 4.1 shows key questions used during the interviews. The interviewer did not strictly follow the list of questions. There were additional questions to encourage interviewees to expand on their points. The questions were under the topics of global R&D projects, including what are the steps in the research projects, who are the members in the meetings, and how the managers manage the project performance. Also, we refined our questions after each interview.

Question category	Example question
Interviewee background	Would you explain your experience in R&D projects? What kind of research projects are you conducting at your laboratory?
Global R&D projects	How do your engineers and researchers communicate with each other? Would you explain your experience in global R&D management?
Difficulties encountered in global R&D projects	Do you feel any difficulty when working on R&D projects? What are the causes of those difficulties?
Solutions to resolve complexities	How would you overcome this kind of difficulty? What are the solutions or approaches you use to overcome difficulties?

Table 4.1: Key interview questions

The interviewees were managers involved in facilitating global R&D projects. In this study, global R&D projects consisted of research activities that require collaboration between teams in the home country along with R&D teams in foreign countries. The inclusion criteria of interviewee selection were that they had to have experience in facilitating global R&D projects, interact with project members of teams in the home country and foreign R&D teams, and belong to the companies that have foreign R&D units.

We interviewed nine managers from five companies of representative global Information Technology (IT) companies in Japan who accepted our invitation. Table 4.2 shows the company profiles of the interviewees. There are five major Japanese IT firms with their own R&D unit and conducting R&D activities with their foreign R&D laboratories in countries other than Japan. We elicited their opinions to serve the purpose of this study, which is, to investigate the difficulties of global R&D project facilitation perceived by individual managers. They were from five different companies. There were three female and six male interviewees, their age range was between 30 to 58, and their positions in organizations include managing director, general manager, and team leader. These managers make up an appropriate sample group for this subsidiary study.

	Company A	**Company B**	**Company C**	**Company D**	**Company E**
Year of establishment	June, 1935	February, 1936	July 1875	February, 1920	June, 1937
Employees	129,071 (2020)	90,141 (2019)	125,648 (2020)	301,056 (2019)	N/A
Net sales	3,857.7 billion of yen (2020)	2,008.58 billion of yen (2020)	3,389.871 billion of yen (2020)	8,767.263 billion of yen (2019)	903.9 billion of yen (2020)
R&D expense	123.3 billion of yen (2020)	102.851 billion of yen (2020)	Approx. 900 billion of yen (2019)	293.799 billion of yen (2019)	N/A

Table 4.2: Company profiles (Source: Annual reports)

Although the number is relatively small, all nine managers comprised characteristics of the research purpose. The managers work in the IT industry, which is a fast-moving industry and has a fast pace of technology advancement. The selected companies were Japanese companies, where collaboration with foreign R&D sites is critical considering the cultural gaps. The selected managers came from major global IT companies. They work with counterparts including management teams in the home country and researchers in foreign R&D sites. The foreign R&D sites are in India, the U.S., China, France, and Germany. The nationalities of managers included Japanese, Chinese, and Indian as shown in Table 4.3. The nine interviewees were suitable for the research purpose under the limited number of global Japanese IT companies.

Interviewee ID	Organization industry	Company	Nationality	Interview date and time
Interviewee 1	IT	Company A	Japanese	September 8, 2017 (60 min.)
Interviewee 2	IT	Company B	Chinese	May 27, 2017 (90 min.)
Interviewee 3	IT	Company C	Japanese	August 28, 2017 (90 min.)
Interviewee 4	IT	Company B	Chinese	August 24, 2017 (90 min.)
Interviewee 5	IT	Company C	Japanese	March 2, 2017
Interviewee 6	IT	Company D	Japanese	February 28, 2017
Interviewee 7	IT	Company E	Japanese	April 27, 2017 (45 min.)
Interviewee 8	IT	Company C	Indian	February 22, 2018 (60 min.)
Interviewee 9	IT	Company C	Indian	February 23, 2018 (45 min.)

Table 4.3: Interviewee information

The English language was used for the interviews. Each audio-recorded interview lasted for 45 to 90 minutes, which was then transcribed. Thematic analysis (Braun & Clarke, 2006) was adopted as a data analysis method. The coding process was undertaken and suggested by Bryman (2016). The researcher developed initial codes after reading interview transcripts several times. In the first stage, the codes were explained by descriptive interview quotes. Then the codes were constructed and consolidated into a higher level of abstraction, categories, and themes. The initial codes were shared with senior researchers (social scientists) for review and discussion. During an iterative discussion between researchers, the researcher revisited the transcripts and revised the codes, categories, and themes. Table 4.4 shows codes, categories, and themes that highlighted the difficulties in facilitating global R&D projects as shown in Appendix A.

Codes	Categories	Themes
Quality evaluation Pre-defined schedule and process Different expectation Using several milestones Visualization of expected results	Quality control technique Awareness of quality Visualization (Solution)	Quality control difficulty

Cultural difference Different ways of thinking Way of thinking issue Switching roles between team members	Alignment of research approach Setting different priority in the research process Mutual understanding (Solution)	Research approach guidance difficulty
Convincing and negotiation with researchers Requirement clarification Dynamic target Making things explicit Understanding of the requirement Understanding of the market Difficult visualization in the early stage of development	Elaborating the requirements Understanding of the requirements	Requirement clarification difficulty
Communication issue Communication breakdown Language barrier High-context communication	Efficiency of communication Obstacle of communication	Team communication difficulty

Table 4.4: Codes, categories, and themes

4.5 Results

4.5.1 Difficulties in global R&D projects

Four difficulties emerged in this subsidiary study and BMs considered them as difficulties of facilitating global R&D projects, including quality control, team communication, research approach guidance, and requirement clarification. It is challenging to overcome these difficulties and thereby enhance research collaboration. BMs facilitate quality control activities by helping deliver research output that satisfies the

interests of all project stakeholders. Communication is facilitated by BMs to create mutual understanding and promote knowledge transfer. BMs also guide research approaches for foreign R&D teams to better use particular research approaches or techniques. Lastly, BMs clarified requirements in more detail so that researchers have a better understanding of the requirements that transferred from headquarters. Each difficulty is described in more detail in the following subsections.

4.5.1.1 Quality control

Delivering output that satisfies stakeholders is one of the most important goals of R&D projects. Facilitating quality control is a difficult activity for BMs, especially in basic research projects. It is more difficult than applied research because, in basic research, researchers aim to find new knowledge without clearly defined goals. The following comments were indicated by Interviewee 1 and Interviewee 2.

> *"In the research level, it is very difficult to manage performance because we don't have ideas on how to involve the problems. So, the big problem for us is how to check and control the performance at the research level."* (Interviewee 2)

> *"In the product level, we have very clear specifications but in the research level, we don't have specifications as to which performance is good and which performance is not. We don't know."* (Interviewee 2)

> *"In Germany, we are at the beginning. We have a big quality problem. We try to do everything and visualize it while keeping it explicit and open. We can achieve a very high level of product quality."* (Interviewee 1)

In addition, it is more complicated when home country teams and foreign R&D teams expect different outcomes. In the case of applied research, teams in the home country expect results that are ready for demonstration in front of customers. The results should be reliable so that they can demonstrate them. In some cases, foreign R&D teams delivered results as quickly as possible without considering the customer's perspective and the results thus lacked the quality level expected by teams in the home country. The following quotations from Interviewee 2 show a situation where R&D teams in China delivered results to teams in Japan. Interviewee 5 gave his opinion on output quality received from the Indian team.

"China thinks that moving demonstrations is ok. At that time, the applications might have some bugs, but that's ok. We can demonstrate it to customers. This is the opinion from China. But for Japan, we think that just moving the demonstration is not enough. We must have higher quality products in order to show the demonstration to customers." (Interviewee 2)

"Quality or output, sometimes they don't care." (Interviewee 5)

Quality refers to the value perceived by stakeholders and a poor-quality outcome is considered to be one that does not match the expectations of stakeholders at the point of delivery (Wingate, 2015). We found that, in the case of applied research, researchers satisfy the quality level from a technological perspective without considering the needs of users. In this study, researchers provided results that were not ready for demonstration as expected by the company's team in the home country.

4.5.1.2 Research approach guidance

Globalization brings more challenges to global R&D projects as BMs face the difficulties of guiding research approaches. It was found that, at least in some cases, teams in the home country asked foreign R&D teams to use specific techniques, but researchers used others based on their way of thinking. They try to deliver output as soon as possible by using existing knowledge and technologies without considering alternatives. Teams in the home country tend to use particular techniques due to marketing or cost-related reasons. Moreover, teams at home country pay attention not only to research results but also to research processes that will be used to improve future projects.

A high level of expected change coupled with unknown outcomes are specific characteristics of R&D projects and, therefore, require a certain level of control (Wingate, 2015). Findings show that, in addition to R&D characteristics, norms and beliefs of researchers need to be recognized by BMs so that BMs could carefully guide research approaches that utilize proper research processes according to the implicit requirements of teams in the home country and then deliver the expected outcomes. Interviewee 3 explained in the following quotation when Indian researchers did not follow the expected approaches.

"Most problems are about the research approach. For example, I say 'please use some new network technology', but they use another technique instead. It may be OK but sometimes our members require them to use newer methods."

"If the result is good, then in that case it's alright. But Indian results usually have some problems. They have to use some type of approach but instead, use a different approach. If the different approach is good, then no problem. But the result is not so good. It doesn't have evidence. If Japanese researchers want to change the approach, they have to show evidence that the new approach is better."

4.5.1.3 Requirement clarification

Another difficulty is the understanding of requirements, specifically, for applied research. In global R&D projects, foreign R&D teams are located in different places from teams in the home country. In many cases, researchers and customers are also in different locations. This situation creates difficulties for BMs because requirements need to be transferred from one location to another. BMs facilitate the conveying of knowledge about customer needs to researchers. Foreign R&D teams cannot deliver outcomes that satisfy customers if they do not clearly understand what the customers need. One of the reasons is that the requirements are ambiguous. Another reason is that researchers find themselves in a different context from customers, so it is difficult for them to understand how products or services will be used by the customers. Moreover, it is difficult to perceive tacit elements of the requirements during the requirement transfer process. The following quotations show difficulty of Interviewee 1 in clarifying customer needs to foreign R&D teams. Interviewee 8 and Interviewee 9 briefly explained the process of transferring requirements from Japan to India.

"During the early stage of product development, visualizing the specification is a critical problem. I think, once the development starts, everything can be visualized pretty well, but before that, visualization is really difficult." (Interviewee 1)

"Japanese people assume a lot of implicit knowledge and this creates a lot of difficulties. Because of this, the Japanese specification is not clear enough and also not detailed enough." (Interviewee 1)

"First, the client from Japan will come to India. And then we discuss the design aspect based on the requirement and what exactly it entails. Then, we will finalize and come up with the design and will again discuss it with the team members. Therefore, the design is finalized and approved by everyone." (Interviewee 8)

"We do it through documents sometimes. Some points and requirement details get drilled so you have to find ways to ask them questions. That is why we have to explore the real requirements." (Interviewee 9)

4.5.1.4 Team communication

Difficulty in communication between project members is another challenge for BMs. Team leaders have to manage people relations to improve project performance (Thamhain, 2009a) because the global projects consist of people from different cultures, organizations, countries, time zones, and those speaking different languages (Binder, 2007). The diverse culture in the workplace creates difficulty in communication. The following quotation by Interviewees 1 and Interviewee 7 explained the difficulty in communication their unit has faced.

"Most Indian people often say 'what do you mean?', but other Asian people don't ask. They simply assume and pretend to understand. So, we say that 'we should develop this problem in this way' and they say 'yes, I understand' but they actually don't understand. This is a typical problem in most Asian people." (Interviewee 1)

"The difficulty is the communication with vendors from Asian countries. Each country has its own character, China, Taiwan, Hong Kong, Korea. The difference in culture will create problems. In China's case, at first, they say they can do anything. But after one or two weeks, they can't. This is common for them. For us, it is abnormal. The communication and misunderstanding between cultures is the biggest problem." (Interviewee 7)

Knowledge codification is one of the conditions to determine the communication effectiveness and efficiency in international teams of product development (Moenaert et al., 2000). Researchers hardly explain their knowledge and their understanding of specifications. It was observed that culture influences

the way researchers convey their knowledge. It is difficult for BMs to find ways how to convince project members to communicate clearly as revealed by the following quotation by Interviewee 4.

> *"When I meet with people of different cultures and languages, I think there are a variety of big issues. I try to repeat my questions, again and again, in order to understand what they really think. That is difficult because they don't ask about everything. Sometimes, they don't provide all the information or don't discuss everything."*

Communication problems in the project teams could have a negative impact on the project's progress. Geographical dispersion, including spatial distance difference and temporal distance difference, are the main coordination barriers in global product development projects (Yang et al., 2015). Specifically, in global R&D projects, researchers and engineers have to explain the detail of their research activities to other project members. Cultural differences in communication are challenging for BMs to create effective communication among project members.

In summary, all four difficulties are depicted in Figure 4.1. The requirements clarification, research approach guide, and quality control are in the process from input to output, while the team communication occurs throughout the process. It is likely that three difficulties, including requirement clarification, research approach guide, and quality control, may occur several times in different stages of the project. They are about the differences in understanding of requirements, conducting research approaches, and expectation of outcome quality between headquarters and foreign R&D teams. Thus, communication is required to mitigate the difficulties, however, cross-cultural communication contains difficulty in itself. It is likely that requirement clarification difficulty should occur at the beginning of the project where requirement gathering takes place, however, this dissertation found that it does not only occur at the beginning. It is difficult for BMs to deal with the dynamically changing requirements, and they have to adaptively communicate the changes to foreign R&D teams. The research approach guide is in a similar situation where BMs have to communicate with foreign R&D teams about changing approaches to align with directions from headquarters that deal with competitors. The quality control difficulty, on the other hand, is difficult for BMs to communicate to foreign R&D teams what is expected by headquarters in different times when headquarters encounter different business situations.

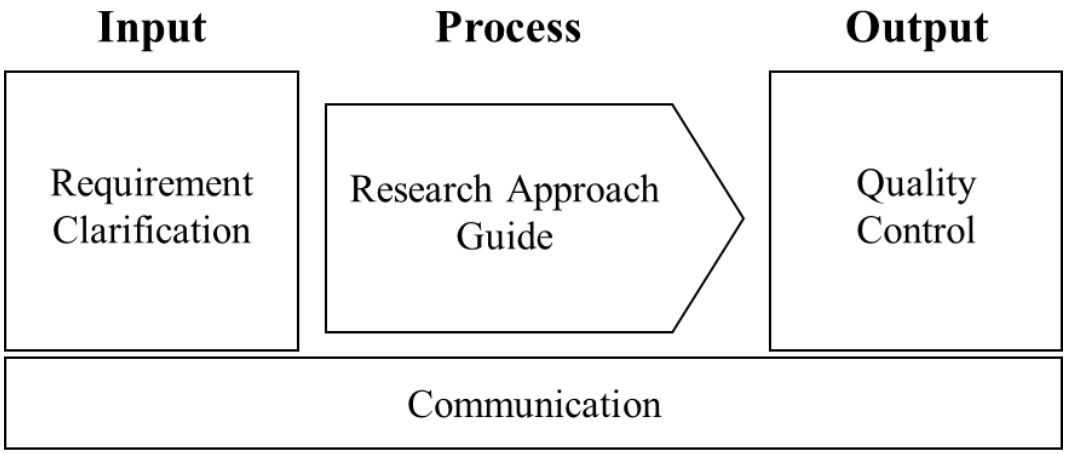


Figure 4.1: Four difficulties in the R&D process

4.5.2 Overcoming difficulties

The scenario where teams from the home country undertake research collaboration with R&D teams in foreign countries is depicted in Figure 4.2. This model shows four difficulties that BMs face in global R&D projects. BMs play different roles to overcome difficulties and facilitate research collaboration.

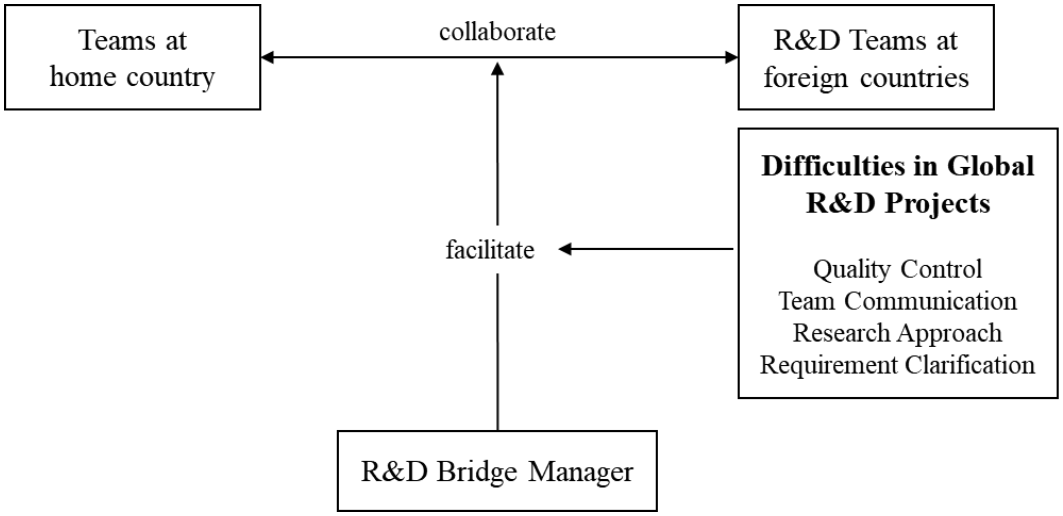


Figure 4.2: BM difficulties in global R&D projects

When difficulties in quality control occur, BMs assist foreign R&D teams in delivering outcomes expected by teams in the home country. BMs neither decide the outcome nor the quality control process, but instead help foreign R&D teams understand the expectations of the teams in the home country. Whenever complications in team communication arise, BMs encourage members to communicate openly and expand their thinking to promote mutual understanding. BMs also simplify information exchange by utilizing additional documents and visualization. Difficulties may occur in pursuing particular research approaches and BMs must guide foreign R&D teams concerning which approach should be followed to carry out projects, and that approach must also satisfy teams in the home country. Lastly, BMs check the essential meaning of requirements that may be understood by all parties to resolve confusion and misunderstandings. While taking on these roles, BMs use particular techniques to overcome complications in global R&D projects. Each technique is described in the ensuing subsections.

4.5.2.1 Using milestones

At the end of some projects, customers or teams in the home country are not satisfied with the results. Waiting until the end of the project to solve such problems is dilatory and costly. Therefore, BMs establish quality measures and use several milestones throughout the R&D process. The results are regularly evaluated to prevent unexpected final results. BMs ask researchers to provide actual existing output instead of asking them to just provide project status updates. By using this technique, BMs may better ensure the quality level of final results. It also prevents projects from backtracking, which is the occurrence of unexpected results. In such cases, researchers need to take steps back and fix prior problems. The below quotation was indicated by Interviewee 1.

> *"At the beginning of the project, I clearly define the schedule, process, and milestones. I also design the output of the milestones and the output of the end of the project. So, I do not say to them 'what is going on?' but I say 'show me the current output of the current milestone'."*

4.5.2.2 Developing additional documents with visualization

BMs develop documents and use visualizations to overcome difficulties in communication among project members. They encourage all members to communicate openly and to make everything as explicit as possible. After face-to-face meetings or video conferences, information is transferred to a written form and shared among members. This technique provides evidence for future references. In some cases, BMs also develop additional documents using visualization intensively instead of only using verbal explanations. BMs find that this technique improves communication and describes pertinent information in greater detail. The following quotations show what BMs said about this issue.

> *"We make formal documents every time. That is the method we use to deal with that problem."* (Interview 4)

> *"We have to specify and write down very detailed specifications, and often, more communication is necessary."* (Interviewee 1)

> *"We ask all members to make everything as explicit as possible. Also, I ask them to communicate in a very open way. I often say 'don't keep underlining assumption, please just make everything explicit and discuss openly'."* (Interviewee 1)

4.5.2.3 Switching roles temporarily

BMs guide research approaches by communicating feedback between different teams. They also ask some project members to temporarily swap their activities with other members so that they may understand projects from different perspectives. In particular, they switch roles between researchers and team members in the home country who know customer needs, helping both of them share the understanding of the requirements. This technique improves collaboration because project members understand each other better. In the following quotation, Interviewee 1 described this technique.

"I have this problem as well. I solve it by switching roles between Japan and Germany. What I mean is that the Japanese always say that they want to create the design so they'll write down specifications and then I'll ask the Japanese to stop. I'll then ask the Germans to start creating the design and specifications, which Japan then checks, and it ends up working better."

The difficulties of BMs in global R&D projects and techniques for solving those difficulties are summarized in Table 4.5.

Difficulty	**Description**	**Technique**
Quality control	Requirements are ambiguous, and home country teams and foreign R&D teams expect different results. Therefore, the resulting quality is not satisfactory at the end of the project.	BMs establish several milestones and regularly evaluate results with teams in the home country. This helps to prevent unexpected final results.
Team communication	Misunderstandings happen in diverse environments because project members have different backgrounds.	Additional documents with more visualizations are used by BMs, allowing detailed information to be elaborated more precisely.
Research approach guidance	Researchers use investigative approaches and techniques differently. BMs find it difficult to guide such members to follow specific approaches or techniques.	BMs cooperate with teams in the home country to evaluate research processes and results. Also, BMs temporarily swap roles between members, so they can understand things from different perspectives.
Requirement clarification	Customers and researchers are in different locations. It is challenging for BMs to transfer customer needs to foreign R&D teams.	BMs ask home country teams and foreign R&D teams to swap their activities so they can share information about requirements. The written documents and visualizations are used to describe detailed information.

Table 4.5: BM difficulties in global R&D projects and their solutions

4.6 Summary

BM interview data about global R&D projects were analyzed and four difficulties were identified. Throughout the R&D process, some activities influence outcome quality. BMs have a difficulty in facilitating product quality control because, in the case of basic research, there is an unclear target to achieve. Another reason is that home country teams and foreign R&D teams expect different results. Thus, BMs set up several project milestones to evaluate results regularly.

Miscommunication occurs in global R&D projects where members who have different backgrounds work together. BMs find it difficult to create mutual understanding among project members. Additional documents and visualizations are used to enhance communication. Researchers in the projects also have different ways of thinking and resolving problems. Such diversity creates difficulties for BMs to guide research approaches. BMs overcome this difficulty by cooperating with teams in the home country to evaluate results and suggest swapping activities between project members. Thus, project members understand research approaches from other perspectives.

Understanding requirements is important for R&D teams to imagine the expected final results. Researchers do not have direct experience to perceive customer needs because they are in different locations and have limited interaction. BMs have a difficulty in transferring requirements and knowledge to foreign R&D teams. They find that written documents and visualizations help clarify requirements. Awareness of these difficulties helps BMs prepare solutions that are adaptable in different contexts.

This subsidiary study explored global R&D projects focusing on the individual level, the managers. Choudhury (2017) found that intrafirm mobility of individual innovators from distance R&D units affects innovation outcomes of the organizations. The face-to-face meetings of the innovators facilitate the diffusion of tacit knowledge among employees. The findings of this subsidiary study extend our understanding of how BMs facilitate global R&D projects in that there are specific difficulties in the projects and individual BMs play important roles to solve such difficulties.

Chapter 5 R&D bridge manager competencies and global R&D project difficulties relationships

This chapter explains subsidiary study 2 which investigates relationships between competencies of BMs and difficulties in global R&D projects and identifies crucial BM competencies. Global R&D projects are common in multinational companies, and it is a topic of interest for many researchers. This subsidiary study aims to improve the global R&D projects by focusing on competencies of individual managers who bridge organizations of different countries and facilitate research collaboration, while prior studies paid attention to the global R&D projects from an organizational perspective. BMs are especially needed in offshore R&D projects to utilize knowledge resources in emerging countries including India. The survey data of 73 managers who have project facilitation experience was analyzed. It was found that knowledge management skills, perception, resilience, decision-making skills, understanding worldwide business, learning foreign culture, and communication skills are relatively more important for BMs to solve difficulties in facilitating global R&D projects. The significance of this subsidiary study is that the clarification of the relationships between competencies of BMs and difficulties in global R&D projects. The managers may plan for competency development to cope with difficulties in their projects. The organizations may analyze the projects and identify qualifications of managers for recruitment and assignment in their human resource management practices.

5.1 Research background

R&D activity is one of the important activities for firms to gain a competitive advantage. In the globalization era, firms expand R&D operations across borders to utilize knowledge resources around the world by setting up R&D sites abroad. The internationalization of R&D activities has received more attention. Studies in the early days of R&D internationalization focused on the establishment of R&D sites abroad (Gassmann & von Zedtwitz, 2003; Kuemmerle, 1997; Kurokawa et al., 2007).

Organizational management and project management of global R&D are among the branches of international R&D research. Organizational management involves corporate strategies of R&D internationalization (Chiesa, 1996), the establishment of new R&D sites (Kuemmerle, 1997), and types of R&D organizations (Gassmann & von Zedtwitz, 1999). The project management deals with research activities and collaboration between R&D units in different countries (Hedlund & Ridderstråle, 1995; Kurokawa et al., 2007; Thamhain & Asgary, 2013), global R&D project management (Chiesa, 2000), and contribution of individuals to the project success (Singh & Hofmann, 2012; Thamhain, 2012). Despite the number of studies at an organizational level, there remain limited studies that focused on the individual level.

Individual project members contribute to the success of global R&D projects helping their organization to achieve strategic goals. Important success factors of R&D projects include recruitment, selection, and training of necessary personnel for the project team (Pinto & Slevin, 1989). Managerial and emotional/social competencies of project managers could explain variations in project success (Geoghegan & Dulewicz, 2008). In global R&D projects, researchers, engineers, and scientists from different countries exchange their knowledge intensively aiming for innovative outcomes. It is challenging for managers to manage such kinds of projects in which many difficulties usually occur. For example, diversity in the background of team members, team virtuality, different languages and time zones (Binder, 2007). Global managers were employed when the company has cross-border operations (Bartlett & Ghoshal, 1992). Although there are studies that investigated contributions of project members to project success, there are a few studies focused on the competency of managers who facilitate research collaboration in global R&D projects.

Leadership competencies influence project success and the degree of influence depends on the types of projects (Podgórska & Pichlak, 2019). The term competency has not been clearly defined (Hoffmann, 1999). For individuals, it is the characteristics of a person which results in effective performance in a job, including a motive, trait, skill, aspect of one's self-image or social role, or a body of knowledge (Boyatzis, 1982). Skill and capability, on the other hand, mean the ability to do something (Pearsall, 1998). This dissertation focuses on the competencies of individual manages to perform their job in global R&D projects. Competency includes knowledge, skills, abilities, attitudes, and characteristics that help individuals to perform their tasks effectively (Athey & Orth, 1999; Fotis & Gregoris, 2006; Lustri et al., 2007; Teodorescu, 2006). The professional competencies have been identified such as laboratory leaders, human resource professionals, and clinical research staff (Albetkova et al., 2019; Gowie et al., 2020; Mansfield, 1996). In the case of global R&D projects, the projects become more complex in a fast-changing business environment and having more diverse project members from around the world working together.

The increasing complexity of the projects necessitated competent managers to facilitate them. This subsidiary study contributes to the field of international R&D research by clarifying the relationships between the competencies of managers and difficulties in global R&D projects.

Project members play different roles in global R&D projects. Technological gatekeepers play an important role to link information among different individuals within and outside organizations (Arora, 1987). In the context of international R&D, Asakawa (2001a) introduced an active broker's role who influences information flow between headquarters and foreign laboratories in global R&D projects. This kind of liaison persons such as BMs who bridge the information and knowledge gaps are indispensable in global R&D projects where the exchange of knowledge is an important activity. The competencies of BMs have not been identified for this specific context, global R&D projects. In small projects, a global project manager (head of the project) takes the role of liaison (Karlsen & Gottschalk, 2006) similar to the role of BM. In large projects, especially off-shore R&D projects, a BM is required to support the global project manager (head of the project) (Wang et al., 2018). It is plausible that competent BMs who have specific abilities, skills, and knowledge could solve difficulties that arise in global R&D projects to improve research collaboration between teams in different countries.

5.2 Research objectives

This subsidiary study contributes to the field of international R&D management by identifying manager's competencies for facilitating global R&D projects. Competency includes knowledge, skills, abilities, attitudes, and characteristics that help individuals to perform their tasks effectively (Athey & Orth, 1999; Fotis & Gregoris, 2006; Lustri et al., 2007; Teodorescu, 2006). The competencies of several professions have been identified such as laboratory leaders, human resource professionals, and clinical research staff (Albetkova et al., 2019; Gowie et al., 2020; Mansfield, 1996). In the case of global R&D, the projects become more complex in a fast-changing business environment. This necessitates the company to hire competent managers such as BMs who would help the organization to cope with difficulties in facilitating global R&D projects.

The competencies of BMs have not been identified for specific context like global R&D projects. In small projects, a global project manager (head of the project) takes the role of liaison (Karlsen & Gottschalk, 2006) similar to the role of BM. In large projects, especially off-shore R&D projects, a BM is required to support the global project manager (head of the project) (Wang et al., 2018). It is helpful for

organizations to have competent managers helping organizations to improve and expand projects across countries. The competencies of BMs could be defined as management skills to fill the gaps between organizational level management and project level management. It is plausible that competent managers having specific abilities, skills, and knowledge could facilitate projects effectively. A research question was formulated: what are the associations between R&D bridge manager's competencies and the difficulties of facilitating global R&D projects?

5.3 Global R&D projects and contribution of managers

Global teams become more important in the era of increased internationalization. The global teams help firms to establish an international network and expand their operation across borders. Collaboration among members of global teams generates innovative ideas. The ability of global teams to share and communicate ideas influences the performance of product innovation projects (Jensen, 2020). It is common for companies nowadays to gain access to knowledge resources around the world by setting up and collaborating with foreign R&D units. In this global R&D context where knowledge sharing is one of the important activities, global R&D teams take advantage of diverse knowledge from around the world to create new knowledge and innovative ideas (Eisenberg & Mattarelli, 2017). The companies benefit from diverse knowledge sources, improve their innovative performance by conducting international R&D activity through global R&D projects.

Knowledge management is one of the important disciplines for international R&D management such as how knowledge flows between foreign R&D laboratories and headquarters. Scholars studied knowledge management in the context of R&D collaboration such as knowledge management model (Kerssens-Van Drongelen et al., 1996), knowledge dissemination (Teigland et al., 2000), different types of knowledge from different partners (Un & Rodríguez, 2018), and knowledge transfer factors and processes (Blumenberg et al., 2009; Cummings & Teng, 2003). More specifically, there are studies that explored R&D operations across borders such as objectives of foreign R&D sites (Kuemmerle, 1997), coordination structures of R&D teams (Chiesa, 1996; Persaud et al., 2002), management of virtual R&D teams (Gassmann & von Zedtwitz, 2003), intellectual property rights (Zhao, 2006), location determinants (Ambos & Ambos, 2011; Siedschlag et al., 2013; Song et al., 2011), and R&D in emerging economies (Asakawa & Som, 2008; Athreye et al., 2014). Prior studies mainly focused on the organizational level, how organizations operate international R&D and how they manage information flows. However, research that analyze project level are limited. To fill this gap, this subsidiary study focuses on project level specifically

basic research projects which aim at creating new knowledge. This kind of project requires strong research collaboration between researchers to exchange their knowledge intensively.

The globalization of business provides more opportunities for organizations to broaden their collaboration with international partners and tap into global knowledge resources, however, it comes with challenges. The global dimension brings difficulty to the projects in terms of collaboration between project members of different backgrounds, and the R&D dimension adds difficulty to the projects in terms of process complexity and outcome uncertainty. von Zedtwitz et al. (2004) identified ten challenges for managing global innovation and two of them require contributions from individual R&D managers. First, decentralized R&D processes and virtual innovation teams, the managers facilitate communication and coordination between team members. Second, managing knowledge and human resources, the managers supervise talented engineers and researchers who have diverse backgrounds to work together effectively. This viewpoint, the contribution of individual managers, is in line with the research of Thamhain (2009b) who explored managerial practice challenges in multinational R&D operations and found that sophisticated people skills of team leaders are crucial to effective role performance in addition to the effective use of project management tools and techniques. Such kind of sophisticated people skills is useful in global projects that involve differences in languages, national cultures, and time zones (Binder, 2007; Vahtera et al., 2017). Scholars further explored the challenges of global team communication, coordination, and knowledge management (Bird & Mendenhall, 2016; Bouncken et al., 2016; Hurtado-Torres et al., 2018). However, the majority of prior studies paid more attention to team innovativeness and performance rather than the contribution of individual team members.

Managing knowledge and human resources are challenges for global innovation management (von Zedtwitz et al., 2004), which pointed out the importance of knowledge management in global R&D operations. Elkins and Keller (2003) reviewed the literature on leadership and found that the skills and roles of leaders in R&D organizations have a relationship with R&D project success. Elkins and Keller (2003) also highlighted the contribution of individual leaders who improve global R&D projects by playing a boundary-spanning role to create links between higher-level management and project team members. Knowledge is highly subjective and embedded within individuals (Nonaka & Takeuchi, 1995; Nonaka et al., 1996), this emphasizes the importance of individual leaders to facilitate knowledge creation process and research collaboration among project members, supervise talent human resources, and promote knowledge exchange in global R&D projects.

5.4 Bridge managers and their competencies

Project managers play several roles in parallel and at some points of the project, one role may be more important than others (Karlsen & Gottschalk, 2006). In global R&D projects, integration of R&D units into a global network and the diversity of global teams add more challenges to the managers (Binder, 2007; von Zedtwitz et al., 2004). By considering the higher complexity of business and global project environments where people of diverse backgrounds work together, project managers may pay more attention to the human aspect of project management. Project managers spend a great time and effort handling a broad range of activities. Thamhain (2009a) explored key factors that influence team performance of technology-intensive teams such as R&D teams and found that managers need sophisticated people skills and leadership to deal with the human aspect which influences team performance.

The managers who take care of collaboration between team members play important roles in R&D projects (Ettlie & Elsenbach, 2007; Thamhain, 2003; von Zedtwitz, 2003, 2004). Asakawa (2001a) explained an active broker's role as an influencer who in charge of information flow between headquarters and local laboratories in global R&D projects; it is important for local laboratory directors to influence information flow. Uchihira et al. (2017) characterized the roles of BMs who promote the utilization of global knowledge resources. BMs facilitate research collaboration between teams in different countries of global R&D projects (Chalarak et al., 2017). The roles of brokers and BMs in global R&D projects have been characterized. However, how BMs perform those roles effectively have not been explored.

It might be necessary for BMs to possess particular competencies to cope with the challenges of global R&D projects. Competency includes knowledge, skills, abilities, attitudes, and characteristics that help individuals to perform their tasks effectively (Athey & Orth, 1999; Fotis & Gregoris, 2006; Lustri et al., 2007; Teodorescu, 2006). The concept of competency has been developing for a few decades since McClelland (1973) reviewed the performance measurement of individuals using traditional intelligence tests and proposed competencies as a better alternative solution considering knowledge, skills, self-concepts, traits, and motives. Since then, competency became well known for researchers and practitioners who are interested in individual performance management. Identification of professional competencies for performing particular jobs has received attention from researchers and practitioners (Albetkova et al., 2019; Gowie et al., 2020; Mansfield, 1996).

The competency lists for specific professionals were identified such as medical workers (Gray, 2007; Mirzazadeh et al., 2014), research laboratory leaders (Albetkova et al., 2019), and construction

project managers (Cheng et al., 2005). This kind of framework helps organizations to maintain their competitiveness in a fast-changing business environment by paying attention to the competence of managers and leaders (Suikki et al., 2006). In the case of project management, the project manager competency development framework (PMCDF) was developed to identify the competencies of project managers for a broad application (Cartwright & Yinger, 2007; PMI, 2017). Scholars found that the competencies of managers have a relationship with project success (Cheng et al., 2005; Elkins & Keller, 2003; Geoghegan & Dulewicz, 2008; Yalaho & Nahar, 2010). In global R&D projects, it might be helpful for BMs to possess particular competencies that help them facilitate global R&D projects effectively. The behavioral competencies are linked to the effective performance of project managers (Cheng et al., 2005). The human side of projects may require managers to possess soft competencies to create an environment in which project members of diverse background can work together effectively.

As seen above, prior studies characterized the roles of BMs without informing how the managers perform their roles effectively and the competencies of managers have not been identified. This subsidiary study explores beyond the limitations of prior studies by examining the competencies of BMs along with their difficulties to facilitate global R&D projects. This subsidiary study examined the association between the competencies of BMs and the difficulties of global R&D projects.

5.5 Research methodology

This subsidiary study examines the relationships between the competencies of BMs and the difficulties they face when facilitating global R&D projects. The R&D bridge manager competency questionnaire was developed and used as a data collection tool. It was an online questionnaire and the uniform resource locator (URL) to access this online questionnaire was distributed by e-mail. The questionnaire was translated to the Japanese language by Japanese native speakers and then cross-check by another Japanese native speaker to ensure consistency of the content. A pilot test was done, and the questionnaire was improved based on suggestions from pilot respondents. On the first page of the questionnaire, participants were assured that answering this questionnaire was voluntary, confidential, no known risk, participants can refuse to answer the questionnaire at any time, and data analysis will be done anonymously for academic research purpose only.

The questionnaire has three sections including 1) context of global R&D projects, 2) difficulties of facilitating the projects and BM competencies, and 3) demographic information. The first section, project context, consisted of questions about the number of project members, project period, project stakeholders, and project outcomes. The second section is about the project difficulties and competencies of BMs. There are statements that describe eight difficult project situations, including quality control, project situation sharing, communication support, communication efficiency, research approach, quality cost and time priority, change request, and customer needs. The eight difficult project situation belong to the four difficulties mentioned in Chapter 4; they were derived from the interviews of managers who have experience in facilitating global R&D projects (Chalarak et al., 2017). The eight difficulties and their description are summarized in Table 5.1. The questionnaire asked participants to think about a global R&D project, and indicate their agreement with a series of statements on a three-point Likert-type scale: 1) strongly agree, 2) agree, 3) disagree or not relevant as shown in Appendix B and C.

Difficulty	**Description**
Quality control	There are differences in the expected quality of outcomes between the leading team and participating R&D teams.
Project situation sharing	The situation of the project on one side is not shared with another side. The leading team and participating R&D teams perceive the project differently.
Communication support	Foreign R&D teams do not have adequate communication with a leading team to get support.
Communication efficiency	The communication between the leading team and participating R&D teams is not efficient for creating mutual understanding.
Research approach	There are diverse approaches to conducting research. It is difficult to align the research approaches of participating R&D teams with the approaches expected by the leading team.
Quality, cost, and time priority	The leading team and participating R&D teams pay attention to quality, cost, and time differently when delivering outcomes.
Change request	The participating R&D teams are not convinced of the changes requested by the leading team.
Customer needs	It is difficult to transfer tacit elements of the requirements from one side to another when they are in globally dispersed locations.

Table 5.1: Difficulties in global R&D projects

Thamhain (2009a) explored key factors that influence performance of R&D teams and found that managers need sophisticated people skills and leadership to deal with the human aspect which influences team performance. Leadership competencies of managers have been recognized as an important driver for success of the company, especially in changing environmental conditions (Podgórska & Pichlak, 2019). In contrast, managerial competencies are knowledge, skills, and attitudes necessary to improve management performance (Martina et al., 2012). Leadership competencies are important for R&D teams in which team members conduct research under high level of uncertainty and dynamically change conditions. Leadership concerns with the influential ability, encourage and guide individuals and groups to achieve goals set by organizations (Asumeng, 2014). In addition, difficulties in global R&D projects such as requirement clarification and team communication are recognized, so existing leadership competencies potentially help the managers to overcome difficulties. Therefore, this subsidiary study focuses on leadership competencies as the primary role of BMs is to facilitate and motivate individual researchers in global R&D projects to conduct research in a complex and dynamically changing environment.

Competencies shown in the questionnaire were derived from relevant literature on competency and leadership. The operational definitions of the competencies are summarized in Table 5.2. There are 11 competencies including knowledge management skills, perception, resilience, decision making, understanding worldwide business environment, learning foreign culture and customs, communication skills, collaboration skills, empowering others, human resource management skills, and strategic perspective. The questionnaire provided additional detail of each competency for a clarification purpose as shown in Appendix D. The competencies were presented in a checkbox format. The questions asked participants to select multiple competencies up to five competencies that use for solving difficulties in the global R&D project. Lastly, demographic questions inquired about the gender, age, nationality, education, and years of experience of the respondents.

Competency	Operational definition	Sources
Managing knowledge and information	The ability of leaders who play roles such as mentor, or facilitator to elicit and integrate knowledge from different cultures.	Jang (2017); Nonaka and Takeuchi (1995); Von Krogh et al. (2012)
Perception (self-awareness)	An understanding of their emotions, strengths and weaknesses, needs and drives, sources of frustration, and reactions to problems. An extent of self-belief in the capability to manage emotions and to control their impact in the environment of the workplace.	Dulewicz and Higgs (2005); Tekleab et al. (2008); Tiina (2005)
Resilience	Ability to behave consistently in different pressing situations and adjust their behavior accordingly. Ability to recover from stress, adjust to stressful occasions, and behave above the norm regardless of stress or adversity.	Azevedo and Shane (2019); Dulewicz and Higgs (2005); Smith et al. (2008)
Decision making	Ability to get information, judging the qualities of things, services, or people.	Dulewicz and Higgs (2005); Ramsey et al. (2017); Rubin and Dierdorff (2009)
Understanding worldwide business environment	Ability to obtain the worldwide perspective and to combine worldwide diversity necessary for multinational firms.	Adler and Bartholomew (1992); Caligiuri (2006); Gregersen et al. (1998)
Learning foreign cultures and customs	Ability to interact with people from diverse cultures at the same time, adjust to living in foreign cultures. Conscious of, appreciation, thoughtful, and adjusting to cultural differences.	Adler and Bartholomew (1992); Caligiuri (2006); Pusch (2009); Terrell and Rosenbusch (2013)
Communication skills	Ability to communicate directions and vision to staff, adapt communication styles to the interest of audiences. Ability to use communication styles to inspire audiences.	Dulewicz and Higgs (2005)

Collaboration skills	Ability to interact with colleagues from different countries as equals.	Adler and Bartholomew (1992)
Empowering others	Ability to encourage staff to take on personally challenging demanding tasks. Delegate followers with responsibility and create an environment that help followers to satisfy needs for growth and autonomy.	Arnold et al. (2000); Dulewicz and Higgs (2005); Tekleab et al. (2008)
Human resource management skills	Ability to coach and develop others, resolve conflicts and negotiate with others, develop and build teams. Ability to utilize diverse practices of human resource management for different groups of employees.	Liu et al. (2003); Rubin and Dierdorff (2009)
Strategic perspective	Ability to see broad issues and implications, balance considerations of short-term and long-term. The knowledge, skills, and abilities needed to formulate value-creating strategic goals and strategies.	Dragoni et al. (2014); Dulewicz and Higgs (2005); Rubin and Dierdorff (2009)

Table 5.2: Operational definitions of competencies

The targeted respondents were identified based on their work experience. An inclusion criterion was that they involve in facilitating global R&D projects which have research activities that require collaboration between teams in the home country along with R&D teams in foreign countries. Respondents who have participated in global R&D projects were invited and asked for their opinions based on their experience. The target respondents were the managers who facilitate research collaboration in global R&D projects. The invitation to answer the questionnaire was sent to managers by e-mail asking them to respond to the questionnaire and forward the questionnaire to their colleagues who they think have experience in facilitating global R&D projects.

The questionnaire instruction asked participants to recall one project that they mostly contributed to. Then responded to the questions based on that project which was referred to as Project X throughout the questionnaire. The questionnaire provided a description of Project X which consists of two sides, one is called a leading team, and another is called the participating teams. The leading team has a project manager, and this team initiates the project. Participating teams have researchers and engineers, locate in foreign

countries. The leading team and participating R&D teams have research collaboration with each other. Figure 5.1 shows BMs in the context of global R&D projects. BMs primarily work with participating teams as Uchihira et al. (2017) identified the role of BMs to decompose R&D requirements and assign them to project members in the local organization. BMs mainly belong to participating teams.

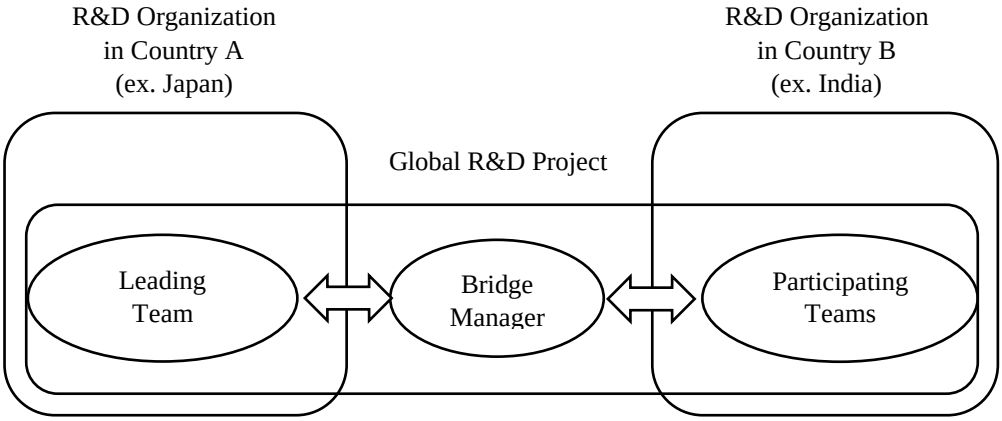


Figure 5.1: BMs in global R&D projects

Qualitative comparative analysis (QCA) was used to analyze data. QCA is defined as a set-theoretic method to analyze causal complexity by using Boolean algebra (Ragin, 1987). This method bridges qualitative and quantitative analysis to assess complex causation that involves different combinations of causal conditions, and it can be applied to research with small to intermediate N data sets e.g., 5 – 50 (Ragin, 1994). Legewie (2013) explained the advantages of using QCA, including it offers a systematic way to analyze complex causality and logical relations between causal factors and an outcome, it provides a cross-case comparison for qualitative research with medium-N data sets, it increases the transparency of data analysis, and it identifies data patterns which help to explain social phenomena.

There are parameters of QCA method that explain the results, including coverage and consistency. Consistency measures the degree to which membership in each combination of conditions is a subset of the outcome, consistency values could be between 0 to 1, 0 indicating no consistency, and 1 indicating perfect consistency (Legewie, 2013). Solution consistency measures the degree to which membership in each combination of conditions is a subset of the outcome. Coverage measures the percentage of an outcome covered by a combination of conditions, similar to R^2 in statistical models, and coverage values are between 0 to 1 (Legewie, 2013). Raw coverage measures the percentage of an outcome covered by each combination of conditions. Solution coverage measures the percentage of an outcome covered by all combinations of conditions. Unique coverage measures the percentage of an outcome covered by a combination of conditions that are not covered by other combinations.

5.6 Results and discussion

5.6.1 Project characteristics, difficulties, and improvement

The project characteristics include project size, project member's nationality, project outcome, project duration, and project stakeholder as shown in Table 5.3 and Table 5.4. Projects with 1 to 10 members account for 47.9% (35) of the responses. Similarly, projects with 11 to 50 members account for 46.6% (34) of all responses. Most of the respondents 68.5% (50) indicated that their projects have 2 to 3 nationalities of project members. Overall, 9.6% (7) of all responses indicate that their projects have only one nationality, 15.1% (11) indicate that they have 4 to 5 nationalities in their projects, and 6.8% (5) have more than 5 nationalities in their projects. The largest number of respondents 45.2% (33) referred to the projects that lasted between 6 to 12 months while 21.9% (16) of all responses referred to the projects that lasted between 13 to 24 months. The questionnaire allowed participants to select multiple choices for project outcomes. One project may deliver more than one type of outcome. The software and application outcome has the highest frequency (26) of all responses followed by system integration (20) and cloud service outcome has the lowest frequency (2).

Project characteristics	**Description**	**Frequency**	**Percentage**
Number of project members	1 to 10	35	47.9%
	11 to 50	34	46.6%
	51 to 100	2	2.7%
	More than 100	2	2.7%
Number of project member's nationalities	1	7	9.6%
	2 to 3	50	68.5%
	4 to 5	11	15.1%
	More than 5	5	6.8%
Project duration	Less than 6 months	13	17.8%
	6 to 12 months	33	45.2%
	13 to 24 months	16	21.9%
	25 to 36 months	2	2.7%
	More than 3 years	2	2.7%
	Ongoing	7	9.6%

Project outcomes	Software, Application	26	
	System Integration	20	
	Hardware, Device	13	
	Consulting	12	
	Elemental Technology	4	
	Cloud Service	2	

Table 5.3: Project characteristics (N = 73)

Besides project characteristics, respondents were asked about stakeholders they interacted with as shown in Table 5.4. The questionnaire separated stakeholders into two groups (under two separated questions) which are stakeholders in the leading country and stakeholders in participating countries. Each group has the same list of stakeholders. The results show that internal customers such as other departments in the company are the most selected stakeholder that the respondents collaborated with in the leading country (37) as same as in participating countries (30).

Project stakeholder	**Frequency**	
	In leading countries	**In participating countries**
External customers	24	21
External partners	26	24
Internal customers	37	30
Internal partners	29	29
Executives	19	25
Human resource department	4	7
University faculty and students	8	6
Government officials	7	5

Table 5.4: Stakeholders of the projects (N = 73)

Respondents reported whether they faced difficulties at the beginning of their projects. The results show that respondents are mostly faced with quality control difficulty (82.19%) and least faced with research approach difficulty (50.68%). In all eight difficulties, respondents reported that they faced difficulties more than 50%. Details on difficulties faced by respondents are illustrated in Table 5.5.

Difficulty	**Strongly agree**	**Agree**	**Disagree or Not relevant**	**Total**	**Percentage of Strongly agree and Agree**
Quality control	25	35	13	73	82.19%
Project situation sharing	19	32	22	73	69.86%
Communication support	13	33	27	73	63.01%
Communication efficiency	19	28	26	73	64.38%
Research approach	10	27	36	73	50.68%
Quality, cost, time priority	18	25	30	73	58.90%
Change request	12	31	30	73	58.90%
Customer needs	20	32	21	73	71.23%

Table 5.5: Project difficulties faced by the respondents (N = 73)

After being asked about each difficulty, the respondents were asked if the situation was changed or not at the end of the project. The results in Table 5.6 show that for the projects that faced difficulty, more than 65% of respondents indicated that the situation was improved. Quality control difficulty shows the highest percentage of improvement (90.00%), and the communication support difficulty shows the least improvement (65.22%).

The results in Table 5.6 suggest that quality control is highlighted in global R&D projects and managers make an effort to improve this difficulty. The quality control difficulty refers to a different expectation of headquarters and foreign R&D teams on the output quality. The headquarters may pay attention to quality as an outcome for customers, product ready for demonstration, or serving market needs. The foreign R&D teams, on the other hand, may pay attention to quality considering scientific or technological perspectives. In addition, the term quality may carry different interpretations in different cultures and this viewpoint is emphasized in the context of global R&D projects where project members are from diverse cultural backgrounds. The continuous improvement of quality or Kaizen is important in all related activities of R&D organizations (Montana, 1992). The concept of “If it isn’t perfect, make it

better" may be implemented in one culture or team but not others. Therefore, it is difficult for BMs to bridge the expectations of two sides and interpret the meaning of quality for the two sides to establish a mutual understanding.

Difficulty		**Not improved**	**Improved**	**Total**	**Percentage of Improved**
Quality control	Disagree or Not relevant	13		13	90.00%
	Agree	4	31	35	
	Strongly agree	2	23	25	
Project situation sharing	Disagree or Not relevant	22		22	76.47%
	Agree	8	24	32	
	Strongly agree	4	15	19	
Communication support	Disagree or Not relevant	27		27	65.22%
	Agree	13	20	33	
	Strongly agree	3	10	13	
Communication efficiency	Disagree or Not relevant	26		26	74.47%
	Agree	5	23	28	
	Strongly agree	7	12	19	
Research approach	Disagree or Not relevant	36		36	72.97%
	Agree	7	20	27	
	Strongly agree	3	7	10	
Quality, cost, time priority	Disagree or Not relevant	30		30	69.77%
	Agree	7	18	25	
	Strongly agree	6	12	18	
Change request	Disagree or Not relevant	30		30	69.77%
	Agree	10	21	31	
	Strongly agree	3	9	12	
Customer needs	Disagree or Not relevant	21		21	73.08%
	Agree	8	24	32	
	Strongly agree	6	14	20	

Table 5.6: Situation improvement at the end of the projects

5.6.2 Competencies for solving difficulties

The questionnaire asked the respondents to indicate whether they have encountered difficulty in their project. Then the following question asked the respondents to indicate whether they have used competencies to solve such difficulty. Based on this data the relevance ratio of competencies used for solving particular difficulties were calculated as shown in Table 5.7. The respondents reported that they used specific competencies to solve particular difficulties. The results in Table 5.7 suggest that different competencies have different levels of importance for solving difficulties in global R&D projects.

In the questionnaire, in addition to the questions asked whether the respondents encountered difficulties and whether they used competencies, there was a question asked whether the project situation was improved or not. Once the respondents indicated that they encountered difficulty and used competencies to solve such difficulty, they also indicated whether their project situation was improved or not. Based on the data that the project situation was improved, the percentage of competencies used for solving particular difficulties and improving the project situation was calculated as shown in Table 5.8. The respondents reported that after using specific competencies to solve particular difficulties, the project situation was improved. The results in Table 5.8 suggest that different competencies have different levels of importance for improving the situation of global R&D projects.

Quality control	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Disagree or Not relevant	13	0	13	0	13	0	13	0	13	0	13	0	13	0	13	0	13	0	13	0	13	0
Agree	17	18	18	17	24	11	24	11	22	13	19	16	15	20	23	12	30	5	32	3	29	6
Strongly agree	12	13	14	11	18	7	16	9	19	6	13	12	11	14	20	5	23	2	22	3	23	2
Total	42	31	45	28	55	18	53	20	54	19	45	28	39	34	56	17	66	7	67	6	65	8
Percentage of Used competency		51.67%		46.67%		30.00%		33.33%		31.67%		46.67%		56.67%		28.33%		11.67%		10.00%		13.33%

Project situation sharing	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Disagree or Not relevant	22	0	22	0	22	0	22	0	22	0	22	0	22	0	22	0	22	0	22	0	22	0
Agree	15	17	19	13	23	9	22	10	19	13	18	14	10	22	22	10	29	3	29	3	24	8
Strongly agree	9	10	11	8	14	5	13	6	13	6	12	7	10	9	15	4	16	3	16	3	18	1
Total	46	27	52	21	59	14	57	16	54	19	52	21	42	31	59	14	67	6	67	6	64	9
Percentage of Used competency		52.94%		41.18%		27.45%		31.37%		37.25%		41.18%		60.78%		27.45%		11.76%		11.76%		17.65%

Communication support	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Disagree or Not relevant	27	0	27	0	27	0	27	0	27	0	27	0	27	0	27	0	27	0	27	0	27	0
Agree	18	15	29	4	24	9	24	9	26	7	27	6	16	17	24	9	28	5	31	2	29	4
Strongly agree	7	6	8	5	9	4	11	2	11	2	11	2	9	4	12	1	12	1	11	2	13	0
Total	52	21	64	9	60	13	62	11	64	9	65	8	52	21	63	10	67	6	69	4	69	4
Percentage of Used competency		45.65%		19.57%		28.26%		23.91%		19.57%		17.39%		45.65%		21.74%		13.04%		8.70%		8.70%

Communication efficiency	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Disagree or Not relevant	26	0	26	0	26	0	26	0	26	0	26	0	26	0	26	0	26	0	26	0	26	0
Agree	15	13	19	9	17	11	22	6	20	8	16	12	13	15	24	4	25	3	26	2	24	4
Strongly agree	13	6	11	8	16	3	17	2	16	3	13	6	5	14	18	1	18	1	17	2	19	0
Total	54	19	56	17	59	14	65	8	62	11	55	18	44	29	68	5	69	4	69	4	69	4
Percentage of Used competency		40.43%		36.17%		29.79%		17.02%		23.40%		38.30%		61.70%		10.64%		8.51%		8.51%		8.51%

Research approach	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Disagree or Not relevant	36	0	36	0	36	0	36	0	36	0	36	0	36	0	36	0	36	0	36	0	36	0
Agree	13	14	16	11	23	4	20	7	18	9	18	9	15	12	17	10	23	4	25	2	22	5
Strongly agree	5	5	4	6	8	2	5	5	8	2	7	3	7	3	10	0	8	2	9	1	10	0
Total	54	19	56	17	67	6	61	12	62	11	61	12	58	15	63	10	67	6	70	3	68	5
Percentage of Used competency		51.35%		45.95%		16.22%		32.43%		29.73%		32.43%		40.54%		27.03%		16.22%		8.11%		13.51%

Quality, cost, time priority	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Disagree or Not relevant	30	0	30	0	30	0	30	0	30	0	30	0	30	0	30	0	30	0	30	0	30	0
Agree	15	10	17	8	17	8	16	9	13	12	19	6	11	14	19	6	22	3	22	3	22	3
Strongly agree	11	7	11	7	13	5	15	3	11	7	11	7	12	6	14	4	18	0	17	1	14	4
Total	56	17	58	15	60	13	61	12	54	19	60	13	53	20	63	10	70	3	69	4	66	7
Percentage of Used competency		39.53%		34.88%		30.23%		27.91%		44.19%		30.23%		46.51%		23.26%		6.98%		9.30%		16.28%

Change request	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Disagree or Not relevant	29	1	29	1	30	0	30	0	29	1	30	0	29	1	29	1	30	0	30	0	29	1
Agree	17	14	22	9	20	11	20	11	20	11	24	7	18	13	23	8	24	7	31	0	26	5
Strongly agree	8	4	10	2	10	2	9	3	9	3	7	5	7	5	9	3	10	2	9	3	11	1
Total	54	19	61	12	60	13	59	14	58	15	61	12	54	19	61	12	64	9	70	3	66	7
Percentage of Used competency		44.19%		27.91%		30.23%		32.56%		34.88%		27.91%		44.19%		27.91%		20.93%		6.98%		16.28%

Customer needs	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Disagree or Not relevant	21	0	21	0	21	0	21	0	21	0	21	0	21	0	21	0	21	0	21	0	21	0
Agree	18	14	24	8	26	6	25	7	22	10	27	5	17	15	25	7	29	3	30	2	26	6
Strongly agree	10	10	14	6	13	7	17	3	13	7	15	5	9	11	13	7	18	2	19	1	20	0
Total	49	24	59	14	60	13	63	10	56	17	63	10	47	26	59	14	68	5	70	3	67	6
Percentage of Used competency		46.15%		26.92%		25.00%		19.23%		32.69%		19.23%		50.00%		26.92%		9.62%		5.77%		11.54%

Table 5.7: Competencies used for difficulties (All data)

Quality control	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Agree	14	17	14	17	21	10	20	11	18	13	15	16	13	18	20	11	26	5	28	3	25	6
Strongly agree	12	11	12	11	17	6	14	9	18	5	13	10	10	13	18	5	21	2	20	3	21	2
Total	26	28	26	28	38	16	34	20	36	18	28	26	23	31	38	16	47	7	48	6	46	8
Percentage of Used competency		51.85%		51.85%		29.63%		37.04%		33.33%		48.15%		57.41%		29.63%		12.96%		11.11%		14.81%

Project situation sharing	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Agree	11	13	13	11	17	7	16	8	13	11	13	11	8	16	16	8	22	2	23	1	17	7
Strongly agree	6	9	8	7	10	5	10	5	12	3	10	5	7	8	11	4	12	3	12	3	14	1
Total	17	22	21	18	27	12	26	13	25	14	23	16	15	24	27	12	34	5	35	4	31	8
Percentage of Used competency		56.41%		46.15%		30.77%		33.33%		35.90%		41.03%		61.54%		30.77%		12.82%		10.26%		20.51%

Communication support	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Agree	12	8	18	2	15	5	13	7	14	6	14	6	8	12	13	7	17	3	19	1	17	3
Strongly agree	4	6	5	5	6	4	8	2	8	2	9	1	6	4	9	1	9	1	9	1	10	
Total	16	14	23	7	21	9	21	9	22	8	23	7	14	16	22	8	26	4	28	2	27	3
Percentage of Used competency		46.67%		23.33%		30.00%		30.00%		26.67%		23.33%		53.33%		26.67%		13.33%		6.67%		10.00%

Communication efficiency	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Agree	14	9	16	7	15	8	18	5	16	7	13	10	10	13	21	2	21	2	22	1	21	2
Strongly agree	7	5	6	6	9	3	10	2	9	3	7	5	2	10	11	1	11	1	12	0	12	0
Total	21	14	22	13	24	11	28	7	25	10	20	15	12	23	32	3	32	3	34	1	33	2
Percentage of Used competency		40.00%		37.14%		31.43%		20.00%		28.57%		42.86%		65.71%		8.57%		8.57%		2.86%		5.71%

Research approach	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Agree	10	10	13	7	16	4	14	6	12	8	12	8	12	8	13	7	17	3	18	2	15	5
Strongly agree	3	4	2	5	5	2	3	4	5	2	5	2	5	2	7	0	5	2	7	0	7	0
Total	13	14	15	12	21	6	17	10	17	10	17	10	17	10	20	7	22	5	25	2	22	5
Percentage of Used competency		51.85%		44.44%		22.22%		37.04%		37.04%		37.04%		37.04%		25.93%		18.52%		7.41%		18.52%

Quality, cost, time priority	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Agree	11	7	11	7	13	5	12	6	8	10	14	4	8	10	14	4	15	3	16	2	15	3
Strongly agree	6	6	6	6	7	5	9	3	6	6	7	5	8	4	9	3	12	0	12	0	8	4
Total	17	13	17	13	20	10	21	9	14	16	21	9	16	14	23	7	27	3	28	2	23	7
Percentage of Used competency		43.33%		43.33%		33.33%		30.00%		53.33%		30.00%		46.67%		23.33%		10.00%		6.67%		23.33%

Change request	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Agree	11	10	13	8	13	8	12	9	13	8	15	6	10	11	15	6	17	4	21	0	17	4
Strongly agree	6	3	8	1	7	2	6	3	7	2	6	3	5	4	6	3	7	2	7	2	8	1
Total	17	13	21	9	20	10	18	12	20	10	21	9	15	15	21	9	24	6	28	2	25	5
Percentage of Used competency		43.33%		30.00%		33.33%		40.00%		33.33%		30.00%		50.00%		30.00%		20.00%		6.67%		16.67%

Customer needs	KM		Perception		Resilience		Decision making		Understanding worldwide business		Learning foreign culture		Communication		Collaboration		Empowering		Human resource management		Strategic perspective	
	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used	Not use	Used
Agree	13	11	18	6	19	5	20	4	15	9	21	3	13	11	19	5	21	3	23	1	20	4
Strongly agree	7	7	9	5	8	6	11	3	8	6	11	3	5	9	8	6	13	1	13	1	14	0
Total	20	18	27	11	27	11	31	7	23	15	32	6	18	20	27	11	34	4	36	2	34	4
Percentage of Used competency		47.37%		28.95%		28.95%		18.42%		39.47%		15.79%		52.63%		28.95%		10.53%		5.26%		10.53%

Table 5.8: Competencies used for difficulties (Improved projects)

Different competencies have different levels of importance for solving difficulties and improving the situation of global R&D projects as shown in Table 5.7 and 5.8. Based on the results in Table 5.8, the percentages of used competencies and improved project situation were arranged in a simplified table as shown in Table 5.9. This table shows the data of improved project situation. It shows the percentage of competencies used for solving different difficulties. The last row shows the average percentages of all difficulties. The columns of competencies were ordered by the average percentages, communication has the highest average percentage and human resource management has the lowest average percentage.

The results in Table 5.9 suggest three groups of competencies. First, communication and knowledge management belong to the group which has a relatively higher percentage of competencies used. Second, perception, understanding worldwide business, learning foreign culture, decision making, resilience, and collaboration belong to the group which has a relatively moderate percentage of competencies used. Third, strategic perspective, empowering other, and human resource management belong to the group which has a relatively lower percentage of competencies used. The competencies in the last group could be considered relatively less important or less relevant for solving difficulties in global R&D projects. By considering the first and the second groups, communication, knowledge management, and collaboration are considered well-recognized and common competencies for the managers to manage their knowledge-intensive projects which require more interactions between project members (Brandl, 2019). Hence, further analysis focuses on the five competencies, including perception, understanding worldwide business, learning foreign culture, decision making, and resilience.

Difficulties	Communication	KM	Perception	Understanding worldwide business	Learning foreign culture	Decision making	Resilience	Collaboration	Strategic perspective	Empowering	Human resource management
Quality control	57.41%	51.85%	51.85%	33.33%	48.15%	37.04%	29.63%	29.63%	14.81%	12.96%	11.11%
Project situation sharing	61.54%	56.41%	46.15%	35.90%	41.03%	33.33%	30.77%	30.77%	20.51%	12.82%	10.26%
Communication support	53.33%	46.67%	23.33%	26.67%	23.33%	30.00%	30.00%	26.67%	10.00%	13.33%	6.67%
Communication efficiency	65.71%	40.00%	37.14%	28.57%	42.86%	20.00%	31.43%	8.57%	5.71%	8.57%	2.86%
Research approach	37.04%	51.85%	44.44%	37.04%	37.04%	37.04%	22.22%	25.93%	18.52%	18.52%	7.41%
Quality, cost, time priority	46.67%	43.33%	43.33%	53.33%	30.00%	30.00%	33.33%	23.33%	23.33%	10.00%	6.67%
Change request	50.00%	43.33%	30.00%	33.33%	30.00%	40.00%	33.33%	30.00%	16.67%	20.00%	6.67%
Customer needs	52.63%	47.37%	28.95%	39.47%	15.79%	18.42%	28.95%	28.95%	10.53%	10.53%	5.26%
Average Percentage	53.04%	47.60%	38.15%	35.96%	33.52%	30.73%	29.96%	25.48%	15.01%	13.34%	7.11%

Table 5.9: Percentage of used competencies (Improved projects)

The competency-based approaches are an important tool in many organizational functions as they provide identification of skills, knowledge, and behaviors for personnel selection and they focus on individuals and groups to develop required competencies (Fotis & Gregoris, 2006). The results in Table 5.9 suggest that different competencies are required to improve different difficulties. It is possible that the competencies of BMs can be identified by considering the difficulties they face when they perform their job in the context of global R&D projects. Competency models in the past emphasized understanding work behavior by focusing on job duties and tasks, later rapidly changing business environment and the globalization of business influence people development independently of specific jobs (Hollenbeck et al., 2006). In the fast-changing global R&D project environment, BM competency identification may benefit from the analysis of global R&D project difficulties. These difficulties may inform important competencies of BMs to facilitate research collaboration in global R&D projects. The results in Table 5.9 suggest that BMs possess different competencies to solve different difficulties.

In the knowledge-intensive era, knowledge management skills and communication are typical competencies that can lead to a more comprehensive and varied information flow in the context of R&D management (Kerssens-Van Drongelen et al., 1996). Collaboration skills, in addition, are also important especially in transnational projects where managers have to interact with colleagues from different countries as equals (Adler & Bartholomew, 1992). The results show that knowledge management and communication skills are used for solving all difficulties by BMs. However, collaboration skills are used for solving some difficulties and in relatively lesser than knowledge management and communication skills. This might be due to the fact that the respondents reported that they interacted mostly with internal stakeholders. Therefore, collaboration with internal stakeholders who share the same organizational goals and strategies may require less effort compared to collaboration with external stakeholders. Although BMs collaborate with foreign researchers having different national cultures making it more challenging for cross-cultural collaboration, they are working in the same organization sharing the same organizational values and practices. Thus, they reported less in using collaboration skills to solve difficulties in their projects.

5.6.3 Combinations of competencies for solving particular difficulties

Qualitative comparative analysis (QCA) was used to analyze the relationships between configurations of competencies and difficulties. Dreyfus (2008) argued that highly effective R&D managers demonstrated two competencies which are managing groups and interpersonal sensitivity. The definitions of managing groups and interpersonal sensitivity cover eight competencies in this dissertation, including knowledge management, perception, resilience, decision making, understanding worldwide business, learning foreign culture, communication, and collaboration. Prior studies also recognized that knowledge management, communication, and collaboration are important competencies for managers to manage their projects in the era of the knowledge economy (Moradi et al., 2019; Ram & Ronggui, 2018; Thamhain, 2003; Vlajčić et al., 2019). Based on the existing understanding, further analysis was conducted focusing on five competencies, including perception, understanding worldwide business, learning foreign culture, decision making, and resilience. The five competencies were analyzed using the QCA method.

The results of the QCA method in Table 5.10 indicate various two-competency configurations with the highest raw coverage that lead to solving difficulties. The results indicate that, first, managers can solve the quality control difficulty through the configuration of perception competency and decision-making skills. This configuration also helps managers to solve project situation sharing difficulty, research approach difficulty, and change request difficulty. Second, managers can solve the communication support difficulty, communication efficiency difficulty, research approach difficulty, and customer need difficulty through the configuration of understanding worldwide business and learning foreign culture. Third, managers can solve the quality, cost, time priority difficulty through the configuration of perception competency and understanding worldwide business.

The results in Table 5.10 also show the relevance ratio of combination between 2 competencies. For example, for quality control difficulty, perception competency combines with decision-making skills, frequency of perception competency alone is 14, frequency of decision-making skills alone is 16, and frequency of perception competency and decision making skills together is 14. Thus, percentage of combination is 14/(14+16+14) = 31.82%. There are three configurations that have a percentage of combination more than or equal to 50%. First, resilience competency combines with understanding worldwide business help to solve communication efficiency difficulty. Second, decision-making skills combine with understanding worldwide business help BMs to solve research approach difficulty. Third, perception competency combines with decision-making skills help BMs to solve change request difficulty.

Difficulty	Competency					Coverage		Frequency			
	Perception	Resilience	Decision making	Understanding worldwide business	Learning foreign culture	Raw	Unique	Competency 1	Competency 2	Combination between competency 1 and 2	Percentage of combination
Quality control	●		●			0.259	0.019	14	16	14	31.82%
Project situation sharing	●		●			0.231	0.026	9	3	9	42.86%
Communication support				●	●	0.167	0.067	3	5	2	20.00%
Communication efficiency	●	●				0.200	0.057	9	7	4	20.00%
		●		●		0.200	0.000	4	3	7	50.00%
				●	●	0.200	0.029	3	8	7	38.89%
Research approach	●		●			0.222	0.037	6	6	6	33.33%
			●	●		0.222	0.037	0	4	6	60.00%
				●	●	0.222	0.074	4	4	6	42.86%
Quality, cost, time priority	●			●		0.233	0.100	6	11	7	29.17%
Change request	●		●			0.233	0.000	2	5	7	50.00%
		●	●			0.233	0.000	3	5	7	46.67%
Customer needs				●	●	0.158	0.053	9	0	6	40.00%

Table 5.10: Configurations of competencies and difficulties

5.6.4 Project attributes and difficulties

Respondents reported their project attributes including, project size – number of project members, project output – types of outputs from the projects, project time – duration of the project, and nationality – number of nationalities of project members. Figure 5.2 and Figure 5.3 show data distribution of the project size and project time respectively. The raw data of project attributes were separated into two groups using threshold considering balancing data between the two groups.

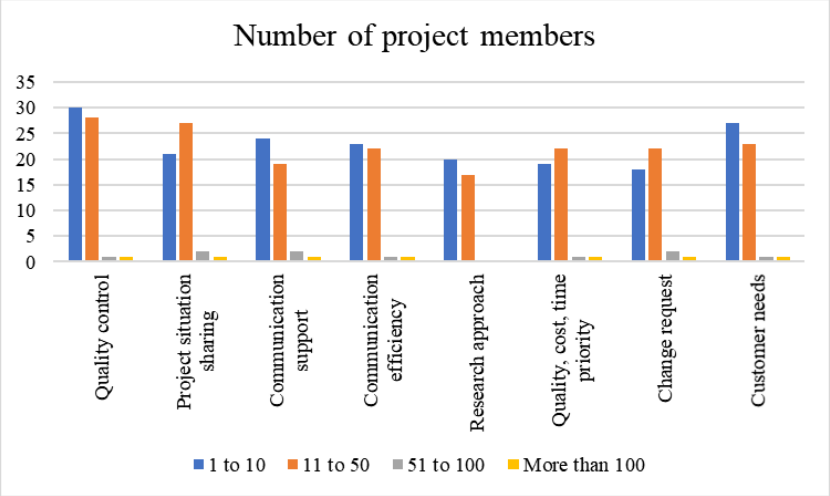


Figure 5.2: Data distribution of project size

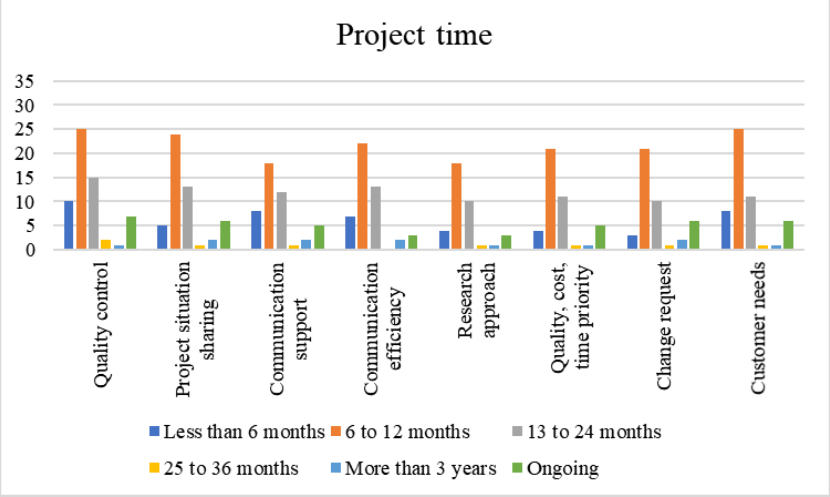


Figure 5.3: Data distribution of project time

The number of project members was separated into 1 to 10 members and more than 10 members. Project time was separated into less than 12 months and more than 12 months. Project output, on the other hand, was categorized into two groups considering the difference between the nature of hardware projects and non-hardware projects. The hardware development typically requires long timescales and significant initial investment (Pearson et al., 2020). Hardware modification requires a thorough change process for redesigning. In contrast, non-hardware projects are more flexible in their research and development activities. The project size can be separated into 2 groups, 1) 1 to 10 members, and 2) more than 10 members. Respondents in different groups reported different difficulties they faced in their projects. The results in Table 5.11 shows that projects with 1 to 10 members faced difficulties (average 65.00%) more than projects with more than 10 members (average 64.80%).

Difficulty	Frequency			Percentage		
	1 to 10 members	More than 10 members	Total	1 to 10 members	More than 10 members	Total
All data	35	38	73	100.00%	100.00%	100.00%
Quality control	30	30	60	85.71%	78.95%	82.19%
Project situation sharing	21	30	51	60.00%	78.95%	69.86%
Communication support	24	22	46	68.57%	57.89%	63.01%
Communication efficiency	23	24	47	65.71%	63.16%	64.38%
Research approach	20	17	37	57.14%	44.74%	50.68%
Quality, cost, time priority	19	24	43	54.29%	63.16%	58.90%
Change request	18	25	43	51.43%	65.79%	58.90%
Customer needs	27	25	52	77.14%	65.79%	71.23%
Average percentage of difficulty				65.00%	64.80%	64.90%

Table 5.11: Project size and difficulty

Respondents reported that their projects delivered several types of outputs which can be categorized into 2 groups, 1) hardware output and 2) non-hardware output. Respondents in different groups reported different difficulties they faced in their project. The results in Table 5.12 shows that projects that delivered hardware output faced difficulties (average 79.81%) more than projects that delivered non-hardware output (average 61.67%).

Difficulty	Frequency			Percentage		
	Hardware	Non-hardware	Total	Hardware	Non-hardware	Total
All data	13	60	73	100.00%	100.00%	100.00%
Quality control	12	48	60	92.31%	80.00%	82.19%
Project situation sharing	12	39	51	92.31%	65.00%	69.86%
Communication support	9	37	46	69.23%	61.67%	63.01%
Communication efficiency	8	39	47	61.54%	65.00%	64.38%
Research approach	10	27	37	76.92%	45.00%	50.68%
Quality, cost, time priority	11	32	43	84.62%	53.33%	58.90%
Change request	10	33	43	76.92%	55.00%	58.90%
Customer needs	11	41	52	84.62%	68.33%	71.23%
Average percentage of difficulty				79.81%	61.67%	64.90%

Table 5.12: Project output and difficulty

Respondents reported their project time which can be categorized into 2 groups, 1) less than 12 months, and 2) more than 12 months. Respondents in different groups reported different difficulties they faced in their project. The results in Table 5.13 shows that projects of less than 12 months faced difficulties (average 60.60%) less than projects of more than 12 months (average 72.22%).

Difficulty	Frequency			Percentage		
	Less than 12 months	More than 12 months	Total	Less than 12 months	More than 12 months	Total
All data	46	27	73	100.00%	100.00%	100.00%
Quality control	35	25	60	76.09%	92.59%	82.19%
Project situation sharing	29	22	51	63.04%	81.48%	69.86%
Communication support	26	20	46	56.52%	74.07%	63.01%
Communication efficiency	29	18	47	63.04%	66.67%	64.38%
Research approach	22	15	37	47.83%	55.56%	50.68%
Quality, cost, time priority	25	18	43	54.35%	66.67%	58.90%
Change request	24	19	43	52.17%	70.37%	58.90%
Customer needs	33	19	52	71.74%	70.37%	71.23%
Average percentage of difficulty				60.60%	72.22%	64.90%

Table 5.13: Project time and difficulty

Respondents reported that their projects had members from diverse nationalities which can be categorized into 2 groups, 1) 1 to 3 nationalities, and 2) more than 3 nationalities. Respondents in different groups reported different difficulties they faced in their project. The results in Table 5.14 shows that projects with 1 to 3 nationalities faced difficulties (average 64.04%) less than projects with more than 3 nationalities (average 67.97%).

Difficulty	Frequency			Percentage		
	1 to 3 nationalities	More than 3 nationalities	Total	1 to 3 nationalities	More than 3 nationalities	Total
All data	57	16	73	100.00%	100.00%	100.00%
Quality control	48	12	60	84.21%	75.00%	82.19%
Project situation sharing	39	12	51	68.42%	75.00%	69.86%
Communication support	36	10	46	63.16%	62.50%	63.01%
Communication efficiency	37	10	47	64.91%	62.50%	64.38%
Research approach	29	8	37	50.88%	50.00%	50.68%
Quality, cost, time priority	33	10	43	57.89%	62.50%	58.90%
Change request	30	13	43	52.63%	81.25%	58.90%
Customer needs	40	12	52	70.18%	75.00%	71.23%
Average percentage of difficulty				64.04%	67.97%	64.90%

Table 5.14: Project member's nationalities and difficulty

In addition, respondents reported their experience of working in the positions in terms of years of experience. This data can be categorized into 2 groups, 1) less than 10 years, and 2) more than 10 years. Respondents in different groups reported different difficulties they faced in their project. The results in Table 5.15 show that managers who have less than 10 years of experience faced difficulties (average 69.19%) more than managers who have more than 10 years of experience (average 58.75%).

Difficulty	Frequency			Percentage		
	Less than 10 years	More than 10 years	Total	Less than 10 years	More than 10 years	Total
All data	43	30	73	100.00%	100.00%	100.00%
Quality control	37	23	60	86.05%	76.67%	82.19%
Project situation sharing	31	20	51	72.09%	66.67%	69.86%
Communication support	29	17	46	67.44%	56.67%	63.01%
Communication efficiency	28	19	47	65.12%	63.33%	64.38%
Research approach	25	12	37	58.14%	40.00%	50.68%
Quality, cost, time priority	28	15	43	65.12%	50.00%	58.90%
Change request	26	17	43	60.47%	56.67%	58.90%
Customer needs	34	18	52	79.07%	60.00%	71.23%
Average percentage of difficulty				69.19%	58.75%	64.90%

Table 5.15: Manager's experience and difficulty

The results in Table 5.11 to Table 5.15 suggest that different project sizes, project outputs, and project time may cause different difficulties in global R&D projects. Thus, BMs may require different competencies to solve difficulties in different project attributes. On the other hand, the results also suggest that differences in the number of nationalities of project members cause no difference in the difficulty. Only one exception in change request difficulty is that projects with more than 3 nationalities have more difficulty than projects with 1 to 3 nationalities. Cultural diversity influences the performance of global innovation teams, especially when communication increases among team members (members from low context have difficulties understanding members from high context) (Winkler & Bouncken, 2011). Change request difficulty in global R&D projects requires intensive communication for the foreign R&D teams to be convinced to implement changes. The more nationalities in global R&D projects, the opportunity for change request difficulty to occur.

5.6.5 Combinations of project attributes and difficulties

Various configurations on the combination of project attributes using the QCA method are proposed which lead to difficulty (Dx) and result in no difficulty (~Dx), as shown in Table 5.16. The full detailed results generated from the software fsQCA 3.0 for Windows can be found in Appendix E. Three project attributes which showed different difficulties between two groups in each attribute were used in this analysis, including project size, project output, and project time. Based on the consistency value more than or equal to 0.8, the results indicate that, first, BMs can face quality control difficulty (D1) through two configurations, including projects with more than 10 members (ID_1), or projects with 1 to 10 members with non-hardware output (ID_2). Second, the BMs can face communication support difficulty (D3), research approach difficulty (D5), quality, cost, time priority difficulty (D6), and change request difficulty (D7) through the configuration of hardware output projects with time more than 12 months (ID_12 = ID_20 = ID_23 = ID_27). Third, BMs can face communication efficiency difficulty (D4), and customer needs difficulty (D8) through the configuration of projects with 1 to 10 members, non-hardware output, and time more than 12 months (ID_15 = ID_33). Fourth, BMs can face quality, cost, time priority difficulty (D6), change request difficulty (D7), and customer needs difficulty (D8) through the configuration of projects with more than 10 members with hardware output (ID_24 = ID_28 = ID_31). Lastly, BMs can face research approach difficulty through the configuration of projects with 1 to 10 members with time more than 12 months (ID_19).

The quality control difficulty is the different expectations of output quality between headquarters and foreign R&D teams. To incorporate quality in R&D, a vision statement by the R&D unit should be presented, thoroughly communicated to all members, and linked to the overall business quality strategy (Montana, 1992). In a small project having less than 10 members, using informal coordination mechanisms, the quality criteria may not be formally and thoroughly communicated to all members. Further, the change request difficulty arises when foreign R&D teams are not convinced of the changes in research requested by headquarters. In international R&D projects, once teams grow up, more R&D sites are involved, target technology has been invented, product structure changes are very costly (von Zedtwitz, 2020). Change implementation that involves more people tends to be a more challenging task. BMs have to establish mutual agreement and convince foreign R&D teams to alter their research which may already be accomplished. Trust between headquarters and foreign R&D teams could be one of the reasons for foreign R&D teams to follow the changes requested by headquarters. Time is required for partners in international R&D projects to build up the relationship and develop trust and respect (von Zedtwitz, 2020).

Difficulty	ID	Project attributes			Coverage		Consistency	Solution	
		Size	Output	Time	Raw	Unique		Coverage	Consistency
D1	1			○	0.417	0.267	0.926	0.800	0.906
	2	●	○		0.417	0.350	0.862		
	3	○	●		0.117	0.033	1.000		
~D1	4			○	0.154	0.077	0.074	0.385	0.094
	5	●	○		0.308	0.231	0.138		
	6	○	●		0.000	0.000	0.000		
D2	7		●	○	0.157	0.059	1.000	0.196	1.000
	8	○	●		0.137	0.039	1.000		
~D2	9		●	○	0.000	0.000	0.000	0.000	0.000
	10	○	●		0.000	0.000	0.000		
D3	11	●		○	0.174	0.109	1.000	0.261	0.923
	12		●	○	0.152	0.087	0.875		
~D3	13	●		○	0.000	0.000	0.000	0.037	0.077
	14		●	○	0.037	0.037	0.125		
D4	15	●	○	○	0.085	0.085	0.800	0.149	0.875
	16	●	●	●	0.064	0.064	1.000		
~D4	17	●	○	○	0.038	0.038	0.200	0.038	0.125
	18	●	●	●	0.000	0.000	0.000		
D5	19	●		○	0.189	0.108	0.875	0.297	0.846
	20		●	○	0.189	0.108	0.875		
~D5	21	●		○	0.028	0.028	0.125	0.056	0.154
	22		●	○	0.028	0.028	0.125		
D6	23		●	○	0.163	0.070	0.875	0.209	0.900
	24	○	●		0.140	0.047	0.857		
~D6	25		●	○	0.033	0.000	0.125	0.033	0.100
	26	○	●		0.033	0.000	0.143		
D7	27		●	○	0.163	0.070	0.875	0.209	0.900
	28	○	●		0.140	0.047	0.857		
~D7	29		●	○	0.033	0.000	0.125	0.033	0.100
	30	○	●		0.033	0.000	0.143		
D8	31	○	●		0.115	0.077	0.857	0.250	0.867
	32		●	●	0.096	0.058	1.000		
	33	●	○	○	0.077	0.077	0.800		
~D8	34	○	●		0.048	0.048	0.143	0.095	0.133
	35		●	●	0.000	0.000	0.000		
	36	●	○	○	0.048	0.048	0.200		

Note:

D1 = Quality control, D2 = Project situation sharing, D3 = Communication support, D4 = Communication efficiency, D5 = Research approach, D6 = Quality, cost, time priority, D7 = Change request, D8 = Customer needs

Blank = presence or absence of a condition

Project size: ● = 1 to 10 members, ○ = More than 10 members

Project output: ● = Hardware, ○ = Non hardware

Project time: ● = Less than 12 months, ○ = More than 12 months

Difficulty: Dx = Strongly agree, Agree, ~Dx = Disagree or Not relevant

Table 5.16: Configurations of project attributes and difficulties

5.6.6 Competencies for solving particular difficulties with specific project attributes

Cross-comparison between project attributes (size, output, time) and difficulties provides insight into which competency the BMs should have for a more specific context. The results in Table 5.17 show three interesting findings. First, for quality control difficulty, projects that last for less than 12 months require managers to have perception competency while projects that last more than 12 months require managers to have decision-making skills. Time-critical is one important reason for organizations to execute transnational R&D projects which require high communication and travel costs; Time-to-market is very important for products that profits mostly depend on early market launch (von Zedtwitz, 2020). The projects with a short period of time may cause quality control difficulty for BMs as they have limited time to communicate quality requirements and criteria to all team members. Time is also important for trust-building in international R&D projects as trust suffers from the spatial distance between members (von Zedtwitz, 2020). This requires BMs to possess perception competency or self-awareness to realize their strengths and confidence to ensure quality throughout the projects and facilitate trust development under pressing time constraints. On the other hand, projects with a longer time could have thoroughly project planning and information about outcome quality are well communicated. However, BMs require decision-making skills to decide which information should be communicated at what time or stage throughout the long project duration.

Second, for quality, cost, time priority difficulty, projects with 1 to 10 members require managers to have an ability to understand worldwide business while projects with more than 10 members require managers to have resilience competency. The projects with a small number of members may have difficulty setting the priority of quality, cost, and time as these kinds of projects have fewer formal mechanisms in their project coordination. The formal coordination mechanisms in global R&D organizations include regular meetings, standard processes, conference calls, or the standard document exchange (Zeschky et al., 2014). Therefore, BMs should possess an ability to understand worldwide business to understand the situation and environment of headquarters and foreign R&D teams. Then, based on such understanding, BMs can facilitate formal coordination, including setting the priority of quality, cost, and time for delivery

of the outcomes. On the contrary, projects with more than 10 members may use more formal coordination mechanisms, have better criteria to define the priority of quality, cost, and time. However, once the outcome is delivered with different priorities between headquarters and foreign R&D teams, BMs may perceive higher pressure as delivery usually occurs at the later stages of the project, making any changes is costly. Under this tough situation, BMs require resilience when working in stressful circumstances to bridge the gap between both sides.

Third, also for quality, cost, time priority difficulty, projects with hardware output require managers to have resilience competency. The quality, cost, time priority difficulty occurs when foreign R&D teams deliver outcome by pay attention to time rather than quality while headquarters are seeking quality outcomes for demonstration with customers. The hardware development typically requires long timescales and significant initial investment (Pearson et al., 2020). After a long period of time and using some amount of investment, foreign R&D teams are likely to deliver hardware output as soon as possible. On contrary, headquarters expect output with high quality or ready to be demonstrated. In addition, modification of hardware requires a thorough change process for design alteration. BMs require resilience to perform consistently in diverse situations under pressure to navigate the change process and adjust the priority expected by both sides.

		Project Size		Project Output		Project Time	
		1-10 members	More than 10 members	Hardware	Non hardware	Less than 12 months	More than 12 months
Quality control	Competency	Perception (10), Understanding worldwide business (10), Learning foreign culture (10)	Perception (18)	Perception (6)	Perception (22)	Perception (17)	Decision making (14)
	Raw coverage	0.40	0.62	0.55	0.51	0.55	0.61
Project situation sharing	Competency	Learning foreign culture (6)	Perception (13)	Perception (5), Decision making (5), Learning foreign culture (5)	Perception (13)	Perception (10)	Decision making (10)
	Raw coverage	0.40	0.54	0.46	0.46	0.44	0.63
Communication support	Competency	Learning foreign culture (4)	Decision making (7)	Decision making (4)	Resilience (6), Understanding worldwide business (6)	Decision making (5)	Resilience (6)
	Raw coverage	0.29	0.44	0.50	0.27	0.29	0.46
Communication efficiency	Competency	Perception (5), Learning foreign culture (5)	Learning foreign culture (10)	Perception (2), Resilience (2), Decision making (2), Understanding worldwide business (2), Learning foreign culture (2)	Learning foreign culture (14)	Learning foreign culture (8)	Understanding worldwide business (7), Learning foreign culture (7)
	Raw coverage	0.29	0.56	0.40	0.47	0.38	0.50
Research approach	Competency	Perception (5)	Decision making (8)	Perception (4), Decision making (4), Understanding worldwide business (4)	Perception (8)	Perception (7)	Understanding worldwide business (7)
	Raw coverage	0.39	0.57	0.50	0.42	0.44	0.64

Quality, cost, time priority	Competency	Understanding worldwide business (7)	Resilience (10)	Resilience (5)	Understand worldwide business (12)	Understanding worldwide business (8)	Resilience (8), Understanding worldwide business (8)
	Raw coverage	0.58	0.56	0.56	0.57	0.47	0.62
Change request	Competency	Resilience (2), Understanding worldwide business (2), Learning foreign culture (2)	Decision making (11)	Decision making (4), Understanding worldwide business (4)	Resilience (10)	Perception (5), Resilience (5), Decision making (5), Understanding worldwide business (5)	Decision making (7)
	Raw coverage	0.18	0.58	0.50	0.46	0.29	0.54
Customer needs	Competency	Understanding worldwide business (7)	Perception (8), Understanding worldwide business (8)	Understanding worldwide business (5)	Understanding worldwide business (10)	Understanding worldwide business (12)	Resilience (5)
	Raw coverage	0.35	0.44	0.50	0.36	0.48	0.39

Number of projects is in parenthesis (x)

Table 5.17: Competencies for particular difficulties and project attributes

5.7 Summary

This subsidiary study clarifies the relationships between the competencies of BMs and difficulties in facilitating global R&D projects. Although prior studies identified competencies using job analysis, they did not analyze the association between competencies of BMs and difficulties in global R&D projects. An online questionnaire was distributed to the managers who have experience in global R&D project facilitation and collected 73 responses. Important findings from section 5.6.1 to 5.6.6 are summarized in Table 5.18. The results show that seven leadership competencies are relatively more important for BMs to solve specific difficulties in facilitating global R&D projects. Knowledge management skills and communication skills are relatively more important in all 8 difficulties in global R&D projects. The other five competencies, including perception, resilience, decision making, understanding worldwide business, and learning foreign culture are relatively more important for different difficulties. While scholars identified competencies of leadership roles (Bolden et al., 2003), they did not explore relationships between the competencies and the difficulties those roles have. Global leadership competencies in this research were not mentioned explicitly but measured in terms of systems perception, resilience to cope with complexity, and consciousness about foreign cultures (Tiina, 2005). These empirical findings highlight the importance of specific competencies for BMs to overcome particular difficulties in facilitating global R&D projects.

Important findings	**Relevance sections**
1. Most of the projects have 1 to 10 members, include 2 to 3 nationalities, last for 6 to 12 months, and deliver software as the outcomes. 2. Project stakeholders mostly internal customers for both at the home country and foreign countries. 3. More than 65% of all projects, the difficulties were improved at the end of the projects.	5.6.1 Project characteristics, difficulties, and improvement
1. Seven competencies including, knowledge management skills, perception, resilience, decision-making skills, understanding worldwide business, learning foreign culture, and communication skills are relatively more important for solving specific difficulties in global R&D projects.	5.6.2. Competencies for solving difficulties

1. The perception competency and decision-making skills together help managers to solve quality control difficulty, project situation sharing difficulty, research approach difficulty, and change request difficulty. 2. The ability to understand worldwide business and ability to learn foreign culture together help managers to solve communication support difficulty, communication efficiency difficulty, research approach difficulty, and customer need difficulty. 3. The perception competency and ability to understand worldwide business together help managers to solve quality, cost, time priority difficulty.	5.6.3 Combinations of competencies for solving particular difficulties
1. Project sizes (1 to 10 members and more than 10 members) have different difficulties in the projects (mixed results). 2. Project output, hardware projects, seem to have more difficulties than non-hardware projects. 3. Project time, less than 12 months projects, seem to have less difficulties than projects that last more than 12 months. 4. Project with 1 to 3 nationalities seems to have less difficulties than projects with more than 3 nationalities. 5. Managers with experience less than 10 years seem to have more difficulties than managers with experience more than 10 years.	5.6.4 Project attributes and difficulties
1. The projects with more than 10 members, or projects with 1 to 10 members with non-hardware output may lead to quality control difficulty. 2. The hardware projects that last for more than 12 months may lead to communication support difficulty, research approach difficulty, quality, cost, time priority difficulty, and change request difficulty. 3. The projects with 1 to 10 members, non-hardware output, and time more than 12 months may lead to communication efficiency difficulty, and customer needs difficulty. 4. The projects with more than 10 members with hardware output may lead to quality, cost, time priority difficulty, change request difficulty, and customer needs difficulty. 5. The projects with 1 to 10 members with time more than 12 months may lead to research approach difficulty.	5.6.5 Combinations of project attributes and difficulties

1. For quality control difficulty, projects that last for less than 12 months require managers to have perception competency while projects that last more than 12 months require managers to have decision-making skills. 2. For quality, cost, time priority difficulty, projects with 1 to 10 members require managers to have an ability to understand worldwide business while projects with more than 10 members require managers to have resilience competency. 3. For quality, cost, time priority difficulty, projects with hardware output require managers to have resilience competency.	5.6.6 Competencies for solving particular difficulties with specific project attributes

Table 5.18: Summary of important findings

The results add new knowledge to the existing literature and suggest implications for researchers and practitioners. Prior global R&D research focused on organizational perspectives such as categorizing types of R&D sites (Kuemmerle, 1997), exploring virtual organizations (Blecker & Neumann, 2000), and presenting concepts of dispersed project teams (Gassmann & von Zedtwitz, 2003). This subsidiary study adds to prior studies by focusing on the contribution of individual managers to bridge the gaps between the organization and its global R&D projects. Global R&D project management can be improved by enhancing relationships between R&D units in the global network. The BMs play a vital role in facilitating research collaboration between headquarters and foreign R&D subsidiaries. Prior studies on competency identification identified the competencies of particular professions based on their tasks and job requirements (Albetkova et al., 2019; Gray, 2007; Mirzazadeh et al., 2014). This subsidiary study contributes to existing knowledge by considering difficulties of BMs in their competency identification process. The results provide a better understanding of the relationships between competencies and difficulties. BMs may pay more attention to the right competencies to enhance research collaboration and to improve issues related to quality, communication, research approach, and requirement in the global R&D projects.

Chapter 6 Conclusion, Implications, and Limitations

This dissertation has explored difficulties the managers faced when facilitating global R&D projects and manager's competencies that help them to overcome the difficulties by analyzing interview and survey data collected from managers who have experience in facilitating research collaboration between teams in different countries of global R&D projects. Based on qualitative analysis of manager interviews on difficulties in global R&D projects, findings show four categories of difficulties, including quality control, research approach guidance, requirement clarification, and team communication. Moreover, based on quantitative analysis of questionnaire survey on BM competencies to solve global R&D project difficulties, findings show seven out of eleven competencies of BMs that are used relatively more for solving difficulties in global R&D projects, including knowledge management skills, perception, resilience, decision-making skills, ability to understand worldwide business, ability to learn foreign cultures, and communication skills. The findings suggest that there are relatively more important BM competencies that could help them solve particular difficulties in global R&D projects. The key contribution of this dissertation is the identification of BM competencies by considering difficulties in global R&D projects. This dissertation clarifies the relationships between competencies and difficulties. The findings provide a better understanding of the difficulties that BMs may have when they work with teams in different countries of global R&D projects. Findings also provide a list of competencies that are relatively more important for BMs to overcome difficulties when facilitating global R&D projects. In this Chapter, findings are reviewed in correspondence to the research gaps and research questions identified in Chapter 1. After that, theoretical contributions and practical implications are discussed, and research limitations are informed.

6.1 Summary of findings

Global R&D projects have long been a critical international operation of the firms to gain a competitive advantage. How the managers facilitate research collaboration between teams in different countries becomes more challenging as project complexity increased in the more connected world. Individual managers play an important role to organize and facilitate the R&D activities of diverse members of global R&D projects. The competencies that help the managers to perform effectively should be particularly important for the management of global R&D. However, there have been limited studies that focused on the manager's competencies. The majority of prior studies on international R&D operation paid attention to the management at an organizational level e.g., how firms organize their global R&D network, a few studies focused on how managers facilitate research collaboration in global R&D projects. Therefore, we have a limited understanding of the role of managers in global R&D projects and their competencies to facilitate research collaboration between teams in different countries.

The global R&D managers have high responsibility and influence the delivery of the projects (Ram & Ronggui, 2018). Literature review showed that prior studies focused on the roles and responsibilities of global R&D managers to lead and deliver the projects. There are also supporting roles such as facilitators who create and maintain a smooth operation of global R&D activities. Skilled and competent facilitators are important for groups and teams to produce effective outcomes (Nelson & McFadzean, 1998). Chapter 4 investigated into the challenge BMs faced when they facilitate global R&D projects. SRQ1 was introduced in Chapter 1: What are the difficulties faced by managers when they facilitate collaboration between teams in different countries of global R&D projects? BMs facilitate research collaboration between teams at headquarters and foreign R&D teams for a well-ordered research collaboration between the two. There are many activities and stages throughout the R&D process, so the working process of BMs needs to be considered. The interviewees explained what they considered as difficulties in global R&D projects. According to the findings of thematic analysis of interview data, four categories of difficulties were identified, including 1) quality control, 2) research approach guidance, 3) requirement clarification, and 4) team communication.

Literature review informed challenges for managers to manage global projects, including differences in cultures, organizations, countries, time zones, and languages (Binder, 2007). This dissertation expanded knowledge about difficulties in global R&D projects. The findings provide new insight into the global R&D project management in that, from BM's perspective, some difficulties hinder project members from having effective research collaboration. These findings should be taken into account when considering

how BMs facilitate research collaboration in global R&D projects. While previous studies have focused on challenges at the organizational level of how companies operate international R&D, these findings demonstrate that there are difficulties at the individual level in how BMs facilitate global R&D projects. Each of the four difficulties is discussed as follows.

First, quality control makes it difficult for BMs to facilitate research collaboration, especially, when outcomes need to be delivered. Teams in different countries tend to have different perceptions of the term quality. The perception of service quality vary across cultural groups e.g., in cultures with a high degree of individualism, customers demand a high level of service quality (Furrer et al., 2000). Considering different types of global R&D projects, the basic research projects are more difficult compared to the applied research projects in terms of expected results. The basic research projects aim to acquire new knowledge not having a defined goal or expected application of the knowledge therefore the target outcomes are ambiguous and dynamically changing while the applied research projects aim at producing particular products or services, having specific goals, and targeting practical problems (Wingate, 2015).

Global projects involve the cooperation of diverse project members who have different cultural backgrounds, work in different locations across time zones, and speak different languages (Binder, 2007). Quality has been indicated as a source of competitive advantage (Prajogo & Sohal, 2006). The quality process does not allow researchers and engineers to do everything correctly the first time, in addition, the R&D professionals define quality as "perfection" rather than simply conforming to customer expectations (Montana, 1992). The results demonstrated in this dissertation show that quality control was highlighted as one difficulty the BMs have to deal with. In particular, the difference in outcome expectations between headquarters and foreign R&D teams is one possible reason for this difficulty. Headquarters, which usually have product demonstration sessions with customers, expect to see R&D outcomes ready to be demonstrated in front of the customers without defects and have workable features. In contrast, researchers in foreign R&D teams focusing on research activities, aim at delivering project outcomes to meet the project schedule. It is challenging for BMs to narrow down this expectation gap because both sides are dealing with their own situation thus lack of understanding of the situation of another side.

Second, guiding foreign R&D teams to pursue a particular research direction is difficult for BMs. The research approaches are certain actions that perform to develop and implement requirements and attain the overall project outcomes (Wingate, 2015). From the perspective of foreign R&D teams, their main focus is on the research activity. On the other hand, teams at the headquarters of the company deal with multiple aspects of business such as emerging technologies, competitive markets, and financial issues. Headquarters teams may have several seasons to specify particular research directions or approaches for foreign R&D teams. At some points in the R&D process, BMs confront difficulty how to align the research approaches

of the two sides while maintaining a good relationship between them. This BM's viewpoint may be different from the project managers who focus on project delivery (time/cost/quality) rather than the relationship between project members.

Managing R&D is not the same as managing other human activities because of the research outcome uncertainty, the difficulty to measure results or impacts of the research, the rapid change of scientific knowledge, and the different expectations, values, attitudes, and motivation of researchers from other employees (Clarke, 2002). Especially the latter, the different expectations, values, attitudes, and motivation of researchers from other employees, may have a significant influence on the alignment between research approaches and business strategies. Clarke (2002) argued that scientists and engineers pay more attention to natural phenomena than people, care more about the research community around the world than their immediate supervisors, have ethical right not to follow the management direction when it goes against their values, think the goal of good science is more important then and transcends organizational goals. In this dissertation, it was found that scientists and engineers in foreign R&D subsidiaries insist on implementing particular research approaches rather than following the approaches which are designed to align with business goals and organizational strategies. BMs play an important role to mitigate this issue and narrow down gaps between R&D team approaches and headquarters approaches. Serving organizational goals and respond to the needs of customers are the ultimate and common goals of the business. BMs work closely with foreign R&D teams to guide them to adapt their research directions toward the direction of the organization. The R&D managers are required to provide substantive advice and act as a sounding board for technical ideas or proposals (Clarke, 2002). Meanwhile, the BMs who work closer to scientists and engineers than the project managers are in a better position to help foreign R&D teams align their activities with the direction provided by headquarters. Encouraging scientists and engineers to change their expectations and values may require intensive conversation and strong interpersonal relationships. Managing research approaches in global R&D projects is considered an additional difficulty and uniqueness of global R&D management.

Third, teams in global R&D projects are dispersed geographically, so it is difficult to transfer requirements from one location to another locations. The requirement is a written definition of the exact functionality or capability that is needed (Wingate, 2015). Requirements are an important input for the researchers to conduct their research. It consists of information from relevant parties including customers. Requirement gathering is a difficult activity as the requirements contain subjective elements which are not easy to elaborate and capture. The requirement documents are produced and transferred to R&D teams. Multiple artifacts are used to support different requirement communication activities (Liskin, 2015). Subjective elements of the requirements could be lost in the requirement transfer process. In addition, if the

requirement documents are ambiguous, there is a possibility of misunderstanding. This highlights the importance of BMs who facilitate requirement clarification by using their knowledge and skills to interpret and translate requirements from headquarters to foreign R&D teams.

R&D is an activity with intensive communication; the process and program documentation such as requirements, design documents, and test plans/results are shared seamlessly (Kar et al., 2009). Sharing requirements across different R&D sites is considered a common collaboration hurdle in global R&D operations. Market orientation and technology orientation are two dimensions that are used to classified four types of global R&D subsidiaries, including local adaptor which performs product adaptations for local markets, and adapt typically low-complex components to local requirements (Zeschky et al., 2014). Collaborative information technology is used in the new product development process to make communication and team information sharing easier, and more frequent (Marion & Fixson, 2019). More specifically in transnational development projects, although the intensive use of information technology minimizes the disadvantages of dispersed R&D teams (e.g. geographic distances, differences in culture and work habits, different time zones), it is not sufficient to guarantee the project's success (Boutellier et al., 1998). This dissertation argues that requirement clarification in global R&D projects is difficult for BMs in that BMs have to mediate, translate, and transfer requirements and specifications from teams at headquarters to foreign R&D teams. Although the advancement of communication technologies can help mitigate barriers of distant communication (Boutellier et al., 1998; Marion & Fixson, 2019), global R&D projects require BMs to play an important role in requirement clarification, especially, transfer of tacit elements of the requirements. While customer requirements, which emerge in one part of the world then research and develop in different locations, become more complex, the role of BMs will turn to be more prevalent in global R&D management. Complex customer requirements should be managed effectively to ensure the requirements are transferred correctly and fully understood by R&D teams.

Fourth, communication seems to be an obvious difficulty in global R&D projects where members of diverse backgrounds work together. BMs aim to promote effective communication between teams in different countries. Researchers and other team members in global R&D projects require intensive effective communication to exchange their knowledge and detail of research activities. Ineffective communication among team members could reduce information sharing and utilization of knowledge, create interpersonal conflict, and slow down the decision-making process (Brett et al., 2006). Knowledge codification determines the effectiveness of communication in teams of international product development (Moenaert et al., 2000). This dissertation explains communication difficulty in global R&D projects. Headquarters from high-context cultures, the meaning of a message heavily depends on the stimulant, and the inherent knowledge plays an important part (Gassmann, 2001). On the other hand, researchers in the projects hardly

elaborate their knowledge and their understanding of specifications. BMs find it difficult to encourage and guide project members to establish effective communication for requirement transfer.

Problems in languages and different frameworks of culture make communication less straightforward (von Zedtwitz et al., 2004). Global virtual teams experience swift trust which is very fragile and temporal, but trust in global virtual teams might be facilitated by communication behaviors (Jarvenpaa & Leidner, 1999). The communication effectiveness and efficiency in teams of international product development are determined by five requirements, including transparent of network, codification of knowledge, credibility of knowledge, cost of communication, secrecy (Moenaert et al., 2000). Especially the network transparency of communication, which means the degree to which the communication network is sufficiently clear and accessible in order for everyone in the project to understand inputs and progress. Results of this dissertation indicate that BMs faced difficulty to facilitate communication between headquarters and foreign R&D teams. Global R&D activities are often characterized by a high level of ambiguity. Headquarters and foreign R&D teams communicate relevant global R&D project information, BMs facilitate communication the improve transparency to ensure both sides understand each other, correct miscommunication, and identify appropriate persons to transfer or obtain information. While the use of electronic communication media mitigates distance issue on technical communication of geographically distributed product development teams (Sosa et al., 2002), BMs play an important role to mitigate communication difficulty in global R&D projects. One technique that BMs used for solving communication difficulty is using additional documents with more visualization. Additional document and visual representation stimulate efficient communication, allows communication partners to clarify and elaborate their ideas and knowledge in addition to the use of formal R&D process documents and verbal communication.

R&D activities in Global R&D projects require an intensive exchange of knowledge and close collaboration between project members, while they work in different locations and have diverse backgrounds. Elkins and Keller (2003) reviewed the literature on leadership and found that skills and roles of leaders in R&D organizations have a relationship with R&D project success. Extant studies have shown that leadership competencies of managers are an important factor for successful cross-cultural collaboration (Jensen, 2020; Lisak & Erez, 2015; Podgórska & Pichlak, 2019; Thamhain, 2012), but these prior studies did not focus on the identification of competencies that are crucial for global R&D project facilitation. The competencies of managers who facilitate research collaboration between headquarters and foreign R&D laboratories in global R&D projects have not been identified. Chapter 5 identified crucial competencies that BMs possess

to overcome difficulties in global R&D projects and strengthen research collaboration between headquarters and foreign R&D teams.

Findings from subsidiary study 1 in Chapter 4 indicated that there are four categories of difficulties that BMs face in global R&D projects. The competency of BMs needs to be identified to help BMs to overcome difficulties. SRQ2 and SRQ3 were introduced in Chapter 1 in this regard. SRQ2: What are the relevant manager's competencies for facilitating global R&D projects? SRQ3: How the managers possess the competencies to solve difficulties in global R&D projects? Competency includes knowledge, skills, attitudes, and behaviors of individuals that related to superior performance (Athey & Orth, 1999). Competencies of BMs need to be identified for them to perform effectively in their jobs. This dissertation, subsidiary study 2 in Chapter 5, considers the competencies of BMs in relation to the difficulties they have in facilitating global R&D projects. Findings from the questionnaire data show that seven out of eleven leadership competencies including, knowledge management skills, perception, resilience, decision-making skills, understanding worldwide business, learning foreign culture, and communication skills are relatively more important for BMs to solve particular difficulties in global R&D projects. More specifically, the combinations of two competencies can help BMs to solve particular difficulties. The results indicate that, first, BMs can solve the quality control difficulty through the combination of perception competency and decision-making skills. This combination also helps managers to solve research approach guidance difficulty and requirement clarification difficulty. Further, BMs can solve the team communication difficulty, research approach guidance difficulty, and requirement clarification difficulty through the combination of understanding worldwide business and learning foreign culture. Lastly, BMs can solve the research approach guidance difficulty through the combination of perception competency and understanding worldwide business.

A smaller list of competencies is easier for BMs to possess with specific difficulties. Anantatmula (2010) identified seven people-related project performance factors to motivate project members and create an effective working environment for the project team to meet greater challenges. The findings of this dissertation in line with the work of Anantatmula (2010) in that the crucial competencies of BMs are important to manage the human side of global R&D projects to create an effective working environment. It is helpful for BMs to have a specific list of competencies so that they can develop the right competencies in addition to the technical competencies. Organizations could utilize this competency list to recruit new managers, assign managers to projects, and develop employee career paths. This dissertation provides new insight into the relationships between difficulties in global R&D projects and the competencies of BMs. The findings should be taken into account when BMs consider how to solve difficulties in their projects and when organizations recruit or assign BMs to their global R&D projects.

6.2 Theoretical contributions

Findings have several theoretical contributions for studies of international R&D management. Three research gaps have been identified in Chapter 1 based on the literature review. The first research gap concerns the lack of studies on the difficulties and role of BMs in global R&D projects. The second research gap indicates the necessity of BM competency identification. The last research gap concerns the clarification of the relationships between difficulties in global R&D projects and the competencies of BMs. The following paragraphs address these research gaps.

Existing studies only argued about organizational challenges of international R&D operation of MNCs (Ambos & Ambos, 2011; Gammeltoft, 2005; von Zedtwitz et al., 2004). This dissertation expands and uncovers the understanding of knowledge by making an attempt to identify the difficulties of individual managers to facilitate global R&D projects. Studies on the facilitator role in global R&D projects are limited. For instance, Asakawa (2001a) introduced an influencer role to facilitate active information exchange between headquarters and foreign R&D laboratories, thus foreign R&D laboratories can attain desired degree of autonomy. Jang (2017) defined cultural brokerage as an act of interaction facilitation between actors across different cultural boundaries to elicit knowledge from different cultures, hence the creative performance of multicultural teams can be enhanced. To date, this kind of supporting role in global R&D projects receives more attention as they can add value to increasingly complex projects. Existing studies investigated the roles of influencers and cultural brokers how they enhance team performance. Effective collaboration in multicultural teams like global R&D teams is also one of the crucial parts to enhance team performance, but the role of managers who in charge of this collaboration receives limited attention.

The results of this dissertation suggest that BMs work in a similar way to those influencers (Asakawa, 2001a) and cultural brokers (Jang, 2017) in that BMs, influencers, and cultural brokers add value to the global projects focusing on the collaboration between project members in headquarters and foreign R&D laboratories. BMs play an important role in global R&D projects to facilitate R&D activities and research collaboration between headquarters and foreign R&D teams. The four difficulties identified in this dissertation indicate that BMs are working to improve global R&D projects by solving difficulties. Individual BMs are facing difficulties to facilitate research collaboration. They are playing important roles to drive research progress and deliver research outcomes. The influencers facilitate active information exchange between headquarters and foreign R&D laboratories to help foreign R&D laboratories attain semi-connected freedom status. Semi-connected freedom is a position of typical overseas laboratories conducting basic research, when they enhance information connectivity with the headquarters side and

keeping autonomy as much as possible (Asakawa, 2001a). This dissertation introduced BM roles which are similar to the influencer roles introduced by Asakawa (2001a) in that both of them facilitate information exchange between headquarters and foreign R&D laboratories in global R&D projects. The results informed potential barriers for managers to help foreign R&D laboratories to attain semi-connected freedom status. Global R&D projects consist of multicultural teams which have members of diverse cultures. Brett et al. (2006) classified four categories of challenges when managing multicultural teams, including direct versus indirect communication, accent and fluency problems, different attitudes about hierarchy and authority, conflict in decision-making norms. This dissertation identified difficulties from the viewpoint of BMs who facilitate research collaboration in multicultural teams. BMs interact with project stakeholders, including researchers, engineers, management team, other departments, and customers. They participate in activities in the global R&D projects. In this context, BMs have a high possibility to face different kinds of difficulties.

Prior studies have shown that the manager leadership competency is an important factor for successful cross-cultural collaboration (Jensen, 2020; Lisak & Erez, 2015; Podgórska & Pichlak, 2019; Thamhain, 2012), but these prior studies did not focus on the identification of competencies that are crucial for global R&D project facilitation. We do not know yet which competency is crucial with regard to global R&D project facilitation. Thus, the crucial competencies of managers who facilitate research collaboration between headquarters and foreign R&D laboratories in global R&D projects need to be identified. To perform tasks effectively, BMs have to possess particular competencies to deal with challenges in global R&D projects. Competencies of several professions have been identified to improve their quality of work such as medical workers, research laboratory leaders, and construction project managers. Different occupations require different competencies to perform tasks effectively. Global R&D projects have become more complex and challenging in the increasingly connected world. Traditional competencies of managers may not be effective for BMs to facilitate research collaboration. It should be helpful for BMs to possess particular competencies that could solve specific difficulties in global R&D projects.

The results of this dissertation suggest that, first, resilience competency combines with understanding worldwide business help to solve communication efficiency difficulty. Misunderstandings may occur between headquarters and foreign R&D teams. Each side understands the situation of themself but may not fully understand the situation of another side. BMs require to grasp the whole picture of research collaboration in global R&D projects by understanding the business situations of both sides. Moreover, BMs require resilience competency when keep communicating with both sides to navigate research collaboration and make communication more efficient.

Second, decision-making skills combine with understanding worldwide business help BMs to solve research approach difficulty. Autonomy, a mechanism used to coordinate and control R&D activities, is important for global R&D laboratories to enhance innovative capability (Persaud et al., 2002). Foreign R&D teams conduct research using approaches designed by themselves which different from business strategies designed by headquarters. They may not concern about business and market situations which the headquarters pay more attention to. BMs require to understand worldwide business and use this understanding to make a sound decision for guiding research approach for foreign R&D teams. Thus, they conduct research in a way that aligns with business strategy. The combination between decision-making skills and the ability to understand worldwide business of BMs can help foreign R&D teams to attain semi-connected freedom which means a position of typical overseas laboratories conducting basic research, when they enhance information connectivity with the headquarters side and keeping autonomy as much as possible (Asakawa, 2001a).

Third, perception competency combines with decision-making skills help BMs to solve change request difficulty. Foreign R&D teams are not willing to implement changes requested by headquarters. The business situation is changing faster, and R&D activities need to catch up with that change. Headquarters have control over the activities of foreign R&D laboratories and occasionally request foreign R&D teams to alter their research. In global R&D organizations, headquarters coordinate with their R&D subsidiaries by informal mechanisms if the subsidiaries have high technology orientation, and by formal mechanisms if the subsidiaries have little technology orientation (Zeschky et al., 2014). BMs require perception competency to understand and grasp the essence of changes before planning with detailed information to convince foreign R&D teams to implement the changes. BMs can support R&D coordination between headquarters and foreign R&D laboratories by using the combination of perception competency and decision-making skills, especially, for informal mechanisms in which the coordination mostly relies on relations between individual employees and R&D people.

Prior studies have shown that different competencies are required in order to perform effectively in different contexts (Dulewicz & Higgs, 2005; Hoffmann, 1999; Tiina, 2005; Yu et al., 2012). Effective performance of individual managers may be assessed by measuring the achievement of objectives or appropriate process execution (Boyatzis, 1982). The competencies of managers are usually identified based on their tasks and behaviors (Alvarenga Jeferson et al., 2019; Asumeng, 2014). In the case of global R&D team leaders, for instance, Thamhain (2003) argued that global R&D team leaders need sophisticated people skills to ensure effective technology transfer; his method concerned work environment, team's leadership, and team's performance of high-technology product or service developments. However, there is no study to identify

the competencies of managers who facilitate research collaboration concerning their difficulties in global R&D projects. This dissertation fills the knowledge gap in this regard by clarifying relationships between competencies of BMs and difficulties in global R&D projects.

6.3 Practical implications

This dissertation focuses on global R&D projects, particularly, the difficulties the BMs face when facilitating the projects. The results have implications for global R&D management for both individual BMs and organizations. BMs contribute to the success of global R&D projects by facilitating collaboration between project members to help them achieve project goals. Managers who are taking or willing to take on the role of BMs might benefit from this study. They are well informed of the difficulties in global R&D projects. Thus, they are able to systematically analyze projects they are facilitating or predict future challenges which may occur in the upcoming projects. Organizations can utilize the results of this dissertation in their human resource management, specifically in the recruitment, training, assignment, and career path design of BMs.

The four identified difficulties in global R&D projects imply that challenges of the global context (different locations, cultures, and time zones) are not the only challenges for BMs in the projects. BMs may take different actions to cope with different difficulties in different project phases from initiation, planning, execution, and closing. For example, during project initiation where requirements are identified, project managers gather customer needs and discuss with headquarters meanwhile BMs talk to foreign R&D teams on feasibility issues. The requirement clarification difficulty should be addressed by BMs to allow scientists and engineers to understand the requirements as much as possible so a feasibility study can be conducted effectively. Difficulties in global R&D projects may be worsened in different project phases. For instance, during project execution, the difficulty in research approach guidance could be tougher for BMs to deal with changing targets thus changing research approaches. BMs are recommended to develop techniques and prepare to cope with different difficulties in different phases of global R&D projects.

Organizations may not be able to fully utilize global knowledge resources if they do not recognize difficulties in global R&D projects and do not incorporate the competencies of BMs in their human resource management practices. We showed that, from BM's perspective, there are four difficulties in facilitating global R&D projects. It is suggested that there is a high possibility for the difficulties to occur in the projects, therefore headquarters can bring difficulty issues upfront during project initiation where relevant

stakeholders brainstorm how they achieve project goals and discuss project planning. Research activities in global R&D projects may be executed effectively when they know in advance what kind of difficulties they are going to encounter, thus persons involved are well prepared.

The practices of human resource management play an important role in retaining employees in organizations. We showed that particular competencies of BMs have relationships with difficulties in global R&D projects. The use of such competencies in human resource management practice may allow organizations to address human resource issues more strategically, especially for the operation of international R&D. Hiring the right people should be considered when organizations look for new members who would add value to them. Crucial competencies for facilitating global R&D projects should be considered to incorporate into the selection process of BMs in addition to the traditional managerial competencies. Employee training becomes more relevant as technology development is growing exponentially and diverse people from all over the world are more collaborated. Difficulties in global R&D projects, as well as competencies of BMs, should be utilized in learning and development program design.

Practical implications drawn from this research should be applicable for non-Japanese BMs as well. The global R&D collaboration of Japanese firms used to have low tension between headquarters and foreign laboratories because they have frequent interaction and socialization to have cultural control (Asakawa, 2001b). However, the situation is changing when their global R&D projects become more diverse having more members from different cultural backgrounds. The difficulties in global R&D projects were identified from the perspective of managers who focus on research collaboration between teams in their home country (Japan) and teams in foreign countries. Then, important competencies of the managers were identified by concerning those difficulties. It is likely that such difficulties could be occurred in the global R&D projects of other countries as well which more diverse project members jointly conduct R&D activities across national and cultural boundaries. Thus, the competencies of non-Japanese BMs who take care of such research collaboration should receive more attention from the organizations.

The Japanese culture of headquarters teams may have effects on the R&D activities of foreign R&D teams. The BMs facilitate research collaboration between teams in the same organizations, while they are in different countries. The cultural dimensions of the host country influence the type of R&D performed by foreign subsidiaries (Pedro Couto & Cabral Vieira, 2004). Foreign team members may inherit organizational culture as well as bring in their national culture. The BMs should pay attention to this cultural aspect when working with members from different cultural backgrounds. BMs who come from the headquarters side, or the foreign R&D side have a better understanding of their own national culture. The

organizational culture may help BMs to narrow down the cultural gap between the two sides and help BMs to establish mutual understanding by using the common ground of organizational culture.

The professional community may greatly benefit from the list of BM competencies within the established project management domain. The results suggest that BMs should possess communication skills that are required throughout the R&D projects to facilitate clarification of the requirements and research approach guidance. It is suggested that BMs use visualization as a supplemental technique to improve the effectiveness of communication between members of global R&D projects. BMs are recommended to use visual and graphic communication while communicating with members of global R&D projects. Furthermore, establishing additional milestones throughout the project helps BMs to gradually clarify specifications to researchers and provides more opportunities for outcomes to be evaluated and improved.

6.4 Limitations and future research direction

This dissertation should be considered in light of some limitations and that open avenues for future research. There are a number of limitations that need to be concerned. First, this study only considered the individual-level analysis. Difficulties of the projects could be considered from different levels such as team level, organization level, and inter-organization level. Such aspects should be considered in future research. The discussion is limited only to the roles of the BM. Global R&D projects consist of many other roles that also contribute to the projects. Future research could analyze the relationships between BMs and other roles. The relationships between project members may help to develop systematic and holistic approaches to improve global R&D project management.

The generalizability of the findings is limited by a specific group of interviewees and survey respondents. Among the nine managers interviewed, there were only three nationalities Japanese, Chinese, and Indian. The nationality of interviewees may influence research findings considering cultural differences. Future research should pay closer attention to the nationality of interviewees and perhaps include a wider spectrum of nationalities. Cross comparison between Japanese practices and western practices may provide more insight into how the managers from different cultural backgrounds facilitate their projects. The companies of the nine interviewees belong to the IT industry. Further studies need to cover broader industries before the result can be generalized. The managers may face different kinds of difficulties in different types of projects. Due to the lack of data on project success, the findings cannot confirm that the competencies of BMs to solve difficulties in global R&D projects could lead to project success. Future studies are needed to establish linkage between crucial competencies identified by this dissertation to the

success of global R&D projects and explain its mechanism. Further studies are also suggested to consider competency improvement and draw a relationship to the project success.

The methodological choices were constrained by the thematic coding method that was used to analyze interview transcripts. Future studies should take the qualitative data analysis methods into account. It is beyond the scope of this dissertation to explain the causes and effects of difficulties in global R&D projects. This dissertation only used relevance ratio and qualitative comparative analysis to investigate relationships between competencies and difficulties. A causal relationship analysis may be needed in future studies to explain whether specific difficulties in global R&D projects can be solved if BMs possess particular competencies.

The techniques to overcome difficulties in global R&D projects and crucial BM competencies are useful for the development of a competency framework that defines knowledge, skills, and attributes needed for employees within an organization. Individual BMs will have their own set of competencies needed to perform the job effectively. An in-depth understanding of BM role within the global R&D context is needed in order to develop the framework. For example, the project manager competency development framework, which is a guide of project management body of knowledge, PMBOK Guide (PMBOK, 2004) suggests that stakeholder communication management keeps projects on track. The objective of communication management is to satisfy the needs of stakeholders and resolve issues. Although the PMBOK Guide (PMBOK, 2004) recommends face-to-face meetings as an effective means of communication, this dissertation found that, for global R&D management, the role of the BM is needed to facilitate communication between project members. BM role is needed to facilitate communication in global R&D projects because they recognize cultural differences in communication and then enhance communication by bridging cultural gaps. In future works, the R&D bridge manager competency development framework can be developed based on the crucial BM competencies.

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Appendix

Appendix A. Interview Quotes

Interview quotes, codes, categories, and themes of thematic analysis of interview data from 9 managers who have experience in facilitating global R&D projects.

Interview quotes	**Codes**	**Categories**	**Themes**
We try to do everything visualize, explicit, and open. We can achieve very high product quality. It is not easy to explain. It is a long story but finally that even Japanese quality assurance are saying that German achieved quality very high. At the beginning, they say German quality is very poor but two years after, they say that perfect quality. (Interviewee 1) Early-stage of development, how to visualize is really critical problem. I think once the development started everything can be visualized pretty well. But before that, visualization is really difficult. (Interviewee 1) We need to understand something from China side such as the problem when they are developing the project. The big problem such as in China you cannot get the device, real device. They do not have the real device to test. Maybe they have to work on the simulator or some development environment. (Interviewee 2) In the research level, it is very difficult to manage the performance because in our side we did not have the idea how to involve the problem currently. So, it is the big problem for us right now how to check, how to control the performance in the research level. It is very	Quality evaluation Different expectation Using several milestones Visualization of expected results	Quality control technique Awareness of quality Visualization (Solution)	Quality control difficulty

difficult because we did not have an idea how to involve it. (Interviewee 2) The quality is very difficult to manage because we did not get the clear idea of how to check. In the product level, we have a very clearly specification in order. But in the research level, we did not have the specification to which performance is good and which performance is the best. We did not know. (Interviewee 2) I think the biggest problem in cultural difference is about the quality. In Japan side, we think the high quality is good. And in China side, if the demonstration is moved, it is good because this is the research level, it is not the product level. So, in the research level, China side think the demonstration is moving it is ok. In that time maybe the applications have some bugs, the demonstration they can know it. So, it is ok. We can demonstrate to a customer. This is the opinion from China side. But in Japan side, we think just moving is not enough. We must have higher quality to show the demonstration to the customers. (Interviewee 2) …because this is the R&D. So, responsible for the development. Quality or output, sometimes they [Foreign researchers] do not care. (Interviewee 5) Indian engineers do not focus on quality first. (Interviewee 6) Indian researchers, actually, they try to concentrate on the work, not the evidence. (Interviewee 8)			
Another is I think the business situation. This also often creates the problems. If this leader is the right person and the leader gives you the right instruction, then no problem. But if the leader is wrong then sometimes because of the relationship between the headquarters and subsidiaries, you cannot say this is wrong. This often creates a big problem. (Interviewee 1) I have this problem as well [Different way of thinking], but I solve it by I change the role between Japan and Germany. What I mean is that Japanese guys always say that they design, they write down specifications and I ask Japanese to stop it and German start to write	Cultural difference Different ways of thinking Switching roles between team members	Alignment of research approach Setting different priority in research process Switching roles (Solution)	Research approach guidance difficulty

the design and the specification and the Japanese just check it and then it works better. (Interviewee 1) Most of the Indian people, some people often say what do you mean. But the Asian people do not ask. They simply assume that pretend to understand what that means. This often happens with Indian people. So, we say that now ok we should develop this problem in this way. And they say yes, I understand but actually they do not understand. (Interviewee 1) …offshore [teams] very often are subcontract. Therefore, [Company name] Japanese's behavior is more arrogant. This is also the problem. Because of the arrogant behavior, subcontract people cannot ask the questions properly. (Interviewee 1) They say yes but maybe they cannot say that they have some big difficulties. So, in the end of that week maybe someone could not finish then what happen I do not know. Indian people very similar to Thai people but if we say what is going on they always say no problem. No problem [Interviewee name], everything is going on. Do not warry [Interviewee name]. This is the difficulty with Indian behavior. (Interviewee 1) …one is the cultural difference, actually. This is actually if you long time work with non-native people you could be aware of that. But it is not easy what is the cultural difference. I cannot say what is the cultural difference. But often one problem is the cultural difference. (Interviewee 1) The biggest problem is in real meetings the developers did not say their opinions. Because the team leaders and the bridge managers will join the TV meeting, so it is difficult to say the real opinion. It is very difficult. (Interviewee 2) I just want to say that the Chinese people and Japan people is the same in this case because team is very important in Asian, in East-Asian such as Korea, Japan, and Thailand. Team is very important, not process. We do not need the hero in the team. We need teamwork. Teamwork is very important. (Interviewee 2)			

And management is difficult too because their thinking is different from Japanese thinking. For example, we try to make goal according to specifications, but they did not. Sometimes, they try to find another approach. Maybe they think a better way. This is different maybe style of culture. (Interviewee 3) Most problem is direction problem. Sometimes, for example, I say please use new network, but they do not use. Another approach such as image processing or some methods. (Interviewee 3) Culture, the way of thinking is different. They easily change jobs. They do not think for a long time, maybe 3-5 years then they will change. The problem is how to keep technology, knowledge that developed inside the company. (Interviewee 5) Indian engineers have different ways of thinking from Japanese. Japanese have an idea to keep improving, but Indian teams will stop when they think they finish the tasks. (Interviewee 6) Indian engineers do not have a working plan. Then Japanese managers have to create KPI to control the working process. (Interviewee 6) …way of thinking, I think the Indian side currently that priority will be to meet the requirements. (Interviewee 9)			
We experienced, generally speaking, to work with the Indian people is not easy. The reason is a lot of confusion often happens about the specifications. We write down the specifications when we work, not with the Indian offshore, but we work with the Japanese sub-contract. As you know Japanese people, we do not need detailed specifications. But when we have to work with the offshore people, we have to specify, we have to write down very detailed specifications. And very often, more communication is necessary. We check whether the Indian colleagues implementing ok or not, very heavy job. (Interviewee 1) I often say to the Japanese colleagues, that is the typical Japanese excuse. My excuse means, from my point of view, the Japanese do not understand the global market. (Interviewee 1)	Convincing and negotiation with researchers Requirement clarification Dynamic target Making things explicit Understanding of the requirement	Elaborating the requirements Understanding of the requirements	Requirement clarification difficulty

The reason is that our research, our order is research level, not production level order. If it is a product level, we can focus only one product to go to the market. But if it is a kind of basic research, you can do many research projects to support one or two products in the future. In the research level, we just have the problems. How to involve the problems we do not know in Japan side. (Interviewee 2) It is very difficult to convince each other. This is a big problem. In the Japan side, we think we are the order so China side must follow us because we are the order. In this project, we are the order and we have carried the money for the order. But in the development side, I think the problem is also only in Japan from the marketing and the technology. So, the marketers think the customers need technology. So, they must develop this technology. Maybe it is impossible, it is very difficult. Maybe they cannot develop it right now, but I do not care. You must do it. This is the customer's needs. It is equal to money. This is more important for the company. How to get the money from the customers? (Interviewee 2) …in China side, they have no idea. They do not have clear specifications. They just do their best. Ok, this is the best we can do. And I give you, Japan side please check and then give us feedback. (Interviewee 2) Communication with United States that for myself. They have debates for discussion. So, we have difficulty to talk with them. When we have a discussion with them, we have difficulty to talk with them because they debate. (Interviewee 7) We cannot describe everything of the specifications. We try to provide the education of new products to the vendors, and we think the concept to develop the products. But actually, we cannot describe everything on the education. (Interviewee 7) Maybe one thing is that, suppose since Japanese would speak everything like they are telling one line lots of meanings. (Interviewee 8) Mostly, like someone will be coming here mainly at the beginning of the projects to explain the requirements so that the gap misunderstanding is as well as they wanted to bring it down. Most of	Understanding of the market		

the customers will be coming in order to explain their expectations in their requirements. (Interviewee 9) Japanese will explain only high-level requirements. Normally, what they do is they give us high-level requirements. They ask us to prepare the design and then they have some consequent meetings in order to bridge the gap. (Interviewee 9) They'll say yes this is what is expected. Sometimes what happens is they give one-line requirements. So, here they try to describe it in detail and get their confirmation, it will go on. (Interviewee 9) Normally, they give high level requirements. Then we prepare the design, or we say is this what is expected. But sometimes some parts they assume like OK this should be included in this requirement. Only they assume or maybe from knowing it does not to be included. It should be separated sometimes. It is just difficult. Eventually, it will come out in two or three meetings with this confirmation going up there. (Interviewee 9) So, in that case like this you say, the requirements are not very clear. So that time, I think we should be as much as possible try to get what exactly they mean. (Interviewee 9)			
Communication is often very difficult because of the English. If the global collaboration is led by the Japanese, this is the biggest problem. The second biggest problem is, so-called, A-Un breathing which mean, very often, Japanese people is assuming a lot of implicit knowledge. (Interviewee 1) I think outside of Japan people communicate with explicit knowledge while Japanese they try to communicate only with implicit knowledge. And this creates a lot of difficulties. This is one of my experiences. Because of this, the Japanese specification is not clear enough and also not detailed enough. (Interviewee 1) In the emergency case we must change order, if we change our order, we must make a TV meeting because we need to show some pictures to make it clear and show the detail of this. The most difficulty we must do the face-to-face communication. (Interviewee 2)	Communication issue Communication breakdown Language barrier High-context communication	Efficiency of communication Obstacle of communication	Team communication difficulty

So, the problem is that the same word, same sentence, the understanding is different. Different meanings from the same word and the same sentence. In this case, the most difficult is how to get the potential order is very difficult thing. (Interviewee 2) Basically, we discuss with each other, firstly, use English. And English I can get this communication, the same sentence, and the same word but the different understanding. I can understand it. This case I will explain in Japan side use Japanese, and to China side use Chinese. This is the reason why the product level usually needs the bridge managers. (Interviewee 2) First is the language problem. Maybe as you know our Japanese are not good at English and the Indian English is more difficult than native English. So, it is very hard to share, very difficult. (Interviewee 3) I mean when I meet with different cultures and also languages. That is fine for [A person name] because he is Chinese, and he knows Japanese very well. I think there are various big issues. I try to repeat my questions, again and again, to know what they really think. That is difficult, I think. (Interviewee 4) Project proposal, maybe they do not ask everything out. Sometimes, they have feeling do not tell everything. Every time, we do the formal documents. This is the method to deal with that problem. (Interviewee 4) …some others maybe a little bit shy or not much to express what is in their mind. I need to ask the real thinking and ask them many questions. (Interviewee 4) Japanese have high context communication, do not explain in deep detail. So, the Indian outsourcing teams cannot understand clearly. (Interviewee 6) Then the difficulty is the communication with vendors with Asian countries. Each country has their own character, China, Taiwan, Hong Kong, Korea. The difference of culture will make problems. In the case of China, they say, at first, they can do anything. Yes, we can do it. We have no problem. At first, they say always. But after			

one week or two weeks, they cannot. This is common for them. For us, it is abnormal. Communication and misunderstanding between cultures that is the first problem. (Interviewee 7) Major issue for all the members up here and the other two teams are working in Japan. We will not be hearing of the contents, what discussion is happening in Japan. We are divided on features, and they are working on something. But we do not know what that is. (Interviewee 8) One of the major problems is that on the cellphone when the coordinator is not there, the communication gap will be there. The second problem is that face-to-face communication is not happening. The discussion is happening on the phone, telephone. We thought we understand fully, then another person is not. (Interviewee 8) One of the differences is that the Japanese they discuss a lot for implementing a thing. They have lots and lots of discussions. (Interviewee 8) I initially had a little difficulty because English and Japanese words can have many many meanings. We do not know what the customer is actually referring to. (Interviewee 9) And certainly, different Japanese people also use different words for the same thing. …so, it is like you have to confirm that. Because different Japanese people tend to use different words. (Interviewee 9) When it is the telephone conference sometimes a voice will not be clear. …sometimes that actually creates a little bit of problem, especially from the other side. When they use the speaker and we also use the speaker so then the voice quality, you cannot get the words. Because different people have different accents. Pronunciation is also different. (Interviewee 9)			

Appendix B. R&D Bridge Manager Competency Questionnaire (English)

Dear Participant:

My name is Nawarerk Chalarak and I am a Ph.D. student at Japan Advanced Institute of Science and Technology (JAIST), Japan. I am conducting research aims at identifying competency** of R&D bridge managers (BMs)*. If you have participated in R&D projects (including new product/service development) conducted by teams in multiple countries, I am inviting you to participate in this research by completing this questionnaire.

This questionnaire requires approximately 20 minutes to complete. In order to ensure that all information will remain confidential, please do not enter your name and personally identifiable information. If you choose to participate in this research, please answer all questions as honestly as possible. Participation is strictly voluntary, and you may refuse to participate at any time.

Thank you for giving your valuable time supporting my research. The collected data will be useful for further analysis within the scope of this research. Completion and return of the questionnaire will indicate your willingness to participate in this study. If you require additional information or have any questions, please contact me at the e-mail address below.

Sincerely,
Nawarerk Chalarak
E-mail: nawarerkc@jaist.ac.jp

*BM is a person who facilitates research collaboration between teams in global research and development (R&D) projects located in multiple countries.

**Competency refers to knowledge, skills, and abilities that are important in performing a particular job, including behavior and psychological attitudes.

***Global R&D teams including team leading the project (with project manager) and participating teams. In many cases, the leading team is in the country of origin of the projects and participating teams are in foreign countries.

Part 1: Global R&D Projects

Instruction: Please recall one R&D project in the past that you participated in to facilitate collaboration between teams in multiple countries. It is called "Project X" in the following questions.

Note: The team that leads Project X (with project manager) will be called "leading team" and teams that participated in Project X will be called "participating teams."

1) What is your main role in Project X?

- ○ Project manager (overall management)
- ○ Project member (leading team leader)
- ○ Project member (leading team assistant, coordinator)
- ○ Project member (leading team developer)
- ○ Project member (participating team leader)
- ○ Project member (participating team assistant, coordinator)
- ○ Project member (participating team developer)
- ○ Project supporter such as the project management office (PMO) of the leading team
- ○ Project supporter such as the project management office (PMO) of participating teams
- ○ Other:_____

2) In Project X, what was the country of the team that you belong to?

- ○ Japan
- ○ India
- ○ China
- ○ Other:_____

3) Approximately, how many project members in Project X?

- ○ 1 to 10
- ○ 11 to 50

○ 51 to 100

○ More than 100

4) Approximately, how many nationalities of project members in Project X?

○ Only 1

○ 2 to 3

○ 4 to 5

○ More than 5

5) What kind of products or services were developed in Project X?

☐ Hardware, Devices (including embedded software)

☐ Software, Applications

☐ System integration (in-house system development, contract system development)

☐ Cloud services (such as SaaS, PaaS, IaaS)

☐ Consulting (management strategy, business improvement)

☐ Elemental technology of products or services (such as algorithm)

☐ Other:_____

6) Does Project X include R&D related to AI or IoT?

☐ Related to AI R&D

☐ Related to IoT R&D

7) Approximately, how long did it take for the development period in Project X?

○ Less than 6 months

○ 6 to 12 months

○ 13 to 24 months

○ 25 to 36 months

○ More than 3 years

○ Ongoing

8) When did Project X finish?

○ More than 11 years ago

○ 6 to 10 years ago

○ 1 to 5 years ago

○ Recently (less than 1 year)

○ Ongoing

9) Who are stakeholders, in the country of leading team, that you have direct contact with when working on Project X? (Check all that apply)

☐ External customers (outside your company)

☐ External partners (such as vendors, suppliers)

☐ Internal customers (other departments of your company or affiliates)

☐ Internal partners other than project members (other departments in the country of the leading team)

☐ Executives of your company (in the country of the leading team)

☐ Human resource department of the company (in the country of the leading team)

☐ University faculty or students (in the country of the leading team)

☐ Government officials (in the country of the leading team)

☐ Other:_____

10) Who are stakeholders, in the countries of participating teams, that you have direct contact with when working on Project X? (Check all that apply)

☐ External customers (outside your company)

☐ External partners (such as vendors, suppliers)

☐ Internal customers (other departments of your company or affiliates)

☐ Internal partners other than project members (other departments in the countries of participating teams)

☐ Executives of your company (in the countries of participating teams)

☐ Human resource department of the company (in the countries of participating teams)

☐ University faculty or students (in the countries of participating teams)

☐ Government officials (in the countries of participating teams)

☐ Other:_____

Part 2: Difficulties in Global R&D Projects

Please indicate your level of agreement with the statements about Project X. Also, indicate your opinion about the changes that happened during the project period. If Project X has not been completed yet, please answer questions base on the "current stage" of the project instead.

Structure of questions:

There are 8 topics in the following section. Each topic consists of 3 questions. First, about the difficulty of this project. Second, how the situation of that difficulty had changed. Lastly, about the competencies that you used/needed to improve that particular difficulty. There are codes at the beginning of each question: D-Difficulty, S-Situation changed, C-Competency.

Q1: In Project X, quality control techniques were not effectively implemented.
Q2: In Project X, there was different awareness of project situations between the leading team and participating teams.
Q3: In Project X, there was insufficient consultation and support between the leading team and participating teams.
Q4: In Project X, there was ineffective communication between the leading team and participating teams.
Q5: In Project X, the R&D strategy and research approaches were usually not aligned between the leading team and participating teams.
Q6: In Project X, there was different priority regarding quality, delivery time, and cost between the leading team and participating teams.
Q7: In Project X, if the leading team requires a major change, participating teams were not convinced of that change.
Q8: In Project X, participating teams usually did not fully understand customer needs and requirements.

Q1: In Project X, quality control techniques were not effectively implemented.

For example, there is a big gap between the quality (performance, completeness) of the outcome expected by the leading team and the quality of the outcome delivered by participating teams.

11) D1: At the beginning of the project, do you agree with this statement?

○ Strongly agree

○ Agree

○ Disagree or Not relevant

12) What are the challenges of the above quality control issues? (Answer if applicable)

☐ No expected quality target

☐ Unsatisfied result

☐ Unexpected research direction

☐ It took longer time than expected

☐ Other:_____

13) What do you think is the main cause of the above difficulty? Example: Differences in something, lack of something. (Answer if applicable)

_____

14) S1: At the end of the project, how this situation was changed?

○ Improved

○ Slightly improved

○ Unchanged

○ Slightly worse

○ Worse

15) C1: What competencies did you use/need to improve this situation? (Select up to 5 that apply)

☐ Ability to manage knowledge and information (collect, share, communicate, transfer, and inherit knowledge and information necessary for the project)

☐ Ability to perceive global perspective (self-awareness, curiosity, inquisitiveness)

☐ Resilience (flexibly respond to unexpected situations)

☐ Decision-making power (making quicks decision with responsibility)

☐ Ability to understand the worldwide business environment (understand foreign customers, and work style in other countries)

☐ Learning foreign cultures and customs (adapting to foreigners thinking and behavior)

☐ Communication skills (language skill for smooth communication)

☐ Collaboration skills (help diverse people to work together smoothly and create synergy)

☐ Empowering others (delegating authority, encouraging people)

☐ Human resource management (human resources required for the project)

☐ Strategic perspective (have a broader perspective, consider long-term results)

16) What are specific improvements you have taken? Example: Change review mechanism. (Answer if applicable)

_____

Q2: In Project X, there was different awareness of project situations between the leading team and participating teams.

For example, the leading team feels a sense of crisis because of the delay in project progress, but participating teams do not have that kind of feeling.

17) D2: At the beginning of the project, do you agree with this statement?

○ Strongly agree

○ Agree

○ Disagree or Not relevant

18) What are the issues of the above-mentioned awareness? (Answer if applicable)

☐ Different perception about the progress of the current situation

☐ Different perception about the company expectation of the current situation

☐ Different perception about risk and crisis of the current situation

☐ Different perception about resources (human, equipment) of the current situation

☐ Other:_____

19) What do you think is the main cause of the above difficulty? Example: Differences in something, lack of something. (Answer if applicable)

_____

20) S2: At the end of the project, how this situation was changed?

○ Improved

○ Slightly improved

○ Unchanged

○ Slightly worse

○ Worse

21) What competencies did you use/need to improve this situation? (Select up to 5 that apply)

☐ Ability to manage knowledge and information (collect, share, communicate, transfer, and inherit knowledge and information necessary for the project)

☐ Ability to perceive global perspective (self-awareness, curiosity, inquisitiveness)

☐ Resilience (flexibly respond to unexpected situations)

☐ Decision-making power (making quicks decision with responsibility)

☐ Ability to understand the worldwide business environment (understand foreign customers, and work style in other countries)

☐ Learning foreign cultures and customs (adapting to foreigners thinking and behavior)

☐ Communication skills (language skill for smooth communication)

☐ Collaboration skills (help diverse people to work together smoothly and create synergy)

☐ Empowering others (delegating authority, encouraging people)

☐ Human resource management (human resources required for the project)

☐ Strategic perspective (have a broader perspective, consider long-term results)

22) What are specific improvements you have taken? Example: Increase frequency of meeting. (Answer if applicable)

_____

Q3: In Project X, there was insufficient consultation and support between the leading team and participating teams.

For example, the leading team assigns research work to the participating teams but does not provide sufficient support during the project. The participating teams also do not seek necessary support from the leading team.

23) D3: At the beginning of the project, do you agree with this statement?

○ Strongly agree

○ Agree

○ Disagree or Not relevant

24) What are the above communication/consultation/support issues? (Answer if applicable)

☐ Insufficient communication/consultation

☐ Insufficient support (difficult to support due to limited resources such as lack of time)

☐ Insufficient support (content is difficult to support)

☐ Other:_____

25) What do you think is the main cause of the above difficulty? Example: Differences in something, lack of something. (Answer if applicable)

_____

26) S3: At the end of the project, how this situation was changed?

○ Improved

○ Slightly improved

○ Unchanged

○ Slightly worse

○ Worse

27) What competencies did you use/need to improve this situation? (Select up to 5 that apply)

☐ Ability to manage knowledge and information (collect, share, communicate, transfer, and inherit knowledge and information necessary for the project)

☐ Ability to perceive global perspective (self-awareness, curiosity, inquisitiveness)

☐ Resilience (flexibly respond to unexpected situations)

☐ Decision-making power (making quicks decision with responsibility)

☐ Ability to understand the worldwide business environment (understand foreign customers, and work style in other countries)

☐ Learning foreign cultures and customs (adapting to foreigners thinking and behavior)

☐ Communication skills (language skill for smooth communication)

☐ Collaboration skills (help diverse people to work together smoothly and create synergy)

☐ Empowering others (delegating authority, encouraging people)

☐ Human resource management (human resources required for the project)

☐ Strategic perspective (have a broader perspective, consider long-term results)

28) What are specific improvements you have taken? Example: Strengthened support system. (Answer if applicable)

_____

Q4: In Project X, there was ineffective communication between the leading team and participating teams. For example, the same information is not exchanged properly between teams.

29) D4: At the beginning of the project, do you agree with this statement?

○ Strongly agree

○ Agree

○ Disagree or Not relevant

30) What are the above communication efficiency issues? (Answer if applicable)

☐ The content is not transferred quickly (it takes some time to understand)

☐ The content is not transferred accurately (there are some misunderstandings)

☐ Other:_____

31) What do you think is the main cause of the above difficulty? Example: Differences in something, lack of something. (Answer if applicable)

_____

32) S4: At the end of the project, how this situation was changed?

○ Improved

○ Slightly improved

○ Unchanged

○ Slightly worse

○ Worse

33) C4: What competencies did you use/need to improve this situation? (Select up to 5 that apply)

☐ Ability to manage knowledge and information (collect, share, communicate, transfer, and inherit knowledge and information necessary for the project)

☐ Ability to perceive global perspective (self-awareness, curiosity, inquisitiveness)

☐ Resilience (flexibly respond to unexpected situations)

☐ Decision-making power (making quicks decision with responsibility)

☐ Ability to understand the worldwide business environment (understand foreign customers, and work style in other countries)

☐ Learning foreign cultures and customs (adapting to foreigners thinking and behavior)

☐ Communication skills (language skill for smooth communication)

☐ Collaboration skills (help diverse people to work together smoothly and create synergy)

☐ Empowering others (delegating authority, encouraging people)

☐ Human resource management (human resources required for the project)

☐ Strategic perspective (have a broader perspective, consider long-term results)

34) What are specific improvements you have taken? Example: Confirm by documents after every communication session. (Answer if applicable)

_____

Q5: In Project X, the R&D strategy and research approaches were usually not aligned between the leading team and participating teams.

R&D strategy and research approach are the technologies, methods (ex. algorithm), and evaluation criteria used in the project.

For example, a leading team focuses on stability, but participating teams focus on performance.

35) D5: At the beginning of the project, do you agree with this statement?

○ Strongly agree

○ Agree

○ Disagree or Not relevant

36) What are the challenges of the above R&D strategy and research approach? (Answer if applicable)

☐ R&D target or evaluation criteria are not exist

☐ R&D approaches do not match

☐ R&D teams in participating countries seek autonomy, but teams in the leading country seek control

☐ Other:_____

37) What do you think is the main cause of the above difficulty? Example: Differences in something, lack of something. (Answer if applicable)

_____

Q5: In Project X, the R&D strategy and research approaches were usually not aligned between the leading team and participating teams.

R&D strategy and research approach are the technologies, methods (ex. algorithm), and evaluation criteria used in the project.

For example, a leading team focuses on stability, but participating teams focus on performance.

38) S5: At the end of the project, how this situation was changed?

○ Improved

○ Slightly improved

○ Unchanged

○ Slightly worse

○ Worse

39) C5: What competencies did you use/need to improve this situation? (Select up to 5 that apply)

☐ Ability to manage knowledge and information (collect, share, communicate, transfer, and inherit knowledge and information necessary for the project)

☐ Ability to perceive global perspective (self-awareness, curiosity, inquisitiveness)

☐ Resilience (flexibly respond to unexpected situations)

☐ Decision-making power (making quicks decision with responsibility)

☐ Ability to understand the worldwide business environment (understand foreign customers, and work style in other countries)

☐ Learning foreign cultures and customs (adapting to foreigners thinking and behavior)

☐ Communication skills (language skill for smooth communication)

☐ Collaboration skills (help diverse people to work together smoothly and create synergy)

☐ Empowering others (delegating authority, encouraging people)

☐ Human resource management (human resources required for the project)

☐ Strategic perspective (have a broader perspective, consider long-term results)

40) What are specific improvements you have taken? Example: Provided a certain level of autonomy. (Answer if applicable)

_____

Q6: In Project X, there was different priority regarding quality, delivery time, and cost between the leading team and participating teams.

For example, participating teams seldom search for new technologies, but focuses on quick delivery using existing technologies.

41) D6: At the beginning of the project, do you agree with this statement?

○ Strongly agree

○ Agree

○ Disagree or Not relevant

42) What are the above quality/delivery (speed)/cost issues? (Answer if applicable)

☐ The leading team focuses on quality, but participating teams focus on delivery time

☐ The leading team focuses on quality, but participating teams focus on cost

☐ The leading team focuses on delivery time, but participating teams focus on quality

☐ The leading team focuses on delivery time, but participating teams focus on cost

☐ The leading team focuses on cost, but participating teams focus on quality

☐ The leading team focuses on cost, but participating teams focus on delivery time

43) What do you think is the main cause of the above difficulty? Example: Differences in something, lack of something. (Answer if applicable)

_____

44) S6: At the end of the project, how this situation was changed?

○ Improved

○ Slightly improved

○ Unchanged

○ Slightly worse

○ Worse

45) C6: What competencies did you use/need to improve this situation? (Select up to 5 that apply)

☐ Ability to manage knowledge and information (collect, share, communicate, transfer, and inherit knowledge and information necessary for the project)

☐ Ability to perceive global perspective (self-awareness, curiosity, inquisitiveness)

☐ Resilience (flexibly respond to unexpected situations)

☐ Decision-making power (making quicks decision with responsibility)

☐ Ability to understand the worldwide business environment (understand foreign customers, and work style in other countries)

☐ Learning foreign cultures and customs (adapting to foreigners thinking and behavior)

☐ Communication skills (language skill for smooth communication)

☐ Collaboration skills (help diverse people to work together smoothly and create synergy)

☐ Empowering others (delegating authority, encouraging people)

☐ Human resource management (human resources required for the project)

☐ Strategic perspective (have a broader perspective, consider long-term results)

46) What are specific improvements you have taken? Example: Communicate awareness about quality/delivery (speed)/cost. (Answer if applicable)

_____

Q7: In Project X, if the leading team requires a major change, participating teams were not convinced of that change.

For example, there is a major change in the technology used by the leading team, but participating teams do not satisfy with the reasons for that change.

47) D7: At the beginning of the project, do you agree with this statement?

○ Strongly agree

○ Agree

○ Disagree or Not relevant

48) What are the challenges of the above change request? (Answer if applicable)

☐ Disappointed by frequent change requests

☐ Disappointed by major change requests

☐ Other:_____

49) What do you think is the main cause of the above difficulty? Example: Differences in something, lack of something. (Answer if applicable)

_____

50) S7: At the end of the project, how this situation was changed?

○ Improved

○ Slightly improved

○ Unchanged

○ Slightly worse

○ Worse

51) C7: What competencies did you use/need to improve this situation? (Select up to 5 that apply)

☐ Ability to manage knowledge and information (collect, share, communicate, transfer, and inherit knowledge and information necessary for the project)

☐ Ability to perceive global perspective (self-awareness, curiosity, inquisitiveness)

☐ Resilience (flexibly respond to unexpected situations)

☐ Decision-making power (making quicks decision with responsibility)

☐ Ability to understand the worldwide business environment (understand foreign customers, and work style in other countries)

☐ Learning foreign cultures and customs (adapting to foreigners thinking and behavior)

☐ Communication skills (language skill for smooth communication)

☐ Collaboration skills (help diverse people to work together smoothly and create synergy)

☐ Empowering others (delegating authority, encouraging people)

☐ Human resource management (human resources required for the project)

☐ Strategic perspective (have a broader perspective, consider long-term results)

52) What are specific improvements you have taken? Example: Explain the reasons for change requests. (Answer if applicable)

_____

Q8: In Project X, participating teams usually did not fully understand customer needs and requirements. Customer requirement means qualification and specification of research output.
The customers include both internal customers such as other departments, subsidiaries, and external customers such as consumers and end-users.
For example, the result developed by participating teams differs greatly from the expectation of the leading team.

53) D8: At the beginning of the project, do you agree with this statement?

○ Strongly agree

○ Agree

○ Disagree or Not relevant

54) What are the challenges of understanding customer needs and requirements? (Answer if applicable)

☐ Customer needs or requirements were not fully shared

☐ Customer needs or requirements were shared, but misunderstood

☐ No interest in customer needs or requirements

☐ Other:_____

55) What do you think is the main cause of the above difficulty? Example: Differences in something, lack of something. (Answer if applicable)

_____

56) S8: At the end of the project, how this situation was changed?

○ Improved

○ Slightly improved

○ Unchanged

○ Slightly worse

○ Worse

57) C8: What competencies did you use/need for improving this situation? (Select up to 5 that apply)

☐ Ability to manage knowledge and information (collect, share, communicate, transfer, and inherit knowledge and information necessary for the project)

☐ Ability to perceive global perspective (self-awareness, curiosity, inquisitiveness)

☐ Resilience (flexibly respond to unexpected situations)

☐ Decision-making power (making quicks decision with responsibility)

☐ Ability to understand the worldwide business environment (understand foreign customers, and work style in other countries)

☐ Learning foreign cultures and customs (adapting to foreigners thinking and behavior)

☐ Communication skills (language skill for smooth communication)

☐ Collaboration skills (help diverse people to work together smoothly and create synergy)

☐ Empowering others (delegating authority, encouraging people)

☐ Human resource management (human resources required for the project)

☐ Strategic perspective (have a broader perspective, consider long-term results)

58) What are specific improvements you have taken? Example: Participated in meetings with customers. (Answer if applicable)

_____

Part 3: General Information

59) What industry your company belongs to when you are participating in Project X?

☐ Information communication and information service industry

☐ Manufacturing industry (other than information communication)

☐ Service industry (such as finance, logistic, medical care, nursing care, tourism, education)

☐ Construction industry

☐ Agriculture, forestry, and fisheries

☐ Social infrastructure (such as transportation, electricity)

☐ University or Research Institute

☐ Public administration

☐ Other:_____

60) What is the approximate total number of employees at all locations of your company?

◯ 1 to 10

◯ 11 to 300

◯ 301 to 10,000

◯ More than 10,000

61) What is your gender?

◯ Male

◯ Female

◯ I would rather not say

◯ Other:_____

62) What is your age?

◯ Under 31 years old

◯ 31 to 40 years old

◯ 41 to 50 years old

◯ 51 to 60 years old

◯ 61 years or older

◯ I would rather not say

63) What is your nationality?

_____

64) What is your highest education level you have completed?

◯ Less than high school

◯ High school degree

◯ College

◯ Bachelor degree

◯ Master degree

◯ Professional degree

◯ Doctorate

◯ I would rather not say

65) How long have you been working in the same job position until Project X finished?

◯ Less than 1 year

◯ 1 to 3 years

◯ 4 to 6 years

◯ 7 to 10 years

◯ More than 10 years

Thank you for responding to this questionnaire.

Appendix C. R&D Bridge Manager Competency Questionnaire (Japanese)

研究開発ブリッジマネジャーのコンピテンシーに関するアンケート調査

アンケートにご協力いただける皆さま

北陸先端科学技術大学院大学(JAIST)の博士課程（知識科学系　内平直志研究室）に在籍している Nawarerk Chalarak と申します．現在，グローバルな研究開発における「ブリッジマネジャー（注１）」が持つべきコンピテンシー（注２）を特定する研究を行っています．過去に，複数の国のチーム（注３）が共同で研究開発（新製品・サービス開発を含む）を行うプロジェクトに参加した経験がある方は，是非このアンケートにご協力いただきたくお願い申し上げます．

このアンケートの所要時間は約 20 分です．回答内容につきましては，完全に匿名で記録致します(名前など個人を特定できる情報は入力しないようお願いします)．このアンケートへの参加は任意であり強制ではありません．しかし，参加される場合にはできる限り正直に全ての質問に回答してください．

私の研究のために貴重な時間を割いていただきありがとうございます．収集されたデータは，この研究の範囲内でのみ利用されます．何か疑問点やご質問がある場合，アンケート結果にご興味ある方は，下記のメールアドレスまでご連絡をお願いします．

Nawarerk Chalarak
E-mail: nawarerkc@jaist.ac.jp

（注１）ブリッジマネジャー（BM）とは、複数の国にチームが存在するグローバルな研究開発プロジェクトにおいて、チーム間の協力関係を促進する人物のこと.

（注２） コンピテンシー: 原文(英語)では Competency. 職務を遂行する上で重要とされる能力のことを指します，それに伴う行動や心理的態度も含まれます.

（注３）複数の国のチーム：プロジェクトを主導する（プロジェクトマネジャーがいる）チーム（主導国チーム）とプロジェクトに参加するチーム（参加国チーム）に分類します．日本企業の場合，主導国チームが日本の研究所にあり，参加国チームが欧米や中国，インドなど海外研究拠点にある場合が多いと思われます.

グローバルな研究開発プロジェクト

過去に、あなたが参加した複数の国のチームが共同で研究開発を行うプロジェクトを１つ思い出してください。以下ではそのプロジェクトを「プロジェクト X」と呼びます。以下，プロジェクト X について教えてください.

（注）プロジェクト X を主導する（プロジェクトマネジャーがいる）チームを「主導国チーム」とプロジェクト X に参加するチームを「参加国チーム」と呼びます．日本企業の場合，主導国チームが日本の研究所にあり，参加国チームが欧米や中国，インドなど海外研究拠点にある場合が多いと思われます.

1) プロジェクト X におけるあなたの主な役割を教えてください

○ プロジェクトマネジャー（全体統括）

○ プロジェクトメンバー（主導国チーム・リーダー役）

○ プロジェクトメンバー（主導国チーム・補佐・調整役）

○ プロジェクトメンバー（主導国チーム・開発担当）

○ プロジェクトメンバー（参加国チーム・リーダー役）

○ プロジェクトメンバー（参加国チーム・補佐・調整役）

○ プロジェクトメンバー（参加国チーム・開発担当）

○ ＰＭＯなどのプロジェクト支援者（主導国チーム）

○ ＰＭＯなどのプロジェクト支援者（参加国チーム）

○ Other:_____

2) プロジェクトＸにおいて，あなたが主に所属したチームがある国はどこですか？

○ 日本

○ Other:_____

3) プロジェクトＸに関わったメンバーの数はおよそ何人ですか？

○ １～１０人

○ １１～５０人

○ ５１～１００人

○ １００人以上

4) プロジェクトＸに関わったメンバーの国籍の数はおよそいくつですか？

○ １国籍

○ ２，３国籍

○ ４，５国籍

○ ５国籍以上

5) プロジェクトＸで開発した製品・サービスの種類はなんですか？

□ ハードウェア・システム製品（組み込みソフトウェアはここに含む）

□ ソフトウェア製品（パッケージソフトウェアなど）

□ システム・インテグレーション（自社システム開発，受託システム開発）

□ クラウドサービス（SaaS, PaaS, IaaS など）

□ コンサルティング（経営戦略，業務改善など）

□ アルゴリズムなどの製品・サービスの要素技術

□ Other:_____

6) プロジェクト X は，AI や IoT に関する研究開発を含みますか？

□ AI の研究開発を含む

□ IoT の研究開発を含む

7) プロジェクト X の(開発)期間はどれくらいの長さですか？

○ 6 ヶ月未満

○ 6～12 ヶ月（半年～1 年）

○ 13～24 ヶ月（1～2 年）

○ 25～36 ヶ月（2～3 年）

○ 3 年以上

○ 継続中

8) プロジェクト X の終了時期はいつですか？

○ 11 年以上前

○ 6 年～10 年前

○ 1 年～5 年前

○ 最近（1 年未満）

○ 継続中

9) 主導国でプロジェクト X に関わっているステークホルダーであなたが直接やり取りをしたメンバーはどのような人ですか？（当てはまるもの全て）

□ 外部顧客（社外）

□ 外部パートナー（代理店，プライムベンダー，サプライヤーなど）

☐ 内部顧客（同じ会社や系列子会社の他部署）

☐ 会社（主導国）の研究者またはエンジニアなどのパートナー（プロジェクトメンバー以外）

☐ 会社（主導国）の経営幹部

☐ 会社（主導国）の人事部

☐ 主導国で連携する大学教職員または学生

☐ 主導国の政府関係者

☐ Other:_____

10) 参加国でプロジェクト X に関わっているステークホルダーであなたが直接やり取りをしたメンバーはどのような人ですか？（当てはまるもの全て）

☐ 外部顧客（社外）

☐ 外部パートナー（代理店，プライムベンダー，サプライヤーなど）

☐ 内部顧客（同じ会社や系列子会社の他部署）

☐ 会社（参加国）の研究者またはエンジニアなどのパートナー（プロジェクトメンバー以外）

☐ 会社（参加国）の経営幹部

☐ 会社（参加国）の人事部

☐ 参加国で連携する大学教職員または学生

☐ 参加国の政府関係者

☐ Other:_____

グローバル研究開発プロジェクトにおける困難について

プロジェクト X に関して当てはまるものを選択してください。また、プロジェクト X の期間中に起こった変化についてあなたが感じたことを回答してください。プロジェク

トXが，まだ終了していない場合は，「終了する段階」を「現段階」に置き換えて回答してください.

質問形式：

このセクションには下記の８つの質問があります。それらは３つに分類されます。まず、プロジェクトの困難さについて。２つ目に、その難しい状況がどのように変化したか。最後に、その状況を改善するためにあなたが使用した/必要としたコンピテンシーについてです。これらは質問文の頭に（D：困難、S：状況変化、C：コンピテンシー）と表示されます。

Q１：プロジェクトXにおける成果物の品質管理に関する質問

Q２：プロジェクトXにおける現状認識に関する質問.

Q３：プロジェクトXにおけるチーム間での連絡・相談・支援に関する質問.

Q４：プロジェクトXにおけるチーム間のコミュニケーション効率に関する質問.

Q５：プロジェクトXにおけるチーム間の研究開発方針・研究方法の不一致に関する質問.

Q６：プロジェクトXにおけるチーム間の品質・納期・コストの優先度の違いに関する質問.

Q７：プロジェクトXにおける変更要求に関する質問.

Q８：プロジェクトXにおける顧客のニーズ・要求の理解に関する質問.

Q1: プロジェクトXでの成果物の品質管理に課題があった

例：主導国チームが期待する成果物の品質（性能，完成度など）と参加国チームの成果物の品質に大きなギャップがあった.

11) D1: プロジェクトの初期段階で上記質問に対して当てはまるものをお選びください

○ とても当てはまる

○ 当てはまる

○ 当てはまらない又は関係ない

12) 上記の品質管理の課題はどのようなものですか？（当てはまる場合のみ回答）

☐ 期待していた性能でない

☐ 期待していた完成度でない（不十分な点が多い）

☐ 期待していた内容ではない（方向性が違う）

☐ 期待していたものより時間がかかった

☐ Other:_____

13) 上記の困難の主な原因は何だと思いますか？例：〇〇の違い，〇〇の不足（当てはまる場合のみ回答）_____

14) S1: プロジェクトが終了する段階で，その状況はどのように変化しましたか？

○ 改善した

○ わずかに改善した

○ 変化しなかった

○ わずかに悪化した

○ 悪化した

15) C1: 状況を改善するためにどのようなコンピテンシーを活用した/必要としましたか？（当てはまるもの上位 5 つ以内）

☐ 知識・情報伝達力 例：プロジェクトに必要な知識・情報を収集，共有，伝達，移転，継承する能力

☐ 現場把握力 例：主導国や参加国の現場の状況を把握するスキル

□ 柔軟な対応力 例：想定外の状況に対しても柔軟に対応できる能力

□ 意思決定力 例：ある程度の責任を持って迅速に意思決定を行う能力

□ 外国のビジネス環境への理解力 例：相手国のビジネス慣習や商習慣や働き方の理解力

□ 外国文化・風習の学習能力 例：外国人の思考や行動パターンを理解し適応する力

□ コミュニケーションスキル 例：円滑な意思疎通を行うためのスキル，語学能力

□ 協働促進スキル 例：多様なメンバーが一緒に働き易くし，シナジー効果を発揮させるスキル

□ エンパワーメント力 例：相手国メンバーに権限を委譲しつつ適切にフォローするスキル

□ 人事管理能力 例：プロジェクトに必要な人材（リソース）の調達・強化力

□ 戦略的な思考力 例：システムの全体最適を考えるなど，より広い長期的な視点で問題を捉える能力

16) 具体的に行った改善施策は何でしょうか？例：レビューの仕組みの変更（当てはまる場合のみ回答）_____

Q2: プロジェクト X では，主導国チームと参加国チームでは現状認識に違いがある.

例：主導国チーム側はプロジェクトの進捗の遅れに危機感を感じていたが，参加国チーム側はあまり危機感を持っていなかった.

17) D2: プロジェクトの初期段階で上記質問に対して当てはまるものをお選びください

○ とても当てはまる

○ 当てはまる

○ 当てはまらない又は関係ない

18) 上記の現状認識の課題はどのようなものですか？（当てはまる場合のみ回答）

□ 進捗状況に関する現状認識の違い

□ 会社の期待に関する現状認識の違い

□ リスク・危機感に関する現状認識の違い

□ リソース（人材，設備）に関する現状認識の違い

□ Other:_____

19) 上記の困難の主な原因は何だと思いますか？例：〇〇の違い，〇〇の不足（当てはまる場合のみ回答）_____

20) S2: プロジェクトが終了した時，その状況はどのように変化したか？

〇 改善した

〇 わずかに改善した

〇 変化しなかった

〇 わずかに悪化した

〇 悪化した

21) C2: 状況を改善するためにどのようなコンピテンシーを利用した/必要としましたか？（当てはまるもの上位 5 つ以内）

□ 知識・情報伝達力 例：プロジェクトに必要な知識・情報を収集，共有，伝達，移転，継承する能力

□ 現場把握力 例：主導国や参加国の現場の状況を把握するスキル

□ 柔軟な対応力 例：想定外の状況に対しても柔軟に対応できる能力

□ 意思決定力 例：ある程度の責任を持って迅速に意思決定を行う能力

□ 外国のビジネス環境への理解力 例：相手国のビジネス慣習や商習慣や働き方の理解力

□ 外国文化・風習の学習能力 例：外国人の思考や行動パターンを理解し適応する力

□ コミュニケーションスキル 例：円滑な意思疎通を行うためのスキル，語学能力

□ 協働促進スキル 例：多様なメンバーが一緒に働き易くし，シナジー効果を発揮させるスキル

□ エンパワーメント力 例：相手国メンバーに権限を委譲しつつ適切にフォローするスキル

□ 人事管理能力 例：プロジェクトに必要な人材（リソース）の調達・強化力

□ 戦略的な思考力 例：システムの全体最適を考えるなど，より広い長期的な視点で問題を捉える能力

22) 具体的に行った改善施策は何でしょうか？例：現地打ち合わせ頻度増やした（当てはまる場合のみ回答）_____

Q3: プロジェクト X では，主導国チームと参加国チーム間での連絡・相談・支援が十分でない.

例）主導国チームは，参加国チームに仕事を丸投げし途中段階での十分なケアが不十分であった．参加国チームも主導国に必要なサポートを求めなかった.

23) D3: プロジェクトの初期段階で上記質問に対して当てはまるものをお選びください

○ とても当てはまる

○ 当てはまる

○ 当てはまらない又は関係ない

24) 上記の連絡・相談・支援の課題はどのようなものですか？（当てはまる場合のみ回答）

□ 連絡・相談が不十分

□ 支援が不十分（時間がない等，リソース的に支援が難しい）

□ 支援が不十分（内容的に支援が難しい）

□ Other:_____

25) 上記の困難の主な原因は何だと思いますか？例：○○の違い，○○の不足（当てはまる場合のみ回答）_____

26) S3: プロジェクトが終了した時，その状況はどのように変化したか？

○ 改善した

○ わずかに改善した

○ 変化しなかった

○ わずかに悪化した

○ 悪化した

27) C3: 状況を改善するためにどのようなコンピテンシーを利用した/必要としましたか？（当てはまるもの上位 5 つ以内）

□ 知識・情報伝達力 例：プロジェクトに必要な知識・情報を収集，共有，伝達，移転，継承する能力

□ 現場把握力 例：主導国や参加国の現場の状況を把握するスキル

□ 柔軟な対応力 例：想定外の状況に対しても柔軟に対応できる能力

□ 意思決定力 例：ある程度の責任を持って迅速に意思決定を行う能力

□ 外国のビジネス環境への理解力 例：相手国のビジネス慣習や商習慣や働き方の理解力

□ 外国文化・風習の学習能力 例：外国人の思考や行動パターンを理解し適応する力

□ コミュニケーションスキル 例：円滑な意思疎通を行うためのスキル，語学能力

□ 協働促進スキル 例：多様なメンバーが一緒に働き易くし，シナジー効果を発揮させるスキル

□ エンパワーメント力 例：相手国メンバーに権限を委譲しつつ適切にフォローするスキル

□ 人事管理能力 例：プロジェクトに必要な人材（リソース）の調達・強化力

□ 戦略的な思考力 例：システムの全体最適を考えるなど，より広い長期的な視点で問題を捉える能力

28) 具体的に行った改善施策は何でしょうか？例：支援体制を強化した（当てはまる場合のみ回答）_____

Q4: プロジェクト X では，主導国チームと参加国チーム間のコミュニケーションの効率が悪い.

例：チーム間で同じ情報を何度もやり取りしないと伝わらなかった.

29) D4: プロジェクトの初期段階で上記質問に対して当てはまるものをお選びください

○ とても当てはまる

○ 当てはまる

○ 当てはまらない又は関係ない

30) 上記のコミュニケーション効率の課題はどのようなものですか？（当てはまる場合のみ回答）

□ 伝達内容が迅速に伝わらない（理解に時間がかかる）

□ 伝達内容が正確に伝わらない（誤解が多い）

□ Other:_____

31) 上記の困難の主な原因は何だと思いますか？例：○○の違い，○○の不足（当てはまる場合のみ回答）_____

32) S4: プロジェクトが終了した時，その状況はどのように変化したか？

○ 改善した

○ わずかに改善した

○ 変化しなかった

○ わずかに悪化した

○ 悪化した

33) C4: 状況を改善するためにどのようなコンピテンシーを利用した/必要としましたか？（当てはまるもの上位 5 つ以内）

□ 知識・情報伝達力 例：プロジェクトに必要な知識・情報を収集，共有，伝達，移転，継承する能力

□ 現場把握力 例：主導国や参加国の現場の状況を把握するスキル

□ 柔軟な対応力 例：想定外の状況に対しても柔軟に対応できる能力

□ 意思決定力 例：ある程度の責任を持って迅速に意思決定を行う能力

□ 外国のビジネス環境への理解力 例：相手国のビジネス慣習や商習慣や働き方の理解力

□ 外国文化・風習の学習能力 例：外国人の思考や行動パターンを理解し適応する力

□ コミュニケーションスキル 例：円滑な意思疎通を行うためのスキル，語学能力

□ 協働促進スキル 例：多様なメンバーが一緒に働き易くし，シナジー効果を発揮させるスキル

□ エンパワーメント力 例：相手国メンバーに権限を委譲しつつ適切にフォローするスキル

□ 人事管理能力 例：プロジェクトに必要な人材（リソース）の調達・強化力

□ 戦略的な思考力 例：システムの全体最適を考えるなど，より広い長期的な視点で問題を捉える能力

34) 具体的に行った改善施策は何でしょうか？例：毎回議事録で確認した（当てはまる場合のみ回答）_____

Q5: プロジェクト X では，主導国チームと参加国チーム間で研究開発方針・研究方法でかみ合わないことが多い.

研究開発方針・研究方法は，研究開発で用いる技術・手法（アルゴリズムなど）・評価基準のこと．例：主導国チームは安定性を重視したが，参加国は性能を重視した．

35) D5: プロジェクトの初期段階で上記質問に対して当てはまるものをお選びください

○ とても当てはまる

○ 当てはまる

○ 当てはまらない又は関係ない

36) 上記の研究開発方針・研究方法の課題はどのようなものですか？（当てはまる場合のみ回答）

☐ 研究開発目標・評価基準がかみ合わない

☐ 研究開発方法がかみ合わない

☐ 参加国チームは自律性を求め，主導国チームは統制を求める

☐ Other:_____

37) 上記の困難の主な原因は何だと思いますか？例：○○の違い，○○の不足（当てはまる場合のみ回答）_____

Q5: プロジェクト X では，主導国チームと参加国チーム間で研究開発方針・研究方法でかみ合わないことが多い．

研究開発方針・研究方法は，研究開発で用いる技術・手法（アルゴリズムなど）・評価基準のこと．例：主導国チームは安定性を重視したが，参加国は性能を重視した．

38) S5: プロジェクトが終了した時，その状況はどのように変化したか？

○ 改善した

○ わずかに改善した

○ 変化しなかった

○ わずかに悪化した

○ 悪化した

39) C5: 状況を改善するためにどのようなコンピテンシーを利用した/必要としましたか？（当てはまるもの上位 5 つ以内）

☐ 知識・情報伝達力 例：プロジェクトに必要な知識・情報を収集，共有，伝達，移転，継承する能力

☐ 現場把握力 例：主導国や参加国の現場の状況を把握するスキル

☐ 柔軟な対応力 例：想定外の状況に対しても柔軟に対応できる能力

☐ 意思決定力 例：ある程度の責任を持って迅速に意思決定を行う能力

☐ 外国のビジネス環境への理解力 例：相手国のビジネス慣習や商習慣や働き方の理解力

☐ 外国文化・風習の学習能力 例：外国人の思考や行動パターンを理解し適応する力

☐ コミュニケーションスキル 例：円滑な意思疎通を行うためのスキル，語学能力

☐ 協働促進スキル 例：多様なメンバーが一緒に働き易くし，シナジー効果を発揮させるスキル

☐ エンパワーメント力 例：相手国メンバーに権限を委譲しつつ適切にフォローするスキル

☐ 人事管理能力 例：プロジェクトに必要な人材（リソース）の調達・強化力

☐ 戦略的な思考力 例：システムの全体最適を考えるなど，より広い長期的な視点で問題を捉える能力

40) 具体的に行った改善施策は何でしょうか？例：ある程度自律性を認めた（当てはまる場合のみ回答）_____

Q6: プロジェクト X では，主導国チームと参加国チーム間では品質・納期・コストに関する優先度に違いがある.

例）参加国チームは新技術の探索はあまり行わず，既存技術を使って成果を素早く出すことを重視した.

41) D6: プロジェクトの初期段階で上記質問に対して当てはまるものをお選びください

○ とても当てはまる

○ 当てはまる

○ 当てはまらない又は関係ない

42) 上記の品質・納期（スピード）・コストの課題はどのようなものですか？（当てはまる場合のみ回答）

□ 主導国：品質重視，参加国：納期（スピード）重視

□ 主導国：品質重視，参加国：コスト重視

□ 主導国：納期（スピード）重視，参加国：品質重視

□ 主導国：納期（スピード）重視，参加国：コスト重視

□ 主導国：コスト重視，参加国：品質重視

□ 主導国：コスト重視，参加国：納期（スピード）重視

43) 上記の困難の主な原因は何だと思いますか？例：〇〇の違い，〇〇の不足（当てはまる場合のみ回答）_____

44) S6: プロジェクトが終了した時，その状況はどのように変化したか？

○ 改善した

○ わずかに改善した

○ 変化しなかった

○ わずかに悪化した

○ 悪化した

45) C6: 状況を改善するためにどのようなコンピテンシーを利用した/必要としましたか？（当てはまるもの上位 5 つ以内）

☐ 知識・情報伝達力 例：プロジェクトに必要な知識・情報を収集，共有，伝達，移転，継承する能力

☐ 現場把握力 例：主導国や参加国の現場の状況を把握するスキル

☐ 柔軟な対応力 例：想定外の状況に対しても柔軟に対応できる能力

☐ 意思決定力 例：ある程度の責任を持って迅速に意思決定を行う能力

☐ 外国のビジネス環境への理解力 例：相手国のビジネス慣習や商習慣や働き方の理解力

☐ 外国文化・風習の学習能力 例：外国人の思考や行動パターンを理解し適応する力

☐ コミュニケーションスキル 例：円滑な意思疎通を行うためのスキル，語学能力

☐ 協働促進スキル 例：多様なメンバーが一緒に働き易くし，シナジー効果を発揮させるスキル

☐ エンパワーメント力 例：相手国メンバーに権限を委譲しつつ適切にフォローするスキル

☐ 人事管理能力 例：プロジェクトに必要な人材（リソース）の調達・強化力

☐ 戦略的な思考力 例：システムの全体最適を考えるなど，より広い長期的な視点で問題を捉える能力

46) 具体的に行った改善施策は何でしょうか？例：事前の意識合わせを行った（当てはまる場合のみ回答）_____

Q7: プロジェクト X では，主導国チームが大きな変更を要求する場合，参加国チームはその変更に納得しない.

例：主導国チームが使用する技術の大幅な変更を要求したが，参加国チームにはその理由がわからず不満が残った.

47) D7: プロジェクトの初期段階で上記質問に対して当てはまるものをお選びください

○ とても当てはまる

○ 当てはまる

○ 当てはまらない又は関係ない

48) 上記の変更要求の課題はどのようなものですか？（当てはまる場合のみ回答）

☐ 頻繁な変更要求に不満

☐ 大きな変更要求に不満

☐ Other:_____

49) 上記の困難の主な原因は何だと思いますか？例：○○の違い，○○の不足（当てはまる場合のみ回答）_____

50) S7: プロジェクトが終了した時，その状況はどのように変化したか？

○ 改善した

○ わずかに改善した

○ 変化しなかった

○ わずかに悪化した

○ 悪化した

51) C7: 状況を改善するためにどのようなコンピテンシーを利用した/必要としましたか？（当てはまるもの上位５つ以内）

☐ 知識・情報伝達力 例：プロジェクトに必要な知識・情報を収集，共有，伝達，移転，継承する能力

☐ 現場把握力 例：主導国や参加国の現場の状況を把握するスキル

□ 柔軟な対応力 例：想定外の状況に対しても柔軟に対応できる能力

□ 意思決定力 例：ある程度の責任を持って迅速に意思決定を行う能力

□ 外国のビジネス環境への理解力 例：相手国のビジネス慣習や商習慣や働き方の理解力

□ 外国文化・風習の学習能力 例：外国人の思考や行動パターンを理解し適応する力

□ コミュニケーションスキル 例：円滑な意思疎通を行うためのスキル，語学能力

□ 協働促進スキル 例：多様なメンバーが一緒に働き易くし，シナジー効果を発揮させるスキル

□ エンパワーメント力 例：相手国メンバーに権限を委譲しつつ適切にフォローするスキル

□ 人事管理能力 例：プロジェクトに必要な人材（リソース）の調達・強化力

□ 戦略的な思考力 例：システムの全体最適を考えるなど，より広い長期的な視点で問題を捉える能力

52) 具体的に行った改善施策は何でしょうか？例：変更理由を説明した（当てはまる場合のみ回答）_____

Q8: プロジェクト X では，参加国チームが顧客のニーズ・要求を十分理解していない.

顧客には，消費者や納品先企業などの外部顧客と自社他部署や子会社などのような内部顧客のどちらも含む．例：参加国チームが研究開発した成果が，主導国の顧客の期待していたイメージと大きく違っていた.

53) D8: プロジェクトの初期段階で上記質問に対して当てはまるものをお選びください

○ とても当てはまる

○ 当てはまる

○ 当てはまらない又は関係ない

54) 上記の顧客ニーズ・要求理解の課題はどのようなものですか？（当てはまる場合のみ回答）

☐ 顧客ニーズ・要求が十分共有されていない

☐ 顧客ニーズ・要求は共有されていたが誤解していた

☐ 顧客ニーズ・要求に関心がなかった

☐ Other:_____

55) 上記の困難の主な原因は何だと思いますか？例：〇〇の違い，〇〇の不足（当てはまる場合のみ回答）_____

56) S8: プロジェクトが終了した時，その状況はどのように変化したか？

〇 改善した

〇 わずかに改善した

〇 変化しなかった

〇 わずかに悪化した

〇 悪化した

57) C8: 状況を改善するためにどのようなコンピテンシーを利用した/必要としましたか？（当てはまるもの上位 5 つ以内）

☐ 知識・情報伝達力 例：プロジェクトに必要な知識・情報を収集，共有，伝達，移転，継承する能力

☐ 現場把握力 例：主導国や参加国の現場の状況を把握するスキル

☐ 柔軟な対応力 例：想定外の状況に対しても柔軟に対応できる能力

☐ 意思決定力 例：ある程度の責任を持って迅速に意思決定を行う能力

☐ 外国のビジネス環境への理解力 例：相手国のビジネス慣習や商習慣や働き方の理解力

☐ 外国文化・風習の学習能力 例：外国人の思考や行動パターンを理解し適応する力

□ コミュニケーションスキル 例：円滑な意思疎通を行うためのスキル，語学能力

□ 協働促進スキル 例：多様なメンバーが一緒に働き易くし，シナジー効果を発揮させるスキル

□ エンパワーメント力 例：相手国メンバーに権限を委譲しつつ適切にフォローするスキル

□ 人事管理能力 例：プロジェクトに必要な人材（リソース）の調達・強化力

□ 戦略的な思考力 例：システムの全体最適を考えるなど，より広い長期的な視点で問題を捉える能力

58) 具体的に行った改善施策は何でしょうか？例：顧客との打ち合わせに参加させた（当てはまる場合のみ回答）

_____

基本的な情報

59) プロジェクト X に関わっていた当時のあなたの会社の属する業界はなんですか

□ 情報通信・情報サービス業

□ 製造業（情報通信以外）

□ サービス業（金融，流通，医療，介護，観光，教育など）

□ 建設業

□ 農林水産業

□ 交通・運輸・電力など社会インフラ

□ 大学・研究機関

□ 公共機関

□ Other:_____

60) その会社の（全ての拠点を含めた）従業員数はおよそ何人ですか

○ 1～10人

○ 11～300人

○ 301人～1万人

○ 1万人以上

61) 性別をお答えください

○ 男性

○ 女性

○ 答えたくない

○ Other:_____

62) プロジェクト X 終了時点でのあなたの年齢をお答えください

○ 31歳以下

○ 31～40歳

○ 41～50歳

○ 51～60歳

○ 61歳以上

○ 答えたくない

63) あなたの国籍をお答えください

_____

64) あなたの最終学歴をお答えください

○ 中卒

○ 高卒

○ 高専・短大・専門学校卒

○ 大学卒・学士

○ 修士号

○ 専門職大学院・ＭＢＡ

○ 博士号

○ 答えたくない

65) プロジェクト X 終了時点での職位の勤続年数をお答えください

○ １年未満

○ １～３年

○ ４～６年

○ ７～１０年

○ １０年以上

ご協力　まことにありがとうございました

Appendix D. Competencies

The competencies used in questionnaire and their additional description.

1) Ability to manage knowledge and information (collect, share, communicate, transfer, and inherit knowledge and information necessary for the project)
2) Ability to perceive global perspective (self-awareness, curiosity, inquisitiveness)
3) Resilience (flexibly respond to unexpected situations)
4) Decision-making power (making quicks decision with responsibility)
5) Ability to understand the worldwide business environment (understand foreign customers, and work style in other countries)
6) Learning foreign cultures and customs (adapting to foreigners thinking and behavior)
7) Communication skills (language skill for smooth communication)
8) Collaboration skills (help diverse people to work together smoothly and create synergy)
9) Empowering others (delegating authority, encouraging people)
10) Human resource management (human resources required for the project)
11) Strategic perspective (have a broader perspective, consider long-term results)

Appendix E. Results of qualitative comparative analysis

****
TRUTH TABLE ANALYSIS
****
Model: D1 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
~Time	0.416667	0.266667	0.925926
Size*~Output	0.416667	0.35	0.862069
~Size*Output	0.116667	0.0333334	1

solution coverage: 0.8
solution consistency: 0.90566

****
TRUTH TABLE ANALYSIS
****
Model: D1 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
~Time	0.416667	0.266667	0.925926

Size*~Output 0.416667 0.35 0.862069
~Size*Output 0.116667 0.0333334 1
solution coverage: 0.8
solution consistency: 0.90566

****
TRUTH TABLE ANALYSIS
****
Model: D1 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8
Assumptions:

	raw coverage	unique coverage	consistency
~Time	0.416667	0.266667	0.925926
Size*~Output	0.416667	0.35	0.862069
~Size*Output	0.116667	0.0333334	1

solution coverage: 0.8
solution consistency: 0.90566

****
TRUTH TABLE ANALYSIS
****
Model: ~D1 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
Assumptions:

```
                raw       unique
               coverage    coverage   consistency
              ----------  ----------  ----------
~Time           0.153846    0.0769231   0.0740741
Size*~Output    0.307692    0.230769    0.137931
~Size*Output    0           0           0
solution coverage: 0.384615
solution consistency: 0.0943396

**********************
*TRUTH TABLE ANALYSIS*
**********************
Model: D2 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
                raw       unique
               coverage    coverage   consistency
              ----------  ----------  ----------
Output*~Time    0.156863    0.0588235   1
~Size*Output    0.137255    0.0392157   1
solution coverage: 0.196078
solution consistency: 1

**********************
*TRUTH TABLE ANALYSIS*
**********************
Model: D2 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
```

consistency cutoff: 1

	raw coverage	unique coverage	consistency
Output*~Time	0.156863	0.0588235	1
~Size*Output	0.137255	0.0392157	1

solution coverage: 0.196078

solution consistency: 1

****

TRUTH TABLE ANALYSIS

****

Model: D2 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2

consistency cutoff: 1

Assumptions:

	raw coverage	unique coverage	consistency
Output*~Time	0.156863	0.0588235	1
~Size*Output	0.137255	0.0392157	1

solution coverage: 0.196078

solution consistency: 1

****

TRUTH TABLE ANALYSIS

****

Model: ~D2 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2

consistency cutoff: 1

Assumptions:

	raw coverage	unique coverage	consistency
Output*~Time	0	0	0
~Size*Output	0	0	0

solution coverage: 0

solution consistency: 0

****

TRUTH TABLE ANALYSIS

****

Model: D3 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff: 2

consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
Size*~Time	0.173913	0.108696	1
Output*~Time	0.152174	0.0869565	0.875

solution coverage: 0.26087

solution consistency: 0.923077

****

TRUTH TABLE ANALYSIS

****

Model: D3 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---

frequency cutoff: 2

consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
Size*~Time	0.173913	0.108696	1
Output*~Time	0.152174	0.0869565	0.875

solution coverage: 0.26087

solution consistency: 0.923077

****

TRUTH TABLE ANALYSIS

****

Model: D3 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2

consistency cutoff: 0.8

Assumptions:

	raw coverage	unique coverage	consistency
Size*~Time	0.173913	0.108696	1
Output*~Time	0.152174	0.0869565	0.875

solution coverage: 0.26087

solution consistency: 0.923077

****

TRUTH TABLE ANALYSIS

****

Model: ~D3 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2

consistency cutoff: 1

Assumptions:

	raw coverage	unique coverage	consistency
Size*~Time	0	0	0
Output*~Time	0.037037	0.037037	0.125

solution coverage: 0.037037

solution consistency: 0.0769231

****

TRUTH TABLE ANALYSIS

****

Model: D4 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff: 2

consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
Size*~Output*~Time	0.0851064	0.0851064	0.8
Size*Output*Time	0.0638298	0.0638298	1

solution coverage: 0.148936

solution consistency: 0.875

****

TRUTH TABLE ANALYSIS

****

Model: D4 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
Size*~Output*~Time	0.0851064	0.0851064	0.8
Size*Output*Time	0.0638298	0.0638298	1

solution coverage: 0.148936
solution consistency: 0.875

****
TRUTH TABLE ANALYSIS
****
Model: D4 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8
Assumptions:

	raw coverage	unique coverage	consistency
Size*~Output*~Time	0.0851064	0.0851064	0.8
Size*Output*Time	0.0638298	0.0638298	1

solution coverage: 0.148936
solution consistency: 0.875

****
TRUTH TABLE ANALYSIS
****

Model: ~D4 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
Size*~Output*~Time	0.0384615	0.0384615	0.2
Size*Output*Time	0	0	0

solution coverage: 0.0384615
solution consistency: 0.125

****
TRUTH TABLE ANALYSIS
****
Model: D5 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
Size*~Time	0.189189	0.108108	0.875
Output*~Time	0.189189	0.108108	0.875

solution coverage: 0.297297
solution consistency: 0.846154

****
TRUTH TABLE ANALYSIS

****

Model: D5 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---

frequency cutoff: 2

consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
Size*~Time	0.189189	0.108108	0.875
Output*~Time	0.189189	0.108108	0.875

solution coverage: 0.297297

solution consistency: 0.846154

****

TRUTH TABLE ANALYSIS

****

Model: D5 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2

consistency cutoff: 0.8

Assumptions:

	raw coverage	unique coverage	consistency
Size*~Time	0.189189	0.108108	0.875
Output*~Time	0.189189	0.108108	0.875

solution coverage: 0.297297

solution consistency: 0.846154

****

TRUTH TABLE ANALYSIS

****

Model: ~D5 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2

consistency cutoff: 1

Assumptions:

	raw coverage	unique coverage	consistency
Size*~Time	0.0277778	0.0277778	0.125
Output*~Time	0.0277778	0.0277778	0.125

solution coverage: 0.0555556

solution consistency: 0.153846

****

TRUTH TABLE ANALYSIS

****

Model: D6 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff: 2

consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
Output*~Time	0.162791	0.0697674	0.875
~Size*Output	0.139535	0.0465116	0.857143

solution coverage: 0.209302

solution consistency: 0.9

****
TRUTH TABLE ANALYSIS
****
Model: D6 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
Output*~Time	0.162791	0.0697674	0.875
~Size*Output	0.139535	0.0465116	0.857143

solution coverage: 0.209302
solution consistency: 0.9

****
TRUTH TABLE ANALYSIS
****
Model: D6 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8
Assumptions:

	raw coverage	unique coverage	consistency
Output*~Time	0.162791	0.0697674	0.875
~Size*Output	0.139535	0.0465116	0.857143

solution coverage: 0.209302
solution consistency: 0.9

****

TRUTH TABLE ANALYSIS

****

Model: ~D6 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2

consistency cutoff: 1

Assumptions:

	raw coverage	unique coverage	consistency
Output*~Time	0.0333333	0	0.125
~Size*Output	0.0333333	0	0.142857

solution coverage: 0.0333333

solution consistency: 0.1

****

TRUTH TABLE ANALYSIS

****

Model: D7 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff: 2

consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
Output*~Time	0.162791	0.0697674	0.875
~Size*Output	0.139535	0.0465116	0.857143

solution coverage: 0.209302

solution consistency: 0.9

****
TRUTH TABLE ANALYSIS
****
Model: D7 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
Output*~Time	0.162791	0.0697674	0.875
~Size*Output	0.139535	0.0465116	0.857143

solution coverage: 0.209302
solution consistency: 0.9

****
TRUTH TABLE ANALYSIS
****
Model: D7 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8
Assumptions:

	raw coverage	unique coverage	consistency
Output*~Time	0.162791	0.0697674	0.875
~Size*Output	0.139535	0.0465116	0.857143

solution coverage: 0.209302
solution consistency: 0.9

****
TRUTH TABLE ANALYSIS
****
Model: ~D7 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
Output*~Time	0.0333333	0	0.125
~Size*Output	0.0333333	0	0.142857

solution coverage: 0.0333333
solution consistency: 0.1

****
TRUTH TABLE ANALYSIS
****
Model: D8 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8

	raw coverage	unique coverage	consistency
~Size*Output	0.115385	0.0769231	0.857143

```
Output*Time           0.0961538   0.0576923   1
Size*~Output*~Time    0.0769231   0.0769231   0.8
solution coverage: 0.25
solution consistency: 0.866667

**********
*TRUTH TABLE ANALYSIS*
**********
Model: D8 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8
                     raw       unique
                    coverage    coverage   consistency
                   ----------  ----------  ----------
~Size*Output          0.115385    0.0769231   0.857143
Output*Time           0.0961538   0.0576923   1
Size*~Output*~Time    0.0769231   0.0769231   0.8
solution coverage: 0.25
solution consistency: 0.866667

**********
*TRUTH TABLE ANALYSIS*
**********
Model: D8 = f(Size, Output, Time)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.8
Assumptions:
                     raw       unique
```

	raw coverage	unique coverage	consistency
~Size*Output	0.115385	0.0769231	0.857143
Output*Time	0.0961538	0.0576923	1
Size*~Output*~Time	0.0769231	0.0769231	0.8

solution coverage: 0.25

solution consistency: 0.866667

****

TRUTH TABLE ANALYSIS

****

Model: ~D8 = f(Size, Output, Time)

Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2

consistency cutoff: 1

Assumptions:

	raw coverage	unique coverage	consistency
~Size*Output	0.047619	0.047619	0.142857
Output*Time	0	0	0
Size*~Output*~Time	0.047619	0.047619	0.2

solution coverage: 0.0952381

solution consistency: 0.133333