# A Method for Innovation Capability Evaluation in Banking

NGO Nu Dieu Khue

Graduate School of Advanced Science and Technology
Japan Advanced Institute of Science and Technology

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Master's Thesis

# A Method for Innovation Capability Evaluation in Banking

1710415 NGO Nu Dieu Khue

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| Supervisor: | Professor HUYNH, Nam Van |
| Main Examiner: | HUYNH, Nam Van |
| Examiners: | Youji Kohda |
| | Kim Eunyoung |
| | Takaya Yuizono |

Graduate School of Advanced Science and Technology
Japan Advanced Institute of Science and Technology
[Knowledge Science]

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# Abstract

Under the strong impact of the fourth industrial revolution, innovation happens in all sectors of the economy and is expected to change the entire production, management systems all around the world. This revolution helps the firms increase productivity, flexibility and efficiency, shorten the time to bring products to market, thereby increasing their competitiveness. Not only the manufacturing sectors, but the banking sector has also been increasingly applying the advanced technologies such as big data, cloud computing, artificial intelligence, Blockchain to change their traditional financial services and distribution channels to bring about new experiences for their customers as well as to compete with the competitors on a global scale. Besides, the banks are also facing severe challenges such as changing existing processes, recruiting and training high-quality personnel and mobilizing other resources to adapt to the digital age. If a bank does not innovate effectively, it cannot survive and develop stably in the current era of fierce competition. In order to innovate productively, the banks have to upgrade their innovation capability regularly by managing well multiple innovation practices. Therefore, measuring innovation processes in banking with various practices becomes urgent and evokes much interest from both academics and bank managers. In literature, there have been many studies related to innovation measurement in the manufacturing and service sectors, but there remain few relevant research on evaluating innovation capability in the banking sector, particularly.

This thesis focuses on developing a framework for assessing innovation capability in banking. Firstly, the evaluation indicators system was established in terms of critical innovation management practices. By conducting a comprehensive literature review on the best innovation practices and then using Pareto analysis, 11 critical innovation management practices (strategic planning, resource management, organization, idea management, process innovation, marketing, R&D, learning, portfolio management, knowledge management, and technological innovation) and their 44 sub-practices were extracted. A group of five experts in banking major was invited to answer the survey questionnaire for scoring these sub-practices in a sample group of three major Vietnamese banks. Then, an innovation capability evaluation method was developed based on Analytic Hierarchy Process (AHP) for analyzing the importance of the 11 critical innovation management practices

as well as their corresponding sub-practices. The result showed that strategic planning, resource management and technological innovation were the most important practices in banking innovation nowadays. Finally, an innovation capability index was computed for each bank and used for ranking. The findings of this research could be a basis for the banks to review their innovation activities, determine the priority areas for development, thereby having reasonable adjustments in their innovation management policies intending to improve their innovation capability, reinforce their innovation outcomes and achieve superior business performance.

**Keywords**: innovation, innovation management, innovation capability, evaluation, banking.

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NGO Nu Dieu Khue

JAIST, August 2019

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# Abbreviation

| | |
|---|---|
| AHP | Analytical Hierarchy Process |
| IC | Innovation Capability |
| ICI | Innovation Capability Index |
| IMP | Innovation Management Practice |
| CIMP | Critical Innovation Management Practice |
| NPD | New Product Development |
| SP | Strategic planning |
| RM | Resource management |
| OR | Organization |
| IM | Idea management |
| PI | Process innovation |
| MA | Marketing |
| RD | R&D |
| LE | Learning |
| PM | Portfolio management |
| KM | Knowledge management |
| TI | Technological innovation |

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# Chapter 1

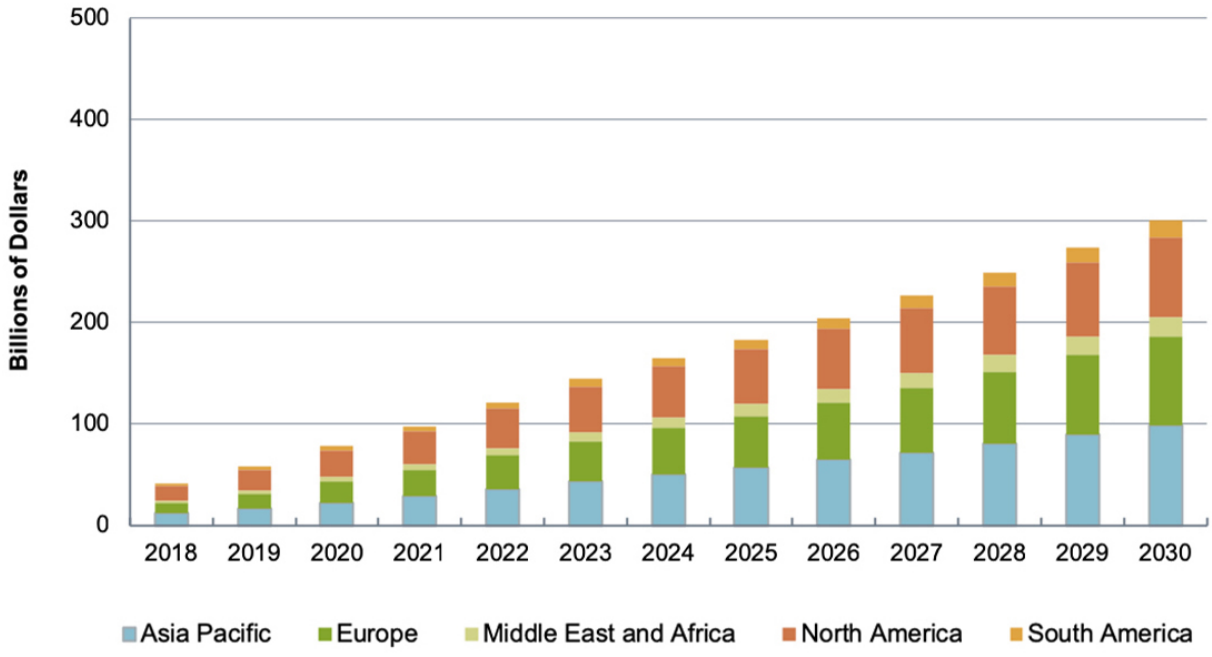
# Introduction

We first introduce current issues and theoretical background of our research in Section 1.1. Then, the research objectives are mentioned in Section 1.2. Section 1.3 indicates the contributions of this study. Finally, the thesis structure is illustrated in Section 1.4.

## 1.1 Background

In the era of increased global competition, highly diversified customer demands, along with the constant changes in sciences and technologies, every firm has to innovate continuously for taking advantages of new technologies to improve their products/services for maintaining competitiveness, retaining customers and ensuring success in business. According to O'Regan et al. (2006), one of the key drivers for enterprises to achieve sustainable competitive advantages is innovation [1]. Therefore, innovation activities are taking place forcefully in all sectors of our society. It can be seen that not only manufacturing companies but also the banks place innovation as a top priority in their strategies. Under the strong impact of the Industrial Revolution 4.0, the banks have increasingly integrated advanced technologies into their services to speed up their provision of services to their customers. They have developed new mobile applications such as mobile banking and Internet banking to enhance access to banking services for their clients from anywhere and at any time. The digital banks become popular with the extensive use of data and analytics to digitize processes. Recently, the emerging trends in banking industry are using new technologies such as big data, Blockchain, and artificial intelligence.

Figure 1.1: The business value for artificial intelligence in banking




Using big data in determining the needs of each customer through transaction histories and data from social networks is a useful tool towards personalized marketing. Then, the banks can create distinctive services for each customer segment, which will help build brand image and a good relationship with each customer. By applying Blockchain technology, interbank transactions and international transfers are operated faster and safer. Shortly, Blockchain is expected to replace existing bank transfer systems. Additionally, the banks can use artificial intelligence to assess credit quality, manage risk portfolios, and automatically interact with customers, optimize transaction execution at a higher level of accuracy and processing speed than humans. With the enormous innovative capabilities that artificial intelligence brings to banking services, the demands for artificial intelligence in banking are projected to overgrow in the future (see Figure 1.1) [2]. Another notable trend is that the banks have expanded cooperation with FinTech companies to launch new services fast and effectively. This cooperation helps take available advantages of both banks and FinTech companies. The banks have strengths on brands, customer platforms, risk management capabilities, and Fintech companies are specialized in advanced technologies, Blockchain or artificial intelligence platforms.

However, besides the opportunities open from Industrial Revolution 4.0, the bank-

ing sector also faces significant challenges in recruiting high-quality personnel, designing training programs for employees, preparing financial resources, building technology infrastructures, and planning proper strategies to catch up with the new trends of the digital age. Innovation is recognized as a very complex process that needs specific management, continuous improvements and reasonable investments into various innovation practices [3]. Thus, innovation capability (IC) evaluation methods from the perspective of an innovation process are required to pinpoint precisely areas that the banks should focus on [4]. By adjusting the efforts in innovation activities and resources dedicated to these practices regularly, the banks can upgrade their IC in order to innovate effectively.

The topics on innovation management and IC measurement have been studied extensively in the manufacturing and service sectors. The most-reported literature focuses on presenting the best innovation management practices (IMPs) in general [5–12]. Nevertheless, the use and effectiveness of IMPs will vary by sectors, so the managers should select suitable IMPs for their business contexts to achieve superior performance. Some studies are to assess innovation process in manufacturing enterprises [3, 13–17]. Despite the growing interest of innovation in banking, little attention has been devoted to innovation management in the banks. Especially, there is still a lack of a systematic method to evaluate IC for banking sector in particular. Drew (2005) benchmarked IMPs in financial institutions, including resources committed to innovation, innovative practices and approaches, and organizational factors [18]. Other existing studies of banking innovation mainly focus on a single aspect, for instance on top management [19], product [20, 21], technology [22], customer knowledge management [23]. There remains a shortcoming in systems thinking of a process of innovation management in banking. Hence, the elements that are essential for developing the banks' IC have not been fully explored. Because of the complicated nature of innovation, IC evaluation must consider a complex process of many different IMPs, not just one or two aspects of IC. In this study, we will exploit and measure multidimensional innovation process in banking sector, whereby we identify the banks' IC, and provide recommendations for the banks to improve their IC, produce better innovation outcomes and obtain higher business results.

## 1.2 Research Objectives

This research aims at evaluating IC of the banks, thereby filling the gap regarding innovation measurement in banking. Based on the findings, we will recommend practical actions for the banks to facilitate and improve innovation processes to innovate effectively and achieve superior performance.

To accomplish the purposes as mentioned above, the thesis focuses on four main issues as follows:

- Firstly, review theories of innovation, IC, IMPs and then determine critical IMPs (CIMPs) for the banking context.
- Secondly, synthesize methods or empirical works on IC evaluation, from which develop an appropriate method to measure the IC of the banks.
- Third, propose a framework for IC evaluation in banking, then apply it into a case study to determine IC of the banks and rank them based on their IC.
- Finally, discuss the empirical results and point out the strengths and weaknesses in innovation process of each bank. That is intended to be useful to top management of the banks in re-evaluating and adjusting their innovation management reasonably for improving their IC and business outcomes.

## 1.3 Research Contributions

The contribution of this thesis is as follows:

- We conduct a comprehensive survey about IMPs from many previous studies, then determine CIMPs that significantly influence the success of innovation.
- We collect primary data by asking experts for scoring sub-CIMPs to evaluate the development degree of CIMPs in the case of Vietnamese banks. Additionally, thanks to these experts, the importance weights of CIMPs and sub-CIMPs for banking context are determined.

- We propose a method for IC evaluation in banking sector where there is few research on innovation measurement. Our evaluation is based on a process of various CIMPs, not just a single aspect of innovation in banking.

## 1.4 Thesis Outline

The thesis is organized into six chapters as follows:

- In Chapter 1, we introduce current contexts and theoretical backgrounds regarding innovation in banking, research objectives, research contributions and thesis outline.
- In Chapter 2, we offer existing theories of innovation, IC, and IMPs. In addition, we also synthesize related works on IC evaluation methods.
- In Chapter 3, we explain in details our proposed process to evaluate IC in banking.
- In Chapter 4, we present the empirical results by applying our proposed method in a case study of Vietnamese banks.
- In Chapter 5, we discuss the research findings and some suggestions for banks to implement innovation successfully.
- In Chapter 6, we summarize the findings of this study, determine some limitations, and research directions for future works to improve the accuracy of IC evaluation in banking.

# Chapter 2

# Literature Review

In this chapter, we explain the terms of innovation in Section 2.1 and IC in Section 2.2. The IMPs obtained from a large body of relevant studies are listed in Section 2.3. Then, Section 2.4 offers a review on IC evaluation methods that were employed in previous research.

## 2.1 Innovation

Today, the concept "innovation" has been mentioned a lot in discussions among scholars, company managers, and governments. Because of its importance, many researchers have studied innovation. Thus, there are many definitions of innovation in the literature. Innovation means creating something new [24]. Rasul (2003) defined innovation as the process of developing ideas in order to create new or improved services/products, and commercialize them in the markets [25]. Rogers (1998) described innovation as the changes in business activities for improving firm performance [26]. Based on these definitions, innovation can be understood as a process of changes in the organization to create new or improved things so as to achieve higher performance.

According to Schumpeter (1947), there are several forms of innovation such as the introduction of a new or improved good, a new or improved method, exploitation of a new market, or setting a new organization [27]. Innovation does not always concern radical changes or a complete novelty. It has also been incremental innovation when adding small improvements in existing products/services. Because radical innovations are more costly

than incremental innovations, so the majority of innovations are incremental innovations.

## 2.2 Innovation Capability

In order to develop innovations, firms have to upgrade their IC continuously. IC refers to the regular improvements of the overall capabilities and resources that the firm possesses to explore and exploit opportunities to develop new products for fulfilling market needs [28]. According to Wang and Ahmed (2004), IC is defined as the ability to create new products through strategic orientation, innovative behaviours and technological processes [29]. Chen and Jaw (2009) described IC as the firm's ability to innovate product or process relying on processes, systems, and organizational structure [30]. From these definitions, the IC of a firm is a complex construct of innovation activities such as strategies, resources, technologies, processes, systems and organizations which support the transformation from ideas into new or improved products/services. Consequently, evaluating IC needs to consider simultaneously multiple criteria.

In an IC assessment for small and medium enterprises, Trindade et al. (2016) considered various factors about governance, organization, people and processes [31]. Boly et al. (2004) evaluated the IC of 39 French manufacturing firms based on 15 ICs that are design, project management, strategy, project portfolio management, organization, process improvement, competence management, moral support, knowledge management, technology intelligence, network management, collective learning, creativity, R&D and customer relationship management [3]. Hence, it is essential to develop a multidimensional scale to measure IC and determine critical dimensions for each context. Based on a comprehensive literature review, we will show the best innovation practices that can be used in IC evaluation in banking in the next section.

## 2.3 Innovation Management Practices

In this study, our approach of assessing IC relies on innovation process concerning different IMPs that foster the firms' capabilities and resources needed for successful innovation. We reviewed on a large body of prior studies related to innovation measurement by searching following keywords: innovation practices, innovation management practices,

innovation management measurement, innovation capability evaluation, empirical innovation management, new product development practices. Then, 28 articles most relevant to our research were selected.

Easingwood (1986) investigated new product development (NPD) practices in a wide range of services companies in the United Kingdom. By interviewing the leading companies in this sector, they claimed the best practices that differed the successful companies from the other were strategy, organization, idea generation and market test, and assessment after launch [32]. A research conducted by Drew (1995) in benchmarking of innovation practices for financial organizations clarified the importance of resources, separate strategic plans for NPD, idea generation and transfer, and organization factors [18]. Sundbo (1997) studied innovation management in services and defined three kinds of organizations classified by their innovation activities focusing on strategic management, participation in the network, or professional recruitment [33]. According to Griffin (1997), besides a specific strategy, a stage-gate process, outcome measure, the best-practice firms focused on organization with the use of multi-functional teams in NPD programs [34]. Balbontin et al. (2000) proposed a NPD model of NPD process, organizational culture, people, marketing, learning, technology and product [35]. In the approach of Lawson and Samson (2001) to develop IC of organizations, they considered the following elements: vision and strategy, competence management, intelligence, organizational structure and culture, and technology management [36]. Human resource management, strategy, technology management, R&D, design marketing, ideas, and performance measure were mentioned by Ulusoy (2003) as IMPs in the Turkey manufacturing sectors [37]. In 2004, Cooper published a series of three articles reporting the best NPD practices that were the main differences between the best and the worst firms. These were a climate of supporting innovation, senior management who lead the road of NPD and commit resources for NPD, the way of organizing the NPD project teams, business strategy, portfolio management, resource availability, and new product process [5] [6] [7]. Researching on topics related to technological ICs in Chinese firms of Yam et al. (2004, 2011) employed the same evaluation criteria including learning, R&D, resource, manufacturing, marketing, organization and strategic planning capabilities [38] [39]. Cormican and O'Sullivan (2004) revealed that the best practices in monitoring product innovation comprise strategy and leadership, culture

and climate, project planning and selection, structure and performance, communication and collaboration [40]. Guan et al. (2006) studied the impact of technological IC on the firms' competitiveness in China. The technological IC in their study was measured by learning, R&D, manufacturing, marketing, organization, and resources allocation [41]. Adam et al. (2006) reviewed diverse literature about the innovation process and summarized into 7 activities regarding input management, knowledge management, strategy, organization and culture, portfolio management, project management, and commercialization [12]. Oke (2007) classified IMPs in service companies into strategy management, idea management, portfolio management, implementation process and human resource management [11]. Koc and Ceylan (2007) investigated the main factors influencing the IC of large-scale companies in Turkey, particularly strategy, idea management, technology acquisition, teamwork, learning, management participation and delegation [9]. Rejeb (2008) employed an IC measurement system of 13 best IMPs: design tasks, projects management, strategic decisions, projects portfolio management, innovation process, working conditions, competence allocation, moral support, collective learning, knowledge management, survey tasks, technological networks, and creativity [42]. A research conducted by Wang et al. (2008) to determine the Taiwanese hi-tech firm's technological IC considers numerous quantitative and qualitative criteria measuring 5 aspects: R&D, innovation decisions, marketing, manufacturing and capital [16]. According to Brophey and Brown (2009) focused on idea management as a major IMP for small to medium-sized mechanical manufacturers [43]. In the most innovative firms, the innovativeness was dominated by the process of generating, screening, and implementing ideas.

Wang and Chang (2011) proposed a diagnosis system of innovation value in new project development that includes the following elements: strategy, product, process, organization and resources innovation. Their applying AHP indicated that process innovation plays the most important role in this innovation system [15]. Sánchez et al. (2011) studied key IMPs in the electronics industry by interviewing the company managers through 93 questions that detail 9 dimensions of innovation management in strategy, culture, human resources, creativity, project management, technology, process, product and commercialization. The interviewees were required to estimate the degree of using the innovation activities in their organizations using a Linkert scale from 1 to 7. Then, an

exploratory factor analysis helps to derive the main factors and their elements. In addition, the authors also found evidence of a positive effect of IMPs on business performance measured by sale growth, profit per employee and ROA [44]. Türker (2012) developed an innovation scale to measure technological IC in the manufacturing industry, particularly in the automotive sector. His measurement scale refers to innovation factors belonging to input, process and output. Specifically, input factors include human resources, knowledge, strategy and entrepreneurship. Process factors consider organizational culture, control, and other related factors. Output factors consist of tangible returns and intellectual capital [14]. In an analysis of technological IC in Thailand technology firms, Sumrit and Anuntavoranich (2013) used DEMATEL method to analyze the importance and casual relationships among criteria: strategic management, organization, resource allocation, risk management, learning, absorptive capacity, knowledge management, network, technology acquisition, R&D, cross-functional team, technology change, design, manufacturing and market [45]. For measuring innovation process in French manufacturing firms, Boly et al. (2014) employed 15 IMPs from a research of Boly (2009) that are design, project management, integrated strategy, project portfolio management, organization, process innovation, competence management, moral support, knowledge management, technology intelligence, network management, collective learning, ideas research, R&D, and customer relationship management [3]. The researchers applied value test to determine the weights of 15 IMPs for each innovative class. In doing so, they identified key IMPs for each companies group. Yang et al. (2015) introduced the IC evaluation indicators system based on uncertain linguistic variables covering idea, marketing, resource, strategy, organizational structure and culture, and knowledge capability [13]. A research was conducted by Vicente et al. (2015) to study IC of exporting companies. A reliable IC construct specified 4 important dimensions: product development, innovativeness, strategy, and technology capability. Furthermore, they also investigated a significantly positive association between IC and annual performance in the case of 471 exporting firms [46]. Trindade et al. (2016) evaluated the IC of cross-sector small and medium-sized firms in terms of governance and organization, people, and processes in each firm. With the help of experts, they established inference rules to decide which innovative class (proactive, active, preactive and passive) a firm belongs to. Contributing to the literature benchmarking IMPs across sec-

tors, Tidd and Thuriaux-Alemán (2016) presented 8 groups of IMPs including innovation strategy, idea management, resources and competence management, technology portfolio management, product portfolio management, development and launch, post-launch, and external business intelligence [8]. They also asserted that the effectiveness of using these IMPs will vary by sectors. Liu and Jiang (2016) studied the relationship between technological IC and product competitiveness [47]. They determined IC by the following elements: organization, strategies, financial, material, and human resources, R&D, knowledge, manufacturing capabilities.

From a variety of IMPs mentioned in these above articles, by grouping the related practices together based on their content described in the literature, we summarized into 25 primary IMPs that can be applied in banking sector as follows: strategic planning, resource management, organization, idea management, process innovation, marketing, R&D, learning, portfolio management, knowledge management, technological innovation, network management, project management, performance measure, product innovation, team management, moral support, commercialization, business intelligence, survey task, senior management, risk management, entrepreneurship, management participation, and delegation (see Table 2.1). We also eliminated some inappropriate practices with the context of banking such as manufacturing and design.

Table 2.1: Summary of IMPs

| No | IMPs | Authors |
|---|---|---|
| 1 | Strategic planning | Easingwood (1986) [32], Drew (1995) [18], Sundbo (1997) [33], Griffin (1997) [34], Lawson and Samson (2001) [36], Ulusoy (2003) [37], Cooper 2004 [6], Yam et al. (2004) [38], Cormican and O'Sullivan (2004) [40], Adam et al. (2006) [12], Oke (2007) [11], Koc and Ceylan (2007) [9], Rejeb et al. (2008) [42], Wang et al. (2008) [16], Wang and Chang (2011) [15], Sánchez et al. (2011) [44], Yam et al. (2011) [39], Türker (2012) [14], Sumrit and Anuntavoranich (2013) [45], Boly et al. (2014) [3], Yang et. al (2015) [13], Vicente et al. (2015) [46], Trindade et al. (2016) [31], Tidd and Thuriaux-Alemán (2016) [8], Liu and Jiang (2016) [47] |
| 2 | Resource management | Drew (1995) [18], Sundbo (1997) [33], Balbontin et al. (2000) [35], Lawson and Samson (2001) [36], Ulusoy (2003) [37], Cooper 2004 [6], Yam et al. (2004) [38], Guan et al. (2006) [41], Adam et al. (2006) [12], Oke (2007) [11], Rejeb et al. (2008) [42], Wang et al. (2008) [16], Wang and Chang (2011) [15], Sánchez et al. (2011) [44], Yam et al. (2011) [39], Türker (2012) [14], Sumrit and Anuntavoranich (2013) [45], Boly et al. (2014) [3], Yang et. al (2015) [13], Trindade et al. (2016) [31], Tidd and Thuriaux-Alemán (2016) [8], Liu and Jiang (2016) [47] |

| | | |
|---|---|---|
| 3 | Organization | Easingwood (1986) [32], Drew (1995) [18], Griffin (1997) [34], Balbontin et al. (2000) [35], Lawson and Samson (2001) [36], Cooper (2004) [5], Yam et al. (2004) [38], Cormican and O'Sullivan (2004) [40], Guan et al. (2006) [41], Adam et al. (2006) [12], Rejeb et al. (2008) [42], Wang and Chang (2011) [15], Sánchez et al. (2011) [44], Yam et al. (2011) [39], Türker (2012) [14], Sumrit and Anuntavoranich (2013) [45], Boly et al. (2014) [3], Yang et. al (2015) [13], Trindade et al. (2016) [31], Liu and Jiang (2016) [47] |
| 4 | Idea management | Easingwood (1986) [32], Drew (1995) [18], Lawson and Samson (2001) [36], Ulusoy (2003) [37], Oke (2007) [11], Koc and Ceylan (2007) [9], Rejeb et al. (2008) [42], Brophey and Brown (2009) [43], Sánchez et al. (2011) [44], Boly et al. (2014) [3], Yang et. al (2015) [13], Vicente et al. (2015) [46], Tidd and Thuriaux-Alemán (2016) [8] |
| 5 | Process innovation | Griffin (1997) [34], Balbontin et al. (2000) [35], Cooper (2004) [7], Oke (2007) [11], Rejeb et al. (2008) [42], Wang and Chang (2011) [15], Sánchez et al. (2011) [44], Türker (2012) [14], Boly et al. (2014) [3], Trindade et al. (2016) [31], Tidd and Thuriaux-Alemán (2016) [8] |
| 6 | Marketing | Balbontin et al. (2000) [35], Ulusoy (2003) [37], Yam et al. (2004) [38], Guan et al. (2006) [41], Wang et al. (2008) [16], Yam et al. (2011) [39], Sumrit and Anuntavoranich (2013) [45], Boly et al. (2014) [3], Yang et. al (2015) [13] |

| | | |
|---|---|---|
| 7 | R&D | Ulusoy (2003) [37], Yam et al. (2004) [38], Guan et al. (2006) [41], Wang et al. (2008) [16], Yam et al. (2011) [39], Sumrit and Anuntavoranich (2013) [45], Boly et al. (2014) [3], Liu and Jiang (2016) [47] |
| 8 | Learning | Balbontin et al. (2000) [35], Yam et al. (2004) [38], Guan et al. (2006) [41], Koc and Ceylan (2007) [9], Rejeb et al. (2008) [42], Yam et al. (2011) [39], Sumrit and Anuntavoranich (2013) [45], Boly et al. (2014) [3] |
| 9 | Portfolio management | Cooper (2004) [6], Cormican and O'Sullivan (2004) [40], Adam et al. (2006) [12], Oke (2007) [11], Rejeb et al. (2008) [42], Boly et al. (2014) [3], Tidd and Thuriaux-Alemán (2016) [8] |
| 10 | Knowledge management | Adam et al. (2006) [12], Rejeb et al. (2008) [42], Türker (2012) [14], Sumrit and Anuntavoranich (2013) [45], Boly et al. (2014) [3], Yang et. al (2015) [13], Liu and Jiang (2016) [47] |
| 11 | Technological innovation | Balbontin et al. (2000) [35], Lawson and Samson (2001) [36], Ulusoy (2003) [37], Koc and Ceylan (2007) [9], Sánchez et al. (2011) [44], Sumrit and Anuntavoranich (2013) [45], Vicente et al. (2015) [46] |
| 12 | Network management | Sundbo (1997) [33], Cormican and O'Sullivan (2004) [40], Rejeb et al. (2008) [42], Sumrit and Anuntavoranich (2013) [45], Boly et al. (2014) [3] |
| 13 | Project management | Adam et al. (2006) [12], Rejeb et al. (2008) [42], Sánchez et al. (2011) [44], Boly et al. (2014) [3] |
| 14 | Performance measure | Easingwood (1986) [32], Griffin (1997) [34], Ulusoy (2003) [37], Cormican and O'Sullivan (2004) [40] |
| 15 | Product innovation | Balbontin et al. (2000) [35], Wang and Chang (2011) [15], Sánchez et al. (2011) [44], Vicente et al. (2015) [46] |

| | | |
|---|---|---|
| 16 | Team management | Cooper (2004) [5], Koc and Ceylan (2007) [9], Sumrit and Anuntavoranich (2013) [45] |
| 17 | Moral support | Rejeb et al. (2008) [42], Boly et al. (2014) [3] |
| 18 | Commercialization | Adam et al. (2006) [12], Sánchez et al. (2011) [44] |
| 19 | Business intelligence | Lawson and Samson (2001) [36], Tidd and Thuriaux-Alemán (2016) [8] |
| 20 | Survey task | Rejeb et al. (2008) [42], Boly et al. (2014) [3] |
| 21 | Senior Management | Cooper (2004) [5] |
| 22 | Risk management | Sumrit and Anuntavoranich (2013) [45] |
| 23 | Entrepreneurship | Türker (2012) [14] |
| 24 | Management participation | Koc and Ceylan (2007) [9] |
| 25 | Delegation | Koc and Ceylan (2007) [9] |

## 2.4 Innovation Capability Evaluation Methods

The most common approach for IC evaluation in the literature was based on multiple criteria. However, the differences exist in various aggregation techniques. Table 2.2 presents different methods used for IC evaluation in previous studies.

Rejeb et al. (2008) proposed a framework of IC measure considering 13 IMPs including design tasks, project management, integrated strategy, portfolio management, process improvement, suitable organization, competence management, moral support, collective learning, knowledge management, survey tasks, network management, and creativity [42]. These criteria are observable. If a criterion is present, its score equals 1 and 0 otherwise. The authors applied value test to determine the characteristic weight vector for each innovative group. As a result, they computed potential innovation index and classified the firms into four groups that are proactive, preactive, reactive and passive. Notice that when an IMP obtains the high level of implementation, IC will become stabilized, the authors considered the threshold effect by fitting each IMP with either S-curve model or condenser load model. In addition, they applied Principal Components Analysis to reduce the number of IMPs. After removing unimportant factors for classification, the

representation of the firms is interpreted by the principal factors. Boly et al. (2014) also approached multi-criteria model and value test to determine IC of 39 manufacturing enterprises in French [3].

In the research of Wang et al. (2008), fuzzy integral method was adopted to measure technological ICs based on 5 following aspects: R&D, decision making, marketing, manufacturing, and capital [16]. Wang and Chang (2011) proposed a five-module innovation value diagnosis system of innovation in strategy, product, process, organization, and resource [15]. By using Analytic Hierarchy Process (AHP), they found the different importance roles of five modules among which process innovation was the most important module in innovation management of new projects. Cheng and Lin (2012) developed a hybrid method of fuzzy and MCDA to evaluate innovation performance and select the best supplier under fuzzy criteria of technological ICs [17].

Table 2.2: Review on IC evaluation methods

| Authors | Evaluated factors | Aggregation method |
|---|---|---|
| Rejeb et al. (2008) | Design tasks<br>Project follow-up<br>Integrated strategy<br>Portfolio management<br>Innovation process<br>Suitable organization<br>Competence management<br>Moral support<br>Collective learning<br>Knowledge management<br>Survey tasks<br>Network animation<br>Research/creativity | Value test<br>Data mining with Principal Components Analysis |

| | | |
|---|---|---|
| Wang et al. (2008) | R&D<br>Innovation decision<br>Marketing<br>Manufacturing<br>Capital | Fuzzy integral |
| Wang and Chang (2011) | Strategy innovation<br>Product innovation<br>Process innovation<br>Organization innovation<br>Resource innovation | Analytic Hierarchy Process (AHP) |
| Cheng and Lin (2012) | Strategic planning<br>Marketing<br>Innovation infrastructure<br>Knowledge and skills<br>TICs capabilities<br>External environment<br>Manufacturing capabilities | Hybrid Fuzzy-MCDA |

| | | |
|---|---|---|
| Boly et al. (2014) | Design<br>Project management<br>Integrated strategy<br>Project portfolio management<br>Suitable organization definition<br>Innovation process improvement<br>Competence management<br>Moral support<br>Knowledge management<br>Competitive technology intelligence<br>Network management<br>Collective learning<br>Ideas research/Creativity<br>R&D activities<br>Customer relationship management | Value test |

# Chapter 3

# Methodology

In this chapter, we first introduce a framework of four steps to evaluate IC of the banks. Then, each step will be explained in details.

## 3.1 Research Framework

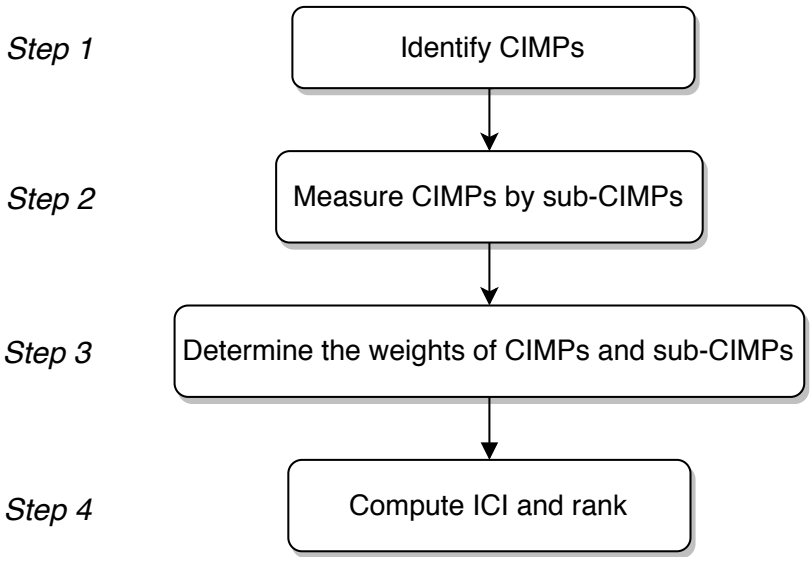
Our proposed research process for identifying IC consists of four steps, as illustrated in Figure 3.1. In step 1, CIMPs are explored by Pareto analysis based on their frequency of occurrences in the literature. Adapting from the prior studies, we establish the measurement items (sub-CIMPs) for each CIMP in step 2. Then, we ask a group of experts in banking sector for assessing the maturity level of sub-CIMPs in a sample group of banks. For step 3, we apply AHP to determine the weights of CIMPs and sub-CIMPs. Then, a composite index called Innovation Capability Index (ICI) is computed for each bank and used for ranking in step 4.

## 3.2 Procedure

### 3.2.1 Identify Critical Innovation Management Practices

Among many IMPs, CIMPs are vital constructs which must be carefully managed for being accomplished well to ensure success for innovation. Because of these practices' more important roles, the managers must put more efforts into them with the aims of improved innovation outcome, increased business outcomes, and strengthened compet-

Figure 3.1: The proposed process of IC evaluation




itive advantages. In order to determine the CIMPs, we employ a statistical technique called Pareto analysis, which is used for choosing which factors or tasks that can produce significant overall effect [48]. Pareto analysis helps to separate the "vital few" from the "use many", which is useful for making management decisions with emphasis on the most crucial problems. In the procedure of Pareto, we first conduct a comprehensive literature review to extract IMPs by searching related key words such as innovation management practices, innovation practices, innovation management measurement, innovation capability evaluation, empirical innovation management, new product development practices (as shown in Section 2.3). Secondly, we count the number of occurrences of each IMP in the literature and then rank all IMPs in the descending order of their occurrences. After that, we can compute the percentage of occurrences as well as cumulative percentage of occurrences for each IMP. Conforming to the rule 80/20 of Pareto analysis, "vital few" items (called CIMPs in this research) will occupy a considerable amount of 80 percent of cumulative percentage of occurrences, and "use many" items fill only the remaining 20 percent of occurrences. Based on this rule, CIMPs are chosen from the IMP with the highest occurrences to the IMP at the cumulative percentage of occurrences around 80 percent. The result of Pareto analysis is usually represented in a table which shows in sequence: all IMPs, occurrences (in descending order), percentage of occurrences, cumulative percentage of occurrences.

### 3.2.2 Measure Critical Innovation Management Practices by sub-Critical Innovation Management Practices

To measure the development degree of each CIMP at a bank, measurement items (called sub-CIMPs) were adapted from prior research, which ensures reliability and validity. Then, all the sub-CIMPs are used to form the survey questionnaire to ask the experts for scoring the maturity level of these sub-CIMPs in the banks. A Linkert scale from 1 (very bad) to 5 (very good) is used for this assessment. The experts here should be the ones who understand well the field of banking, and work independently from the banks in case study.

The score of each sub-CIMP is calculated by averaging five scores that five experts assess it, using the equation (3.1) below:

$$sp(ij)(X) = \frac{1}{k}\sum_{1}^{k} sp_{ij,k}(X) \tag{3.1}$$

where $sp_{ij}(X)$ is the score of the sub-CIMP $j$ associated with the CIMP $i$ at a bank X, $sp_{ij} \in$[1,5]; $k$ is the number of the experts; $sp_{ij,k}(X)$ is the judgment value of the expert $k$ for the sub-CIMP $j$ associated with the CIMP $i$ at a bank X, $sp_{ij,k} \in$[1,5]. The data from this step will be used to calculate the development degree of CIMPs in step 4 after getting the weights of sub-CIMPs in step 3.

### 3.2.3 Determine the weights of Critical Innovation Management Practices and sub-Critical Innovation Management Practices

In this research, we target at selecting the most innovative bank from a sample of banks based on their IC evaluated by a number of CIMPs and sub-CIMPs. Because Analytical Hierarchy Process (AHP) methodology is a powerful tool widely used in multiple-criteria decision-making [49]. It provides an effortlessly proper way to decrease a complex issue into a littler steps. The implementation of this method does not take much time but still assure the effectiveness. Therefore, we employ AHP to solve our problem.

In AHP analysis, the problem is decomposed by a hierarchy tree with different levels of decision elements. The highest level of the hierarchy shows the goal that is to select

the most innovative bank or ranking the banks according to their IC. The intermediate levels represent decision criteria and sub-criteria that are CIMPs and sub-CIMPs. The lowest level shows alternatives that are several banks in our case study.

AHP uses pairwise comparisons to consider the importance of a decision element over another element at the same level with respect to the element of the higher level by using Saaty scale (see Table 3.1) [50]. A group of experts is invited to conduct these comparisons. The judgments of all experts for each pair comparison are then averaged and used to make the pairwise comparison matrix. The pairwise comparison matrix is normalized by the sum of each column. Then, by averaging the values in each row, we will get a relative priority (a set of weights) of elements in a level with respect to the element of the higher level.

Table 3.1: Saaty scale of relative importance

| Intensity of importance | Definition |
|---|---|
| 1 | Equal importance |
| 3 | Moderate importance |
| 5 | Strong importance |
| 7 | Very strong importance |
| 9 | Extreme importance |
| 2, 4, 6, 8 | For compromises between the above |

Finally, the consistency ratio ($CR$) is calculated by equation 3.2 to check how consistent the judgments of the experts and large samples of purely random judgments are.

$$CR = CI/RI \tag{3.2}$$

where $CI$ is the consistency index reflecting the consistency of judgments in a pairwise comparison matrix ($CI$ is computed by using equation 3.3 in which $\lambda max$ is Eigenvalue, $n$ is the number of elements in a level); $RI$ (Random Index) is $CI$ of a pairwise comparison matrix that is generated randomly (see Table 3.2). In practice, the value of $CR$ of 0.1 or less will be accepted.

$$CI = \frac{\lambda max - n}{n - 1} \tag{3.3}$$

Table 3.2: Random Index

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 | 1.51 | 1.58 |

### 3.2.4 Compute Innovation Capability Index and rank

After getting the weights of all the sub-CIMPs, we can compute the development degree of CIMPs in the bank by equation (3.4).

$$p_i(X) = \sum_{j=1}^{m_i} w_{ij} sp_{ij}(X) \text{ with } \sum_{j=1}^{m_i} w_{ij} = 1 \tag{3.4}$$

where $p_i(X)$ is the development degree of the CIMP $i$ at bank $X$; $p_i \in [1, 5]$; $sp_{ij}(X)$ is the score of the sub-CIMP $j$ associated with the CIMP $i$ at bank $X$, $sp_{ij} \in [1, 5]$; $m_i$ is the number of the sub-CIMPs associated with the CIMP $i$; $w_{ij}$ is the weight of the sub-CIMP $j$ associated with the CIMP $i$, $w_{ij} \in [0, 1]$.

With the goal of ranking the banks according to their IC, multiple CIMPs are taken into account for IC evaluation. The IC of a bank is expressed through a composite index called Innovation Capability Index (ICI). Considering a bank X, its ICI is calculated by the following equation (3.5):

$$ICI(X) = \sum_{i=1}^{n} W_i p_i(X) \text{ with } \sum_{i=1}^{n} W_i = 1 \tag{3.5}$$

where $ICI(X)$ is the innovation capability index of the bank X, $ICI(X) \in [1, 5]$; $n$ is the number of CIMPs; $p_i(X)$ is the development degree of the CIMP $i$ at bank $X$; $p_i \in [1, 5]$; $W_i$ is the weight of the CIMP $i$; $W_i \in [0; 1]$. Based on the ICI of the banks, we can make a ranking from the bank with the highest ICI (the most innovative bank) to the bank with the lowest ICI (the least innovative bank).

# Chapter 4

# Empirical Results

By applying our proposed framework of IC evaluation introduced in Chapter 3, this chapter reports the results of evaluating the IC in a case study of three major banks in Vietnam. To maintain the confidentiality of the banks, the three banks are called as Bank A, Bank B, Bank C in this study.

## 4.1 Identify Critical Innovation Management Practices

The results of Pareto analysis is revealed in Table 4.1. From all the 28 selected articles mentioned in Section 2.3, we extracted totally 25 IMPs: strategic planning, resource management, organization, idea management, process innovation, marketing, R&D, learning, portfolio management, knowledge management, technological innovation, network management, project management, performance measure, product innovation, team management, moral support, commercialization, business intelligence, survey task, senior management, risk management, entrepreneurship, management participation, and delegation. These IMPs were then ranked in the descending order of their occurrences in the 28 selected articles. Next, we calculated the percentage of occurrences as well as cumulative percentage of occurrences for each IMP. Based on the rule 80/20 of Pareto analysis, the first 11 IMPs in Table 4.1 were chosen as CIMPs that occupy 80.588 percent of cumulative percentage of occurrences. CIMPs are strategic planning (SP), resource management (RM), organization (OR), idea management (IM), process innovation (PI),

marketing (MA), R&D (RD), learning (LE), portfolio management (PM), knowledge management (KM), and technological innovation (TI).

Table 4.1: Pareto analysis for IMPs

| No | IMPs | Occurrences | Percentage of occurrences (%) | Cumulative percentage of occurences (%) |
|---|---|---|---|---|
| 1 | Strategic planning | 25 | 14.706 | 14.706 |
| 2 | Resource management | 22 | 12.941 | 27.647 |
| 3 | Organization | 20 | 11.765 | 39.412 |
| 4 | Idea management | 13 | 7.647 | 47.059 |
| 5 | Process innovation | 11 | 6.471 | 53.529 |
| 6 | Marketing | 9 | 5.294 | 58.824 |
| 7 | R&D | 8 | 4.706 | 63.529 |
| 8 | Learning | 8 | 4.706 | 68.235 |
| 9 | Portfolio management | 7 | 4.118 | 72.353 |
| 10 | Knowledge management | 7 | 4.118 | 76.471 |
| 11 | Technology management | 7 | 4.118 | 80.588 |
| 12 | Network management | 5 | 2.941 | 83.529 |
| 13 | Project management | 4 | 2.353 | 85.882 |
| 14 | Performance measure | 4 | 2.353 | 88.235 |
| 15 | Product innovation | 4 | 2.353 | 90.588 |
| 16 | Team management | 3 | 1.765 | 92.353 |
| 17 | Moral support | 2 | 1.176 | 93.529 |
| 18 | Commercialization | 2 | 1.176 | 94.706 |
| 19 | Business intelligence | 2 | 1.176 | 95.882 |
| 20 | Survey task | 2 | 1.176 | 97.059 |
| 21 | Senior management | 1 | 0.588 | 97.647 |
| 22 | Risk management | 1 | 0.588 | 98.235 |
| 23 | Entrepreneurship | 1 | 0.588 | 98.824 |

| | | | | |
|---|---|---|---|---|
| 24 | Management participation | 1 | 0.588 | 99.412 |
| 25 | Delegation | 1 | 0.588 | 100 |
| | Total | 170 | 100 | |

## 4.2 Measure Critical Innovation Management Practices by sub-Critical Innovation Management Practices

Each CIMP was measured by four sub-CIMPs, as shown in Table 4.2. In total, the survey questionnaire for the experts to evaluate 11 CIMPs at each bank includes 44 questions (see Appendix A - Part 1), using the Linkert scale from 1 (very bad) to 5 (very good). Five experts who understand well about Vietnamese banking system were invited to join in CIMPs assessment for the case study of three Vietnamese banks. Two of them are vice directors of the banks. Two other experts are lecturers in the Banking University of Hochiminh City. And the final expert is an auditor in banking.

Table 4.2: Constructs and measurement items

| No | CIMPs | Sub-CIMPs | Sources |
|---|---|---|---|
| 1 | SP | SP1: Define clearly goals relating to innovation in strategic plans<br>SP2: Innovation strategy is widely understood throughout the bank<br>SP3: Top management is committed to support innovation activities<br>SP4: Use decision aid tools such as SWOT to build the bank strategy | Easingwood (1986) [32],<br>Cooper 2004 [6],<br>Oke (2007) [11],<br>Rejeb et al. (2008) [42],<br>Wang and Chang (2011) [15],<br>Boly et al. (2014) [3] |
| 2 | RM | RM1: Provide adequate resources for innovation<br>RM2: Have flexible and diversified capital origins<br>RM3: Actively hire talented employees<br>RM4: Organize regular training programs for knowledge required for future product development | Kuczmarski (1994) [51],<br>Guan et al. (2006) [41],<br>Yam et al. (2011) [39],<br>Wang and Chang (2011) [15],<br>Boly et al. (2014) [3] |

| | | | |
|---|---|---|---|
| 3 | OR | OR1: Culture and climate encourage for innovation<br>OR2: Reward employees for innovation<br>OR3: Tolerate innovation failures<br>OR4: Have open communication network in the bank | Cooper (2004) [5],<br>Oke (2007) [11],<br>Rejeb et al. (2008) [42],<br>Wang and Chang (2011) [15],<br>Boly et al. (2014) [3] |
| 4 | IM | IM1: Have a formalized procedure to collect ideas from different areas in the bank<br>IM2: Cooperate with external organizations such as universities, competitors, etc. for idea creation<br>IM3: Have a fast assessment process for new ideas<br>IM4: Use a test market before launching new products | Easingwood (1986) [32],<br>Oke (2007) [11],<br>Boly et al. (2014) [3] |
| 5 | PI | PI1: Use a structured innovation process<br>PI2: Have facilitator groups for the stages of innovation process<br>PI3: Cary out meetings to analyze innovation activities<br>PI4: Top management regularly reviews progress of innovation projects | Griffin (1997) [34],<br>Rejeb et al. (2008) [42],<br>Boly et al. (2014) [3] |
| 6 | MA | MA1: Have close relationship with major customers<br>MA2: Have highly efficient salesforce<br>MA3: Track customer satisfaction level after using the bank's services<br>MA4: Maintain a good brand image in the mind of customers | Yam et al. (2004) [38],<br>Yam et al. (2011) [39],<br>Boly et al. (2014) [3] |
| 7 | RD | RD1: Have a formalized R&D program<br>RD2: Continuously improve budget dedicated to R&D activities<br>RD3: Use cross-functional teamwork<br>RD4: Hold regular meetings for research themes programming | Boly et al. (2014) [3],<br>Tidd and Thuriaux-Alemán (2016) [8] |

| | | | |
|---|---|---|---|
| 8 | LE | LE1: Have methodologies for collective learning such as inter-service meetings<br>LE2: Some managers take responsibilities for collective learning tasks<br>LE3: Hold assessment meetings at the end of projects<br>LE4: Pass lessons learned from past experiences and failures across the bank | Guan et al. (2006) [41],<br>Boly et al. (2014) [3],<br>Liu and Jiang (2016) [47] |
| 9 | PM | PM1: Align the bank strategy with portfolio<br>PM2: Use multi-criteria analysis to supervise all ongoing projects<br>PM3: Have regular reports about resource allocation into multi-projects<br>PM4: Balance long-versus short-term, high-versus low-risk, etc. projects | Cooper (2004) [6],<br>Boly et al. (2014) [3],<br>Tidd and Thuriaux-Alemán (2016) [8] |
| 10 | KM | KM1: Identify employees' knowledge and adjust with required knowledge<br>KM2: Encourage knowledge exchange and sharing<br>KM3: Have a dedicated system for organizing and storing knowledge and experience for easy access by employees<br>KM4: Use knowledge dissemination methodologies | Boly et al. (2014) [3],<br>Liu and Jiang (2016) [47] |
| 11 | TI | TI1: Technology development and application is regarded as a key success factor<br>TI2: Have methodologies such as scenario planning to predict accurately new technology trends<br>TI3: Understand competitors' core technology competence<br>TI4: Technology acquisition from other parties compatible with the infrastructures and activities in the bank | Guan et al. (2006) [41],<br>Koc and Ceylan (2007) [9],<br>Sumrit and Anuntavoranich (2013) [45] |

Due to the different work nature and workplaces, it is difficult to gather all the experts together to discuss the assessment. Thus, we conducted survey questionnaires

with five experts separately and then calculated the average of their judgments to get the score of each sub-CIMP, using Equation (3.1). The detailed assessment of each expert for 44 sub-CIMPs at each bank is shown in Appendix B. Table 4.3 shows the scores of 44 sub-CIMPs in three Vietnamese banks based on synthesized judgments of five experts.

Table 4.3: Scores of sub-CIMPs in three Vietnamese banks

| sub_CIMP | Bank A | Bank B | Bank C |
|---|---|---|---|
| SP1 | 4.40 | 4.60 | 4.00 |
| SP2 | 4.20 | 4.40 | 4.00 |
| SP3 | 3.80 | 4.40 | 4.80 |
| SP4 | 4.00 | 4.40 | 4.40 |
| RM1 | 3.40 | 4.00 | 4.00 |
| RM2 | 4.20 | 4.00 | 4.80 |
| RM3 | 4.00 | 4.60 | 4.40 |
| RM4 | 3.40 | 4.20 | 4.20 |
| OR1 | 3.80 | 4.40 | 3.40 |
| OR2 | 4.00 | 4.00 | 4.20 |
| OR3 | 3.60 | 3.60 | 3.40 |
| OR4 | 3.40 | 4.20 | 4.00 |
| IM1 | 3.20 | 3.80 | 4.20 |
| IM2 | 3.40 | 4.00 | 3.60 |
| IM3 | 3.20 | 3.80 | 3.80 |
| IM4 | 3.40 | 4.20 | 3.60 |
| PI1 | 3.40 | 4.20 | 4.20 |
| PI2 | 3.80 | 4.20 | 4.00 |
| PI3 | 3.80 | 4.20 | 4.00 |
| PI4 | 3.60 | 4.20 | 3.80 |
| MA1 | 4.00 | 4.60 | 4.40 |
| MA2 | 3.80 | 4.20 | 3.60 |
| MA3 | 3.60 | 4.20 | 3.80 |
| MA4 | 3.80 | 4.40 | 4.20 |

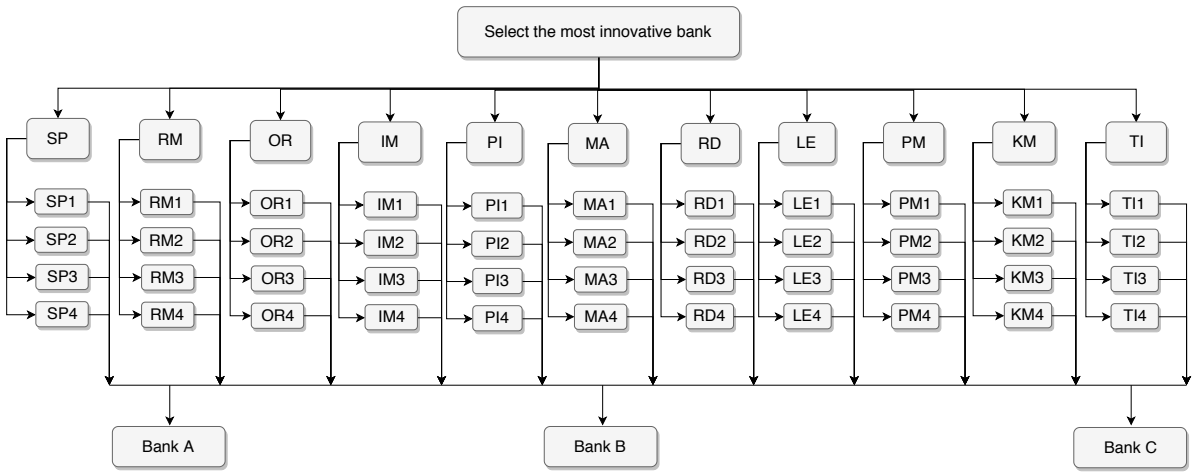
| | | | |
|---|---|---|---|
| RD1 | 3.60 | 4.40 | 4.00 |
| RD2 | 3.80 | 4.00 | 3.80 |
| RD3 | 3.60 | 4.40 | 3.60 |
| RD4 | 3.60 | 4.20 | 3.60 |
| LE1 | 4.00 | 4.00 | 4.20 |
| LE2 | 3.40 | 4.00 | 4.20 |
| LE3 | 3.60 | 4.20 | 4.20 |
| LE4 | 3.20 | 4.00 | 4.00 |
| PM1 | 4.20 | 4.40 | 4.40 |
| PM2 | 3.40 | 4.20 | 4.40 |
| PM3 | 3.80 | 4.20 | 4.00 |
| PM4 | 3.80 | 4.00 | 4.20 |
| KM1 | 4.60 | 4.00 | 4.20 |
| KM2 | 3.80 | 4.20 | 4.20 |
| KM3 | 3.80 | 4.00 | 4.00 |
| KM4 | 4.60 | 4.00 | 3.80 |
| TI1 | 4.50 | 4.20 | 3.80 |
| TI2 | 3.60 | 4.20 | 3.80 |
| TI3 | 3.80 | 4.40 | 3.80 |
| TI4 | 3.40 | 4.20 | 4.20 |

## 4.3 Determine the weights of Critical Innovation Management Practices and sub-Critical Innovation Management Practices

In this research, we approached AHP to rank the banks based on their IC evaluated by a number of CIMPs and sub-CIMPs. The hierarchy tree for decomposing our problem is shown in Figure 4.1. In the first level of the hierarchy, the goal is to select the most innovative bank among three Vietnamese banks. The intermediate level represents 11 criteria that are 11 CIMPs and 44 sub-criteria that are 44 sub-CIMPs. The lowest level

shows three alternatives, including Bank A, Bank B, and Bank C.

Figure 4.1: AHP model for ranking the banks




The different practices will have different roles in banking innovation, so we need to consider the priorities among 11 CIMPs and 44 sub-CIMPs. By using pairwise comparisons, AHP helps to determine the importance weights of CIMPs with respect to the decision problem and the weights of sub-CIMPs with respect to each CIMP. The five experts who were invited in step 2 also participated in the survey questionnaires of pairwise comparisons (see Appendix A - Part 2 & Part 3), using Saaty scale from 1 - equal importance to 9 - extreme importance (see Table 3.1). Then, we used the average of their judgments to develop the pairwise comparison matrices as displayed in Table 4.4 and 4.5.

The weight vector of CIMPs was determined to be W={0.28, 0.19, 0.05, 0.05, 0.02, 0.06, 0.08, 0.05, 0.02, 0.09, 0.10}. When evaluating the IC of the banks, according to the viewpoints of these five experts, strategic planning (ST) is the most important practice in innovation process; resource management is the second one; technological innovation is the thirst one; knowledge management is on the fourth; R&D is on the fifth; marketing is on the sixth; organization, idea management and learning are on the seventh; process innovation and portfolio management are the last ones (see Table 4.4).

By similar calculations, the weight vector of sub-CIMPs (SP1, SP2, SP3, SP4) was identified to be W={0.45, 0.09, 0.14, 0.32}. The weight vector of sub-CIMPs (RM1, RM2, RM3, RM4) was W={0.36, 0.09, 0.34, 0.20}. For sub-CIMPs (OR1, OR2, OR3, OR4), their weights were in sequence: 0.35, 0.32, 0.11, 0.22. The weights of IM1, IM2, IM3, IM4 were 0.43, 0.15, 0.07, 0.35, respectively. With respect to PI, the weight vector of its

sub-CIMPs (PI1, PI2, PI3, PI4) was 0.44, 0.29, 0.12, 0.16. For sub-CIMPs of MA (MA1, MA2, MA3, MA4), their weights were in sequence: 0.17, 0.39, 0.24, 0.21. With respect to RD, the weights of RD1, RD2, RD3, RD4 were 0.39, 0.10, 0.37, 0.15, respectively. The weight vector of sub-CIMPs (LE1, LE2, LE3, LE4) was identified to be W={0.11, 0.40, 0.17, 0.32}. For sub-CIMPs (PM1, PM2, PM3, PM4), their weights were in sequence: 0.12, 0.45, 0.26, 0.17. The weight vector of sub-CIMPs (KM1, KM2, KM3, KM4) was determined to be W={0.35, 0.32, 0.11, 0.22}. The weights of TI1, TI2, TI3, TI4 were 0.08, 0.50, 0.27, 0.14, respectively (see Table 4.5).

As all the CR values were less than 0.1, the judgments in our research are reliable.

Table 4.4: Pairwise comparisons of CIMPs with respect to IC

| IMPs | SP | RM | OR | IM | PI | MA | RD | LE | PM | KM | TI | Weights ($W_i$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SP | 1 | 3 | 5 | 5 | 7 | 5 | 5 | 5 | 7 | 5 | 4 | 0.28 |
| RM | 1/3 | 1 | 5 | 4 | 6 | 3 | 4 | 4 | 5 | 4 | 4 | 0.19 |
| OR | 1/5 | 1/5 | 1 | 2 | 3 | 1/3 | 1/2 | 1/2 | 4 | 1/3 | 1/4 | 0.05 |
| IM | 1/5 | 1/4 | 1/2 | 1 | 4 | 1 | 1/2 | 1 | 4 | 1/2 | 1 | 0.05 |
| PI | 1/7 | 1/6 | 1/3 | 1/4 | 1 | 1/4 | 1/4 | 1/3 | 2 | 1/4 | 1/5 | 0.02 |
| MA | 1/5 | 1/3 | 3 | 1 | 4 | 1 | 1/2 | 2 | 4 | 1/3 | 1/2 | 0.06 |
| RD | 1/5 | 1/4 | 2 | 2 | 4 | 2 | 1 | 3 | 5 | 1 | 1/2 | 0.08 |
| LE | 1/5 | 1/4 | 2 | 1 | 3 | 1/2 | 1/3 | 1 | 3 | 1/2 | 1/2 | 0.05 |
| PM | 1/7 | 1/5 | 1/4 | 1/4 | 1/2 | 1/4 | 1/5 | 1/3 | 1 | 1/6 | 1/6 | 0.02 |
| KM | 1/5 | 1/4 | 3 | 2 | 4 | 3 | 1 | 2 | 6 | 1 | 1/2 | 0.09 |
| TI | 1/4 | 1/4 | 4 | 1 | 5 | 2 | 2 | 2 | 6 | 2 | 1 | 0.10 |
| CR=0.06 | | | | | | | | | | | | |

Table 4.5: Pairwise comparisons of sub-CIMPs with respect to CIMPs

| A. Pairwise comparisons of sub-CIMPs with respect to SP | | | | | |
|---|---|---|---|---|---|
| SP | SP1 | SP2 | SP3 | SP4 | Weight ($w_{ij}$) |
| SP1 | 1 | 4 | 3 | 2 | 0.45 |
| SP2 | 1/4 | 1 | 1/2 | 1/4 | 0.09 |
| SP3 | 1/3 | 2 | 1 | 1/3 | 0.14 |

| | | | | | |
|---|---|---|---|---|---|
| SP4 | 1/2 | 4 | 3 | 1 | 0.32 |
| CR = 0.03 | | | | | |
| B. Pairwise comparisons of sub-CIMPs with respect to RM | | | | | |
| RM | RM1 | RM2 | RM3 | RM4 | Weight ($w_{ij}$) |
| RM1 | 1 | 4 | 1 | 2 | 0.36 |
| RM2 | 1/4 | 1 | 1/3 | 1/3 | 0.09 |
| RM3 | 1 | 3 | 1 | 2 | 0.34 |
| RM4 | 1/2 | 3 | 1/2 | 1 | 0.20 |
| CR = 0.02 | | | | | |
| C. Pairwise comparisons of sub-CIMPs with respect to OR | | | | | |
| OR | OR1 | OR2 | OR3 | OR4 | Weight ($w_{ij}$) |
| OR1 | 1 | 1 | 3 | 2 | 0.35 |
| OR2 | 1 | 1 | 2 | 2 | 0.32 |
| OR3 | 1/3 | 1/2 | 1 | 1/3 | 0.11 |
| OR4 | 1/2 | 1/2 | 3 | 1 | 0.22 |
| CR = 0.04 | | | | | |
| D. Pairwise comparisons of sub-CIMPs with respect to SP | | | | | |
| IM | IM1 | IM2 | IM3 | IM4 | Weight ($w_{ij}$) |
| IM1 | 1 | 3 | 4 | 2 | 0.43 |
| IM2 | 1/3 | 1 | 3 | 1/4 | 0.15 |
| IM3 | 1/4 | 1/3 | 1 | 1/5 | 0.07 |
| IM4 | 1/2 | 4 | 5 | 1 | 0.35 |
| CR = 0.08 | | | | | |
| E. Pairwise comparisons of sub-CIMPs with respect to PI | | | | | |
| PI | PI1 | PI2 | PI3 | PI4 | Weight ($w_{ij}$) |
| PI1 | 1 | 2 | 3 | 3 | 0.44 |
| PI2 | 1/2 | 1 | 2 | 3 | 0.29 |
| PI3 | 1/3 | 1/2 | 1 | 1/2 | 0.12 |
| PI4 | 1/3 | 1/3 | 2 | 1 | 0.16 |
| CR = 0.05 | | | | | |

| F. Pairwise comparisons of sub-CIMPs with respect to MA | | | | | |
|---|---|---|---|---|---|
| MA | MA1 | MA2 | MA3 | MA4 | Weight ($w_{ij}$) |
| MA1 | 1 | 1/2 | 1 | 1/2 | 0.17 |
| MA2 | 2 | 1 | 2 | 2 | 0.39 |
| MA3 | 1 | 1/2 | 1 | 2 | 0.24 |
| MA4 | 2 | 1/2 | 1/2 | 1 | 0.21 |
| CR = 0.07 | | | | | |
| F. Pairwise comparisons of sub-CIMPs with respect to RD | | | | | |
| RD | RD1 | RD2 | RD3 | RD4 | Weight ($w_{ij}$) |
| RD1 | 1 | 4 | 1 | 3 | 0.39 |
| RD2 | 1/4 | 1 | 1/3 | 1/2 | 0.10 |
| RD3 | 1 | 3 | 1 | 3 | 0.37 |
| RD4 | 1/3 | 2 | 1/3 | 1 | 0.15 |
| CR = 0.02 | | | | | |
| G. Pairwise comparisons of sub-CIMPs with respect to LE | | | | | |
| LE | LE1 | LE2 | LE3 | LE4 | Weight ($w_{ij}$) |
| LE1 | 1 | 1/3 | 1/2 | 1/3 | 0.11 |
| LE2 | 3 | 1 | 2 | 2 | 0.40 |
| LE3 | 2 | 1/2 | 1 | 1/3 | 0.17 |
| LE4 | 3 | 1/2 | 3 | 1 | 0.32 |
| CR = 0.05 | | | | | |
| H. Pairwise comparisons of sub-CIMPs with respect to PM | | | | | |
| PM | PM1 | PM2 | PM3 | PM4 | Weight ($w_{ij}$) |
| PM1 | 1 | 1/3 | 1/2 | 1/2 | 0.12 |
| PM2 | 3 | 1 | 2 | 3 | 0.45 |
| PM3 | 2 | 1/2 | 1 | 2 | 0.26 |
| PM4 | 2 | 1/3 | 1/2 | 1 | 0.17 |
| CR = 0.03 | | | | | |
| I. Pairwise comparisons of sub-CIMPs with respect to KM | | | | | |
| KM | KM1 | KM2 | KM3 | KM4 | Weight ($w_{ij}$) |

| KM1 | 1 | 1 | 3 | 2 | 0.35 |
|---|---|---|---|---|---|
| KM2 | 1 | 1 | 2 | 2 | 0.32 |
| KM3 | 1/3 | 1/2 | 1 | 1/3 | 0.11 |
| KM4 | 1/2 | 1/2 | 3 | 1 | 0.22 |
| CR = 0.04 | | | | | |
| J. Pairwise comparisons of sub-CIMPs with respect to TI | | | | | |
| TI | TI1 | TI2 | TI3 | TI4 | Weight ($w_{ij}$) |
| TI1 | 1 | 1/4 | 1/4 | 1/3 | 0.08 |
| TI2 | 4 | 1 | 3 | 4 | 0.50 |
| TI3 | 4 | 1/3 | 1 | 3 | 0.27 |
| TI4 | 3 | 1/4 | 1/3 | 1 | 0.14 |
| CR = 0.09 | | | | | |

## 4.4 Compute Innovation Capability Index and rank

By using the equation (3.4), the development degrees of CIMPs in each bank were computed and the results are presented in Table 4.6.

Table 4.6: Development degree of CIMPs in three Vietnamese banks

| | SP | RM | OR | IM | PI | MA | RD | LE | PM | KM | TI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bank A | 4.17 | 3.64 | 3.75 | 3.30 | 3.63 | 3.82 | 3.66 | 3.44 | 3.67 | 4.26 | 3.66 |
| Bank B | 4.49 | 4.20 | 4.14 | 3.97 | 4.24 | 4.35 | 4.37 | 4.03 | 4.19 | 4.06 | 4.21 |
| Bank C | 4.24 | 4.21 | 3.79 | 3.87 | 4.10 | 3.95 | 3.81 | 4.14 | 4.26 | 4.09 | 3.82 |

Then, the ICIs were calculated by feeding the equation (3.5). As a result, the ICIs of the banks A, B, C were determined to be 3.80, 4.23, 4.04, respectively. Consequently, bank B with the highest ICI value of 4.23 is the most innovative bank in the sample. Bank C having the ICI value of 4.04 stands at the second position in the ranking of IC. The least innovative bank is bank A with ICI value of 3.80 (see Table 4.7).

Table 4.7: ICI and rank of three Vietnamese banks

| | ICI | Rank |
|---|---|---|
| Bank A | 3.80 | 3 |
| Bank B | 4.23 | 1 |
| Bank C | 4.04 | 2 |

# Chapter 5

# Discussions

## 5.1 Justification

The innovation measurement in banking sector has been not largely clarified in literature. Our study contributes a theoretical framework of IC evaluation in the case of three Vietnamsese banks. When a bank innovate better and faster than their rivals by continuously providing services that are new, differentiated and high-quality, this bank will attract more customers to use their services, thereby increase their performance and competitiveness. Many previous research asserted the positive association between innovativeness and firm performance [44, 52–54]. Firm performance can be considered by financial performance [44, 54, 55]. Return on assets (ROA) as a popular accounting indicator was used to measure the firm's financial performance [56]. It was employed in the study of Calantone et al. (2002) to find the correlations of learning orientation, firm IC, and firm performance [53], the research of Jen Huang and Ju Liu (2005) to investigate the effect of innovation on firm performance [52], and the study of Dibrell et al. (2014) to test the impact of strategic planning process, planning flexibility and innovativeness on firm performance in 448 multi-industry firms [54]. For this reason, in this study, we also employed ROA indicator to evaluate the performance of the banks - result from their innovation process.

A review on the financial statements of three Vietnamese banks in our sample during the last three years from 2016 to 2018 revealed that bank B had the highest averaged ROA of 1.11, the next was bank C with averaged ROA of 0.67, and bank A had the lowest

averaged ROA of 0.63 (see Table 5.1). According to ROA indicators, bank B, C, A are in the ranking from the highest to the lowest ROA. That is in line with the ranking of three banks evaluated by IC. In addition, with modern and creative applications integrating various features, Bank B was awarded by a prestigious magazine in the field of finance in Asia - Asian Banking & Finance (ABF) for "Mobile banking initiative of the year - the most innovative mobile banking product in 2018". Bank B has innovated and caught up with technology trends, meeting customers' needs. Specifically, Bank B's mobile banking service have prominent interfaces, ensuring uniformity, youthfulness and brings a lot of experiences to users. Because of the facts above, our research results can be justified.

Table 5.1: ROA of three Vietnamese banks in period 2016-2018

| Bank | 2016 | 2017 | 2018 | 3-year average |
|---|---|---|---|---|
| B | 0.94 | 1.00 | 1.39 | 1.11 |
| C | 0.79 | 0.73 | 0.48 | 0.67 |
| A | 0.67 | 0.63 | 0.60 | 0.63 |

## 5.2 Managerial Implications

Our research framework is useful for bank managers to evaluate the impacts of CIMPs on their banks' IC. Applying AHP indicates that strategic planning, resource management and technological innovation are the three most important CIMPs for banking innovation. Therefore, to improve the innovation process to achieve better IC and approach higher rank, the bank managers must prioritize to develop the CIMPs that have the strongest weights first. Especially, they should pay much more attention to strategic plans that are the guidelines for all activities of the banks, ensure comprehensive and synchronous development, also create breakthroughs for the banks. In addition, they also need to mobilize the whole bank from top managers to employees in the branches to realize innovation strategies. It can be noted that in our study, the most innovative bank B has the most developed strategic planning practice among three banks with a development degree of 4.45 (see Table 4.6). Furthermore, Bank B is also the most mature bank in technological innovation with a development degree of 4.25. But for resource

management, bank B has a development degree of 4.20 that is slightly lower than Bank C, but still higher than Bank A. For other CIMPs (except LE, PM, KM), Bank B all have the highest development degrees compared with the other banks. In contrast, the least innovative bank (Bank A) is the weakest at all practices except KM. That results in the differences in their ranking by IC. To catch up with the competitors, the lower innovative bank should invest more in CIMPs; especially under limited resources, it can give priority to improve the most significant CIMPs first. For IMPs with low weights for IC, they can be considered as basic practices. Even they do not contribute much to IC improvement, but their realization may be necessary for the development of other IMPs.

Furthermore, the IC evaluation should be conducted periodically because of the changes in the development degree of IMPs and their roles for IC improvement in increasingly changing business environments. Besides, new IMPs are also emerging, which should also be taken into account to keep up with new trends.

# Chapter 6

# Conclusions

## 6.1 Summary

In this thesis, we have presented a method to evaluate IC in banking based on multiple criteria for successful innovation. By conducting a comprehensive investigation into the best IMPs from successful cases of innovation from previous related works, we attracted 25 primary IMPs. Then, a Pareto analysis was applied and found out 11 CIMPs for the banks: strategic planning, resource management, organization, idea management, process innovation, marketing, R&D, learning, portfolio management, knowledge management, and technological innovation. These practices were subdivided into 44 sub-CIMPs for measurement. A group of five experts who are professionals in banking major was invited to score these sub-CIMPs in the case of three major banks in Vietnam, using a Linkert scale from 1 (very bad) to 5 (very good). Then, AHP was used to determine the importance weights of 11 CIMPs and 44 sub-CIMPs. The results indicated that for banking innovation, strategic planning, resource management, and technological innovation are the most important practices with the weights of 0.28, 0.19 and 0.10, respectively. In practice, the banks should put more efforts into these practices to leverage their IC effectively. Finally, the index ICI that was representative for IC of each bank was calculated. By applying our research framework, three Vietnamese banks were ranked according to their IC. Our research findings could be a basis for the banks to determine the strengths and weaknesses in their processes of innovation management, thereby propose reasonable adjustments to improve their IC and achieve better innovation outcomes.

## 6.2 Limitations

This research has some following limitations. First, in this research, we only focus on the IMPs from existing research. They were benchmarked as the best innovation practices in general. Therefore, there may be new and unique IMPs for the context of banking that we have not captured. Second, the data used in this study depended much on the opinions of five experts. The judgment values might also be distorted by human emotions. In such a qualitative research, the quality of research is influenced much by the accuracy in the experts' judgments. Third, we carried out the surveys with five experts separately and then averaged their judgments. During data collection, when conflicts occurred among the experts' judgments, we must discuss them again, which was very time-consuming. Thus, it is better to gather all experts into a joint meeting for them to together discuss and make unified judgments. Forth, our IC evaluation method was conducted in a small sample with only three banks. The significance of findings might be limited in the case of these banks. Those limitations can be overcome by taking further research directions in Section 6.3.

## 6.3 Future Works

Each field has its unique characteristics in managing innovation. To evaluate more precisely the IC of the banks, we should conduct additional interviews with professionals in innovation and banking major with the aims of exploring and updating new IMPs in the concrete context of banking sector. That will also contribute to expanding literature about IMPs, especially for innovation measurement in banking. Additionally, we should persuade more experts to participate in a joint meeting for assessment to increase the accuracy of the data. Furthermore, a larger sample of banks is needed to check the reliability and validity of the proposed method.

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# Appendices

## A Survey Questionnaires

**RESEARCH ON INNOVATION CAPABILITY IN BANKING**

Our research aims at evaluating the innovation capability of the banks based on 11 critical innovation management practices (CIMPs) that are measured by 44 specific innovation management practices (sub-CIMPs).

Brief explanation:

| CIMPs | Sub-CIMPs |
|---|---|
| Strategic Planning (SP) | SP1: Define clearly goals relating to innovation in strategic plans<br>SP2: Innovation strategy is widely understood throughout the bank<br>SP3: Top management is committed to support innovation activities<br>SP4: Use decision aid tools such as SWOT to build the bank strategy |
| Resources Management (RM) | RM1: Provide adequate resources for innovation activities<br>RM2: Have flexible and diversified capital origins<br>RM3: Actively hire talented employees<br>RM4: Organize regular training programs for knowledge required for future product development |
| Organization (OR) | OR1: Culture and climate encourage for innovation<br>OR2: Reward employees for innovation<br>OR3: Tolerate innovation failures<br>OR4: Have open communication network in the bank |
| Idea Management (IM) | IM1: Have a formalized procedure to collect ideas from different areas in the bank<br>IM2: Cooperate with external organizations such as universities, competitors, etc. for idea creation<br>IM3: Have a fast assessment process for new ideas<br>IM4: Use a test market before launching new products |
| Process Innovation (PI) | PI1: Use a structured innovation process<br>PI2: Have facilitator groups for the stages of innovation process<br>PI3: Cary out meetings to analyze innovation activities<br>PI4: Top management regularly reviews progress of innovation projects |
| Marketing (MA) | MA1: Have close relationship with major customers<br>MA2: Have highly efficient salesforce<br>MA3: Track customer satisfaction level after using the bank's services<br>MA4: Maintain a good brand image in the mind of customers |
| R&D (RD) | RD1: Have a formalized R&D program<br>RD2: Continuously improve budget dedicated to R&D activities<br>RD3: Use cross-functional teamwork<br>RD4: Hold regular meetings for research themes programming |
| Learning (LE) | LE1: Have methodologies for collective learning such as inter-service meetings<br>LE2: Some managers take responsibilities for collective learning tasks<br>LE3: Hold assessment meetings at the end of projects<br>LE4: Pass lessons learned from past experiences and failures across the bank |
| Portfolio Management (PM) | PM1: Align the bank strategy with portfolio<br>PM2: Use multi-criteria analysis to supervise all ongoing projects<br>PM3: Have regular reports about resource allocation into multi-projects<br>PM4: Balance long-versus short-term, high-versus low-risk, etc. projects |
| Knowledge Management (KM) | KM1: Identify employees' knowledge and adjust with required knowledge<br>KM2: Encourage knowledge exchange and sharing<br>KM3: Have a dedicated system for organizing and storing knowledge and experience for easy access by employees<br>KM4: Use knowledge dissemination methodologies |
| Technological Innovation (TI) | TI1: Technology development and application is regarded as a key success factor<br>TI2: Have methodologies such as scenario planning to predict accurately new technology trends<br>TI3: Understand competitors' core technology competence<br>TI4: Technology acquisition from other parties compatible with the infrastructures and activities in the bank |

**PART 1: Score sub-CIMPs in three Vietnamese banks**

This part is to assess the maturity level of 44 sub-CIMPs in three Vietnamese banks. Based on your opinion, please score these practices in Bank A, Bank B, Bank C by ticking the appropriate cell. Use the following scale:

1 – Very bad, 2 – Bad, 3 – Neutral, 4 – Good, 5 – Very good.

| | Bank A | | | | | Bank B | | | | | Bank C | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| SP1 | | | | | | | | | | | | | | | |
| SP2 | | | | | | | | | | | | | | | |
| SP3 | | | | | | | | | | | | | | | |
| SP4 | | | | | | | | | | | | | | | |
| RM1 | | | | | | | | | | | | | | | |
| RM2 | | | | | | | | | | | | | | | |
| RM3 | | | | | | | | | | | | | | | |
| RM4 | | | | | | | | | | | | | | | |
| OR1 | | | | | | | | | | | | | | | |
| OR2 | | | | | | | | | | | | | | | |
| OR3 | | | | | | | | | | | | | | | |
| OR4 | | | | | | | | | | | | | | | |
| IM1 | | | | | | | | | | | | | | | |
| IM2 | | | | | | | | | | | | | | | |
| IM3 | | | | | | | | | | | | | | | |
| IM4 | | | | | | | | | | | | | | | |
| PI1 | | | | | | | | | | | | | | | |
| PI2 | | | | | | | | | | | | | | | |
| PI3 | | | | | | | | | | | | | | | |
| PI4 | | | | | | | | | | | | | | | |
| MA1 | | | | | | | | | | | | | | | |
| MA2 | | | | | | | | | | | | | | | |
| MA3 | | | | | | | | | | | | | | | |
| MA4 | | | | | | | | | | | | | | | |
| RD1 | | | | | | | | | | | | | | | |
| RD2 | | | | | | | | | | | | | | | |
| RD3 | | | | | | | | | | | | | | | |
| RD4 | | | | | | | | | | | | | | | |
| LE1 | | | | | | | | | | | | | | | |
| LE2 | | | | | | | | | | | | | | | |
| LE3 | | | | | | | | | | | | | | | |
| LE4 | | | | | | | | | | | | | | | |
| PM1 | | | | | | | | | | | | | | | |
| PM2 | | | | | | | | | | | | | | | |
| PM3 | | | | | | | | | | | | | | | |
| PM4 | | | | | | | | | | | | | | | |
| KM1 | | | | | | | | | | | | | | | |
| KM2 | | | | | | | | | | | | | | | |
| KM3 | | | | | | | | | | | | | | | |
| KM4 | | | | | | | | | | | | | | | |
| TI1 | | | | | | | | | | | | | | | |
| TI2 | | | | | | | | | | | | | | | |
| TI3 | | | | | | | | | | | | | | | |
| TI4 | | | | | | | | | | | | | | | |

**PART 2: Pairwise comparisons of CIMPs with respect to innovation capability in banking**

This part is to evaluate the relative importance of 11 CIMPs in banking innovation based on pairwise comparisons. Use the following scale:

| Intensity of importance | Definition |
|---|---|
| 1 | Equal importance |
| 3 | Moderate importance |
| 5 | Strong importance |
| 7 | Very strong importance |
| 9 | Extreme importance |
| 2, 4, 6, 8 | For compromises between the above |

Please circle one appropriate number expressing the relative importance of a CIMP against others:

| CIMPs | Factor weighting score | | | CIMPs |
|---|---|---|---|---|
| | More important than | Equal | Less important than | |
| SP | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | OR |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | IM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PI |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | MA |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI |
| RM | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | OR |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | IM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PI |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | MA |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI |
| OR | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | IM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PI |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | MA |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI |
| IM | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PI |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | MA |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI |
| PI | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | MA |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI |
| MA | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI |
| RD | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI |
| LE | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM |

| | | | | |
|---|---|---|---|---|
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI |
| PM | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI |
| KM | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI |

**PART 3: Pairwise comparisons of sub-CIMPs with respect to CIMPs**

This part is to determine to relative importance of 4 sub-CIMPs for each CIMP based on pairwise comparisons. Use the same scale from 1 to 9 as in PART 2. Please circle one appropriate number expressing the relative importance of a sub-CIMP against others:

| Sub-CIMPs | Factor weighting score | | | Sub-CIMPs |
|---|---|---|---|---|
| | More important than | Equal | Less important than | |
| With respect to SP | | | | |
| SP1 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | SP2 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | SP3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | SP4 |
| SP2 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | SP3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | SP4 |
| SP3 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | SP4 |
| With respect to RM | | | | |
| RM1 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RM2 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RM3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RM4 |
| RM2 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RM3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RM4 |
| RM3 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RM4 |
| With respect to OR | | | | |
| OR1 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | OR2 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | OR3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | OR4 |
| OR2 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | OR3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | OR4 |
| OR3 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | OR4 |
| With respect to IM | | | | |
| IM1 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | IM2 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | IM3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | IM4 |
| IM2 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | IM3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | IM4 |
| IM3 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | IM4 |
| With respect to PI | | | | |
| PI1 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PI2 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PI3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PI4 |
| PI2 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PI3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PI4 |
| PI3 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PI4 |
| With respect to MA | | | | |
| MA1 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | MA2 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | MA3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | MA4 |
| MA2 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | MA3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | MA4 |
| MA3 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | MA4 |
| With respect to RD | | | | |
| RD1 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD2 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD4 |

| | | | | |
|---|---|---|---|---|
| RD2 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD4 |
| RD3 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | RD4 |
| With respect to LE | | | | |
| LE1 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE2 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE4 |
| LE3 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE4 |
| LE4 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | LE4 |
| With respect to PM | | | | |
| PM1 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM2 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM4 |
| PM2 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM4 |
| PM3 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | PM4 |
| With respect to KM | | | | |
| KM1 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM2 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM4 |
| KM2 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM4 |
| KM3 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | KM4 |
| With respect to TI | | | | |
| TI1 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI2 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI4 |
| TI2 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI3 |
| | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI4 |
| TI3 | 9 8 7 6 5 4 3 2 | 1 | 2 3 4 5 6 7 8 9 | TI4 |

# B Scores of sub-Critical Innovation Management Practices in three Vietnamese banks according to each expert

| Bank | Expert | SP1 | SP2 | SP3 | SP4 | RM1 | RM2 | RM3 | RM4 | OR1 | OR2 | OR3 | OR4 | IM1 | IM2 | IM3 | IM4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 1 | 5 | 4 | 4 | 5 | 3 | 4 | 5 | 5 | 5 | 5 | 4 | 5 | 4 | 5 | 4 | 4 |
| | 2 | 4 | 4 | 4 | 5 | 4 | 3 | 5 | 4 | 4 | 5 | 4 | 3 | 3 | 3 | 3 | 4 |
| | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 |
| | 4 | 5 | 5 | 4 | 3 | 3 | 5 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | 5 | 5 | 5 | 4 | 3 | 3 | 5 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| B | 1 | 5 | 5 | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 |
| | 2 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 3 | 4 | 3 | 4 |
| | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 4 |
| | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 4 | 3 | 4 | 5 | 5 | 5 | 5 |
| C | 1 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 4 | 3 | 4 | 4 | 5 | 5 | 5 |
| | 2 | 5 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 3 | 4 | 3 | 5 | 4 | 2 | 3 | 3 |
| | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 4 | 3 | 3 |
| | 4 | 4 | 4 | 5 | 5 | 4 | 5 | 3 | 4 | 3 | 5 | 3 | 4 | 5 | 4 | 3 | 2 |
| | 5 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 5 | 4 | 5 | 3 | 5 | 5 |
| Bank | Expert | PI1 | PI2 | PI3 | PI4 | MA1 | MA2 | MA3 | MA4 | RD1 | RD2 | RD3 | RD4 | LE1 | LE2 | LE3 | LE4 |
| A | 1 | 4 | 4 | 5 | 5 | 5 | 5 | 4 | 5 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 |
| | 2 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 |
| | 3 | 4 | 5 | 4 | 3 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 4 | 4 |
| | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 2 | 3 | 2 |
| | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 2 | 3 | 2 |
| B | 1 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | 2 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 4 |
| | 3 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 4 | 5 | 4 | 4 | 4 | 5 | 4 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| C | 1 | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | 2 | 4 | 5 | 3 | 2 | 4 | 4 | 5 | 4 | 4 | 3 | 3 | 2 | 4 | 4 | 4 | 4 |
| | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 4 |
| | 4 | 4 | 4 | 5 | 4 | 5 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 5 |
| | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 3 | 5 | 5 | 5 | 4 | 4 | 4 | 5 | 5 | 3 |

| Bank | Expert | PM1 | PM2 | PM3 | PM4 | KM1 | KM2 | KM3 | KM4 | TI1 | TI2 | TI3 | TI4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 1 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | 5 | 5 | 5 |
| | 2 | 5 | 4 | 4 | 3 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 |
| | 3 | 4 | 4 | 4 | 3 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 |
| | 4 | 4 | 2 | 3 | 4 | 4 | 3 | 3 | 5 | 5 | 3 | 4 | 3 |
| | 5 | 4 | 2 | 3 | 4 | 4 | 3 | 3 | 5 | 5 | 3 | 4 | 3 |
| B | 1 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 |
| | 2 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 |
| | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| C | 1 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 |
| | 2 | 5 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 3 | 3 | 4 |
| | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 |
| | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 3 | 4 |
| | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 5 | 5 |

# C Pairwise comparisons of Critical Innovation Management Practices with respect to Innovation Capability according to each expert

| **Expert 1** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CIMPs | SP | RM | OR | IM | PI | MA | RD | LE | PM | KM | TI |
| SP | 1 | 3 | 5 | 5 | 6 | 5 | 5 | 5 | 7 | 5 | 4 |
| RM | 1/3 | 1 | 4 | 3 | 5 | 3 | 4 | 4 | 5 | 3 | 3 |
| OR | 1/5 | 1/3 | 1 | 2 | 2 | 1/2 | 1/2 | 1 | 4 | 1/3 | 1/3 |
| IM | 1/5 | 1/3 | 1/2 | 1 | 3 | 1 | 1 | 1 | 5 | 1 | 1 |
| PI | 1/6 | 1/5 | 1/2 | 1/3 | 1 | 1/3 | 1/3 | 1/3 | 3 | 1/3 | 1/4 |
| MA | 1/5 | 1/3 | 2 | 1 | 3 | 1 | 1/2 | 2 | 4 | 1/3 | 1/3 |
| RD | 1/5 | 1/4 | 2 | 1 | 3 | 2 | 1 | 3 | 5 | 1 | 1/2 |
| LE | 1/5 | 1/4 | 1 | 1 | 3 | 1/2 | 1/3 | 1 | 2 | 1/2 | 1/2 |
| PM | 1/7 | 1/5 | 1/4 | 1/5 | 1/3 | 1/4 | 1/5 | 1/2 | 1 | 1/5 | 1/6 |
| KM | 1/5 | 1/3 | 3 | 1 | 3 | 3 | 1 | 2 | 5 | 1 | 1/3 |
| TI | 1/4 | 1/3 | 3 | 1 | 4 | 3 | 2 | 2 | 6 | 3 | 1 |
| **Expert 2** | | | | | | | | | | | |
| IMPs | SP | RM | OR | IM | PI | MA | RD | LE | PM | KM | TI |
| SP | 1 | 2 | 5 | 6 | 7 | 5 | 4 | 5 | 7 | 5 | 4 |
| RM | 1/2 | 1 | 3 | 4 | 6 | 3 | 4 | 4 | 6 | 5 | 4 |
| OR | 1/5 | 1/3 | 1 | 1 | 2 | 1/4 | 1/3 | 1/3 | 3 | 1/3 | 1/4 |
| IM | 1/6 | 1/3 | 1 | 1 | 3 | 1 | 1/3 | 2 | 3 | 1/2 | 1/2 |
| PI | 1/7 | 1/5 | 1/2 | 1/3 | 1 | 1/4 | 1/5 | 1/4 | 2 | 1/2 | 1/5 |
| MA | 1/5 | 1/3 | 4 | 1 | 4 | 1 | 1/2 | 2 | 5 | 1/4 | 1/3 |
| RD | 1/4 | 1/4 | 3 | 3 | 5 | 2 | 1 | 3 | 7 | 1 | 1 |
| LE | 1/5 | 1/4 | 3 | 1/2 | 4 | 1/2 | 1/3 | 1 | 5 | 1/2 | 1/2 |
| PM | 1/7 | 1/6 | 1/3 | 1/3 | 1/2 | 1/5 | 1/7 | 1/5 | 1 | 1/4 | 1/5 |
| KM | 1/5 | 1/5 | 3 | 2 | 2 | 4 | 1 | 2 | 4 | 1 | 1/2 |
| TI | 1/4 | 1/4 | 4 | 2 | 5 | 3 | 1 | 2 | 5 | 2 | 1 |
| **Expert 3** | | | | | | | | | | | |
| IMPs | SP | RM | OR | IM | PI | MA | RD | LE | PM | KM | TI |
| SP | 1 | 5 | 7 | 6 | 7 | 7 | 7 | 7 | 8 | 6 | 5 |
| RM | 1/5 | 1 | 4 | 2 | 4 | 2 | 3 | 5 | 4 | 3 | 3 |
| OR | 1/7 | 1/3 | 1 | 3 | 2 | 1/3 | 1 | 1 | 3 | 1/3 | 1/5 |
| IM | 1/6 | 1/2 | 1/3 | 1 | 4 | 1 | 1 | 2 | 3 | 1 | 1 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PI | 1/7 | 1/4 | 1/2 | 1/4 | 1 | 1/3 | 1/2 | 1/2 | 2 | 1/4 | 1/4 |
| MA | 1/7 | 1/2 | 3 | 1 | 1/3 | 1 | 1/2 | 1 | 3 | 1/2 | 1/2 |
| RD | 1/7 | 1/3 | 1 | 1 | 2 | 2 | 1 | 2 | 4 | 1/2 | 1/2 |
| LE | 1/7 | 1/5 | 1 | 1/2 | 2 | 1 | 1/2 | 1 | 2 | 1/2 | 1/3 |
| PM | 1/8 | 1/4 | 1/3 | 1/3 | 1/2 | 1/3 | 1/4 | 1/2 | 1 | 1/6 | 1/7 |
| KM | 1/6 | 1/3 | 3 | 1 | 4 | 2 | 2 | 2 | 6 | 1 | 1/3 |
| TI | 1/5 | 1/3 | 5 | 1 | 4 | 2 | 2 | 3 | 7 | 3 | 1 |
| **Expert 4** | | | | | | | | | | | |
| IMPs | SP | RM | OR | IM | PI | MA | RD | LE | PM | KM | TI |
| SP | 1 | 2 | 4 | 5 | 7 | 3 | 4 | 4 | 6 | 4 | 3 |
| RM | 1/2 | 1 | 7 | 6 | 7 | 5 | 6 | 4 | 6 | 4 | 4 |
| OR | 1/4 | 1/7 | 1 | 1 | 3 | 1/4 | 1/2 | 1/2 | 4 | 1/2 | 1/3 |
| IM | 1/5 | 1/6 | 1 | 1 | 4 | 1/2 | 1/3 | 1 | 3 | 1/3 | 1/2 |
| PI | 1/7 | 1/7 | 1/3 | 1/4 | 1 | 1/6 | 1/5 | 1/2 | 1 | 1/6 | 1/6 |
| MA | 1/3 | 1/5 | 4 | 2 | 6 | 1 | 1 | 2 | 4 | 1 | 1/2 |
| RD | 1/4 | 1/6 | 2 | 3 | 5 | 1 | 1 | 2 | 4 | 1 | 1/2 |
| LE | 1/4 | 1/4 | 2 | 1 | 2 | 1/2 | 1/2 | 1 | 3 | 1 | 1/2 |
| PM | 1/6 | 1/6 | 1/4 | 1/3 | 1 | 1/4 | 1/4 | 1/3 | 1 | 1/7 | 1/7 |
| KM | 1/4 | 1/4 | 2 | 3 | 6 | 1 | 1 | 1 | 7 | 1 | 1/2 |
| TI | 1/3 | 1/4 | 3 | 2 | 6 | 2 | 2 | 2 | 7 | 2 | 1 |
| **Expert 5** | | | | | | | | | | | |
| IMPs | SP | RM | OR | IM | PI | MA | RD | LE | PM | KM | TI |
| SP | 1 | 2 | 4 | 3 | 6 | 4 | 4 | 3 | 5 | 4 | 3 |
| RM | 1/2 | 1 | 5 | 3 | 6 | 2 | 3 | 3 | 4 | 4 | 5 |
| OR | 1/4 | 1/5 | 1 | 2 | 4 | 1 | 1 | 1/2 | 5 | 1/2 | 1/3 |
| IM | 1/3 | 1/2 | 1/2 | 1 | 5 | 1 | 1/2 | 1 | 6 | 1 | 1 |
| PI | 1/6 | 1/6 | 1/4 | 1/5 | 1 | 1/3 | 1/4 | 1/3 | 1 | 1/4 | 1/6 |
| MA | 1/4 | 1/2 | 1 | 1 | 3 | 1 | 1 | 1 | 3 | 1/3 | 1/2 |
| RD | 1/4 | 1/3 | 1 | 2 | 4 | 1 | 1 | 5 | 4 | 1 | 1/3 |
| LE | 1/3 | 1/3 | 2 | 1 | 3 | 1 | 1/5 | 1 | 4 | 1 | 1 |
| PM | 1/5 | 1/4 | 1/5 | 1/6 | 1 | 1/3 | 1/4 | 1/4 | 1 | 1/6 | 1/7 |
| KM | 1/4 | 1/4 | 2 | 1 | 4 | 3 | 1 | 1 | 6 | 1 | 1/2 |
| TI | 1/3 | 1/5 | 3 | 1 | 6 | 2 | 3 | 1 | 7 | 2 | 1 |

# D Pairwise comparisons of sub-Critical Innovation Management Practices with respect to Critical Innovation Management Practices according to each expert

| **Pairwise comparison with respect to SP** | | | | |
|---|---|---|---|---|
| Expert 1 | | | | |
| SP | SP1 | SP2 | SP3 | SP4 |
| SP1 | 1 | 3 | 2 | 2 |
| SP2 | 1/3 | 1 | 1 | 1/3 |
| SP3 | 1/2 | 1 | 1 | 1/3 |
| SP4 | 1/2 | 3 | 3 | 1 |
| Expert 2 | | | | |
| SP | SP1 | SP2 | SP3 | SP4 |
| SP1 | 1 | 5 | 4 | 3 |
| SP2 | 1/5 | 1 | 1/3 | 1/5 |
| SP3 | 1/4 | 3 | 1 | 1/4 |
| SP4 | 1/3 | 5 | 4 | 1 |
| Expert 3 | | | | |
| SP | SP1 | SP2 | SP3 | SP4 |
| SP1 | 1 | 4 | 3 | 2 |
| SP2 | 1/4 | 1 | 1/2 | 1/4 |
| SP3 | 1/3 | 2 | 1 | 1/3 |
| SP4 | 1/2 | 4 | 3 | 1 |
| Expert 4 | | | | |
| SP | SP1 | SP2 | SP3 | SP4 |

| **Pairwise comparison with respect to RD** | | | | |
|---|---|---|---|---|
| Expert 1 | | | | |
| RD | RD1 | RD2 | RD3 | RD4 |
| RD1 | 1 | 4 | 1 | 3 |
| RD2 | 1/4 | 1 | 1/3 | 1/2 |
| RD3 | 1 | 3 | 1 | 3 |
| RD4 | 1/3 | 2 | 1/3 | 1 |
| Expert 2 | | | | |
| RD | RD1 | RD2 | RD3 | RD4 |
| RD1 | 1 | 3 | 1 | 2 |
| RD2 | 1/3 | 1 | 1/2 | 1/2 |
| RD3 | 1 | 2 | 1 | 3 |
| RD4 | 1/2 | 2 | 1/3 | 1 |
| Expert 3 | | | | |
| RD | RD1 | RD2 | RD3 | RD4 |
| RD1 | 1 | 4 | 2 | 3 |
| RD2 | 1/4 | 1 | 1/2 | 1 |
| RD3 | 1/2 | 2 | 1 | 4 |
| RD4 | 1/3 | 1 | 1/4 | 1 |
| Expert 4 | | | | |
| RD | RD1 | RD2 | RD3 | RD4 |

| SP1 | 1 | 5 | 3 | 3 |
|---|---|---|---|---|
| SP2 | 1/5 | 1 | 1/3 | 1/4 |
| SP3 | 1/3 | 3 | 1 | 1/3 |
| SP4 | 1/3 | 4 | 3 | 1 |
| Expert 5 | | | | |
| SP | SP1 | SP2 | SP3 | SP4 |
| SP1 | 1 | 4 | 2 | 2 |
| SP2 | 1/4 | 1 | 1/2 | 1/3 |
| SP3 | 1/2 | 2 | 1 | 1/2 |
| SP4 | 1/2 | 3 | 2 | 1 |
| **Pairwise comparison with respect to RM** | | | | |
| Expert 1 | | | | |
| RM | RM1 | RM2 | RM3 | RM4 |
| RM1 | 1 | 4 | 1 | 2 |
| RM2 | 1/4 | 1 | 1/3 | 1/3 |
| RM3 | 1 | 3 | 1 | 2 |
| RM4 | 1/2 | 3 | 1/2 | 1 |
| Expert 2 | | | | |
| RM | RM1 | RM2 | RM3 | RM4 |
| RM1 | 1 | 5 | 2 | 3 |
| RM2 | 1/5 | 1 | 1/4 | 1/3 |
| RM3 | 1/2 | 4 | 1 | 3 |
| RM4 | 1/3 | 3 | 1/3 | 1 |
| Expert 3 | | | | |
| RM | RM1 | RM2 | RM3 | RM4 |
| RM1 | 1 | 4 | 2 | 2 |
| RM2 | 1/4 | 1 | 1/2 | 1/2 |
| RM3 | 1/2 | 2 | 1 | 1 |
| RM4 | 1/2 | 2 | 1 | 1 |
| Expert 4 | | | | |
| RM | RM1 | RM2 | RM3 | RM4 |
| RM1 | 1 | 3 | 1 | 2 |
| RM2 | 1/3 | 1 | 1/3 | 1/2 |
| RM3 | 1 | 3 | 1 | 3 |
| RM4 | 1/2 | 2 | 1/3 | 1 |
| Expert 5 | | | | |
| RM | RM1 | RM2 | RM3 | RM4 |
| RM1 | 1 | 3 | 1 | 3 |
| RM2 | 1/3 | 1 | 1/4 | 1/3 |
| RM3 | 1 | 4 | 1 | 2 |
| RM4 | 1/3 | 3 | 1/2 | 1 |
| **Pairwise comparison with respect to OR** | | | | |
| Expert 1 | | | | |
| OR | OR1 | OR2 | OR3 | OR4 |
| OR1 | 1 | 1 | 3 | 2 |
| OR2 | 1 | 1 | 2 | 2 |
| OR3 | 1/3 | 1/2 | 1 | 1/3 |
| OR4 | 1/2 | 1/2 | 3 | 1 |
| Expert 2 | | | | |
| OR | OR1 | OR2 | OR3 | OR4 |
| OR1 | 1 | 2 | 4 | 3 |
| OR2 | 1/2 | 1 | 3 | 3 |
| OR3 | 1/4 | 1/3 | 1 | 1/4 |
| OR4 | 1/3 | 1/3 | 4 | 1 |
| Expert 3 | | | | |
| OR | OR1 | OR2 | OR3 | OR4 |
| OR1 | 1 | 1 | 2 | 1 |
| OR2 | 1 | 1 | 2 | 1 |
| OR3 | 1/2 | 1/2 | 1 | 1/3 |
| OR4 | 1 | 1 | 3 | 1 |
| Expert 4 | | | | |
| OR | OR1 | OR2 | OR3 | OR4 |
| OR1 | 1 | 2 | 3 | 3 |
| OR2 | 1/2 | 1 | 3 | 2 |
| OR3 | 1/3 | 1/3 | 1 | 1/2 |
| OR4 | 1/3 | 1/2 | 2 | 1 |
| Expert 5 | | | | |

| RD1 | 1 | 5 | 1 | 3 |
|---|---|---|---|---|
| RD2 | 1/5 | 1 | 1/3 | 1/3 |
| RD3 | 1 | 3 | 1 | 3 |
| RD4 | 1/3 | 3 | 1/3 | 1 |
| Expert 5 | | | | |
| RD | RD1 | RD2 | RD3 | RD4 |
| RD1 | 1 | 4 | 2 | 4 |
| RD2 | 1/4 | 1 | 1/4 | 1/2 |
| RD3 | 1/2 | 4 | 1 | 2 |
| RD4 | 1/4 | 2 | 1/2 | 1 |
| **Pairwise comparison with respect to LE** | | | | |
| Expert 1 | | | | |
| LE | LE1 | LE2 | LE3 | LE4 |
| LE1 | 1 | 1/3 | 1/2 | 1/3 |
| LE2 | 3 | 1 | 2 | 2 |
| LE3 | 2 | 1/2 | 1 | 1/3 |
| LE4 | 3 | 1/2 | 3 | 1 |
| Expert 2 | | | | |
| LE | LE1 | LE2 | LE3 | LE4 |
| LE1 | 1 | 1/4 | 1/3 | 1/3 |
| LE2 | 4 | 1 | 3 | 2 |
| LE3 | 3 | 1/3 | 1 | 1/2 |
| LE4 | 3 | 1/2 | 2 | 1 |
| Expert 3 | | | | |
| LE | LE1 | LE2 | LE3 | LE4 |
| LE1 | 1 | 1/2 | 1 | 1/2 |
| LE2 | 2 | 1 | 3 | 1 |
| LE3 | 1 | 1/3 | 1 | 1/4 |
| LE4 | 2 | 1 | 4 | 1 |
| Expert 4 | | | | |
| LE | LE1 | LE2 | LE3 | LE4 |
| LE1 | 1 | 1/3 | 1/2 | 1/2 |
| LE2 | 3 | 1 | 2 | 3 |
| LE3 | 2 | 1/2 | 1 | 1/2 |
| LE4 | 2 | 1/3 | 2 | 1 |
| Expert 5 | | | | |
| LE | LE1 | LE2 | LE3 | LE4 |
| LE1 | 1 | 1/4 | 1/2 | 1/3 |
| LE2 | 4 | 1 | 2 | 1 |
| LE3 | 2 | 1/2 | 1 | 1/3 |
| LE4 | 3 | 1 | 3 | 1 |
| **Pairwise comparison with respect to PM** | | | | |
| Expert 1 | | | | |
| PM | PM1 | PM2 | PM3 | PM4 |
| PM1 | 1 | 1/3 | 1/2 | 1/2 |
| PM2 | 3 | 1 | 2 | 3 |
| PM3 | 2 | 1/2 | 1 | 2 |
| PM4 | 2 | 1/3 | 1/2 | 1 |
| Expert 2 | | | | |
| PM | PM1 | PM2 | PM3 | PM4 |
| PM1 | 1 | 1/4 | 1/3 | 1/3 |
| PM2 | 4 | 1 | 3 | 4 |
| PM3 | 3 | 1/3 | 1 | 3 |
| PM4 | 3 | 1/4 | 1/3 | 1 |
| Expert 3 | | | | |
| PM | PM1 | PM2 | PM3 | PM4 |
| PM1 | 1 | 1/3 | 1/3 | 1/2 |
| PM2 | 3 | 1 | 2 | 2 |
| PM3 | 3 | 1/2 | 1 | 3 |
| PM4 | 2 | 1/2 | 1/3 | 1 |
| Expert 4 | | | | |
| PM | PM1 | PM2 | PM3 | PM4 |
| PM1 | 1 | 1/3 | 1/2 | 1 |
| PM2 | 3 | 1 | 3 | 3 |
| PM3 | 2 | 1/3 | 1 | 1 |
| PM4 | 1 | 1/3 | 1 | 1 |
| Expert 5 | | | | |

| OR | OR1 | OR2 | OR3 | OR4 |
|---|---|---|---|---|
| OR1 | 1 | 1 | 4 | 2 |
| OR2 | 1 | 1 | 2 | 1 |
| OR3 | 1/4 | 1/2 | 1 | 1/4 |
| OR4 | 1/2 | 1 | 4 | 1 |
| **Pairwise comparison with respect to IM** | | | | |
| Expert 1 | | | | |
| IM | IM1 | IM2 | IM3 | IM4 |
| IM1 | 1 | 3 | 4 | 2 |
| IM2 | 1/3 | 1 | 3 | 1/4 |
| IM3 | 1/4 | 1/3 | 1 | 1/5 |
| IM4 | 1/2 | 4 | 5 | 1 |
| Expert 2 | | | | |
| IM | IM1 | IM2 | IM3 | IM4 |
| IM1 | 1 | 4 | 5 | 3 |
| IM2 | 1/4 | 1 | 2 | 1/3 |
| IM3 | 1/5 | 1/2 | 1 | 1/4 |
| IM4 | 1/3 | 3 | 4 | 1 |
| Expert 3 | | | | |
| IM | IM1 | IM2 | IM3 | IM4 |
| IM1 | 1 | 2 | 3 | 1 |
| IM2 | 1/2 | 1 | 4 | 1/5 |
| IM3 | 1/3 | 1/4 | 1 | 1/6 |
| IM4 | 1 | 5 | 6 | 1 |
| Expert 4 | | | | |
| IM | IM1 | IM2 | IM3 | IM4 |
| IM1 | 1 | 4 | 4 | 2 |
| IM2 | 1/4 | 1 | 2 | 1/3 |
| IM3 | 1/4 | 1/2 | 1 | 1/4 |
| IM4 | 1/2 | 3 | 4 | 1 |
| Expert 5 | | | | |
| IM | IM1 | IM2 | IM3 | IM4 |
| IM1 | 1 | 3 | 3 | 1 |
| IM2 | 1/3 | 1 | 3 | 1/5 |
| IM3 | 1/3 | 1/3 | 1 | 1/5 |
| IM4 | 1 | 5 | 5 | 1 |
| **Pairwise comparison with respect to PI** | | | | |
| Expert 1 | | | | |
| PI | PI1 | PI2 | PI3 | PI4 |
| PI1 | 1 | 2 | 3 | 3 |
| PI2 | 1/2 | 1 | 2 | 3 |
| PI3 | 1/3 | 1/2 | 1 | 1/2 |
| PI4 | 1/3 | 1/3 | 2 | 1 |
| Expert 2 | | | | |
| PI | PI1 | PI2 | PI3 | PI4 |
| PI1 | 1 | 3 | 4 | 4 |
| PI2 | 1/3 | 1 | 3 | 4 |
| PI3 | 1/4 | 1/3 | 1 | 1/2 |
| PI4 | 1/4 | 1/4 | 2 | 1 |
| Expert 3 | | | | |
| PI | PI1 | PI2 | PI3 | PI4 |
| PI1 | 1 | 1 | 2 | 2 |
| PI2 | 1 | 1 | 2 | 1 |
| PI3 | 1/2 | 1/2 | 1 | 1/3 |
| PI4 | 1/2 | 1 | 3 | 1 |
| Expert 4 | | | | |
| PI | PI1 | PI2 | PI3 | PI4 |
| PI1 | 1 | 2 | 4 | 3 |
| PI2 | 1/2 | 1 | 3 | 3 |
| PI3 | 1/4 | 1/3 | 1 | 1/4 |
| PI4 | 1/3 | 1/3 | 4 | 1 |
| Expert 5 | | | | |
| PI | PI1 | PI2 | PI3 | PI4 |
| PI1 | 1 | 3 | 3 | 2 |
| PI2 | 1/3 | 1 | 1 | 2 |
| PI3 | 1/3 | 1 | 1 | 1 |
| PI4 | 1/2 | 1/2 | 1 | 1 |

| PM | PM1 | PM2 | PM3 | PM4 |
|---|---|---|---|---|
| PM1 | 1 | 1/4 | 1/2 | 1/2 |
| PM2 | 4 | 1 | 2 | 4 |
| PM3 | 2 | 1/2 | 1 | 2 |
| PM4 | 2 | 1/4 | 1/2 | 1 |
| **Pairwise comparison with respect to KM** | | | | |
| Expert 1 | | | | |
| KM | KM1 | KM2 | KM3 | KM4 |
| KM1 | 1 | 1 | 3 | 2 |
| KM2 | 1 | 1 | 2 | 2 |
| KM3 | 1/3 | 1/2 | 1 | 1/3 |
| KM4 | 1/2 | 1/2 | 3 | 1 |
| Expert 2 | | | | |
| KM | KM1 | KM2 | KM3 | KM4 |
| KM1 | 1 | 1 | 3 | 3 |
| KM2 | 1 | 1 | 3 | 2 |
| KM3 | 1/3 | 1/3 | 1 | 1/2 |
| KM4 | 1/3 | 1/2 | 2 | 1 |
| Expert 3 | | | | |
| KM | KM1 | KM2 | KM3 | KM4 |
| KM1 | 1 | 2 | 4 | 3 |
| KM2 | 1/2 | 1 | 3 | 3 |
| KM3 | 1/4 | 1/3 | 1 | 1/4 |
| KM4 | 1/3 | 1/3 | 4 | 1 |
| Expert 4 | | | | |
| KM | KM1 | KM2 | KM3 | KM4 |
| KM1 | 1 | 1 | 3 | 2 |
| KM2 | 1 | 1 | 2 | 3 |
| KM3 | 1/3 | 1/2 | 1 | 1/2 |
| KM4 | 1/2 | 1/3 | 2 | 1 |
| Expert 5 | | | | |
| KM | KM1 | KM2 | KM3 | KM4 |
| KM1 | 1 | 1 | 4 | 2 |
| KM2 | 1 | 1 | 2 | 1 |
| KM3 | 1/4 | 1/2 | 1 | 1/3 |
| KM4 | 1/2 | 1 | 3 | 1 |
| **Pairwise comparison with respect to TI** | | | | |
| Expert 1 | | | | |
| TI | TI1 | TI2 | TI3 | TI4 |
| TI1 | 1 | 1/4 | 1/4 | 1/3 |
| TI2 | 4 | 1 | 3 | 4 |
| TI3 | 4 | 1/3 | 1 | 3 |
| TI4 | 3 | 1/4 | 1/3 | 1 |
| Expert 2 | | | | |
| TI | TI1 | TI2 | TI3 | TI4 |
| TI1 | 1 | 1/5 | 1/4 | 1/4 |
| TI2 | 5 | 1 | 4 | 5 |
| TI3 | 4 | 1/4 | 1 | 2 |
| TI4 | 4 | 1/5 | 1/2 | 1 |
| Expert 3 | | | | |
| TI | TI1 | TI2 | TI3 | TI4 |
| TI1 | 1 | 1/4 | 1/3 | 1/2 |
| TI2 | 4 | 1 | 3 | 3 |
| TI3 | 3 | 1/3 | 1 | 4 |
| TI4 | 2 | 1/3 | 1/4 | 1 |
| Expert 4 | | | | |
| TI | TI1 | TI2 | TI3 | TI4 |
| TI1 | 1 | 1/3 | 1/3 | 1/2 |
| TI2 | 3 | 1 | 2 | 4 |
| TI3 | 3 | 1/2 | 1 | 3 |
| TI4 | 2 | 1/4 | 1/3 | 1 |
| Expert 5 | | | | |
| TI | TI1 | TI2 | TI3 | TI4 |
| TI1 | 1 | 1/3 | 1/4 | 1/2 |
| TI2 | 3 | 1 | 1 | 3 |
| TI3 | 4 | 1 | 1 | 2 |
| TI4 | 2 | 1/3 | 1/2 | 1 |

| **Pairwise comparison with respect to MA** | | | | |
|---|---|---|---|---|
| Expert 1 | | | | |
| MA | MA1 | MA2 | MA3 | MA4 |
| MA1 | 1 | 1/2 | 1 | 1/2 |
| MA2 | 2 | 1 | 2 | 2 |
| MA3 | 1 | 1/2 | 1 | 2 |
| MA4 | 2 | 1/2 | 1/2 | 1 |
| Expert 2 | | | | |
| MA | MA1 | MA2 | MA3 | MA4 |
| MA1 | 1 | 1/3 | 1/2 | 1/3 |
| MA2 | 3 | 1 | 3 | 3 |
| MA3 | 2 | 1/3 | 1 | 1 |
| MA4 | 3 | 1/3 | 1 | 1 |
| Expert 3 | | | | |
| MA | MA1 | MA2 | MA3 | MA4 |
| MA1 | 1 | 1/3 | 1 | 1 |
| MA2 | 3 | 1 | 2 | 1 |
| MA3 | 1 | 1/2 | 1 | 2 |
| MA4 | 1 | 1 | 1/2 | 1 |
| Expert 4 | | | | |
| MA | MA1 | MA2 | MA3 | MA4 |
| MA1 | 1 | 1/2 | 1 | 1/3 |
| MA2 | 2 | 1 | 3 | 2 |
| MA3 | 1 | 1/3 | 1 | 1 |
| MA4 | 3 | 1/2 | 1 | 1 |
| Expert 5 | | | | |
| MA | MA1 | MA2 | MA3 | MA4 |
| MA1 | 1 | 1/2 | 1 | 1 |
| MA2 | 2 | 1 | 2 | 3 |
| MA3 | 1 | 1/2 | 1 | 3 |
| MA4 | 1 | 1/3 | 1/3 | 1 |