An Innovation Capability Assessment Method for Early-stage Start-ups in Thailand

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Abstract

The Thai government recognizes innovation as a key driver of economic development. This has led to an emphasis on innovation-driven growth and the establishment of science and technology parks within universities. These parks serve as incubators to support the delivery of innovative products and services. This research used Chiang Mai University's Science and Technology Park (STeP) as a case study and focused on the assessment of Technological Innovation Capability (TIC) among SMEs and start-ups in Thailand.

An initial literature review coupled with interviews with members of STeP identified TIC as a high priority because it facilitates companies to build competitive advantage. Furthermore, a need for practical models to inform developments within companies was identified. A mock-up of an assessment method that used the maturity level system to quantify aspects of TIC was designed and evaluated through application to eight companies from STeP. Results from the evaluation revealed that, while there was potential value in understanding TIC capability, the mock-up was overly complex for use in practice. Moreover, a need for more specific support in new product development (NPD) capability was identified. As a result, the scope of the assessment method was narrowed to concentrate on the development of NPD capability in early-stage start-ups.

The contribution of this thesis is a method for assessing NPD capability in early-stage start-ups in Thailand. The method was designed for use as part of continuous improvement processes and in response to two design goals: a need for NPD capability assessment tools and suitability for use in target user companies. This assessment method starts with an NPD process template which users tailor to reflect the development stage of their company. Maturity levels are then used to quantify a company's existing NPD capability. Its effectiveness was evaluated through application to seven start-ups within STeP. Results indicated that the method facilitated both understanding of current NPD capability and the identification of improvement opportunities.

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Chapter 1 Introduction

In today's dynamic global markets, rapid technological advancements and evolving consumer demands have reshaped the competitive landscape. Around the world, governments have published strategic policies targeting technology-driven innovation, fueling economic development, and addressing societal challenges. Examples include Germany's 'Industry 4.0' strategy, which centers on digitalization, AI-driven technologies, and intelligent networking (Xu et al., 2021). The European Commission's 'Industry 5.0,' introduced in 2021, extends this focus by emphasizing human-centricity, sustainability, and resilience. In Asia, Japan has embarked on its 'Society 5.0' initiative, striving to create a human-centric society while fostering economic growth and technological advancement (Fukuyama, 2018). In China, 'Made in China 2025' represents a 10-year economic development plan aimed at elevating innovation-driven manufacturing to world-class status (Li, 2018). These global trends underscore the importance of technological innovation in addressing economic and societal challenges.

The significance of innovation is not confined to technology-led nations. In Thailand, the government has recognized innovation as a key driver of economic development and has promoted ‘Thailand 4.0’, the innovation-driven model as the cornerstone of its economic development strategy (Languepin, 2019). Thailand 4.0 represents a strategic shift towards a value-based economy, driven by Research&Development (R&D), science and technology, creative thinking, and innovation. Within the framework of Thailand 4.0, New Product Development (NPD) represents a critical aspect of innovation, enabling companies to introduce novel products and services into the market, thus driving economic growth and fostering competitiveness. Despite increased R&D investments, Thailand's innovation index ranks 43rd out of 132 economies globally (World Intellectual Property Organization, 2023). The nation faces various challenges, including a heavy reliance on foreign technologies (Intarakumnerd, 2019; Karaveg et al., 2014), a tendency to prioritize low-risk and simple product development (Rujirawanich et al., 2011), an emphasis on incremental rather than radical innovations (Karaveg et al., 2014), and a concentration on embryonic-stage development in research (Wonglimpiyarat, 2016). Furthermore, Thailand lags behind other Asian nations in implementing policies to support Small and Medium-sized Enterprise (SME)’s entrepreneurial development (Wonglimpiyarat, 2016). These SMEs and start-ups, despite their important role in the Thai economy, have historically conducted limited R&D and struggled to generate product innovations. To foster sustainable economic growth and industrial development in Thailand, supporting technological innovation and facilitating NPD processes among SMEs and start-ups. NPD is critical for introducing novel products and services, particularly among SMEs and start-ups, becomes essential.

In response to the global and local need for innovation, numerous innovation capability assessment and development models have been proposed. These models focus on an organization's ability to swiftly transform existing knowledge into new ideas and products. While various innovation capability assessment models have been developed theoretically, their practical application remains limited, especially in the case of SMEs and start-ups, which are necessary to the nation's economy. The focus of this research was the technological innovation capability (TIC) and NPD capability of Thai SMEs and start-ups, comprehensively assessing their capabilities for developing innovative products and services. The ultimate goal was to provide insights into the continuous improvement of this capability, thus promoting sustainability in the business landscape and driving the Thai economy forward.

This chapter begins with an exploration of the research's background in Section 1.1, explaining why it is important to assess and develop TIC of Thai SMEs and start-ups. Section 1.2 articulates the research aim and objectives, while Section 1.3 introduces the case study of Science and Technology Park, Chiang Mai University (STeP), offering an overview of STeP's role, evolution, and support for SMEs and start-ups. Finally, in Section 1.4, the structure of the thesis is outlined.

1.1 Background

The journey to this research began with a preliminary literature review and fieldwork conducted in collaboration with twelve SMEs and start-ups at STeP. STeP, the hub of the Northern Science Park in Thailand, plays an essential role in supporting entrepreneurs for innovation. The preliminary work aimed to build an understanding of current practices in these companies, identify industrial challenges, and prioritize needs. This preliminary work resulted in identifying three opportunities for this research, positioning on three overlapping areas as illustrated in Figure 1.1: TIC and NPD capability, Innovation Capability Maturity Model (ICMM), and SMEs and start-ups in Thailand.

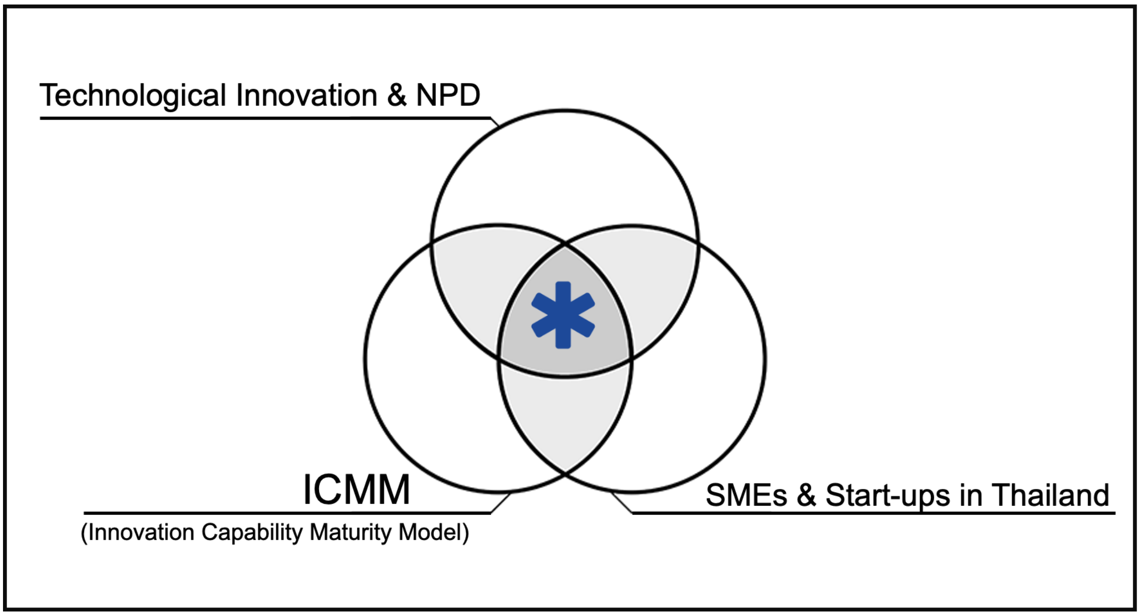


Figure 1.1 Overlapping Intersections between Three Opportunities for This Research: TIC, ICMM, and SMEs and start-ups in Thailand

First, Technological innovation recognized as a pivotal element of the nation's economic development strategy, emphasizing the need to foster TIC and facilitate NPD process among SMEs and start-ups. Research by Rujirawanich et al. (2011) and Karaveg et al. (2014) highlights the prevalence of incremental innovations among Thai companies, underscoring the need for fostering radical innovation and new product development initiatives. Moreover, Intarakumnerd (2019) points to the limited R&D investments and capabilities among Thai SMEs, which pose barriers to their participation in technological innovation and NPD activities. Wonglimpiyarat (2016) also notes that university research in Thailand often remains in the embryonic stage, failing to reach the marketplace and achieve commercialization, thereby highlighting the need to foster technological innovation and NPD activities.

Second, while various scholars have proposed innovation capability assessment models, such as Innovation Capability Maturity Model (ICMM) from Essmann and Du Preez (2009) and Corsi and Neau (2015), there remains significant opportunity for further research in this area. Arends (2018) found that research in this domain remains in its early stages, with a predominant emphasis on model development. Giménez-Medina et al. (2023) revealed a scarcity of studies involving industrial validation, highlighting the need for practical validation of these models. Therefore, a research opportunity exists regarding the assessment and development of capability in practice. Additionally, most of the existing models focus on general innovation capability management and organization rather than particularly concerning TIC and NPD. Moultrie et al. (2007)

emphasized the need for more accessible and practical approaches in maturity-based tools applied in NPD, particularly in SMEs. Consequently, an opportunity was identified to design a customized innovation capability assessment method for TIC and NPD capability with a focus on practical applicability in SMEs and startups.

Third, discussions with Thai SMEs and start-ups at STeP during the preliminary phase revealed a distinct emphasis on TIC. These enterprises were determined to prioritize developing product innovation, especially in terms of adopting new technologies to drive improvements. Furthermore, while ICMMs have found applications worldwide, they remain insufficiently explored within the Thai context, especially in the case of SMEs and start-ups. The interview with STeP members also led to the finding that, there was no assessment tool that STeP used to evaluate capability of the SMEs and start-ups in the programs. Thus, the identified research opportunity underscored the need for an approach tailored specifically for TIC assessment in SMEs and start-ups in Thailand.

1.2 Research Question (RQ)

To guide this research, the following RQ was formulated:

RQ: *How can new product development capability (as an aspect of technological innovation capability) be assessed among Thai SMEs and start-ups?*

By focusing on this question, this research focuses on identifying strategies for assessing and improving TIC and NPD capability among Thai SMEs and start-ups, thus contributing to the advancement of the nation's innovation ecosystem.

1.3 Research Aim and Objectives

The aim of the research was to explore ways in which TIC can be assessed by SMEs and start-ups in STeP. To achieve this research aim, the following research objectives were proposed.

1) To elicit stakeholder needs for TIC assessment and development methods from a review of literature and in conjunction with STeP member companies.
2) To evaluate selected TIC assessment methods through application to STeP member companies.

3) To identify design goals and requirements for TIC assessment methods in STeP member companies.
4) To propose a TIC assessment method in response to the design goals.
5) To evaluate the efficacy of the developed method with respect to the stakeholder needs.

1.4 Introduction of STeP

This section introduces STeP. The information presented in this section is a synthesis of the researcher’s understanding of STeP based on pre-existing knowledge, insights gained from interviews, and supplementary details obtained from STeP documents as well as reputable sources on the web. Interviews conducted with Assistant Manager of the Innovative Start-up Development Department, provided perspectives on STeP's objectives and strategic directions. More details on STeP roles were also gained from the interviews with other two STeP members from the the Innovative Start-up Development Department. In the subsequent sections, the specifics of STeP's background, role and evolution, and support programs are explained.

1.4.1 STeP Background

STeP is an institution under the responsibility of the Office of the University Council at Chiang Mai University. Its establishment in 2012 aims to foster collaboration among the university, industrial and private sectors, and government bodies. STeP plays a pivotal role in supporting student and alumni start-ups, researchers, and local SMEs in the northern region of Thailand, promoting both research and business development. Beyond its support for individual entrepreneurs, STeP also acts as the hub for science and technology parks across Northern Thailand, thereby assisting other regional science and technology parks in fulfilling their missions.

1.4.2 STeP Role and Evolution

STeP divides its roles into eight departments that are responsible for different works. The organization chart shows in Figure 1.2. Among its various departments, the Innovative Start-up Development Department stands out as a key contributor to entrepreneurship and innovation. This department is primarily responsible for creating an ecosystem for business development, innovatively bridging the gap between academia and the industry. It organizes business coaching programs, builds business networks, and facilitates access to capital investments, thus offering critical support for entrepreneurs. Notably, this support extends beyond the boundaries of academic affiliations; it includes students, alumni, and researchers from the university, as well as private companies seeking to foster innovation or improve their operations. Furthermore, the department plays a role in encouraging entrepreneurial skills among university students, cultivating innovation and business behaviour from an early stage.

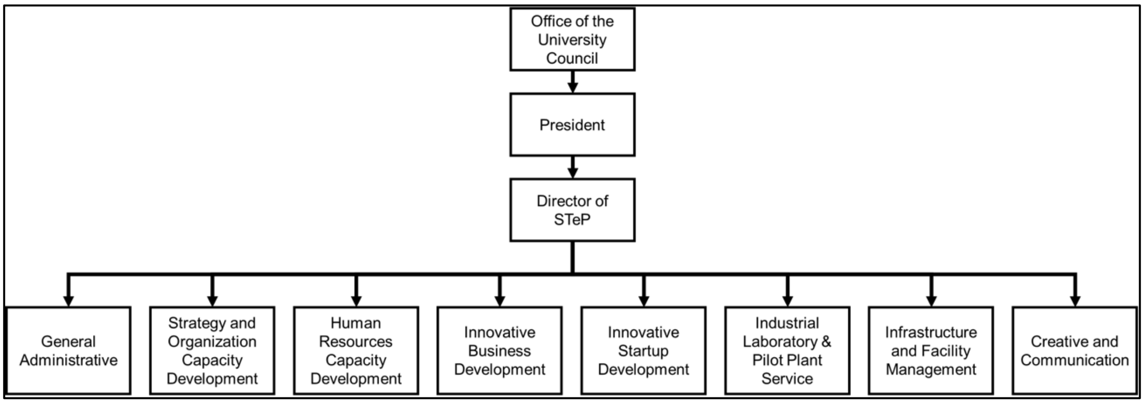


Figure 1.2 STeP Organization Chart (Sources: STeP)

Since its establishment in 2012, STeP has undergone a significant evolution in its support programs, aligning with the timeline of this research. Significant changes occurred in how STeP provides support and assistance to entrepreneurs, resulting in a notable impact on its operations and services. During the fieldwork in 2021, the researcher observed the early stages of the Technology Business Incubation (TBI) program, a cornerstone of STeP's support structure. Subsequent fieldwork in 2022 marked a transformative shift with the introduction of Basecamp24, signalling a strategic change of the incubation process. In March 2022, with the introduction of Basecamp24, STeP underwent a transformative shift. This rebranding aimed to create a clearer understanding of the incubation process among participants. The basecamp and Camp1 serve as educational programs inspiring university students to embrace entrepreneurship. Subsequent camps, Camp2, Camp3, and Camp4, focus on achieving market fit, customer expansion, and further business growth.

1.4.3 Technology Business Incubation (TBI) Program

During the previous TBI program, the STeP support program was divided into two stages, which were pre-incubation and TBI (incubation). The incubation journey shows in Figure 1.3.

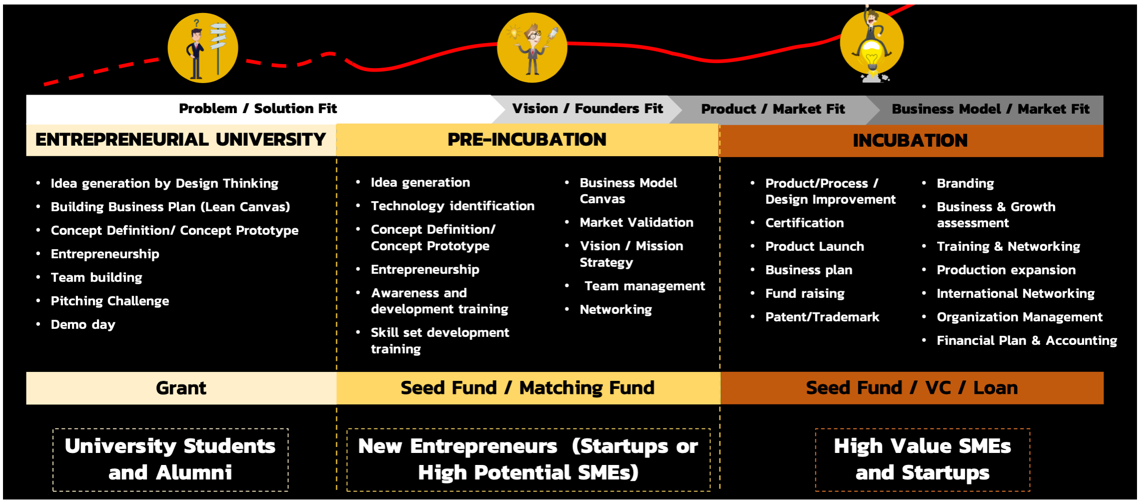


Figure 1.3 STeP's Technology Business Incubation (Sources: STeP)

Pre-incubation laid the foundation for entrepreneurial ventures, progressing from problem/solution fit to product/market fit. It fostered an entrepreneurial mindset and equipped participants with essential tools, such as idea generation, design thinking, lean canvas development, team building, pitching, market entry, and prototype testing. Within pre-incubation, diverse programs served varied objectives. The Entrepreneurial Ecosystem Development Program guided students and alumni from team formation to prototype development. The Research2Market Program transformed university research into business plans, tailored for students. The Startup Thailand League Program targeted funding for existing start-ups. However, the interviewee noted that the availability of programs can vary yearly based on funding.

While programs mainly catered to students and alumni, the Startup's Guide welcomed SMEs as a precursor to TBI. Beginning with a two-month training program for 70 teams/companies, it narrowed down to 35 advancing to a four-month training and consulting phase. A pitching competition selected the top 12 to enter the two-year TBI program. TBI focused on nurturing businesses with established product/market fit, providing training in team and innovation management, fundraising, investor engagement, financial and intellectual property management. Supplementary support included international networking and business matching. Since inception, STeP has successfully supported and incubated 56 companies within the TBI program. Notably, the interviewee observed that though open to all business types, TBI predominantly attracted students and alumni, who having undergone pre-incubation and being better prepared. In contrast, SMEs, often well-established, might lack the inclination to modify their business models or incorporate innovation.

1.4.4 BaseCamp24

A transformative shift reshaped STeP's support paradigm with the introduction of 'Basecamp24' on March 31, 2022. The interviewee clarified,

> *“The term 'Basecamp24' signifies around-the-clock availability, emphasizing continuous support. This rebranding aimed to create a clearer understanding of the incubation process among participants. The traditional view misunderstood incubation as free support, leading to misguided expectations. To address this, the process was redefined with a more private enterprise-oriented identity.”*

This change led to a reorganization of start-ups into five camps: Basecamp (Inspiration), Camp1 (Ideation), Camp2 (Market validation), Camp3 (Market expansion), and Camp4 (Market scale-up). The Basecamp24 journey shows in Figure 1.4.

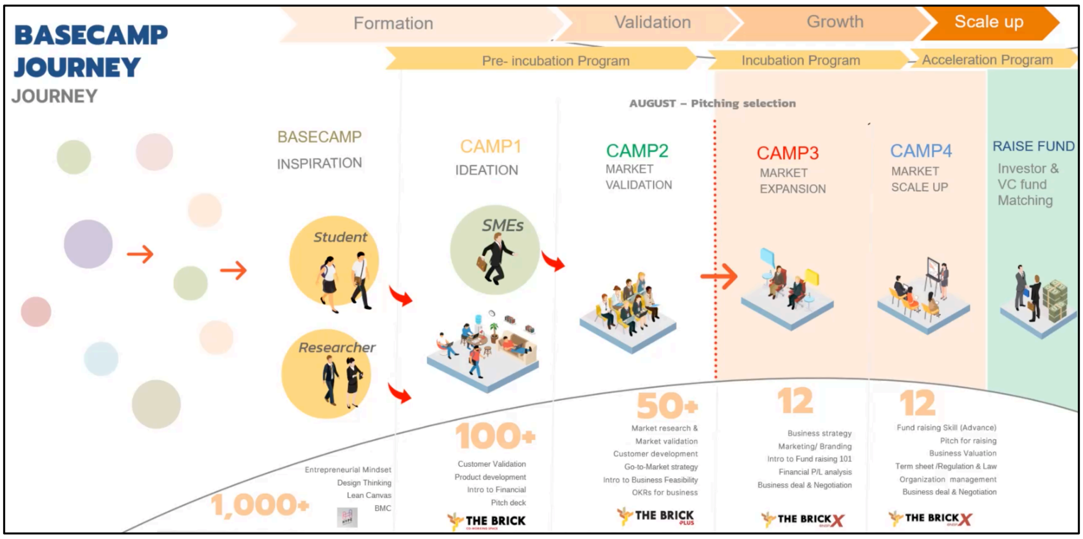


Figure 1.4 STeP’s Basecamp24 (Sources: STeP)

The basecamp and Camp1 act as platforms within university settings, fostering inspiration and knowledge. The basecamp, open to all, hosts activities, such as workshops and hackathons. Transitioning to Camp1 depends on team commitment, narrowing down from around 3000 participants in Basecamp to 30-50 ideation teams. Camp1 focuses on Problem/Solution fit and Vision/Founder fit. Teams aspiring to join need a well-defined idea, a dedicated team, and concepts with rigorous market research. Camp2 shifts to market validation, expecting teams to introduce prototypes or Minimum Viable Products (MVPs), securing the first dollar of revenue. Camp3 targets customer base expansion, delving into profit/loss and financial aspects, preparing companies for venture capitalist engagement. Market expansion in Camp4 involves introducing new features or products, running parallel to existing offerings.

Contrary to the previous structure of Pre-incubation and TBI spanning three years, STeP restructured Basecamp24 into three camps: Camp2 aligns with TBI year 1, Camp3 with TBI year 2, and Camp4 with TBI year 3. Transitioning from Camp2 to Camp3 involves a pivotal pitching event, serving as the selection process for TBI entry in Camp3 and Camp4. STeP condensed TBI into a two-year program, streamlining it into comprehensive pre-incubation, laying the foundation for teams to compete for TBI entry, supporting 12 teams annually. More detail of STeP support program is in Appendix A.

1.5 Structure of the Thesis

The thesis is organized into seven chapters. This chapter (Introduction) offers an introductory overview, presenting the background, identification of the research question, aim and objectives of the study, an introduction to STeP as the case study, and an outline of the thesis structure.

Chapter 2 (Literature Review) explores key concepts related to innovation and the innovation landscape in Thailand, innovation capability, TIC, and new product development (NPD). It sets the theoretical foundation that guide the study.

Chapter 3 (Methodology) introduces the research methodology employed in the study to answer RQ. The methodology emphasizes the use of Action Design Research (ADR) within the framework by Sein et al. (2011) and interview-based research. The methodology is divided into two phases, detailing the design of ICAT in Phase 1 and the subsequent design of NPDWise in Phase 2.

Chapter 4 (Innovation Capability Assessment Tool - ICAT) details the activities and outcomes of Phase 1, where the mock-up of ICAT was developed and interviews with target users were conducted. The insights gained in this phase informed the refinement of research focus and the improvement opportunity to focus on NPD in Phase 2.

Building upon Phase 1, Chapter 5 (New Product Development Capability Assessment Method - NPDWise) outlines the development of NPDWise. This phase started from re-determining of goal, target users, design requirements in response to the feedback from Phase 1, and thereby designing the NPDWise method for evaluating and developing NPD.

In Chapter 6 (Application of NPDWise to the Case Study), NPDWise was applied to a real case study. The process and results of implementing the method to assess NPD capability among early-stage start-ups within the STeP program are detailed. The application of NPDWise led to identifying improvement opportunities for STeP to better support early-stage start-ups in their NPD process.

Chapter 7 serves as a reflective conclusion to the entire research journey. It summarizes key findings, answering RQ, highlighting contributions to knowledge in alignment with the research objectives. Additionally, it discusses limitations encountered during the study and proposes opportunities for future research.

Chapter 2 Literature Review

After the brief explanation of research introduction and describing the main goal of research in Chapter 1, this chapter reviews the relevant literature describing how this research relates to existing works on innovation, innovation capability, TIC, and NPD. The structure of literature review consists of five parts as illustrated in Figure 2.1. The chapter begins by explaining innovation in Section 2.1, including innovation definition and process, type of innovation, and innovation practice in Thailand. Then, the literature of innovation capability was reviewed and summarized in Section 2.2, consisting of definitions of capability, competence, competency, and capacity, innovation capability and its assessment, and the existing innovation capability assessment approaches. It is followed by reviewing the literature on TIC, together with existing TIC assessment models and comparisons between TIC development and ISO9001 in Section 2.3. Section 2.4 reviews literature on NPD, consisting of NPD and its process, and extending the understanding of design. Finally, Section 2.5 presents conclusion of this chapter, including identifying research opportunities.

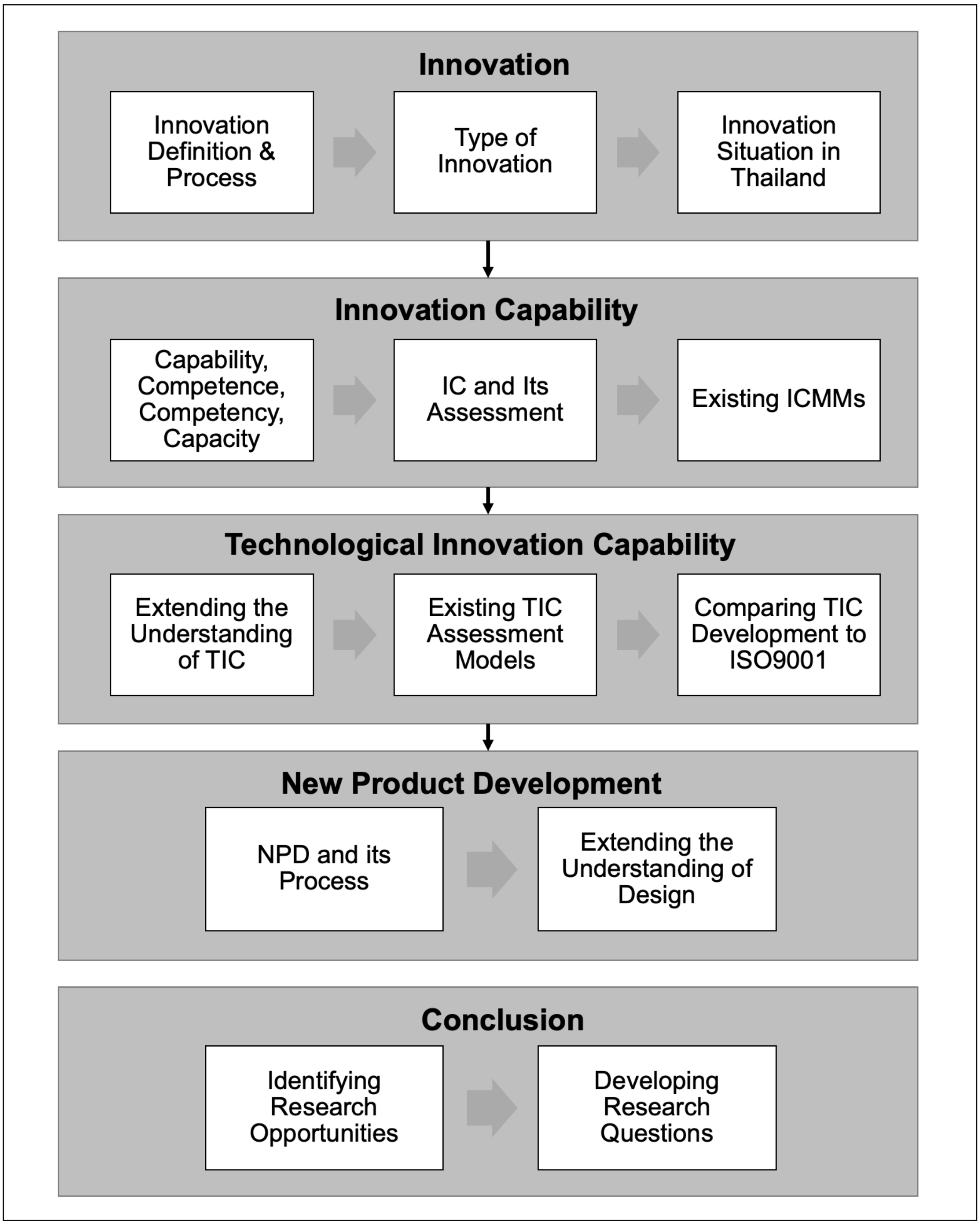


Figure 2.1 Structure of the Literature Review

2.1 Innovation

Innovation has extremely been taken into consideration by many studies, as there is a rapid technological change and new products have been increasingly created and brought to business world. It is an important source of competitive advantage which lead to growth and success. Porter (1985) describes that company can achieve competitive advantage through the approach of innovation in its broadest sense, including new technology and way to do something. This section starts from the definition of innovation in Sub-section 2.1.1. Then, types of innovation are identified and summarized in Sub-section 2.1.2, following by explaining the innovation process in Sub-section 2.1.3.

2.1.1 Innovation Definition and Process

Innovation, as defined by Drucker (2014), is a tool for entrepreneurs, enabling the exploitation of change as an opportunity for distinct advancements in business, products, and services. Tidd and Bessant (2013) further elaborate that innovation is a process of transforming opportunities into new ideas and implementing them widely. Schumpeter (1934) emphasizes that innovation encompasses not only new products but also new production methods, market channels, markets, and forms of organization. Consequently, innovation can be a process of creating or transforming ideas into new products, processes, and systems.

Innovation, as articulated by Drucker (2014), stands as a tool utilized by entrepreneurs to exploit transformative changes. Entrepreneurs, exemplified by visionaries such as Steve Jobs and Elon Musk, deploy innovation to not only create novel products and processes but to actively capitalize on emerging opportunities. Drucker's perspective underscores the dynamic role of innovation in the entrepreneurial toolkit, enabling them to navigate change for distinct business advantages. Complementing this, Schumpeter (1934) concept of "creative destruction" broadens the lens on innovation, emphasizing its disruptive force in reshaping established markets and industries. The nature of innovation goes beyond product development, extending into a boundary where existing norms are challenged and replaced. This dual perspective, one of exploiting change and the other of industry-wide disruption, encapsulates the multifaceted nature of innovation as a driving force in the entrepreneurial landscape.

To effectively develop and organize innovation, Tidd and Bessant (2013) propose a comprehensive process model depicted in Figure 2.2. The model consists of four processes, including search, select, implement, and capture.

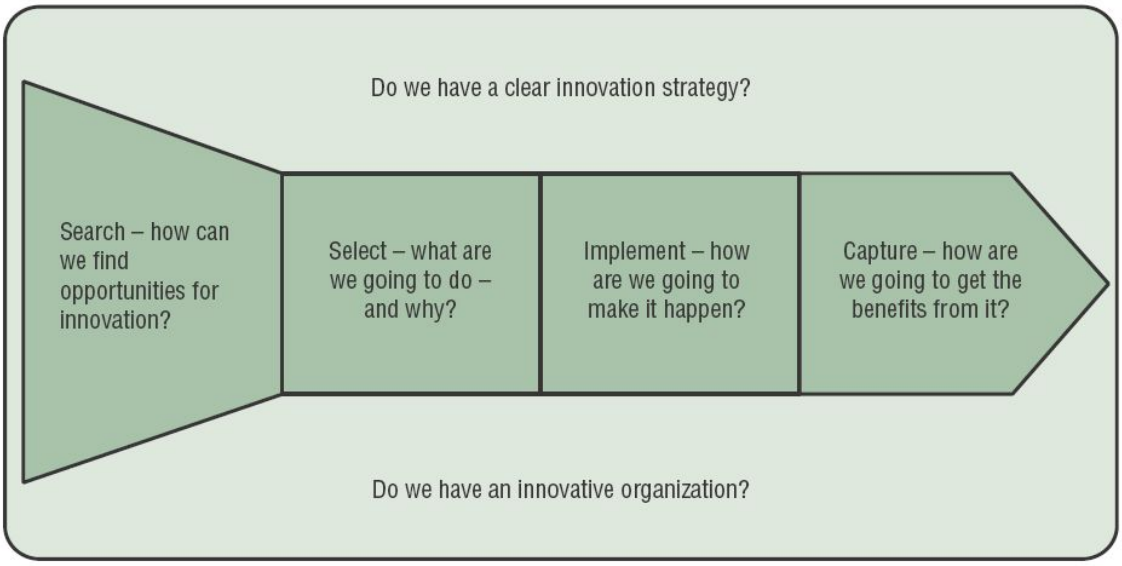


Figure 2.2 Innovation Process Model (Tidd & Bessant, 2013)

The search process is of significance as it involves recognizing various sources of innovation and configuring appropriate search mechanisms. Two primary sources identified are knowledge push and need pull. Knowledge push emerges from scientific research outcomes, while need pull involves understanding and responding to customers' needs. Configuring search mechanisms involves establishing effective ways to tap into these sources, ensuring a rich influx of ideas.

The selection process revolves around decision-making, and organizations employ various methods based on specific situations. Decision-making methods include good practices, clear decision criteria, and stage-gate reviews when relying on existing knowledge. In situations involving technological and market risks, risk assessment tools become instrumental. Additionally, building a business plan serves as a crucial selection method, offering insights into technological innovation and market dynamics. Considering innovation characteristics, such as relative advantage, compatibility, complexity, trialability, and observability, aids in making informed decisions.

Implementation involves the development of new products or services and is heavily influenced by market and technological contexts. The four key stages of implementation include concept generation, project assessment and selection, product development, and product commercialization. Establishing external relationships, such as subcontracting, licensing, consortia, strategic alliances, joint ventures, and networks, is essential for exploiting open innovation. Furthermore, embracing entrepreneurship and ventures provides opportunities to secure financing and manage growth.

The capture process ensures that a company captures the value of innovation. This involves understanding the relationship between knowledge, innovation, and performance. Organizations must also focus on organizing innovation as a continuous learning process for ongoing improvement. Critical aspects of capturing value include the capability to translate technological advantages into commercial products or processes, defend these advantages against competitors, and effective management of the entire process.

In summary, the innovation process, as proposed by Tidd and Bessant (2013), is a dynamic journey that begins with sourcing ideas, involves strategic decision-making, encompasses development and implementation, and concludes with the effective capture of innovation value.

2.1.2 Type of Innovation

Investing in innovation is crucial for businesses, but understanding the different types of innovation is equally important for strategic planning and effective implementation. Literature has categorized innovation types in various ways, as summarized in Table 2.1.

Early research, as highlighted by Rowley et al. (2011), often focused on pairwise categorizations, such as product or process innovation, technological or administrative innovation, and radical or incremental innovation. Product innovation involves the development of new products or services for customers, while process innovation explores novel approaches to production or operations. Technological innovation is driven by advancements in technology, whereas administrative innovation brings about organizational structural and procedural changes. It's important to note that radical and incremental innovations, as described by Rowley et al. (2011), represent the degree of change rather than distinct types. Radical innovation, exemplified by Schumpeter (1934), entails the creation of entirely new products, services, or processes, often leading to the emergence of new markets. On the other hand, incremental innovation involves continuous improvement of existing products, services, and processes, as emphasized by Kirzner (1973).

Table 2.1 Summary of Types of Innovation from Literature

Author(s)	Dimension	Type
Cooper, J.R. (1998)	Multi-dimension	Product innovation Process innovation Technological innovation Administrative innovation Radical innovation Incremental innovation
Knight (1967)	Form	Product or service innovation Production-process innovation Organizational structure innovation People innovation
Tidd and Bessant (2013)	Form	Product innovation Process innovation Position innovation Paradigm innovation
Christensen, C.M. (1997)	Market	Sustaining innovation Disruptive innovation

Cooper, J.R. (1998) proposed multidimensional innovation model drawing together the binary categorization of innovation as illustrated in Figure 2.3. Cooper state that one innovation may possess some aspects of any of these six types of innovation.

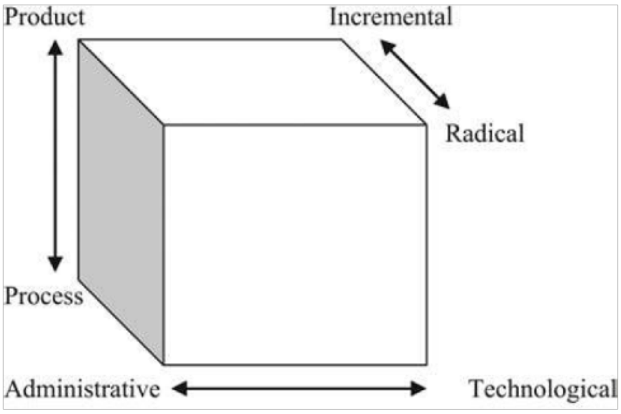


Figure 2.3 Types of Innovation (Cooper, J.R., 1998)

Knight (1967) presented a model based on the form of innovation, categorizing it into product or service innovation, production-process innovation, organizational structure innovation, and people innovation. The definitions of product or service innovation and production-process innovation are similar to those of Rowley et al. (2011). Organizational structure innovation is related to system change, such as communication system (Knight, 1967). People innovation is concerned with staff, role, culture, and behaviour.

Tidd and Bessant (2013) also propose model of innovation type regarding innovation forms, including product innovation, process innovation, position innovation and paradigm innovation. The definitions of product innovation and process innovation are same as the others. Position innovation is a change in context which the established products or processes are introduced to new customers. Paradigm innovation is a change in the mental models which frame the company. These four innovation types can be both incremental and radical innovation.

Interestingly, Christensen, C.M. (1997) categorized innovation differently, focusing on target markets: sustaining and disruptive innovation. The innovation can be either product, process, or business model, and either incremental or radical. Sustaining innovation is to improve the technology performance in order to value the mainstream customers. This concept is called Technology S-curve, which progresses from slow to accelerated improvement and eventually approaches maturity. As a result, the technologies of sustaining innovation often exist in a given time and a given amount of engineering effort. In contrast, disruptive innovation creates new streams of innovation, targeting new and smaller markets.

The analysis of various frameworks reveals distinctions and overlaps. Product innovation, involving changes in tangible things, and process innovation, encompassing changes in creation and delivery methods, are consistently defined across different authors (Cooper, J.R., 1998; Knight, 1967; Rowley et al., 2011; Tidd and Bessant, 2013). There are also notable overlaps in definitions. Tidd and Bessant's Position Innovation, focusing on the change of market, aligns with Christensen's Sustaining and Disruptive Innovations. Tidd and Bessant's Paradigm Innovation resembling Cooper's administrative innovation and Knight's organizational structure innovation and people innovation. Rowley et al. (2011) emphasize that innovation can be both incremental and radical as these are attributes representing the degree of newness rather than distinct types of innovation.

2.1.3 Innovation Practices in Thailand

In the fiercely competitive business landscape, enterprises continually seek novel ways and products to meet customer demands and sustain their position. Simultaneously, governments worldwide, including Thailand, strive to foster innovation-driven economies through dedicated policies and programs. Despite these efforts, Thai SMEs and start-ups still face challenges to produce technological innovation, which are summarized as five main issues.

1) Limited science and technology

The science and technology are limited due to three reasons. (1) Entrepreneurs do not have in-house Research&Development (R&D). The investment in R&D, science and technology are not appropriated. The number of in-house R&D in large companies is 25% whereas those of SMEs is 10% (Intarakumnerd, 2019). This is because the technology used in Thailand are from abroad rather than developing in the country (Intarakumnerd, 2019; Karaveg et al., 2014). Multinational corporations and joint ventures also manufacture regarding the specifications of parent companies or customers. (2) The R&D is mostly in science-based industry. There is an increase of R&D activity in small companies and collaboration with university; however, there have been only limited outstanding cases which usually in science-based industries (Intarakumnerd, 2019). The old local-owned companies are likely to collaborate with universities, whereas start-ups usually operated by entrepreneurs with strong R&D backgrounds and rely on their own engineering or design. (3) There are more incremental innovations than radical innovations (Rujirawanich et al., 2011). SMEs prefer to develop incremental innovation because there is high simplicity rate of incremental innovation creation as well as this type of innovation requires lower resources than those of radical innovation. This is similar to the R&D institutes, which focus on basic research and produce incremental innovation rather than radical innovation (Karaveg et al., 2014). The university research is also developed in embryonic stage which cannot reach marketplace and commercialization (Wonglimpiyarat, 2016) as well as the technology do not meet demand of industry and cannot create competitive advantage (Karaveg et al., 2014).

2) Limited entrepreneurial skills and innovation cultures

Many businesses in Thailand lack the essential entrepreneurial skill. The Global Entrepreneurship and Development Institute (2019) reports the Global Entrepreneurship Index of Thailand that Thai entrepreneurs get low scores of risk acceptance, technology absorption, and networking. These limited skills have negative effect on producing innovation. In addition, Rujirawanich et al. (2011) found that Thai companies have high negative attitude to change. Due to the culture of unwillingness to take risk, they avoid uncertainty by producing simple products, resulting in incremental innovation. Another cultural challenge is the hierarchy system. Many senior managers, who have work for long time are not willing to create innovation, leading to lower-level employees conforming senior managers and ignoring to improve.

3) Financial problem

SMEs and start-ups face financial problem to produce innovation (Intarakumnerd, 2019; Wonglimpiyarat, 2016). High cost is needed to create innovation which is the major problem for small companies (Intarakumnerd, 2019). There is also the scarcity of venture capital funds and private equity investments, resulting in entrepreneurs do not receive appropriated financial support from private sectors (Wonglimpiyarat, 2016). At the same time, the university research institutes also suffer from limitation of government funding support owing to the political issue and the change of government and policies. For incubators, they also face the financial constrain which leads to insufficient mentoring and referral services.

4) Limited access to information

Intarakumnerd (2019) finds that the sources of information to innovation in Thailand is limited. These sources include the interaction, such as customers, parent firms and suppliers. Moreover, the sophisticated sources such as patents, research institutes, and universities are minimally significant. Chaminade et al. (2012) also finds that there are lack of information of marketing and funding opportunity, consultancy, and technology transfer.

5) Insufficient supports from incubator and government

Although the university business incubators are established, there are many challenges for them to support innovation (Munkongsujarit, 2016). Incubators have attempted to produce start-up or spin-off companies that can generate annual revenue or gross profit margin, rather than foster the incubatees. Incubators' staffs have insufficient essential skill and experience to support incubates. Incubators also face problems of unable to find specialists and consultants to support and enhance incubatees' technical knowledge as well as find business partners to match the incubatees. Furthermore, there are insufficient policies to promote innovation (Chaminade et al., 2012). The science and technology policies are bias because they mainly focus on encouraging science-based and research-based activities while non-research-based firms do not perceive appropriated supports. Other policies are also limited, such as policy to accept the failure of entrepreneurs that doing innovative companies, and policy to advocate customers to use innovative products and services.

It is found from literature that there are the challenges that Thai entrepreneurs have faced when producing innovation. The challenges are limited science and technology, limited entrepreneurial skills and innovation cultures, financial problem, limited access to information, and insufficient supports from incubator and government. This results in Thai entrepreneurs developing insufficient number of technologies and innovations. Simultaneously, the developed technologies and innovations do not meet demand of industry and cannot create competitive advantage. This leads to the opportunity to conduct further research on how Thai entrepreneurs could produce technological innovation. In addition, the existing research on innovation in Thailand place emphasis on investigating innovation situation and the challenge of producing innovation while there is limited research on how to increase TIC, particularly in SMEs that are an important driver of Thai economy, but they produce less innovation.

2.2 Innovation Capability

Measuring innovation is a complex action as it is influenced by many factors. Crossan and Apaydin (2010) state that linking innovation outcomes with company performance is critical because it is difficult to address what and how innovation create value. In response, a focus on understanding how innovation capabilities translate into tangible outcomes and performance emerges as an approach to measurement. This section emphasizes the concept of innovation capability, a lens employed by many scholars to measure the company' ability of generating innovation. The discussion encompasses an exploration of capability, competence, competency, and capacity in Sub-section 2.2.1, an examination of innovation capability and its assessment in Sub-section 2.2.2, and a review of existing innovation capability maturity models in Sub-section 2.2.3.

2.2.1 Definitions of Capability, Competence, Competency, and Capacity

The terms capability, competence, competency, and capacity are often used interchangeably, contributing to confusion due to their close association. “Capability” involves the generation of knowledge, adaptability to various situations, and a commitment to continuous improvement (Nagarajan and Prabhu, 2015). It denotes a deployable and developable process (Vincent, 2008). “Competence”, on the other hand, is an ingredient of capability, representing a state of possessing adequate knowledge and skills, typically referenced in the context of individual know-how and skills (Vincent, 2008). An example of competence includes understanding how to enhance profitability or reduce costs (Hase and Davis, 1999). “Competency” extends to encompass knowledge, skill, movement, or characteristic that excels in performance (McClelland and Boyatzis, 1980). Prahalad and Hamel (1997) introduce the term "Core competency" to signify the distinctive competencies that set a company apart from its competitors. The example of competency is found in the study of Patel and Pavitt (1997), which studies on the technological competencies. Patel and Pavitt use this term to explain why the companies are different from their competitors and refer to the fields in which the companies are active in their corresponding distinctive technologies. For instance, background competencies such as machinery and chemical process, and niche competencies such as agricultural chemical and bleaching and dyeing. “Capacity”, in turn, refers to the quantity or volume of something (Vincent, 2008). For example, Forsman (2011) interprets innovation capacity as the continuous improvement of innovation capability, coupled with the resources a company utilizes to explore opportunities and develop new products aligned with market needs. Forsman gauges innovation capacity through variables such as R&D activities, the degree of innovation capabilities, and external inputs.

In the mid-1980s, the emphasis on capability emerged in UK studies to address the enterprise's necessity to compete in a turbulent market (Hase and Davis, 1999). Both individuals and organizations require adaptability to navigate rapid changes. Capability enhances the functioning of individuals, empowering them to acquire the ability and skill needed to effectively navigate chaotic circumstances. While competence pertains to an individual's ability to perform a task, capability refers to an organization's ability to deliver products or services. This aligns with Christensen, C.M. (1997)'s distinction between skill as an intangible resource accessible in the marketplace and capability as the capacity to align resources in activities toward strategic objectives, accumulated within the organization.

Therefore, TIC cannot purely comprise technical skill and technical recipe; however, it necessitates experience and knowledge. Vincent (2008) underscores that, for innovation success, a company must not only know what makes it successful but also possess the ability to generate new knowledge. Flexible and adaptable capabilities, therefore, serve as tools for innovation success, while competencies consistently require development.

2.2.2 Innovation Capability and Its Assessment

Innovation capability encompasses the ability to early introduce novel products and adopt new processes to stay competitive (Zawislak et al., 2018). Crossan and Apaydin (2010) characterize innovation capability as a managerial mechanism that facilitates innovation. A definition echoed by Saunila and Ukko (2012), who emphasize elements influencing the capability to manage innovation. Beyond the organizational and managerial dimensions, Tesfaye and Kitaw (2018) define innovation capability as an organization's ability of applying knowledge acquired and enhanced, for the successful development of products, processes, and the organization development. In essence, innovation capability involves the ability to (1) manage innovation and (2) generate innovation by transforming existing knowledge.

The measurement of innovation capability has evolved with diverse approaches. Early studies often relied on single-dimensional metrics. Ayhan and Oztemel (2014), for instance, measures managerial innovation capability by considering planning, organizing, leading, controlling and coordinating aspects. Wang et al. (2008) measure TIC through considerations such as R&D capability, innovation decision capability, marketing capability, manufacturing capability, and capital capability. Some studies measure the innovation capability more comprehensive by considering the holistic innovation process. Crossan and Apaydin (2010) assess innovation capability by considering inputs (such as organizational culture, portfolio management, commercialization), processes (such as individual/group/firm level, top-down/bottom-up direction), and outputs (such as product/process innovation, incremental/radical innovation). Saunila and Ukko

(2012) also proposed the framework to measure innovation capabilities involving three elements, innovation potential (such as leadership and decision-making processes), innovation processes (such as opportunity identification and analysis, idea genesis and selection), and the results of innovation activities (such as product/service innovation, process innovation). In addition, the framework links three elements of innovation capability to the business performances, including personal, process, customer, and financial. Türker (2012) measures TIC by assessing three elements: inputs (such as HR, knowledge creation, vision strategy, and entrepreneurship), processes (such as organizational culture and control), and outputs (such as tangible return, intellectual capital).

2.2.3 Existing Innovation Capability Assessment Approaches

Traditional assessment methods, such as quantitative measurement and benchmarking, are valuable for data collection but often fall short in providing actionable insights for improvement (Moultrie et al., 2007). Moultrie et al. emphasize the need for audit tools that go beyond mere measurement, enabling organizations to identify gaps between current and desired performance and develop actionable improvement plans. These tools include binary yes–no responses, Likert scales, and maturity processes. While binary yes–no responses and Likert scales offer greater granularity, these approaches may still lack a comprehensive roadmap for organizational enhancement to progress between each level. However, maturity-based process audit tools address these shortcomings, providing a structured approach to assess the degree to which processes or activities are effective, identify gaps and prioritize improvement efforts (Moultrie et al., 2007).

Essmann (2009) also underscores the critical importance of understanding an organization's current position and performance relative to successful industry peers. Benchmarking against best practices or successful examples is crucial for determining the extent of needed improvement and the direction to pursue. Once an organization benchmarks its performance, it can strategically develop a plan to enhance its capability maturity. Therefore, several studies emphasize the need to move beyond simplistic measurement approaches toward assessments that facilitate continuous improvement and organizational development.

Several studies have proposed models that integrate the concept of Capability Maturity Model (CMM) to measure innovation capability. Initially developed by the Software Engineering Institute (SEI) for process improvement (Paulk et al., 1993). CMM provides a structured approach to organizational assessment against five process maturity levels. These levels progress from initial (Level 1) to repeatable (Level 2), defined (Level 3), managed (Level 4), and optimizing (Level 5), each representing increasing levels of process effectiveness and control. Level 1 is initial; organization does not provide a stable environment. Level 2 is repeatable; development successes are repeatable. Level 3 is defined; standard processes are established and improved over time. Level 4 is managed; there are precise measurement and control. Level 5 is optimizing; there are incremental and innovative improvements. Essmann (2009) explained that the main purposes of deploying CMM concept in organization are (1) to understand the current position of the enterprises and their competitors and (2) to establish the direction for improving the capability to suit the enterprises or imitate the best practices of the domain. Therefore, the adoption of the CMM concept has extended to various organizational activities, including innovation capability assessment and NPD. Several studies proposed the Innovation Capability Maturity Model (ICMM).

Moultrie et al. (2007) reviews several existing maturity-based tools applied in NPD, including NPD management, technical innovation, R&D management, and project management. Moultrie's identification of gaps in the literature emphasizes the need for more accessible and practical approaches to implementing best practices, particularly in SMEs, where managers may have limited time, financial, and human resource to dedicate to process improvement efforts as well as staffs may face skill limitations. Another specific gap mentioned by Moultrie et al. is the lack of the development of maturity models that address specific areas, particularly design process execution within product development.

In a systematic literature review on the Innovation Capability Maturity Model (ICMM) conducted by Arends (2018), a comprehensive examination was undertaken to identify studies conducted between 2006 and 2017. From an initial pool of 55 primary studies, it was found that despite the substantial number of models identified, none have achieved widespread acceptance or practical application, indicating that research in this domain remains in its early stages. As illustrated in Figure 2.4, Arends (2018) identified four primary focuses within the literature: development of new models, validation of existing models, application of existing models, and studies offering descriptive or comparative analyses of these models. Notably, the predominant emphasis in assessing innovation capability lies in model development, with relatively limited attention devoted to model validation and application.

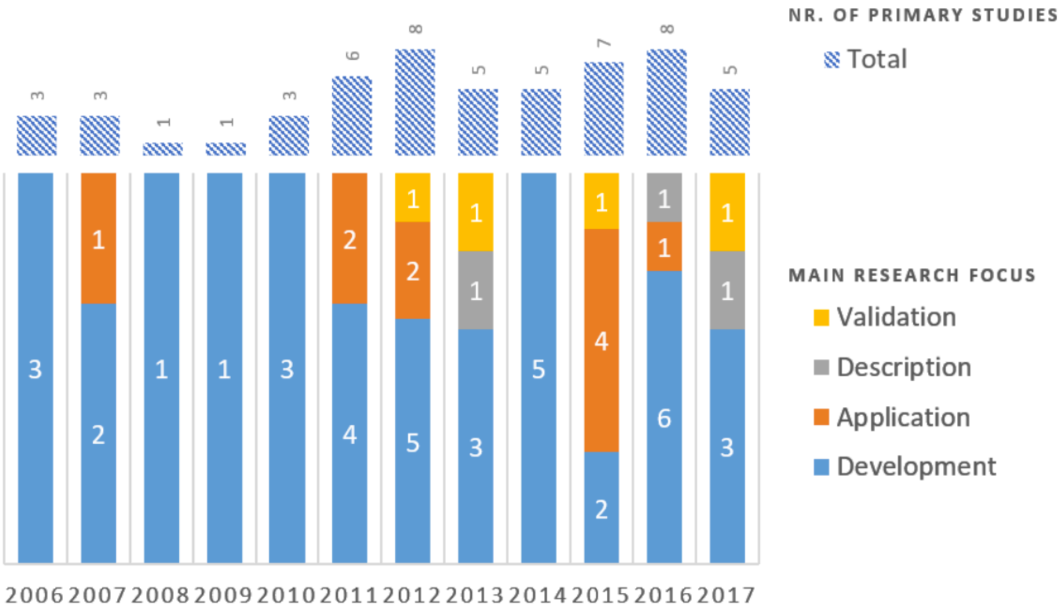


Figure 2.4 Literature Review Conducted my Arends (2018) Showing Main Research Focus on ICMM Distribution Per Year (Source: Arends, 2018)

Giménez-Medina et al. (2023) conducted a systematic literature review on capability and maturity innovation assessment models in the context of ICT organizations. The author included 78 primary studies since 2000. As shown in Figure 2.5, the study found that most studies (75%) proposing models without specific methods, with only a few studies presented instantiation supporting their proposed models. This finding confirms Arends (2018) observation that existing ICMM research mainly focuses on model development, with limited applications. However, Giménez-Medina (2023) found a different result regarding model validation. The study noted a reliance on academic validation (68%), with a scarcity of studies involving industrial validation (less than 13%) or lacking validation (20%). Additionally, case studies (49%) and surveys (31%) were the predominant validation types.

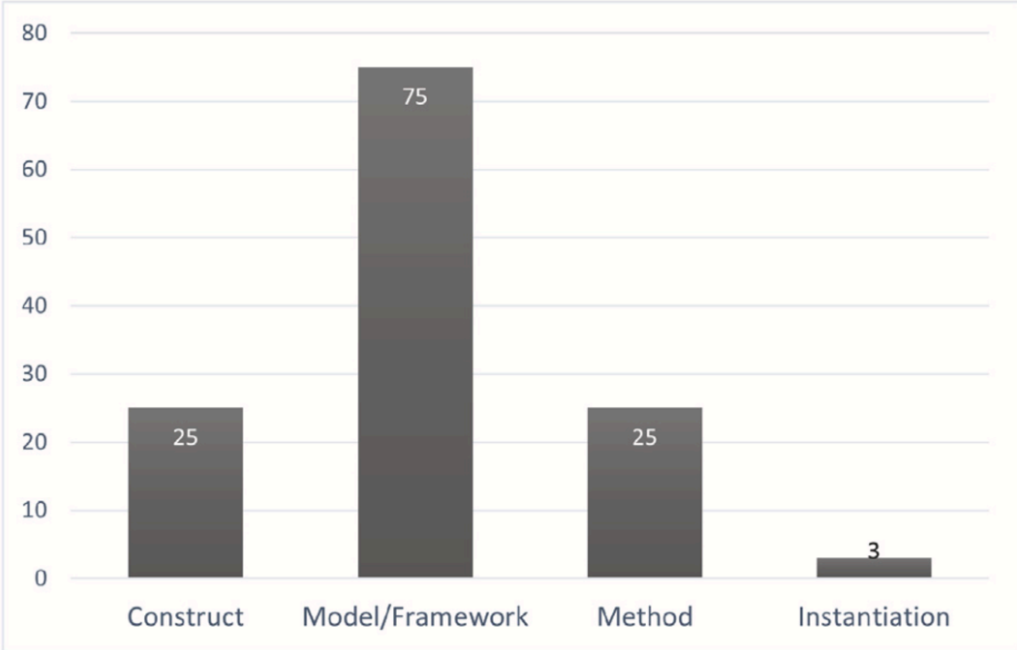


Figure 2.5 Literature Review Conducted by Giménez-Medina (2023) Showing Main Research Focus on ICMM in ICT Organizations (Source: Giménez-Medina, 2023)

This section examines 30 existing ICMMs from 2009 to 2024. The details of each sample were summarized in Appendix B. The sample encompasses not only ICMMs for innovation but also those with specific focuses related to technological innovation and organizational innovation. The focuses were distributed as follows: 9 models on general innovation capability, 3 on Technological Innovation Capability (TIC), 9 on New Product or New Service Development (NPD/NSD) capability, 6 on digital transformation or IT capability, and 3 on sustainability-oriented innovation/NPD capability. To verify the identified gaps by Moultrie et al. (2007), Arends (2018), and Giménez-Medina et al. (2023), each model is compared based on critical issues such as assessment focus, maturity level, and model validation.

The review confirms Moultrie et al. (2007) findings that existing models lack specificity, focusing broadly on innovation or NPD. Some models focus on TIC but have limitations; for example, the model from Shaygan and Daim (2019) targets TIC in healthcare organizations but uses a Hierarchical Decision Model instead of a maturity model. Similarly, The model from Kreiling and Bounfour (2020) focuses on TIC but specifically assesses the capabilities of technology transfer organizations. Existing models are often unsuitable for practical use by SMEs due to their complexity, including numerous assessment metrics or questions (Essmann, 2009; Rossi and Terzi, 2017), different definitions for each level (Arends, 2018; Jin et al., 2014; Münch et al., 2019), and varied metrics within each level (Narcizo et al., 2019; Shpak et al., 2022). This complexity may require substantial time and resources for SMEs to implement.

The review also confirms Arends (2018) and Giménez-Medina et al. (2023) observation that existing studies focus primarily on model construction with limited discussion on assessment procedures (Corsi and Neau, 2015; Narcizo et al., 2019; Petzolt et al., 2022; Podmetina et al., 2019; Stahl et al., 2017; Viklander and Möller, 2011; Wei et al., 2013). Furthermore, existing studies lack model validation processes (Aguiar et al., 2019; Carroll and Helfert, 2015; Corsi and Neau, 2015; Demir, 2018; El Bassiti, 2018; Jin et al., 2014; Müller-Prothmann and Stein, 2011; Münch et al., 2019; Pfenning et al., 2020; Shaygan and Daim, 2019; Sukrat and Leeraphong, 2024; Wei et al., 2013), which confirms Arends (2018) observations. Therefore, there is a research opportunity to develop ICMM practical for SMEs and start-ups by ensuring they are not overly complex and do not require extensive time, skills, and resources, and there is also an opportunity to develop models that include explicit assessment methods and can be validated through industrial application.

2.3 Technological Innovation Capability

Technological innovation capability (TIC) stands out as a crucial element enhancing overall innovation capability (Ince et al., 2016; Tesfaye and Kitaw, 2018). It contributes significantly to a company's competitive advantage, product development, improved performance, and sustainable competitive positioning (Azubuike, 2013). The landscape of TIC is explored in this section, beginning with an in-depth examination in Sub-section 2.3.1, followed by a review of existing TIC assessment models in Sub-section 2.3.2. The comparison between TIC development and ISO9001 is explained in Sub-section 2.3.3.

2.3.1 Extending the Understanding of Technological Innovation Capability

TIC has captured the attention of numerous studies, defining it as the company's ability to promptly respond to environmental shifts through the selection, diffusion, and improvement of technology (Burgelman et al., 2009). Zawislak et al. (2018) introduce related terms, such as technology development capability and technological capability, emphasizing the skills, knowledge, experience, and routines integral to developing new products, services, and managing technological change. Differently, Trott (2008) said that technological innovation is referred as innovation because innovation is often accompanied by additional organizational change. In the context of this thesis, TIC is conceptualized as the ability to adapt to technological change by acquiring new technology and developing technological products, processes, and services.

Chiesa et al. (1996) view TIC as process approach, forming by concept generation capability, product development capability, process innovation capability, technology acquisition capability, leadership capability, resource deployment capability, and the effective use of systems and tools. Zawislak et al. (2018) also propose the process of TIC, consisting of monitoring technology, assimilating technology, and forming development process. Meanwhile, Burgelman et al. (2009) view TIC as a set of characteristics that facilitates company to execute technological innovation strategy, including resource availability and allocation, capacity to understand competitors, industry, and technological development, structural and cultural context, and strategic management capacity. Christensen, J.F. (1995) identifies TIC as an asset encompassing scientific research, process innovation, product innovation application, and aesthetic design. Christensen also points out that the latter asset, aesthetic design, has usually been ignored in technological innovation literature although this asset is an essential bridge between technical features of product and marketing strategy. Tesfaye and Kitaw (2018) further classify TIC into two capabilities: product innovation and process innovation, while Azubuike (2013) expands it to include marketing innovation.

The positive impact of TIC on developing new product and increasing innovation capability is evident. Azubuike (2013) notes the affirmative influence of TIC on New Product Development (NPD) performance, and Ince et al. (2016) find that TIC supports innovation strategy and facilitates company to develop new product. Tesfaye and Kitaw (2018) echo this sentiment, emphasizing that TIC results in the development of both product and process innovation. Moreover, companies equipped with high absorptive capacity and knowledge utilization capability can develop more technological innovation as well as enhance their overall innovation capability.

2.3.2 Existing Technological Innovation Capability Assessment Models

Various models have been developed to assess TIC, each offering unique perspectives and criteria for evaluation.

1) Yam et al. (2004)

Yam et al. introduced a widely adopted TIC audit framework based on a functional approach. This framework includes learning capability, R&D capability, manufacturing capability, marketing capability, resource allocation capability, organizing capability, and strategic planning capability. The study found that R&D capability and resource allocation capability significantly influence a firm's performance, distinguishing them as crucial TIC factors, while learning capability and organizing capabilities contribute less significantly. Yam et al.’s TIC audit framework has been widespread and adopted in many later studies (bin Zainuddin, 2017; Guan et al., 2006; Liu, L. and Jiang, 2016) to assess the TIC because of the easiness to understand.

2) Wang et al. (2008)

Another TIC evaluation framework that has been applied extensively is from Wang et al. The framework presented a distinct TIC evaluation framework specifically tailored for hi-tech companies. Unlike Yam et al. (2004)’s model, Wang et al.'s framework concentrates solely on technology development and commercialization perspectives, omitting aspects related to learning and organizing. This divergence in focus highlights the diverse considerations in TIC assessment.

3) Liu, L. and Jiang (2016)

Liu and Jiang (2016) incorporated the TIC audit framework by Yam et al. (2004) into their model, modifying it based on expert interviews. Their TIC model assesses seven criteria within technology, management, and learning dimensions. Notably, marketing-related dimensions are excluded as they are perceived as outcomes rather than influencers of TIC. The study underscores the influence of strategic capability, followed by knowledge resource, on NPD performance.

4) Sumrit and Anuntavoranich (2013)

Sumrit and Anuntavoranich investigated TIC in the Thai context, categorizing it into six main perspectives with sixteen criteria. The study introduced perspectives such as innovation sourcing and robustness of product and process design. The prioritization of these perspectives revealed that innovation management capability was deemed the most critical, suggesting a focus on strategic management capability, absorptive capability, and R&D capability for Thai technology-based firms.

There are also other TIC evaluation frameworks. Khayyat and Lee (2015) study technological capability in developing countries and found that most of the advanced technologies adopted by developing countries are imported, rather than locally developed. Therefore, he suggests evaluation model includes technology import and local availability of specialized research and training services. Camisón-Haba et al. (2019) identify factors that make the distinction between technology-based firms and technology-based and highly innovative firms and claims that firms that innovative should focus on managerial capabilities, which include managerial experience, exercise of power, technological education, and managerial education. The comparison of TIC criteria across existing assessment models was summarized in Table 2.2.

The comparison of various TIC assessment models reveals a commonality in perspectives across multiple studies. These perspectives revolve around R&D, manufacturing, market, strategic management, resource management, organization management, and learning dimensions. Notably, the frameworks developed by Wang et al. (2008) and Liu, L. and Jiang (2016) are different from this patterns. Wang et al.'s framework excludes consideration for organization and learning perspectives, while Liu and Jiang's model excludes the market perspective. Conversely, Sumrit and Anuntavoranich (2013)'s framework introduces additional criteria, incorporating innovation sourcing and robustness in product and process design perspectives. This diversity underscores the dynamic nature of TIC evaluation, emphasizing the need for an understanding of various dimensions of technological innovation within different organizational contexts.

Table 2.2 Comparison Between TIC Criteria of the Existing TIC Assessment Models in Literature

TIC Perspectives	TIC Criteria				
	Yam et al. (2004)	Wang et al. (2008)	Liu, L. and Jiang (2016)	Sumrit and Anuntavoranich (2013)	Other interesting Criteria
R&D	- R&D Capability	- R&D Capability	- Fundamental Research - Application R&D	- R&D Capability - Project Cross functional team integration capability	- Technology Import - Local Availability of Specialized Research and Training Service (Khayyat & Lee, 2014)
Manufacturing	- Manufacturing Capability	- Manufacturing Capability	- Manufacturing Capability	- Manufacturing Capability	
Market	- Market Capability	- Market Capability		- Market Capability	
Strategic Management	- Strategic Management Capability	- Innovation decision capability	- Strategic Capability	- Strategic Management Capability - Technology Change Management Capability	
Resource Management	- Resource Allocation Capability	- Capital capability	- FHM Resource (Finance, Human, Material resource)	- Resource Allocation Capability	

Table 2.2 Comparison Between TIC Criteria of the Existing TIC Assessment Models in Literature (Cont.)

TIC Perspectives	TIC Criteria				
	Yam et al. (2004)	Wang et al. (2008)	Liu, L. and Jiang (2016)	Sumrit and Anuntavoranich (2013)	Other interesting Criteria
Organization Management	- Organizing Capability		- Organization Capability	- Organization Capability - Risk Management Capability	- Managerial Capability (Camisón-Haba et. al., 2019)
Learning	- Learning Capability		- Knowledge resource	- Learning Capability - Absorptive Capacity - Knowledge Management Capability	
Other				- Technology Acquisition Capability - Network Linkage Capability - Product Structural Design and Engineering Capability - Process Design and Engineering Capability	

2.3.3 Comparing Technological Innovation Capability Development to ISO9001

Comparing TIC development to ISO9001 reveals shared similarities that underscore their interconnectedness. ISO9001, a framework for quality management, extends from manufacturing to delivery stages, emphasizing productivity, efficiency, and meeting customer expectations (Manders et al., 2016). Prajogo et al. (2007) distinguish quality as an order qualifier and innovation as an order winner. Manders et al. (2016) establish a positive relationship between ISO9001 and product innovation, attributing it to leadership, people involvement, and mutually beneficial supplier relationships. Leadership promotes innovation culture and encourage employees to generate ideas. Involvement of people results in giving employees responsibility and sense of ownership which increases innovative behavior. Mutually beneficial supplier relationships result in sharing expectations, information and resources which foster innovation. ISO9001 and TIC development can be connected due to some shared distinct similarities between them as compared in Table 2.3.

- TIC and ISO9001 find common ground in leadership and management. While ISO9001 emphasizes management responsibility and people involvement, TIC focuses on innovation management encompassing strategy, organization, resource allocation, and risk management.
- Both perspectives underscore the importance of organizational learning. ISO9001 prioritizes data-driven decision-making, while TIC emphasizes learning from innovation project evaluation, portfolio management, and absorptive learning from external parties.
- Network linkage is a key element for both. ISO9001 centres on customer expectations and supplier relationships, while TIC focuses on network linkage with customers and suppliers throughout the innovation process.
- Continuous improvement is integral to both perspectives. ISO9001 emphasizes ongoing enhancement and TIC focusing on both incremental and radical improvement.
- Process integration is crucial in both. ISO9001 emphasizes managing interrelated processes as a system and TIC focuses on cross-functional team integration to coordinate all phases of the R&D process.

This comparison highlights the complementary aspects of TIC and ISO9001, suggesting that their concurrent implementation could yield enhanced outcomes.

Table 2.3 Comparison between ISO9001 and TIC Perspectives

Focus point	ISO9001	TIC
Leadership and management	- Leadership - Involvement of people	- Innovation management
Organization learning	- Factual approach to decision making	- Innovation project evaluation - Portfolio management - Absorptive learning
Network linkage	- Customer focus - Mutually beneficial supplier relationships	- Network linkage with customers and suppliers
Improvement	- Continual improvement	- Incremental improvement - Radical improvement
Process integration as a system	- System approach to management	- Project cross junctional team integration

While ISO9001 has been widely adopted by companies globally, Manders et al. (2016) note that some companies obtain the standard without proper implementation in daily operations, highlighting potential challenges in its effective use. SMEs face specific obstacles in implementing ISO9001, including difficulties in understanding and adopting concepts such as organizational context, organizational knowledge, process approach, and risk-based thinking (ISO, 2016). Additionally, resource constraints and high setup and maintenance costs pose challenges for SMEs in establishing and sustaining a quality management system. Manders et al. (2016) also noted that the cost of certification further strains SMEs, potentially leading to reduced investment in innovation projects or collaborations with external parties due to financial constraints.

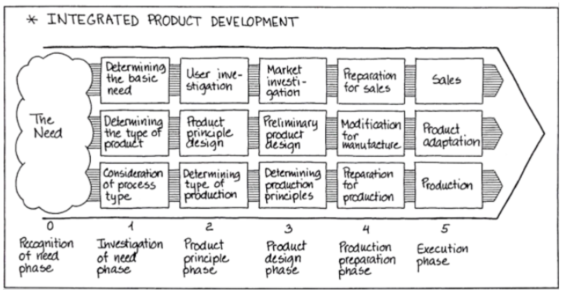
The development of TIC and the implementation of ISO9001 are interconnected as tools that enable companies to enhance themselves and gain a competitive advantage. Both approaches focus on key perspectives such as organizational learning, continuous improvement, and network linkage. Challenges identified in SMEs adopting ISO9001 suggest that similar challenges may arise in developing TIC. Addressing these challenges requires a mechanism that guides SMEs in prioritizing essential capabilities rather than mandating the adoption of all perspectives. This approach could enable SMEs to optimize resources and costs while enhancing organizational capabilities and developing TIC.

2.4 New Product Development

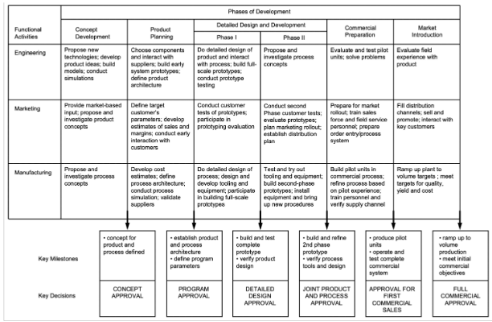
New products emerge as a result of the innovation process. In the same way, new product development (NPD) process is the sub-process of innovation. Trott (2008) asserts that managing innovation involves ensuring organizations seize opportunities for new product development. Azubuike (2013) identifies TIC as a key driver of company performance in NPD. Section 2.6.1 provides a detailed explanation of NPD and its processes, while Section 2.6.2 further explores the concept of design.

2.4.1 New Product Development and Its Process

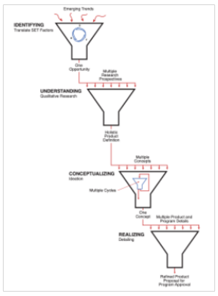
NPD, sometimes referred to as Product Development by certain authors, encompasses the procedures for designing and delivering new products to the market (Unger and Eppinger, 2011). This definition aligns closely with that of Cagan et al. (2002) who describe product development as the process of creating products aligned with customer value. Marxt and Hacklin (2005) expand NPD to include the development of improved products. Cooper, R.G. (1990) identifies product development as a method for managing the innovation process. Many authors use NPD to describe a situation where artifact design integrates with three main functions: design, marketing, and manufacturing (Andreasen and Hein, 2000; Cagan et al., 2002; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992). From these definitions, NPD capability is defined as the organization's ability to create or enhance products across three activities related to design, marketing, and manufacturing. Various NPD processes proposed by different authors are illustrated in Figure 2.6.



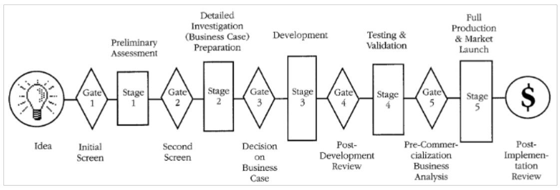
Integrated Product Development Process with Parallel Execution of Market, Product, and Production (Andreasen and Hein, 2000)



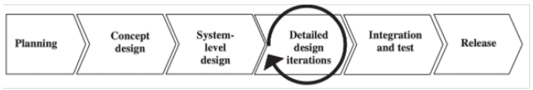
Integrated Product Development Process across Three Functional Activities related to Engineering, Marketing, and Manufacturing (Wheelwright and Clark, 1992)



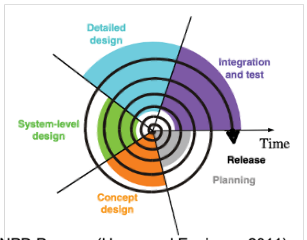
User-Centered integrated New Product Development Process and Its Four Phases, which are Identifying, Understanding, Conceptualizing, and Realizing (Cagan et al., 2002)



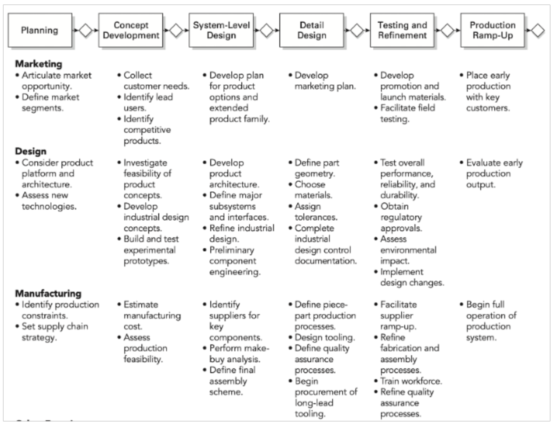
Stage-gate System Product Development Process (Cooper, 1990)



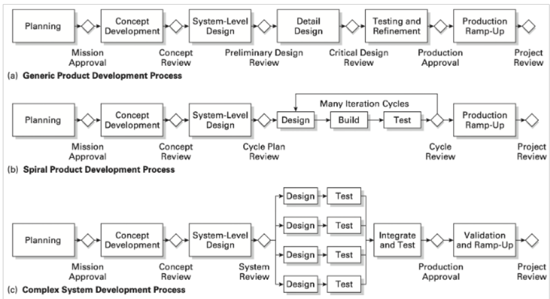
General NPD Staged Process (Unger and Eppinger, 2011)



Spiral NPD Process (Unger and Eppinger, 2011)



Stage-gate System Product Development Process across Three Functional Activities related to Marketing, Design, and Manufacturing (Ulrich, 2003)



Product Development Process for Different Types of Process and Product (Ulrich, 2003)

Figure 2.6 Example of NPD Process (Andreasen and Hein, 2000; Cagan et al., 2002; Cooper, R.G., 1990; Ulrich and Eppinger, 2016; Unger and Eppinger, 2011; Wheelwright and Clark, 1992)

Summarizing the examples of NPD processes reveals three major observations. Firstly, models differ in their starting and ending points. For instance, the models of Andreasen and Hein (2000), Cagan et al. (2002), and Cooper, R.G. (1990) begin with recognizing needs or identifying opportunities, whereas Unger and Eppinger (2011) and Ulrich and Eppinger (2016) start with planning, and Wheelwright and Clark (1992) initiate at developing the concept. Regarding the endpoint, Cagan et al. (2002) is the only model that concludes at program approval while others finish at product launch. In essence, the process can be summarized as 'Opportunity recognition – Concept development – Early system design - Detail design – Commercial preparation – Market introduction’.

In addition, Ulrich and Eppinger (2016) introduces three product development flow diagrams for different processes and products, illustrated at the bottom-right of Figure2.6. For generic process, it is suitable for the development of such products as market-pull and technology-push products. The spiral process, suitable for software and electronics, involves cycles of design, build, and test phases. When there is not enough budget or times to carry-on another cycle, high and medium priority features have usually been determined. The complex system process, fitting large-scale products, such as automobiles and airplanes, divides design and test phases into subsystems, allowing many teams to work in parallel. The second observation is that many models share the integration of three major viewpoints in the NPD process (Andreasen and Hein, 2000; Cagan et al., 2002; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992). As summarized in Table 2.4, despite different terminology, these viewpoints are consistently design, market, and production.

1) **Design:** This discipline involves product architecture and new technology (Ulrich and Eppinger, 2016). The definition is similar to product discipline in Andreasen and Hein (2000) and engineering discipline in Wheelwright and Clark (1992). This is except of Cagan et al. (2002) who separated this aspect into two disciplines: design discipline focusing on product concepts based on the visual appearance or human factors, and engineering discipline focusing on product concepts based on technological innovations.
2) **Market:** This discipline focus on product concepts based on marketing criteria (Andreasen and Hein, 2000; Cagan et al., 2002; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992).
3) **Production:** Manufacturing discipline (Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992), or production discipline in Andreasen and Hein (2000) relates to production and supply chain system.

Table 2.4 Comparison of NPD Processes

<table>
<tr><th rowspan="2">Authors</th><th colspan="4">Integration</th><th rowspan="2">Stage-Gate</th></tr>
<tr><th colspan="2">Design</th><th>Market</th><th>Production</th></tr>
<tr><td>Andreasen and Hein (2000)</td><td colspan="2">✓
(Product)</td><td>✓
(Market)</td><td>✓
(Production)</td><td>✗</td></tr>
<tr><td>Wheelwright and Clark (1992)</td><td colspan="2">✓
(Engineering)</td><td>✓
(Marketing)</td><td>✓
(Manufacturing)</td><td>✗</td></tr>
<tr><td>Cagan et al. (2002)</td><td>✓
(Design)</td><td>✓
(Engineering)</td><td>✓
(Marketing)</td><td>✗</td><td>✗</td></tr>
<tr><td>Cooper, R.G. (1990)</td><td colspan="2">✗</td><td>✗</td><td>✗</td><td>✓</td></tr>
<tr><td>Unger and Eppinger (2011)</td><td colspan="2">✗</td><td>✗</td><td>✗</td><td>✓</td></tr>
<tr><td>Ulrich and Eppinger (2016)</td><td colspan="2">✓
(Design)</td><td>✓
(Marketing)</td><td>✓
(Manufacturing)</td><td>✓</td></tr>
</table>

Cagan et al. (2002) explain that involve interdisciplinary structure is beneficial to reflect the nature of the product as the overlaps in disciplines could define product value to the customers as shown in Figure 2.7. Design and engineering overlap leads to product usability. Design and marketing overlap leads to product desirability. Marketing and engineering overlap leads to product usefulness.

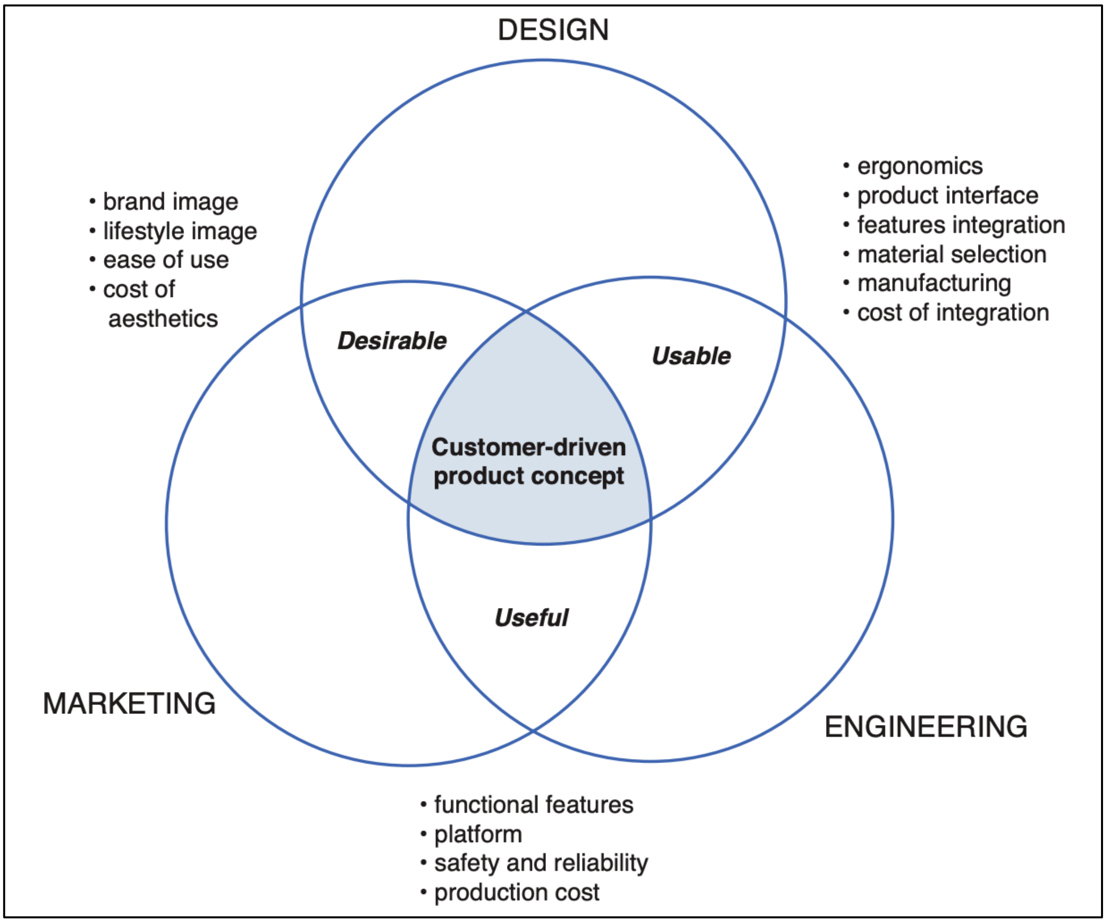


Figure 2.7 Overlaps in Disciplines Defining Product Value (Cagan et al., 2002)

The third observation is that some authors incorporate the concept of a stage-gate (Cooper, R.G., 1990; Ulrich and Eppinger, 2016; Unger and Eppinger, 2011). Cooper, R.G. (1990) explains that gatekeepers, often senior managers from various disciplines, review, assess, and approve project quality before each stage. However, Unger and Eppinger (2011) highlight limitations in flexibility, making it more suitable for companies with stable product definitions and well-understood technologies. However, the stage-gate process might be not flexible for companies in dynamic markets.

2.4.2 Extending the Understanding of Design

Given the overlapping use of the terms NPD and Design, it is essential to clarify their distinct meanings. The definition of design varies across disciplines and contexts where the term is employed. It has been found to mean different things, such as physical product, architecture, product development, process, IT, or system. Historically, 'Designers' referred to design and development engineers (Pahl et al., 2007). In a meantime, the term ‘Design’ has been used to describe engineering activities to execute with shape, colour, and material of objects (Marxt and Hacklin, 2005), to find solutions and develop products in a specific way (Pahl et al., 2007). However, the definition has later evolved to associate with other aspects (Marxt and Hacklin, 2005; Pahl et al., 2007). Suh (1990) defines design as the creation of solutions not only in the form of products but also processes, systems, software, or organizations. Similarly, the term is used by Simon (1996) to refer to a method toward transforming of problem into solutions that meet requirements.

The design process involves defining problems, generating alternatives, and testing those alternatives against requirements (Simon, 1996). This cycle continues to develop the design in detail and create various possible components. Simon emphasizes the importance of a satisfactory design rather than an optimum one. The design process of Suh (1990) is a transformation process, starting with recognizing needs, determining functional requirements, generating ideas, and creating products. The design is then analyzed, compared against functional requirements through feedback loops until the result is acceptable. Suh’s process is shown Figure 2.8.

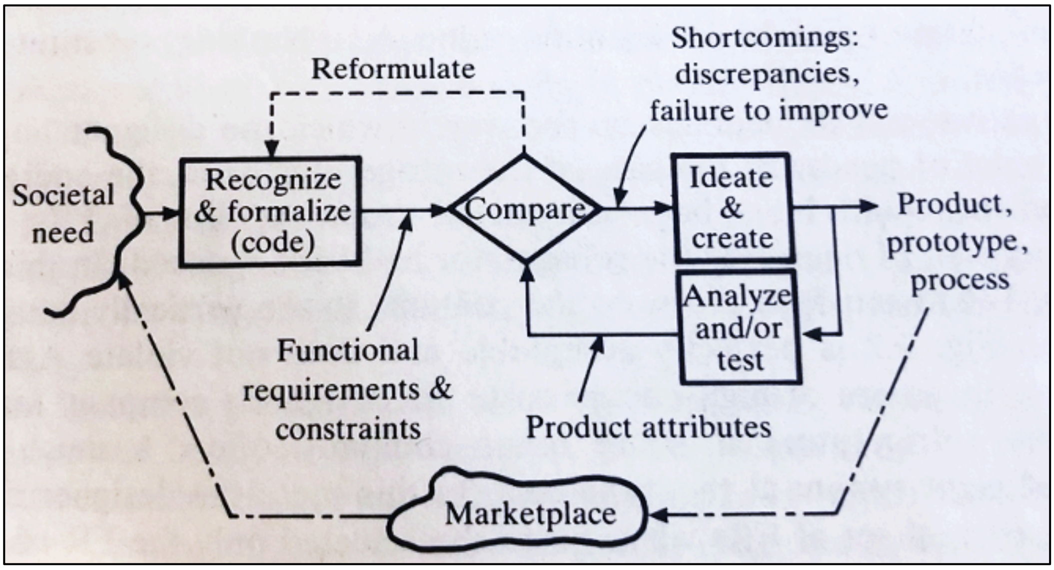


Figure 2.8 Design Process (Suh, 1990)

Apart from design in engineering aspect, Sanders and Stappers (2008) explain the design process in fuzzy front-end view, shown in Figure 2.9. The process starts from a chaotic nature with unpredictable results, eventually moving closer to users. The process involves understanding users and their contexts, exploring and selecting technological opportunities, deciding what to design, developing resulting ideas into concepts, prototyping, and refining based on user feedback. Design, as explained by Rittel (1977) differs from engineering and business approaches, where the process is pre-defined, the problem-solving process is controlled and the goal is to find the right answer. However, in design approach, the problem is unbounded and often changes overtime. Rittel calls this as ‘wicked problem’.

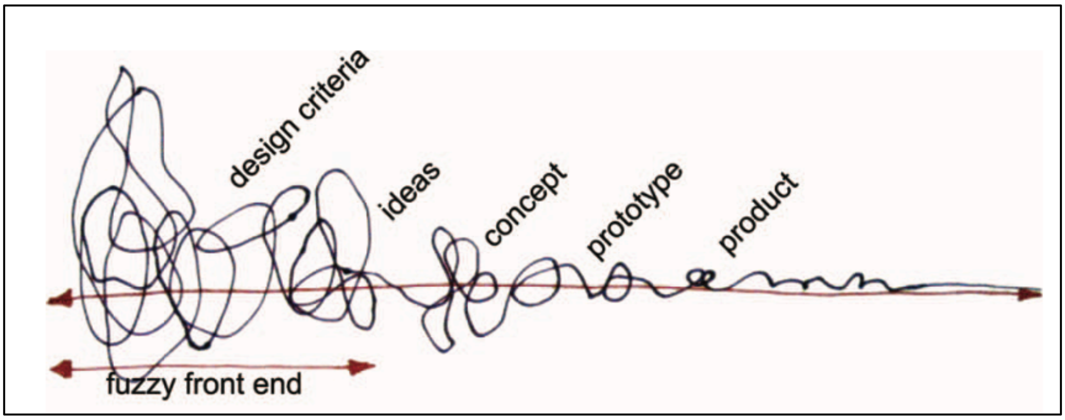


Figure 2.9 The Front End of the Design Process (Sanders and Stappers, 2008)

Looking at these terms used, design can be defined in engineering aspect as process to create products, process, system, or organization by transforming problem into solutions that meet requirements (Simon, 1996; Suh, 1990). At the same time, it is defined in another aspect as process to transform fuzzy front-end to the result by understanding users’ demand (Sanders and Stappers, 2008). Comparing design to NPD, NPD extends beyond design by integrating teams of engineers, designers, and market researchers. Different views emerge regarding the roles of design in NPD. Perks et al. (2005) suggest the designers have business background, undertake a role as leader of NPD process, and manage the whole NPD effort. On the contrary, Sanders and Stappers (2008) propose a shift from user-centric design to co-design, involving collaboration between three roles: user who is passive object, researcher who develops knowledge based on theory, interview and observation, and designer who brings knowledge from the researcher, fill technology and creativity, and generate ideas. The separated roles are insufficient; however, co-design approach results in shifting from ‘design as products or technology’ to ‘design as people’s purpose’.

Design capability is an essential element to develop both NPD capability and TIC. The literature review on NPD in Sub-section 2.4.1 highlights the importance of design in the NPD process, involving the development of product concepts based on product architecture and new technology (Andreasen and Hein, 2000; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992). Moreover, technological innovation literature in Section 2.3, underscores the significance of design capability in developing TIC (Christensen, J.F., 1995; Liu, X., 2016). Christensen, J.F. (1995) found that design capability has usually been ignored in technological innovation literature although this asset is an essential bridge between technical features of product and marketing strategy. Liu, X. (2016) found that technology in China is developed through absorptive and re-innovation; however, this path of innovation is currently not sustainable. Therefore, a focus on design in innovation strategy could replace traditional approaches. The study of Liu can be good example for case of Thailand as the current technology in Thailand is also from abroad rather than producing internally (Intarakumnerd, 2019; Karaveg et al., 2014).

2.5 Summary

In the dynamic landscape of rapid technological change, possessing TIC emerges as a determinant for companies seeking a competitive advantage, sustained growth, and overall success. The literature review on the innovation landscape in Thailand underscores the significance of enhancing TIC, especially within the context of SMEs. Current observations reveal limitations in technology and innovation within Thailand. a substantial reliance on foreign technologies due to a lack of in-house R&D (Intarakumnerd, 2019; Karaveg et al., 2014). The innovations do not have competitive advantage because they are produced incrementally rather than radically (Karaveg et al., 2014; Rujirawanich et al., 2011). The entrepreneurs have insufficient skills of risk acceptance, technology absorption, and networking (The Global Entrepreneurship and Development Institute, 2019). In many Thai companies, there are cultures of unwillingness to take risk and fix ways of working and thinking (Rujirawanich et al., 2011). These obstacles result in the opportunity to research on how Thai SMEs could produce technological innovation and how to increase TIC.

The literature further unveils various innovation capability assessment models, especially ICMM. While these models offer theoretical concepts, there is a notable research gap in understanding how these capabilities are practically assessed and developed within organizations. Moreover, existing ICMMs tend to focus on the general management and organization of innovation capability, with limited attention to the unique TIC. This presents a valuable research opportunity to develop an ICMM in the specific context of Thai SMEs.

Drawing parallels between ISO9001 and TIC development, commonalities in leadership, management, organizational learning, improvement, and network linkage are evident. However, the challenges faced by SMEs in implementing ISO9001, including conceptual complexities and resource constraints, highlight the potential difficulties in developing a method for assessing TIC. Learning from these challenges, it becomes apparent that when developing a method for assessing TIC, similar challenges may emerge. By addressing these challenges, the method proposed in this thesis should be concerned of SMEs' resource constraints. The proposed method can potentially offer SMEs a more feasible and tailored approach to assess their innovation capabilities, optimizing resources and fostering innovation within the constraints of SME operational environments.

Next chapter explains how the research will be conducted.

Chapter 3 Methodology

This research was initiative by the Thai government whose has identified and promoted an innovation-driven economic development model to drive future growth in its country. To achieve these goals, a number of regional science and technology parks were established. In Chiangmai, a university-led initiative program, STeP, was one of these science and technology parks. STeP was established to develop Thai innovation capability in resident SMEs and start-ups through a range of mechanisms including incubation programs, academic research services and technology agents. In 2019, the researcher won a Thai government-funded PhD scholarship to explore ways in which technology commercialization and innovation management processes and national innovation capability might be improved. As a result, this was the primary driver for this thesis to use STeP as a case study to assess TIC in companies participating in its program, and decision to deploying Action Design Research (ADR) of Sein et al. (2011) as the research framework.

Following a thorough literature review in Chapter 2, in this chapter, the methodology used in the research is introduced. Section 3.1 describes ADR, starting from introducing the reason of selecting ADR as a framework, and clarifies how ADR was deployed in the research. Section 3.2 delves into interview-based research, the primary method used for data collection. Section 3.3 explains in detail the research design of Phase 1 and Phase 2. Lastly, the summary of this chapter explains in Section 3.4.

3.1 The Use of ADR in This Research

ADR represents the integration of ‘Design research’ and ‘Action research.’ Design Research involves the creation and evaluation of artifacts, encompassing a focus on designing solutions and evaluating their efficacy. Action Research, on the other hand, centers on solving organizational problems through iterative experimentation. A key characteristic of ADR is its emphasis on the active involvement of stakeholders throughout the entire research process. This framework aligns with the aim and objectives of this research, as the companies in the STeP program serve as the case study. By engaging stakeholders, ADR aims to have a tangible impact on real-world problems, involving creating solutions that are not only theoretically grounded but also practically applicable. Through the design and implementation of interventions, researcher seeks to build theoretical insights into TIC assessment in Thai SMEs and start-ups.

Simultaneously, STeP stands to benefit by gaining an opportunity to enhance the companies in its program.

ADR operates in an iterative cycle of problem formulation, building and evaluating interventions, reflection and learning, and formalization of knowledge, as depicted in Figure 3.1. This iterative nature of the ADR process enables continuous refinement and improvement of the designed solutions. Feedback and insights gained from practical implementation are systematically integrated into the ongoing research process, ensuring that interventions are responsive to the needs and challenges faced by the participating organizations.

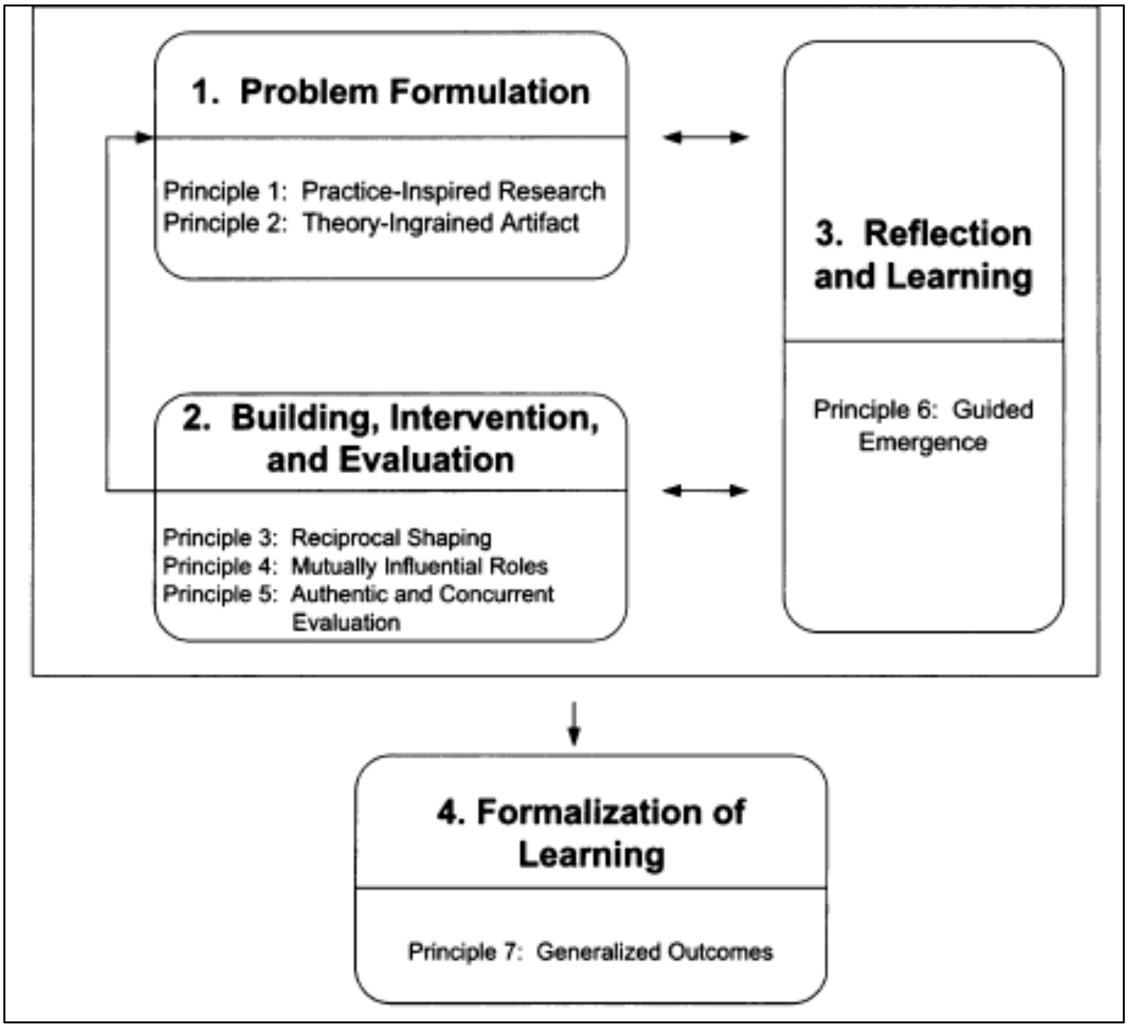


Figure 3.1 Action Design Research (Sein et al., 2011)

The formulation of the initial problem in this research aligns with Sein et al.'s principles of 'Practice-inspired Research' and 'Theory-ingrained Artifact.' These principles assert that research should be inspired by real-world problems and relevant theoretical frameworks. In this context, the research was initiated with a literature review to clarify the research goals and identify the research opportunities. While the literature review identified existing approaches to assess and develop innovation capability, it also brought attention to the research opportunity of understanding how TIC is assessed and developed by Thai SMEs and start-ups in practice. In parallel with the literature review, a series of interviews were conducted with SMEs and start-ups on the STeP program and STeP members to build understanding of the current situation. The interviews with Thai SMEs and start-ups led to the understanding that the companies considered technological innovation an important factor.

Meanwhile, the interview with STeP members led to the understanding that, there was no assessment tool that STeP used to evaluate capabilities of the SMEs and start-ups on the programs. The manager explained that,

> *"To assess participants in our program, we do not have strict criteria. Instead, we ask participants about their targets and goals and evaluate each case individually. This approach recognizes the diversity of businesses; criteria vary depending on the nature of the business. For instance, if STeP were to set a universal criterion of acquiring 1000 customers for entry into the pre-incubation program, a cosmetic company might meet this easily whereas a software company might struggle."*

This led to the identification of a need for TIC assessment tools that can be used as parts of continuous improvement processes. A flow chart depicting the overarching research process is shown in Figure 3.2.

The results from the literature review and preliminary work led to the decision to design the mock-up of ICAT (Innovation Capability Assessment Tool), specialized for TIC assessment in Phase 1. Cycle of ADR was used. Stage 1 (Problem formulation) started from identifying target users and target goal as well as formulating design requirements (DRs) informed by the literature review's outcomes. In Stage 2 (Building, intervention, and evaluation), ICAT was developed from DRs established in Stage 1 with on-going evaluation against DRs. Sein et al.'s principle of 'Authentic and Concurrent Evaluation' played a role during this stage, as ongoing evaluation activities were conducted with the artifact's development. The first ICAT mock-up, alpha (α) version was designed. Parallel with Stage 3 (Reflection and learning), the evaluation led to finding the opportunity to improve the mock-up, and continuing to Stage 1, deciding to design the second mock-up, beta (β) version. After that, in Stage 2, the interviews with target users, SMEs and start-ups on STeP program, were conducted to gain the opinions of target users on the mock-up and to identify the opportunities to improve the mock-up. Stage 3 reflected on the learning from the design and the interview. This resulted in Formalization of learning (Stage 4), forming the knowledge of innovation capability assessment within the context of the studied case. This encompassed an understanding of the challenges encountered in developing technological innovation by the cases, as well as the identification of key characteristics essential for TIC assessment. This alignment with Sein et al.'s principle of 'Generalized Outcome' is significant, as it underscores that the outcomes do not have to be the design principles; however, it can be generalization of the problem instance or solution instance. The insights gained in Stage 3 not only facilitated the formalization of learning but also paved the way for identifying opportunities to drive Phase 2, with a specific focus on assessing NPD capability.

Phase 2 started from prioritizing the improvement opportunities, re-determining research focus, and developing research plan. This led to the decision to develop a method to assess NPD capability. Stage 1 of this phase started from proposing the new focus of NPDWise, including the modified target user, the modified goal, and the modified DRs. Proceeding to Stage 2, NPDWise was developed and applied to the case study which is the early-stage start-ups in the STeP program. During this stage, the interview with STeP members were conducted and the data was compared to the interview data of the cases. This led to the elements for success and areas for improvement being proposed. Stage 3 observed a reflective process, aligning with Sein et al.'s principle of 'Guided Emergence.' This principle asserts that the artifact is not only a product of the researchers' design but also its ongoing shaping through organizational use. Reflecting on the insights gained during this stage resulted in Stage 4, where formalization of the acquired knowledge took place.

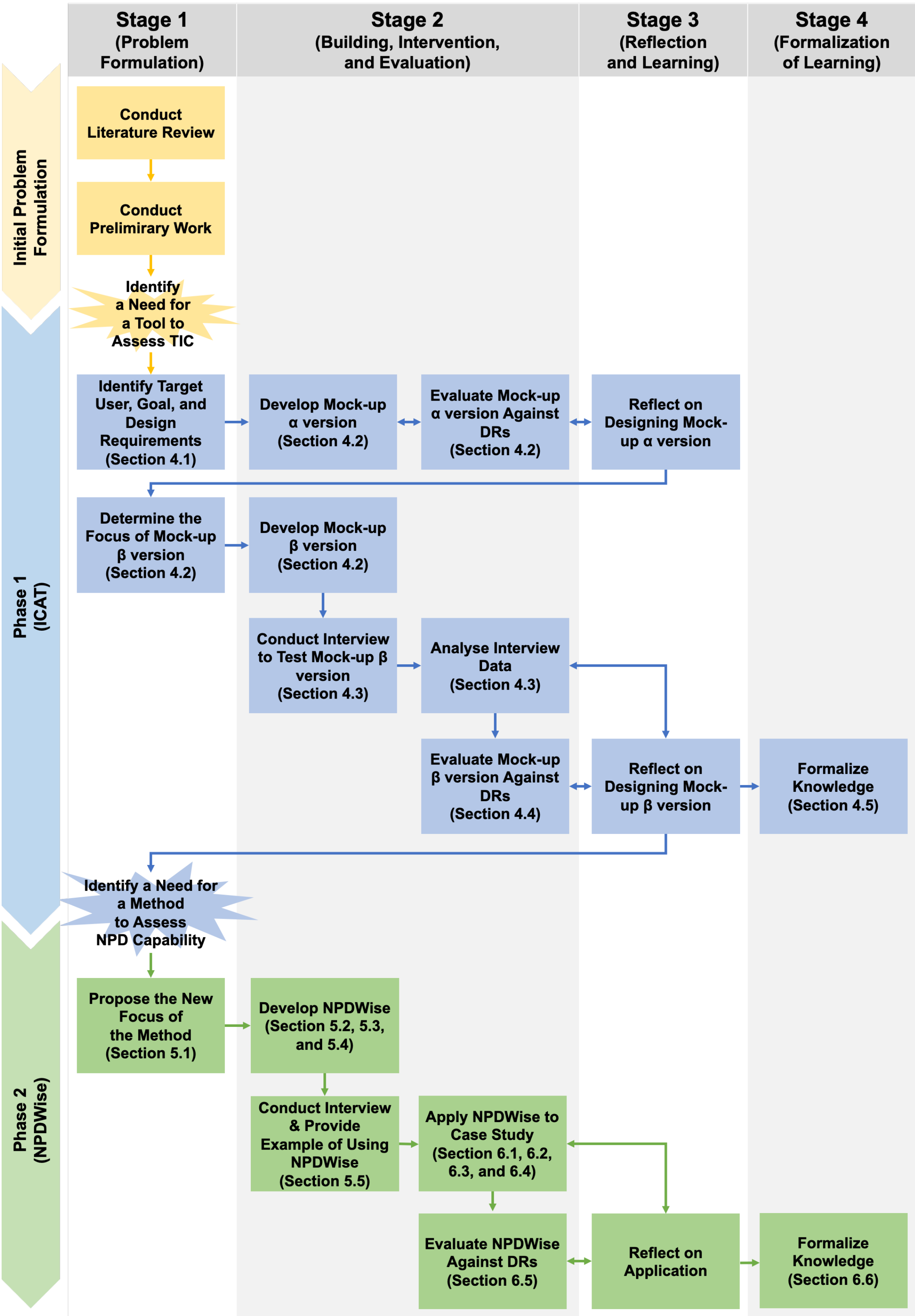


Figure 3.2 Overview of Research Process, Using ADR Framework That Adopted from Sein et al. (2011)

3.2 The Use of Interview-Based Research

In Design research, Blessing and Chakrabarti (2009) underscore the significance of employing a variety of methodologies to address the multi-dimensional nature of design problems. In action research, data are derived through active engagement with participants (Coghlan, 2019). Given the dual nature of this study as ADR, which combines elements of design research and action research, interview-based research was selected as the primary method for data collection in the case study.

This section elaborates on the utilization of interview-based research within the context of this study. Section 3.2.1 details the process of data collection, highlighting the methods employed to gather information from participants. In Section 3.2.2, the approach to generating interview questions is discussed. Section 3.2.3 provides insights into the selection criteria for cases involved in the study. Section 3.2.4 explores the procedures for processing interview data, coding methodologies. Finally, Section 3.2.5 delves into the interview data analysis.

3.2.1 Data Collection

Semi-structured interviews were employed as the data collection method in this research. As suggested by Saunders et al. (2009), this format allowed for conversational questioning, enabling participants to provide detailed responses. A list of open-ended questions was prepared to encourage participants to describe situations and provide extensive answers, often beginning with "what," "how," and "why." During the interviews, certain questions were omitted based on the flow of the conversation.

Given the challenges posed by the COVID-19 pandemic, which necessitated physical distancing measures, face-to-face interviews were impractical. Instead, telephone and video interviews were conducted based on participant convenience, facilitating engagement with individuals over long distances. This approach ensured real-time interaction and allowed for conversational questioning. Interviews were conducted in Thai, the native language, to ensure participants' comfort and facilitate comprehensive information sharing. Each interview session lasted approximately 30 to 60 minutes and was scheduled during official working hours. Subsequently, audio recordings were transcribed and translated into English for analysis.

3.2.2 Interview Questions

Following the recommendations of Creswell and Poth (2016), the initial interview questions were designed to gain insights into participants' experiences and process steps. Subsequent questions were tailored to elicit specific details that informed coding and thematic analysis.

Each interview session in this research began with an overview of the company and background information of the interviewees before delving into detailed questions.

3.2.3 Case Selection

Creswell and Poth (2016) recommend identifying the sampling strategy in earliest stage by deciding about what and who should be sampled, what form of sampling and how many people. According to the selecting sampling technique of Saunders et al. (2009), the Heterogenous sampling was selected for this research as this technique is suitable for small sample size, such as case study and grounded theory. Heterogenous sampling may lead to cased being completely different; however, this is the advantage of this strategy. Furthermore, Saunder et al. also recommend identifying variety of sample characteristics so that researcher can maximize the variation.

Samples were drawn from Thai SMEs and start-ups registered in the STeP database, representing various industries, enterprise sizes, and collaboration types. So that the researcher could access to various sizes of enterprise, types of industry and experiences of participant. This led to identifying different characteristics that users wanted the design to be as well as identifying improvement opportunity.

3.2.4 Interview Data Processing

Data processing involves several tasks prior to analysis, such as transcribing handwritten notes or voice recordings, entering data into spreadsheets, and coding (Blessing and Chakrabarti, 2009). Coding is a common practice in qualitative research for organizing and indexing data into meaningful categories. These categories can be predefined by the researcher or emerge from the data itself. Blessing and Chakrabarti recommend using post-defined categories, which are developed after data collection and during analysis. This approach is akin to theme generation in the inductive approach described by Braun and Clarke

(2006), where themes emerge directly from the data rather than being driven by the researcher's theoretical interests.

In this research, after the semi-structured interviews in Thai language, the audio records were transcribed and translated to English. Then, the inductive approach and post-defined code was deployed.

3.2.5 Interview Data Analysis

There are several methods for analyzing qualitative data. Saunders et al. (2009) outline three main types of data analysis processes: summarizing data, categorizing data, and structuring data. Summarizing data involves condensing large amounts of text into concise summaries. Categorizing data entails grouping data into meaningful categories, which can be derived from existing theories or emerge from the collected data. Structuring data involves organizing the narrative in a sequential manner.

Braun and Clarke (2006) propose another approach known as thematic analysis, a flexible method for identifying and interpreting patterns or themes across various data sources. Thematic analysis is independent of specific theoretical frameworks and does not require prior theoretical knowledge. This approach allows for the identification of themes even from smaller datasets or less uniformly represented data points, depending on the researcher's discretion. The process of thematic data analysis can be summarized into the following steps:

- Familiarization with Data: After data collection, researchers familiarize themselves with the dataset.
- Generating Initial Codes: Researchers create initial codes to organize and condense the data.
- Identifying Themes: Codes are collated and grouped into potential themes that capture significant aspects related to the research question.
- Reviewing and Developing Themes: Themes are reviewed, modified, and refined to develop a thematic map that represents the dataset.
- Defining and Naming Themes: Themes are defined and named to refine the specifics of each theme and the overall narrative.

Eisenhardt (1989) suggests an approach for generating theory grounded in case study data, involving within-case analysis and cross-case analysis. Within-case analysis helps researchers become familiar with individual cases, extract insights, and identify unique patterns before conducting cross-case comparisons to explore similarities and differences across cases. Eisenhardt emphasizes that case studies not only describe phenomena but also test and generate theories, resulting in novel theoretical insights.

In this research, within-case analysis and cross-case analysis techniques from Eisenhardt (1989) were used alongside thematic analysis from Braun and Clarke (2006). Within-case analysis was employed to manage large datasets efficiently, followed by cross-case analysis to examine variations across cases. Thematic analysis was applied throughout both within-case and cross-case analyses to define and analyze themes derived from the data.

3.3 Research Design

This section explains in detail the activities in the research. Section 3.3.1 explains the activities of Phase 1, where the mock-up of ICAT was developed and the interview with target users was conducted. Section 3.3.2 explains the activities of Phase 2 where NPDWise was developed and Section 3.3.3 explains the application to the case study.

3.3.1 Research Design: Phase 1

The goal of Phase 1 is to identify what are key perspectives of TIC that are relevant to Thai SMEs and start-ups in STeP and understand how Thai SMEs and start-ups in STeP perceive and prioritize TIC. The details of each stage are provided in the remainder of this section.

3.3.1.1 Determining Research Focus

The initial scope was determined in this stage, starting from identifying the research opportunities from the review of prior research on developing technological innovation in Thai context. After that, target users and goal were determined. DRs were defined and the test method was identified how the design was evaluated against the DRs and the evidence to measure the requirement was also determined.

3.3.1.2 Designing the Mock-up

This phase involved the sequential design of two mock-up versions: α and β. The α version drew upon insights from the literature review on TIC and Innovation capability maturity model (ICMM) in Chapter 2. Specifically, TIC perspectives and criteria from the study by Sumrit and Anuntavoranich (2013) were incorporated into the initial mock-up. The choice of Sumrit and Anuntavoranich's perspectives and criteria was motivated by the fact that their research was conducted with Thai technology-based companies, making their findings potentially more relevant to the Thai context. However, since the applicability of these TICs to Thai SMEs and start-ups needed further validation, these perspectives and criteria was considered for future investigation. Furthermore, the definitions of each maturity level, sourced from the literature, were employed to characterize the maturity levels of ICAT mock-up. The researcher developed an assessment sheet, outlining details such as rating methodologies, the number of items for assessment, evidence requirements from users, and the visualization of assessment results. Simultaneously, the mock-up underwent evaluation against DRs, and discussions with supervisors provided valuable insights. Parallel to this, the design evolved through a continuous reflection and learning process, prompting the decision to progress to the development of the β version.

For the β version, the focus narrowed down to one TIC perspective: innovation management capability. Further literature on this capability perspective was reviewed, leading to the further refinement and evaluation of the β version. Discussions with supervisors continued to shape the design.

3.3.1.3 Interviewing with Target Users

To intervene in organizational contexts, the interview with the target users were conducted for two main purposes. The first purpose was to gain the opinions of target users on the mock-up β version and to build the understanding of characteristics of the design that the target users were highly valued. Second, the interview also aimed to identify TIC perspectives and criteria that were valuable to the Thai SMEs and start-ups. This was expected to identify the challenges and plan the research design of Phase 2.

The interview questions were divided into three parts. The first part was to gather the overview of company. The second part focused on identifying TIC criteria. The third part aimed to collect users' opinion on the mock-up, so they were asked to use some parts of the mock-up to assess their company's TIC and express their opinions on the mock-up. The list of question is shown in Table 3.1.

Table 3.1 List of Interview Questions of Phase 1

Part	List of Questions
1. Overview of company	- What is technology/innovation/research of your company?
2. Identifying TIC criteria	- How do you usually develop technological innovation in your company? - Have you ever used any mechanism to increase the company's TIC? - What are the difficulties to drive technological innovation in your company? - If there is any model to support your business, what things you want that model to support?
3. Opinion on the mock-up (Ask after using the mock-up)	- Is the mock-up clear and easy to use? - Do you think this mock-up can support your company to overcome the difficulties? - Are the criteria in this mock-up suitable for your situation or Thai context? - Are the maturity levels suitable?

Eight participants, representing both start-ups and SMEs from various business sectors, were interviewed. The participants' profiles are detailed in Table 3.2, showcasing a mix of businesses developing software platforms (referred to as platform developing companies, PD companies) and businesses commercializing laboratory technologies (referred to as technology commercializing companies, TC companies).

Table 3.2 Profile of Participants in Phase 1 Interview

Company	Product Information	Type of Innovation	Type of Business	Establish	Stage of Company/Product
1-A	Platform for consignment retail	Platform developing	Start-ups	2 years	Market validation
1-B	Platform for agriculture matching	Platform developing	Start-ups	2 years	Market expansion
1-C	Platform for property management	Platform developing	Start-ups	5 years	Market scale up
1-D	Platforms for online retail store, senior citizen support, store's point collection, hotel property, part-time job searching and queue management	Platform developing	Start-ups	5 years	Market scale up
1-E	Machine for increasing the efficiency of Ozone in fish farming	Technology commercializing	Start-ups	2 years	Market expansion
1-F	Cream for curing Myasthenia Gravis using Thai herb and Nanotechnology	Technology commercializing	Start-ups	4 years	Market expansion
1-G	Dried fish seasoning using high-tech transforming method to develop food and adding ingredient to be healthier	Technology commercializing	Small enterprise	4 years	Market scale up
1-H	Cup from Coffee Grounds	Technology commercializing	Small enterprise	4 years	Ideation

3.3.1.4 Identifying Improvement Opportunities

Throughout the design cycles and ADR iterations, reflection and learning occurred concurrently with the design process. For the reflection on the design of mock-up α version, the challenge on designing led to the decision to design mock-up β version that focused on one TIC perspective. The research process of mock-up β version was also adjusted based on the evaluation result.

Following the design and implementation of the mock-up β version and the subsequent interviews with target users, the analysis of user opinions revealed opportunities to enhance the mock-up further. In alignment with Sein et al. (2011) perspective on the reflection and learning stage, which encompasses both design reflection and the analysis of intervention results, improvement opportunities were identified. These opportunities were categorized into four areas, as illustrated in Figure 3.3. The first area involved refining the ICAT mock-up itself to ensure its applicability and relevance to the target users. The remaining three areas focused on interventions in the broader context, including opportunities for improving TIC, ICMM and Thai SMEs' and start-ups' context.

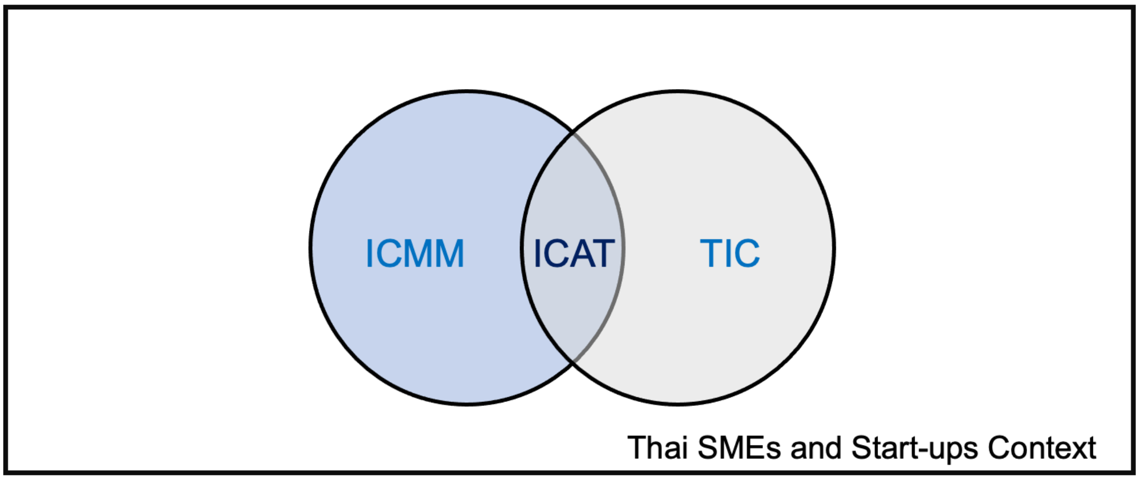


Figure 3.3 Improvement Opportunity Area of Phase 1

3.3.1.5 Formalizing the Knowledge

This stage formed the knowledge of innovation capability assessment and knowledge of TIC key characteristics that are important for Thai SMEs and start-ups.

3.3.2 Research Design: Phase 2

The learning from the previous phase led to narrowing Phase 2 and aims to develop and implement tailored assessment methods that can effectively support NPD process and foster technological innovation among Thai SMEs and start-ups in STeP. To achieve this, NPDWise was developed based on the improvement opportunities identified in Phase 1 and then applied to the case study. The further details provided in this section.

3.3.2.1 Proposing the New Focus

The commencement of Phase 2 involved a refinement of the research focus. This phase prioritized improvement opportunities identified in Phase 1 and the unique challenges faced by the participating companies. The study narrowed its scope to focus on NPD and selected early-stage start-ups in the STeP program as the case study context. Subsequently, the target users, research goals, and DRs for NPDWise were re-defined.

3.3.2.2 Designing Define Phase

To design NPDWise, a literature review on NPD was conducted. An overarching NPD process model was derived from the existing literature and integrated with the improvement opportunities identified in Phase 1. This model serves as a foundational framework for understanding the stages of NPD within companies.

3.3.2.3 Designing Measure Phase

Building on the foundation laid in the Define phase, the Measure phase was developed to evaluate NPD capability. Modification of the ICAT from Phase 1 facilitated this assessment sheet, empowering target users to assess the NPD capability across diverse stages. The goal is to pinpoint strengths and specific areas for improvement within the NPD process.

3.3.2.4 Designing the Visualizing NPD Capability Result

Recognizing the need for enhanced user-friendliness and actionable insights, efforts were directed at representing NPD capability levels within the NPD process. This addition to NPDWise ensures that early-stage start-ups can grasp the visualizing assessment outcomes, emphasizing areas of strength and opportunities for improvement.

3.3.2.5 Example of Using NPDWise

A case study of Company 2-A, a start-up within the incubation program operating a platform connecting automotive vocational students with part-time job opportunities in garages, was presented as an illustrative example. This section demonstrated the practical application of NPDWise to understand Company 2-A's NPD process and assess its NPD capability based on key metrics. The evaluation offered the visualization of assessment result as the insight into the company's different stages of the NPD process and its capability maturity level of different NPD aspects.

3.3.3 Application of NPDWise to the Case Study

The applicability of NPDWise was validated in the context of the early-stage startups in the STeP program. This stage employs a case study research design to investigate and assess NPD capability of early-stage start-ups participating in the STeP program. The case study approach was chosen due to its ability to provide an understanding of the NPD processes and capabilities of individual companies. By conducting multiple case studies, the research aimed to identify common patterns, strengths, and areas for improvement in the NPD practices of these start-ups.

The questions were divided into three main parts. The first part was to gather the overview of companies. After that, the questions in the second part aimed to build the understanding of NPD process of the participants' companies. The key metrics, which are NPD stage, serve as guidelines for conducting open-ended question interviews to gain insights into how companies develop new products. Finally, the questions in the last part aimed to understand what the current supports from STeP are, what supports from STeP that could facilitate the participants' companies to develop new product, and how the current STeP supports could be improved. The list of question is shown in Table 3.3.

Table 3.3 List of Interview Questions in Phase 2

Part	List of Questions
1. Overview of company	- What is technology/innovation/research of your company?
2. Assessing NPD Capability	- How do you usually develop product in your company? - To what extent the company recognizes the opportunity? - To what extent the company develops the concept? - To what extent the company designs product? - To what extent the company tests product? - To what extent the company launches product?
3. Supports from STeP that could facilitate NPD	- What are the current supports that your company receives from STeP? - What are the difficulties to develop product in your company? - What supports do you think STeP could provide to facilitate your company to overcome the challenges?

The selection of the seven early-stage start-ups for the case study was based on specific criteria to ensure a diverse representation of industries and NPD challenges within the STeP program. The interviewees were selected based on their roles and responsibilities in the NPD processes, such as founders and product experts. The case selection process in this phase was snowball sampling approach because the researcher found during the interview with STeP members in April 2022 that STeP has changed the identity of the program and established 'Basecamp24' on 31st March 2022. This resulted in STeP changed the way to categorize the start-ups in the program. Furthermore, as the researcher had planned to conduct the interview with the early-stage start-ups on STeP program during May - July 2022, the concept of basecamp was in the starting process and the companies in the program were being categorized by STeP. Instead of the researcher contacting the cases for interviewing, STeP members were the moderators who contacted the cases and made the interview appointments for the researcher. The participants' companies were companies from two types of business, PD companies and TC companies, and two camps that mainly relate to NPD process, ideation camp and market validation camp. The interviewee profile is shown in Table 3.4.

Table 3.4 Profile of Participants in Phase 2 Interview

Company	Product Information	Type of Innovation	Type of Business	Establish	Stage of Company/Product
2-A	Platform for part-time job for students that study vocational course	Platform developing	Start-ups	3 months	Ideation
2-B	Platform for studying crafting course & online crafting marketplace	Platform developing	Start-ups	3 years	Market validation
2-C	Platform providing the sensory testing service to support the customer to the testing their prototype with their target group. (The platform is for the experimental group to choose the product to test)	Platform developing	Start-ups	1 years	Market validation
2-D	Platform for finding contractor for house extension/renovation	Platform developing	Start-ups	1 years	Ideation
2-E	Platform for making appointment with clinic/treatment shop & managing the appointment system	Platform developing	Start-ups	5 years	Market validation
2-F	Product to heal a wound of the livestock	Technology commercializing	Start-ups	1 years	Market validation
2-G	Alternative medicine (nutraceutical) to reduce cholesterol	Technology commercializing	Start-ups	2 years	Market validation

After conducting the interview, the diagram of NPD process of each company was produced, adopted from the overarching NPD process. Following this, key metrics, which is the stages of the NPD process, were measured. Data analysis in this study utilized both within-case analysis and cross-case analysis as proposed by Eisenhardt (1989).

Within-case analysis involved an examination of the interview data obtained from each early-stage start-up participating in the STeP program. The data were reviewed and coded to identify themes related to NPD capability and three key aspects of NPD. Each company's strengths in the NPD process were identified. Moreover, areas for improvement were identified, pinpointing specific areas of the NPD process that required attention. The key metrics served as a guide during within-case analysis. The researcher also assessed each company's capability in market understanding, product design, and production.

Cross-case analysis was conducted among the seven early-stage start-ups participating in Phase 2 of the study. Similarities and differences in their NPD capabilities were compared to identify common patterns and trends. This cross-case analysis revealed both shared strengths and areas for improvement among the companies. Furthermore, the cross-case analysis extended to comparing between Phase 1 and Phase 2 cases. As the interview questions in Phase 1 was about how the cases developed technological innovation, some answers were around how they develop their products. Therefore, in this phase, the interview results of Phase 2 were not only compared between themselves, but it was also compared to the data of start-up and SME cases in Phase 1. It allowed for the identification of best practices and challenges faced by multiple companies.

In addition to the comparisons between cases, the researcher conducted cross-case analysis to understand how the challenges faced by the studied cases aligned with the supports provided by STeP. This analysis aimed to identify gaps and areas where STeP could further support the NPD processes of the start-ups. By analyzing the interview data on challenges and comparing them with the reported supports from STeP, the researcher gained insights into how incubator programs could be tailored to better address the specific needs and challenges of start-ups in the program.

3.4 Summary

This research, instigated by the Thai government's commitment to fostering innovation-driven economic development, to enhance technological innovation development within Thai SMEs and start-ups. The study was conducted within the framework of ADR, a methodology integrating design and action research elements. Through the design and implementation of interventions, ADR aims to contribute to both practice and theory. ADR operates iteratively, encompassing problem formulation, intervention building and evaluation, reflection and learning, and knowledge formalization.

The initial problem formulation involved a literature review and interviews, identifying opportunity to assess TIC among Thai SMEs and start-ups. This led to the design of ICAT in Phase 1, with iterative cycles refining the tool based on user feedback. The reflection on ICAT's design prompted the development of NPDWise for Phase 2. The NPDWise application facilitated the method evaluation and formalized knowledge about NPD capability and TIC continuous improvement in Thai contexts.

Throughout this study, efforts were made to mitigate intrinsic limitations associated with interview-based research. Firstly, the semi-structured interview format was chosen to allow for flexibility in questioning while still maintaining a degree of consistency across interviews. Additionally, efforts were made to conduct interviews in the participants' native language, Thai, to ensure clarity and accuracy of responses. Furthermore, audio recordings of interviews conducted in the native language were transcribed and translated into English to facilitate accurate analysis and interpretation of data. By employing these strategies, the study aimed to enhance the validity of the data collected through interview-based research within the ADR framework.

Chapter 4 Innovation Capability Assessment Tool (ICAT)

The results from the literature review and preliminary work in Chapter 2 led to the decision to design Innovation Capability Assessment Tool (ICAT), specialized for technological innovation capability (TIC) assessment This chapter describes the design, implementation, and evaluation of the mock-up of ICAT. According to Action Design Research (ADR) framework of Sein et al. (2011), this chapter begins with ADR Stage 1 to determine the target users, the goals and the design requirements in Section 4.1. Following this, ADR Stage 2 is divided into Section 4.2 and Section 4.3. Section 4.2 determines the tool concept and describes the mock-up α and β versions developing. Section 4.3 explains the interviews with target users and interview data analysis. In Section 4.4, ADR Stage 2 and 3 is described, the mock-up evaluation was presented and reflected, together with the opportunities to improve the assessment tool. In Section 4.5, ADR Stage 4 is explained, formalizing the knowledge. Lastly, the summary of this chapter explains in Section 4.6.

4.1 Determining Research Focus

There are several existing types of innovation capability measurement mechanism. One interesting mechanism is the combination of innovation capability and Capability Maturity Model, naming Innovation Capability Maturity Model (ICMM). According to literature review in Chapter 2, the focus of the models in existing studies tends to be on managing and organizing innovation capability while TIC has sorely been considered in ICMM research. Nevertheless, the literature review on innovation practice in Thailand has highlighted the importance of increasing TIC in Thai SMEs and start-ups. As a result, ICAT was developed to fill the research opportunity and be a framework for guiding the Thai SMEs and start-ups to assess their capabilities of developing technological innovation.

According to the comparison between ISO9001 and TIC development in Chapter 2, developing TIC and implementing ISO9001 are connected because both tools focus on the same perspectives, such as organization learning, improvement, and network linkage. Reflection on the challenges of SMEs adopting ISO9001 leads to the observation that there is a need for some alternative tools which SMEs could use to optimize resources and costs when improving the organization regarding the ISO9001 requirements. This learning can be adapted in the case of designing TIC assessment tool. Therefore, instead of forcing the

SMEs to adopt all perspectives of TIC, the tool is designed to guide them in assessing their current capabilities, enabling the development of higher-priority capabilities. This section outlines the target users, goals, and design requirements for ICAT.

4.1.1 Target Users and Design Goal

The target users and goals of the tool were determined as follows.

Target Users: This tool is expected to be used by SMEs and start-ups in Science and Technology Park, Chiang Mai University (STeP) programs. The users can be (1) Companies that have already been stable in their existing market and would like to improve original products by adding technological innovation to explore new market, (2) Startups in initial stage that want to create technological innovation and disrupt the market. The target users can be both business owners and department managers in such relate departments as NPD and marketing.

Design Goal: The aim of this tool is to be an easy and useful tool that guides the users to assess their current capabilities and develop some priorities capabilities step-by-step. This tool is expected to be used in not only organization scope, but also in separated departments, small teams, and individuals.

4.1.2 Design Requirements

The outcomes of the literature review in Chapter 2 have led to the formulation of specific design requirements for ICAT, as detailed in Table 4.1.

Table 4.1 Design Requirements of ICAT

Design Requirement	Test Method	Evidence
DR1: The tool supports users to understand their current TIC.	Ask users in target user group if they could recognize to what extent are the users capable of developing technological innovation.	The design could show clear TIC result to the users and cover wide range of TIC level.
DR2: The TIC perspectives and criteria are suitable for the situation of users.	Ask users in target user group if they agree that its perspectives and criteria meet their needs of improvement.	The design could consist of perspectives and criteria that show significant to the technological innovation development situation.
DR3: The tool is easy to use.	Ask users in target user group if they find that the tool is easy to use, do not get confused when using, and do not spend too many resources and knowledges when using.	The design could have simply process to assess TIC and show the visualization of assessment result that easy to understand. The design could also not require specific knowledges, high costs nor a number of resources.
DR4: The tool is suitable for self-assessment.	Ask users in target user group if the tool ensures that the users are aware of and understand the concept of TIC and the users are willing to use without forcing.	The design could consist of criteria that are possible to achieve and are not too specific for the user to assess themselves.
DR5: The tool guides users to develop TIC.	Ask users in target user group if they could recognize that the tool could guide them to increase TIC result.	The design could show key criteria that the users need in order to achieve better result of TIC assessment.

DR1: The tool supports users to understand their current TIC.

This design requirement takes priority, reflecting the primary purpose of the tool: to enable users to measure and comprehend their existing TIC. Success in design will be evident when the target user group recognizes the tool's ability to showcase the extent of their capabilities in developing technological innovation. A well-designed tool will provide clear visualization of assessment results, covering wide range of TIC levels and accommodating users at various stages of technological innovation development.

DR2: The TIC perspectives and criteria are suitable for the situation of users.

This design requirement is essential, emphasizing the necessity for the tool to possess relevant perspectives and criteria that align with the users' technological innovation development context. A well-designed design will incorporate perspectives and criteria that show significant to the users' situation. The design will achieve this requirement if user agreement regarding the perspectives and criteria' relevance to their improvement needs.

DR3: The tool is easy to use.

Recognizing that the target users include SMEs and start-ups in Thailand, some with limited experience in technological innovation, the design ensures simplicity in the assessment process and result visualization. The design avoids the need for specific knowledge, high costs, or extensive resources. The design will achieve this requirement if user feedback indicates ease of use, lack of confusion during use, and minimal resource and knowledge requirements.

DR4: The tool is suitable for self-assessment.

As this design is expected to be self-assessment tool, the design allows users the freedom to choose whether to engage with it. A well-designed tool includes achievable criteria that are not overly specific for users to self-assess. Success is evaluated by users' awareness and understanding of TIC concepts, along with their voluntary use of the tool.

DR5: The tool guides users to develop TIC.

While not mandatory for users to use the tool for TIC development, it serves as a guide for prioritizing improvement areas. Success lies in users recognizing the tool's capacity to guide them toward enhanced TIC results. The design emphasizes key criteria essential for achieving better TIC assessment outcomes.

4.2 Designing the Mock-up of ICAT

To design the mock-up α version, insights from the literature review on TIC and ICMM in Chapter 2 were utilized to establish the initial TIC criteria and maturity levels for the mock-up. Subsequently, the mock-up was executed.

4.2.1 Determining the Concept of the Tool

The decision to incorporate the six main perspectives and sixteen criteria outlined by Sumrit and Anuntavoranich (2013) was rooted in the relevance of their study to the Thai context. Their research, conducted in Thailand, provided criteria that were deemed well-suited to the local setting. The six main perspectives encompass Innovation Management Capability, Technology Commercialization Capability, Innovation Sourcing Capability, Collective Learning Capability, Technology Development Capability, and Robust Product and Process Design Capability.

The conceptualization of ICAT is depicted in Figure 4.1, outlining a five-level trajectory for SMEs and start-ups to continuously enhance their TIC.

- **Level 1 – Initial:** Company has already developed at least one successful innovation.
- **Level 2 – Repeatable:** Company reuses or reproduces successful practice.
- **Level 3 – Defined:** Company has actual innovation procedure and plan.
- **Level 4 – Managed:** The innovation procedure and plan are deployed and managed.
- **Level 5 – Sustained:** Innovation activities are evaluated and improved continuously.

The characteristics of TIC criteria at each maturity level were determined as shown in Table 4.2.

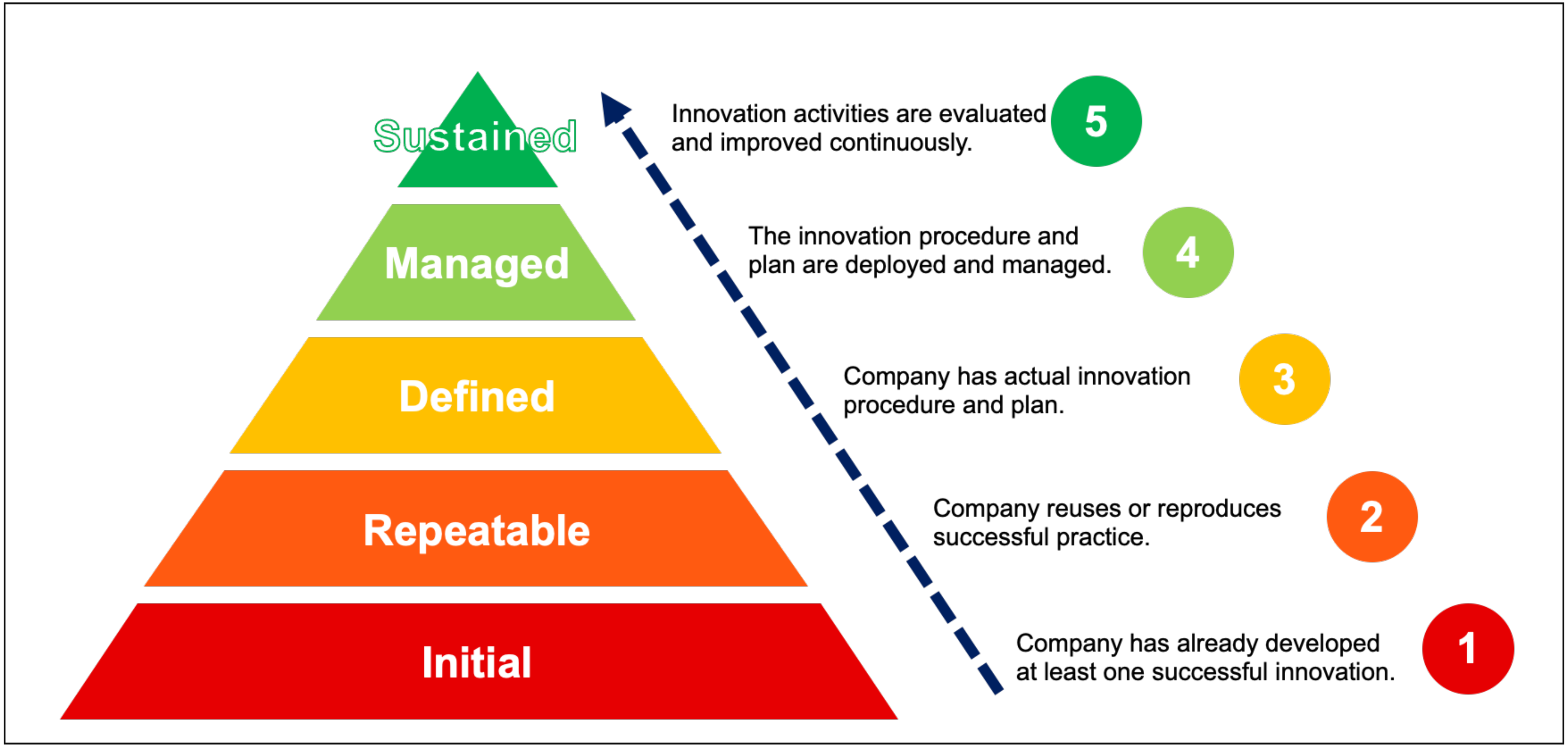


Figure 4.1 Concept of Maturity Model of the Mock-up of ICAT

Table 4.2 Characteristics of TIC Criteria at Each Maturity Level

TIC Perspective	Level1	Level2	Level3	Level4	Level5
Innovation Management Capability	- The management inspiration & resource allocation & project uncertainties are seldom addressed (Essmann, 2009).	- Small support initiatives are set up to support innovation (Arends, 2018).	- Innovation support tools are present (Arends, 2018). - There are initiatives to motivate innovation (Essmann, 2009).	- Leadership actively stimulate innovation activities (Arends, 2018). - Employees are actively encouraged to use supported tools (Arends, 2018).	- Employees on all levels inspire each other (Arends, 2018). - Support tools are integrated and available to all employees (Arends, 2018).
Collective Learning Capability	- Information is seldom summarized, captured or stored (Essmann, 2009).	- The organization has defined some basic metrics which are relevant to past project (Arends, 2018).	- Relevant metrics are defined and stored in every innovation project (Arends, 2018).	- Innovation project related metrics are defined, measured, stored in integrated database and accessible by employees (Arends, 2018).	- The organization continuously reflects and updates the metrics. The evaluation process is constantly improved (Arends, 2018).

Table 4.2 Characteristics of TIC Criteria at Each Maturity Level (Cont.)

TIC Perspective	Level1	Level2	Level3	Level4	Level5
Innovation Sourcing Capability	- There is little or no networking with external parties (Essmann, 2009).	- Networking is irregularly occurred for innovation activities (Arends, 2018).	- Practices to network has been defined (Essmann, 2009).	- A diverse range of external partner relations are exploited (Arends, 2018).	- Customers and suppliers play an essential role throughout the innovation process (Essmann, 2009).
Technology Development Capability	- Research is limited to known fields and focus on building on existing knowledge (Essmann, 2009).	- Research is conducted based on past innovation experience that is successful	- The practice of exploring existing and new fields of research has been established. Projects tasks are planned as a portfolio based on prioritization (Essmann, 2009).	- Employees have empowerment to manage own research and freedom to seek new solution (Narcizo et al., 2019).	- Employees explore & expands knowledge related to organizational learning objectives. Projects are integrated by overlapping tasks that share objectives (Essmann, 2009).

Table 4.2 Characteristics of TIC Criteria at Each Maturity Level (Cont.)

TIC Perspective	Level1	Level2	Level3	Level4	Level5
Robustness Product and Process Design Capability	- New product structure or production process design are seldom discussed.	- Product structure or production process design from successful innovation are reused.	- Product structures and production process design are defined.	- Product structures and production process design are well managed to support diverse projects.	- New product structures and production process design are frequently designed, evaluated and improved continuously.
Technology Commercialization Capability	- The resource and investment are limited, so that company maintains the most profitable products (Narcizo et al., 2019).	- Company explores main market. Reliability of manufacture increases and product quality is improved incrementally (Narcizo et al., 2019).	- There are periodical initiatives to probe market & market procedure (Narcizo et al., 2019).	- There is a significantly increase in sale volume and profit as company enters new markets and explores other niches (Narcizo et al., 2019).	- Profit margin is optimized. Innovative outputs provide sustained competitive advantage in existing and new markets (Narcizo et al., 2019).

4.2.2 Designing the Mock-up Alfa (α) Version

After determining concept of the mock-up, the mock-up α version was executed with ongoing evaluation against design requirements as well as discussion with supervisors. The part of the mock-up α version is in Appendix C. The design evolved through a series of iterations, accompanied by continuous learning and improvement as follows:

1) The rating scale might lead to users' bias.

The rating scale was initially decided to use yes/no question. After that, there was the estimate that the answer could not be 0% performed or 100% performed because they might perform between 0% and 100%. So, the rating scale was changed to low/medium/high. Nevertheless, there was possibility that users might bias and answer only medium. This issue resulted in not meeting DR1 because the mechanism did not properly measure current TIC, and further led to not meeting DR5 as well. Therefore, in mock-up β version, the rating scale will be modified to contain even number to reduce this bias. In addition, the answers as texts, would be quantified as numbers in order to calculate the score in the summary.

2) Requiring too much evidence might lead to users not wishing to use the tool.

The model initially adopted the idea of ISO9001 which required supporting material as the evidence. However, requiring too many evident did not meet DR3 and DR4 as the users might think the tool was too difficult to use and did not want to spend many resources. Moreover, it was possible that the users might lie to themselves because this design was the self-assessment rather than audit. As a result, the mock-up β version will be modified to be assessment without evident required.

3) The visualization of assessment result should be obvious and lead to the motivation for improvement.

The initial version of design only showed the assessment result as overall level of organization. Then, it was modified to show the percentage of the level. In the meantime, the assessment result presented overall level while level of each perspective was not considered. On the other hand, there was the probability that each perspective and criteria might have different level. As a result, the heat map was considered to use in mock-up β version in order to show percentage of each perspective and criteria as well as present the strength and weakness of the organization. This could lead to the users being able to decide which aspect can be firstly improved and meet DR1 and DR5.

4) There were too many assessment items which might scare the users.

This challenge led to several improvements such as making drop-down selection, separating into many sheets, starting from a few perspectives at level1 and increasing more perspectives at the higher level, starting from a few questions, and continuing to more assessment criteria at the next column. Nevertheless, it was possible that mock-up with six perspectives might take long time to interview the users and resulted in users' bias. Moreover, this issue might lead to not meeting DR3 and DR4. For this reason, the mock-up β version was decided to focus on one perspective, which is 'Innovation Management Capability'. This decision is based on the study of Sumrit and Anuntavoranich (2013), who conduct research with Thai technology-based firms and found that this perspective is the most critical perspective. Camisón-Haba et al. (2019) also support that management capability could make the distinction between regular and highly innovative technology-based firms.

4.2.3 Designing the Mock-up Beta (β) Version

The reflection and learning of developing mock-up α version led to the mock-up β version (1) containing even number to reduce the user bias (2) not asking the users to provide the evidence to reduce using too many resources during assessing (3) using heat map to be easy for the users to understand their strength and weakness (4) focusing on one perspective to reduce the time during interview. The mock-up β version is in Appendix D.

4.3 Interview with Target Users

In this section, insights gathered from interviews with eight diverse participants is presented. These interviews aimed to delve into their motivations and challenges on developing technological innovation, results from using the mock-up of ICAT, and opinions on using the mock-up of ICAT.

4.3.1 Overview of Each Company

Eight participants representing a diverse range of businesses, including start-ups and SMEs from various sectors, were interviewed to gather insights into their perspectives on technological innovation and new product development. The participants were segmented into two primary categories based on their business focus. The first four companies interviewed fall under the category of platform developing companies (PD companies). These start-ups, all originating from Chiang Mai University, both students and new graduated, specialize in developing software platforms and applications to address specific market needs. They represent a new generation of entrepreneurs leveraging technology to create innovative solutions for diverse industries. The subsequent four companies interviewed are categorized as technology commercializing companies (TC companies). These businesses specialize in commercializing laboratory technologies and scientific innovations. Among the participants, Company 1-E and Company 1-F stand out as start-ups that emerged from research commercialization efforts. Lastly, Company 1-G and Company 1-H represent small businesses seeking to integrate innovation into their existing product offerings. These SMEs are exploring opportunities to enhance their competitiveness through technology-driven solutions and product innovation.

Company 1-A is focused on developing a platform for consigning products, facilitating partnerships between multi-brand stores and brands. The platform aims to address the challenge of connecting brands seeking retail opportunities with multi-brand stores looking to diversify their product offerings. Currently incubated at STeP, Company 1-A began its journey in September, with a growing user base of approximately 300 individuals. Despite being in the early stages of market validation, the company is actively engaging in product refinement and business development.

Company 1-B has transitioned its business model to focus on "Farmmate," a platform that matches farmers seeking land for agriculture with landowners interested in renting out their properties. This strategic shift from farm record management to land rental underscores the company's evolution within the agriculture supply chain. Despite facing challenges during the COVID-19 lockdown, the company has begun generating revenue and is currently in the product-market fit stage, supported by STeP's incubation program.

Company 1-C specializes in accommodation management applications catering to various sectors, including apartments, condominiums, fresh markets, and commercial buildings. Originating from a computer engineering dissertation project at Chiang Mai University, the company has grown to manage over 7,000 properties and 300,000 rooms. With a team of four co-founders, the company has leveraged its technical expertise to integrate IoT solutions and payment systems into their platform.

Company 1-D had initially conceived as a carpool app and pivoted its focus to become a venture builder, supporting other startups with technology development and business growth strategies. The company's portfolio includes a diverse range of applications such as online retail store management, senior citizen support, and part-time job searching. With five co-founders and a significant technical team of around 30 members in Chiang Mai and an expanded presence in Bangkok, the company emphasizes technology development and strategic partnerships with various businesses.

Company 1-E specializes in innovative products derived from research commercialization efforts. Initially focused on developing a product to remove chemical residues from vegetables and fruits using plasma technology, the company has since expanded its scope to incorporate "Micro bubble technology" for fish farming applications. Company is led by three co-founders, including a PhD student specializing in engineering at Chiang Mai University who uses the core of his PhD research to commercialize.

Company 1-F specializes in developing innovative cream and spray products aimed at addressing Myasthenia Gravis using natural Thai herbs, specifically Cassumunar ginger and Turmeric, enhanced with nanotechnology. The company's founder, originally a programmer, embarked on this entrepreneurial journey after personal experiences with a family member's illness. Motivated by the desire to find effective remedies, the founder transitioned from a corporate career to focus on researching and developing products to aid in recovery.

Company 1-G specializes in producing dried fish seasoning, offering ready-to-eat products rich in protein and calcium. Founded by two individuals, this venture emerged as a spin-off business from Mae Jo University, renowned for its expertise in agricultural studies. Currently, the company is part of the incubation program at STeP and also collaborates on R&D projects with external parties, including various universities.

Company 1-H originated from a coffee shop experience where the surplus of coffee grounds sparked the idea of creating cups from this resource. The two co-founders, with backgrounds in agricultural engineering and food science, recognized the potential to add value to coffee grounds. They embarked on a research journey in collaboration with the Food Innovation and Packaging Center at Chiang Mai University. Acknowledging environmental concerns associated with single-use plastic cups and the aesthetic trends of coffee shops, the company aimed to transform coffee grounds into an eco-friendly, marketable product. Their initial 3-month exploration involved mixing coffee grounds with bioplastic to develop a sustainable cup alternative.

4.3.2 Result of Using the Mock-up of ICAT

Interviews with the target users were conducted to collect users' opinion on the mock-up β version. The participants were asked to use some parts of the mock-up to assess their company's TIC and express their opinions on the mock-up. One example of an interview transcript is provided in Appendix E. The results of the assessment were collected as Table 4.3. There were five companies disclosed the whole assessment result while one company, company 1-F, disclosed only the overall result of each perspective. The other two companies, company 1-C and company 1-G, are not willing to disclose the information.

Table 4.3 Results of Using the Mock-up of ICAT

Criteria	Topic	Company											
		1-A		1-B		1-D		1-E		1-F		1-H	
Strategic Management Capability	Explicitness of innovation strategy	4	4	1	1	2	3	4	4		4	1	1
	Importance of innovation activities	5		4		4		3				1	
	Communication about innovation strategy within company	4		1		3		4				1	
	Employee awareness of innovation strategy	2		1		2		2				1	
Organization Capability	Innovation project plan	3	3	4	4	4	4	4	4		3	1	1
	Management encouragement of innovation activities	3		4		4		5				1	
	Infrastructures/systems/tools to support innovation activities	5		2		3		4				1	

Table 4.3 Results of Using the Mock-up of ICAT (Cont.)

Criteria	Topic	Company											
		1-A		1-B		1-D		1-E		1-F		1-H	
Resource Allocation Capability	Material resources allocation	2	3	1	1	3	3	3	3		4	-	-
	Investment allocation	3		1		3		3				-	
	Human resource allocation	3		3		3		2				-	
Risk Management Capability	Willingness to take risk	5	5	1	1	3	3	3	4		1	-	-
	Tolerance of failure	5		3		3		4				-	
	Project uncertainties management	5		1		1		4				-	

The analysis and comparison of the self-assessed results by participating companies with their business stages and the insights gathered during interviews revealed noteworthy observations. Companies 1-D, 1-E, and 1-F, all in the scaling stage, demonstrated similar outcomes, achieving levels 3 (defined) and 4 (managed). Company 1-H, in the ideation stage, obtained level 1 (initial) results in some perspectives, while other perspectives remained unperformed.

Conversely, two companies in the validation stage, Company 1-A and Company 1-B, which had undergone changes in their business models and products within less than a year, yielded significantly different results. Company 1-B predominantly assesses itself at level 1 (initial), although based on the interviewee's explanations, the researcher suggests they should be at a higher level. In contrast, Company 1-A attained levels 3 (defined), 4 (managed), and 5 (sustained), although the researcher believes they should be rated lower. Notably, some results obtained by users did not consistently align with the company stage and insights gathered during interviews, suggesting potential issues with the mock-up's applicability. It is possible to assume that the current mock-up did not accurately reflect the real situations of the companies.

Beyond the assessment results, the analysis of opinion on the mock-up was conducted. This analysis was divided into two sections. The first section presents the cross-case analysis outcomes of the opinions on the mock-up, detailed in Section 4.3.1. Subsequently, Section 4.3.2 reports on the cross-case analysis outcomes of challenges faced by the SMEs and start-ups when developing innovation. The reflection and learning from the interview explain in Section 4.3.3.

4.3.3 Opinions on the Mock-up

The interview results from SMEs and start-ups have been analyzed between the cases and categorized into four main themes as shown in Table 4.4.

Table 4.4 Themes of Opinions on the Mock-up

Theme	Code
OP1: Criteria	OP1.1: Lean and Business Model Canvas OP1.2: Standard OP1.3: People Management OP1.4: Money
OP2: Characteristic	OP2.1: Simplicity OP2.2: Level OP2.3: Rating OP2.4: Version OP2.5: Language
OP3: Suitability	OP3.1: Type of Business OP3.2: Stage of Business
OP4: Model Objective	OP4.1: Understand Capability OP4.2: Suggestion

4.3.3.1 OP1: Criteria

One common opinion is on modifying the criteria which includes lean and business model canvas, standard, people management and money. Company E founder said, “If the criteria of the tool fit the challenges that companies faced, users will use the tool to solve their problem”.

- **OP1.1: Lean and Business Model Canvas**

Some cases suggested the tool includes criteria from Lean Canvas or Business Model Canvas. Company 1-A founder said,

> *“Startups often utilize Lean Canvas because it assists in mitigating risks, specifically product risk, market risk, and customer risk. These risks are critical for startups to address and manage effectively. As startups mature and grow, we may transition to using the Business Model Canvas”*

This is similar to Company 1-D founder who explained that,

> *“The Business Model Canvas is valuable because it guides our thinking not only in the initial stages of starting a business but also in developing new business models or ventures later on. The canvas*

prompts us to consider important topics regardless of our product, such as customer segments, the value proposition for customers, resources needed to deliver that value, customer retention strategies, customer expansion strategies, distribution channels, and cost structure.”

On the other hand, the founder of Company 1-E holds a different view, asserting that,

“The Lean Canvas alone represents an unclear idea, and there should be guidance or steps suggested to achieve success.”

- **OP1.2: Standard**

Two cases said the model should link to ISO9001 and GMP (Good Manufacturing Practice) which is the Thai standard that requires periodically check in good manufacturing. Company 1-G founder explained that,

“Because GMP is needed in Thai manufacturers, the criteria of model should be similar to GMP, so that the SMEs are willing to use the model.” He also suggested that “The model may separate into several versions, such as version of applying for ISO, and version of applying for GMP.”

In addition, Company 1-F founder stated that,

“GMP and ISO might be in ‘Defined’ (level3) in order to plan to apply the standard. After that, the users can follow and control the standard requirement in ‘Managed’ (level4).”

- **OP1.3: People Management**

Managing people is another common criterion that the cases have mentioned. Company 1-H founder suggested that,

“Human resource management should be one of the main perspectives of the tool rather than sub-element because it is significant for the business.” She explained that “If company cannot manage people, the technological innovation cannot be developed.”

Another case, company 1-B founder, also stated that,

“I want the tool that could support the business to manage employees because many start-ups are new graduate and do not have working experience. Therefore, it is difficult to manage team.”

- **OP1.4: Money**

Two cases said money is the main factor to run business as company 1-H founder explained that,

“Money is essential for not only R&D funding but also for everything.”

Company 1-F founder also suggested that, *"The model should include way to seek investment and VC."*

4.3.3.2 OP2: Characteristic

This theme, characteristic of the tool, contains five codes which are simplicity, level, rating, version, and language.

- **OP2.1: Simplicity**

Half of the cases said the mock-up is too complicated to use. Company 1-C founder said that,

> *"It is too detailed."*

This is the same as company 1-H founder who explained that,

> *"There are too many questions, and each question is too details, The tool should be modified, such as the starting point of the assessment and step to develop capability. The model should start from overview of the capability by asking only main perspectives in the first sheet. After that, the users can continue to the next page that is specific to the capability they need to improve. Moreover, you should let people improve level by level. Starting from improving all criteria in level1 to be green and go on. If they can't improve level1, they can't continue to level2."*

Company 1-D founder also stated that,

> *"I think it contains too many items, and it is complicated. The questions in each level are quite similar. I don't really understand the difference between the questions."*

Company 1-E suggested that,

> *"The model could use mobile application format, such as answering and linking to other question in other page automatically. When it is in Excel file, we feel that there are too many words."*

- **OP2.2: Level**

There are some opinions on modifying the level. One suggestion from Company 1-B founder is that,

> *"I suggest placing "Initial," "Defined," and "Managed" on the same level, as they often occur simultaneously. Subsequently, incorporate "Repeatable" and "Sustained." Ensure that "Defined" and "Managed" are addressed at all levels."*

Differently, company 1-F founder suggested the model rearranges the level to be 'Defined', 'Initial', 'Manage', 'Repeat' and 'Sustained' respectively. He explained that, *"Users should define the problems and customers in the first stage. The product should be tested before repeating. If the users repeat too early, it means they spend money before they know whether the product meets customer's need. So, 'Repeat' comes later, followed by 'Sustain' by developing new S-curve to be Version 2, Version 3, and Version 4."*

- **OP2.3: Rating**

Company 1-D founder suggested the model can reduce the complexity by changing the rating to yes/no questions. He explained that,

"While there are five levels, the users need to rate 1-4 in each level which is too difficult to assess. If it is yes/no, it might be easier."

On the other hand, company 1-B founder suggested the model provides two opposite sites. He said,

"You may develop 2 opposite sites and ask where between these sites they are at."

- **OP2.4: Version**

Company 1-B founder suggests the model is separated into several versions. He said that,

"You may separate into start-up version, SMEs version, and large company version. This is because there are different points for different types of business to focus on."

In addition, he also suggested about producing different versions for various users as he said,

"I recommend segmenting it by user type, such as co-founders and employees, to accommodate different perspectives. Additionally, consider dividing it by stages, like ideation and company setup."

- **OP2.5: Language**

Some cases have opinions on the language. Company 1-G founder, who runs small enterprise, said that,

"The language is too deep for SMEs because the model uses technical term. Practically, many SMEs do not have business or management knowledge."

On the other hand, company 1-B founder, who is young start-up, stated that,

"Regarding language, using English instead of Thai would eliminate translation confusion. For example, this question is not clear, "innovation awareness". People don't understand what it is. (in Thai)"

In addition, he suggested the way to ask questions is changed to be indirectly, *Instead of "Have employees been aware of innovation strategy?", You may change to "Do the employees often find new solution? Do the employees often generate idea?" I think we can't measure how people are aware of innovation, so your question should be changed."*

4.3.3.3 OP3: Suitability

The suitability theme includes type of business and stage of business.

- **OP3.1: Type of Business**

Four start-up cases stated that this mock-up does not suitable for them; however, it suits for SMEs. This is because start-ups' business model or product have not been stable, so that start-ups do not have time to think about optimization or improving organization. Company 1-A founder said,

"This tool might be suitable for businesses that are in stable stage, such as SMEs. It might be difficult for startups because startups' products aren't stable."

This is supported by company 1-D who said that,

"If you are in initial stage and just start your business, I think they are not going to be interested in this kind of thing. When start-ups are in the first stage, they only think about how to stay alive."

Some interviewees thought the tool is suitable for SMEs who want to start developing innovation. Company 1-B founder explained that,

"This mock-up seems most beneficial for SMEs venturing into innovation rather than those well-versed in the field."

Company 1-C founder also supported that,

"I think this is suitable for the University students who plan to do start-up or SMEs who plan to add innovation to their companies. If you talk about start-ups, innovation is our DNA. We don't have problem about developing innovation."

On the other hand, two SMEs thought this mock-up is suitable for only young SMEs or someone who do smart business. Company 1-H founder said,

"Your current mock-up is too difficult for SMEs. I think young SME owners may use it, but I'm not sure about the old owners."

Company 1-G founder explained that,

"It is only suitable to SMEs who have knowledge. For example, young smart farm. I mean I'm young; however, our products are not that smart."

- **OP3.2: Stage of Business**

There is suggestion on stage of business that the model should be separated into different stages of business as different stages face different challenges. Company 1-B founder suggested that,

> *"You may separate into different stage. For example, level 1 is start-ups in idea seeking stage and level 2 is start-ups that is setting up the company."*

Company 1-C founder also has similar suggestion that,

> *"Level 1 can be start-ups in idea stage, such as university students because the purpose of level 1 is to understand the problems. This purpose is not suitable for start-ups in seed, series A or series B funding."*

In addition, company 1-D founder suggested the tool starts from defining the stage of business, followed by providing different type of assessment tool to the users. He said,

> *"Growing stage and mature stage start-ups need different questions about expand market, compete with rivals. You may start from defining the stage of business. Then, you can give them the suitable questionnaire."*

4.3.3.4 OP4: Model objective

The last theme is model objective which are understand capability and suggestion.

- **OP4.1: Understand Capability**

Three of cases said they like the idea of this model that shows the current capability, strength, and weakness. Company 1-F founder explained that,

> *"Many local SMEs have not had business background, but they just produce products and sell. So, this model should be used since the starting point to help them measure their potential and improve to achieve level5." Company D founder said that "I like the idea that tell me my strength and weakness. Because when we work, people don't really tell us the truth. So, we will never know if there are problems. This summary is good feedback."*

Company 1-H founder also said,

> *"The aim of this model is very good. This make people know how good they are."*

On the other hand, half of the cases said users might not use the model because the objective is not clear and specific. Company 1-G founder explained that,

> *"The users will not perform something if that is not necessary; however, they will do if it is required by law, such as GMP."*

Company 1-E founder also stated that,

> *"The users will use any tool that fits their problems. For example, if they face problem on product quality, they use DoE (Design of Experiment). However, this mock-up is too general, so that it might not benefit to users."*

This is supported by company 1-A who said,

> *"This model can't guarantee that we will really sustain when we use. You should be more specific."*

Company 1-D founder also thought that,

> *"Users will use the tool if results of the tool meet their needs."*

- **OP4.2: Suggestion**

One common opinion which was mentioned by half of the cases was on suggestion. The users were not only willing to understand their abilities, but also need the suggestion to develop. They suggested the mock-up needs to tell steps to follow in order to improve the ability. Company 1-H founder said,

> *"When my company is in red zone, how can I improve to move to yellow zone? How about if I get all red? I have no idea where to start to improve. You should tell us that what user can do when they get yellow, what the next step is."*

This is similar to company 1-E founder, who mentioned that,

> *"This colour thing makes me have question what the next step is. If I'm in red zone, what should I do?"*

Some interviewees would like the assessment tool to be a guideline to achieve the next level. Company 1-B founder explained that,

> *"If this mock-up serves as a guideline, a corresponding solution guide would be essential. For instance, if the mock-up indicates a red area, suggest methods to transition it to green or yellow. The tool should help us to follow the plan, such as providing timeline to achieve target."*

Company 1-G founder also supported that,

> *"You should establish clear steps for users to follow. For instance, if users intend to apply for ISO certification, they should follow Form 1; if they plan to apply for GMP, they should follow Form 2. The current mock-up may not be beneficial to users. If you ask them to assess, they might not take action. Users will engage if it's necessary.*

Therefore, the form should outline the necessary steps clearly. By following these steps, they can obtain GMP certification.”

4.3.4 Challenges the Users Have Faced When Developing Technological Innovation

The interview results from SMEs and start-ups were systematically compared across cases to identify both commonalities and differences. The challenges encountered by users in the process of developing technological innovation were identified and organized into five overarching themes, detailed in Table 4.5

Table 4.5 Themes of Challenges the Users Have Faced When Developing Technological Innovation

Theme	Code
CH1: NPD	CH1.1: Identifying Target Customers CH1.2: Identifying Customers’ Need CH1.3: Testing Prototype CH1.4: Right Time
CH2: Management	CH2.1: Knowledge and Experience CH2.2: Production and Operation CH2.3: Co-founder Passion
CH3: Resource	CH3.1: Investment CH3.2: People
CH4: Collaboration and Support	CH4.1: Sales and Marketing CH4.2: Government Funding CH4.3: Contract and Standard CH4.4: Research Institute CH4.5: Other Collaborations and Supports from Incubator
CH5: External Factors	CH5.1: Covid-19 CH5.2: Law CH5.3: Location CH5.4: Bad Economy

4.3.4.1 CH1: NPD

One common challenge is NPD which includes identifying target customers, identifying customers' need, testing prototype and right time.

- **CH1.1: Identifying target customers**

Two out of eight have faced challenge of identifying real target customers. When they started the business, they tried to enter many potential markets which led to spending a lot of money on marketing as company 1-F founder explained that,

> *"I think SMEs just try to enter every market. However, they should focus on only some markets."*

This is similar to company 1-E founder, saying that,

> *"At first, when we decided to produce product for removing chemical residues, the potential customers can be many groups. We didn't decide who would be our customers. So, we spend a lot of money to promote rather than focusing on one target group."*

Moreover, he also faced challenge when he tried to develop new technology to meet the needs of those target group. However, he finally realized that those customers were not his real target group because the customers needed product that was not company's core technology and knowledge. He explained that,

> *"Some customers asked us to solve others problem apart from what we have already had. If we solve problem for them, we need more investment to do R&D. By the way, we later realized that they weren't our real customer."*

- **CH1.2: Identifying Customers' Need**

The challenge on identifying the needs of customers has occurred to several cases. Company 1-B founder explained that,

> *"Understanding customer needs has proven challenging. Although we developed our products based on theory, customer feedback has been unexpected. We marketed our products as time-saving solutions, but customers prioritized cost savings, particularly Thai farmers who value frugality. In the customer view, they are willing to spend more time if they can save a little money. Despite our efforts to emphasize our product's value and its role in facilitating interactions with landowners, customers perceive us as mere land agents rather than a comprehensive platform or supporter."*

Company 1-H founder said that,

> *"Our business is concerned about environment. We attempted to use less plastic according to eco-friendly trend. However, our customers did not care of the same point and wanted to use more plastic when purchasing her product."*

- **CH1.3: Testing Prototype**

Taking long time to test the prototype has been the problem that usually happens. Company 1-A founder explanted that,

> *"Testing product with users and collecting data need long time to do. This results in spending an amount of money without any income."*

Company 1-D founder supported that,

> *"During this process, the competitors might recognize the gap and enter the market. This leads company to scaling harder because company needs to seek another new technology to compete."*

Another interesting challenge is on customers' bias. When testing product with users, the users might not tell the truth or say their wants rather than their needs. Company 1-C founder explained that,

> *"When we told customers our idea and ask for opinion, customers always say they want those idea to be realistic. So, we need to identify whether those answer are needs, wants, or dreams."*

This is supported by company 1-A founder who said,

> *"They don't tell the truth when we test the product with them."*

Another problem has been on user's acceptance to test the product. Company 1-A founder explained that,

> *"Some companies have already had own system, so that they are not willing to try new product."*

- **CH1.4: Right Time**

One interesting challenge is about the right time to develop product. Company 1-C founder said,

> *"We had developed the product for managing accommodation five years ago when Thai people were using paper letter to notify the bill and paying the rent by cash. At that time, most of Thai people did not know what the cloud technology is. This kind of platform has just become popular today."*

Although this challenge has been mentioned by one interviewee, it is possible that other Thai SMEs and start-ups might face similar challenge on producing product while the target customers do not need that technological innovation at that time. For example, company 1-B that firstly aimed to develop platform for sourcing the agricultural product from Thai farmers to international buyers and supporting Thai farmer do marketing, expand market, manage sales. He explained that, *"We marketed our products as time-saving solutions, but customers prioritized cost savings, particularly Thai farmers who value frugality. In the customer view, they are willing to spend more time if they can save a little money."*

Therefore, the company changed business model to develop farmmate platform, matching between the farmer who want to rend the land and the owner of land for agriculture. This is similar to company 1-A which firstly attempted to produce several platforms; however, the company could not achieve target and finally changed the business model.

4.3.4.2 CH2: Management

This theme, management, contains three codes, which are knowledge and experience, production and operation, and co-founder passion.

- **CH2.1: Knowledge and Experience**

Two of the cases who are start-ups have faced problem of no experience. Both have engineering background and have attended some business courses. However, they have no experience on real business. Company 1-B founder explained that,

"Us, who are new graduated startups lacking professional experience, often involves trial and error."

This is supported by company 1-E founder who said that,

"I graduate from Engineering school and another co-founder graduate from economic school without working experience. We only know the theory. We were trained by STeP such as Lean or Business Model Canvas, those tools are only the idea. When we faced problems, the real problems were different from Lean Canvas. So, we read the books that tell steps to solve problems and knew where to focus and solve."

- **CH2.2: Production and Operation**

Two interviewees which are in idea stage were afraid of facing production and operation problems after their ideas work. Company 1-H founder said that,

"There might be no place to produce our product when we finish developing R&D in the future. This is because coffee grounds are able to be stuck in the machine, so that it is difficult to OEM. Moreover, our company does not have enough investment to build own plant."

Company 1-B founder said,

"Although our company is during researching stage, we might face operation problem when the application starts to use. This is because

we cannot estimate the future customer, so that we might face problems, such as application error. In addition, because our company is going to be partner with other platform which is possible to increase the number of users. So, we might need to prepare the operation in case of overload of users. On the other hand, if we spend the money on developing this operation while there is no new user, the investment is wasted."

CH2.3: Co-founder Passion: Company 1-B has changed not only business model but also co-founder. The founder explained that,

"Since the inception of our company, we have encountered significant turnover among co-founders. The previous leader, whom you interviewed previously, decided to step down. I assumed leadership because I believed in the potential of agricultural work. However, when I attempted to recruit two individuals as co-founders, the COVID-19 situation forced them to resign. I've come to realize that the traditional approach of offering equity to co-founders may not be effective for us, given that our equity currently holds little value."

4.3.4.3 CH3: Resource

Resource theme includes investment and people.

- **CH3.1: Investment**

Investment is the challenge that the interviewees have usually faced as this challenge was mentioned by six out of eight cases. For example, company 1-H founder said,

"We had only small investment to develop the prototype for 3 months. After that, we could not find more investment to improve the prototype and test it. No investment leads to difficulty from the first stage to develop innovation."

Company 1-D founder also said that,

"Investment is needed in product development stage because the company needs to search for new technology and develop new product's feature to solve customers' problem."

Apart from investment problem in idea stage, some company also need investment in scaling stage. Company 1-F founder explained that,

"Although the R&D had been done, if there was no investment, the company could not do marketing and build customers' awareness."

- **CH3.2: People**

Managing people is another challenge. It is difficult to manage people, such as maintaining them and developing their competences. Company 1-B founder said that,

> *"Since the inception of our company, we have encountered significant turnover among co-founders. The previous leader, whom you interviewed previously, decided to step down. However, when I attempted to recruit two individuals as co-founders, the COVID-19 situation forced them to resign."*

Company 1-D founder also explained that,

> *"Our business attempts to make good work environment; however, there are both pros and cons. The staffs might feel comfortable and do not want to improve their abilities. On the other hand, the staffs might feel comfortable and have more creativity. In addition, hiring qualified staffs is also challenge. In the past, when our business had started, we had time to train new staffs. However, the business is growing faster now, and work speed is required. As a result, we do not have time to train new staffs and wants to hire people that are ready to work."*

4.3.4.4 CH4: Collaboration and Support

The collaboration and support theme includes sales and marketing, contract and standard, government funding, research institute and other collaborations and supports from incubator.

- **CH4.1: Sales and Marketing**

Connection to sales and marketing is needed by some interviewees. Company 1-D founder said,

> *"We needs the support of connection to customers from the incubation. It is difficult if we deal with large company by ourselves because of no creditability. On the other hand, if we have the connection from the incubator, it is easier to access to customers."*

Company 1-F founder said,

> *"I want the platform that help people recognize our products and we can choose the area of advertisement."*

- **CH4.2: Contract and Standard**

Another challenge is to write contract and to apply for standard. Company 1-B founder stated that,

> *"We want the incubator, like STeP support on writing contract. Incubator should provide the sample of contract for start-ups, so that the incubatees are able to adapt to their businesses"*

Company 1-E founder supported that,

> *"We did not know whether we need to apply for standard or patent. Therefore, the guideline for applying standard is needed."*

- **CH4.3: Government Funding**

One common challenge that has occurred to several cases is insufficient government funding. Company 1-G founder explained that,

> *"The criteria for SMEs to obtain the government funding are too difficult. Government requires enterprise that have already made more than 1M Baht which is almost impossible for small enterprise."*

Company 1-E founder supported that,

> *"The government funding for start-ups is rough. Our business joined the program which government had promised to provide 1.5M Baht funding. However, we received the funding in the third year which was too late to launch the products."*

- **CH4.4: Research Institute**

There was one interviewee who explained about the challenge on collaboration with research institute. Company 1-H founder stated that,

> *"Our idea was the low priority for research institute. This might be because our business is a small enterprise, and our research has less impact to the institute comparing to the research of larger companies."*

- **CH4.5: Other Collaborations and Supports from Incubator**

There are some needs of collaboration and support from incubator. Company 1-E founder stated that,

> *"The incubator should provide connection to someone who develops the prototype or produces product."*

Another need is the connection to partners as company 1-E founder also said that,

> *"Incubator should support us by providing connection to partners who have new technology and knowledge. I know one start-up here who develop farmmate platform (Company 1-B). They don't have knowledge of farm, so they connect to the partner and get the technology."*

4.3.4.5 CH5: External Factors

The last theme is external factors, which are Covid-19, law, location, and bad economy.

- **CH5.1: Covid-19**

The new pandemic virus crisis, Covid-19, had effect on four from eight cases. Covid-19 affects the sales and marketing, the financial situation, and the growth of business. Company 1-F founder explained that,

> *"Companies producing medical cream usually promote the products by displaying in exhibition booth. However, due to physical distancing these days, we cannot use this marketing tool."*

Company 1-G said,

> *"We had planned to export this product that year. Due to Covid-19 crisis, we faced financial problem and needed to change business way to be OEM and produces goods as components in the products of other businesses."*

Some cases that had been starting to grow were affected by Covid-19. Company 1-B founder explained that,

> *"The idea generation phase began around January to March, but progress was halted for three months due to the COVID-19 lockdown. We have been actively operating for the past six months but have not yet turned a profit."*

This is similar to company 1-E founder who said that,

> *"We were starting to grow. However, the Covid-19 stopped us."*

- **CH5.2: Law**

One common challenge was the law. Company 1-G founder said that,

> *"Thai law is weak. When we develop product with third party, it is possible that the third party may copy our recipe and change a bit."*

One start-up thought Thai law did not support start-up as company 1-D founder said,

> *"The corporate fee law does not up-to-date and the government agency who is related to this problem works very slowly to modify the law."*

In addition, some start-ups do not have knowledge on law. Company 1-B founder said,

> *"We faced numerous challenges during the setup phase, such as learning to navigate legal requirements like contract drafting—an area where Thai law presents unique obstacles. Despite having acquired*

basic knowledge, we often had to find solutions independently. For instance, learning how to draft contracts presented a significant challenge. Moreover, Thai law doesn't adequately support startups."

Company 1-G founder also explained that,

"We did not know which standard is needed when selling products. We thought we needed the FDA (Food and drug submission) and applied for it. After applying, the Food and Drug Administration told us that our product was not relate to the FDA. So, we wasted the time to prepare and apply for it which was not needed."

- **CH5.3: Location**

One challenge that was mentioned by company 1-B founder is on location. He said,

"Another hurdle is our geographical location; our office in Chiang Mai limits our access to networking events typically held in Bangkok, which offers more extensive connections and seminars."

Although this challenge was mentioned only by one case, it is possible that other companies faced the same problem because most of the cases are based on Chiang Mai. For example, company 1-G firstly spined-off Mae Jo University, another university in Chiang Mai and part of Northern Thai Science and Technology Park. After that, the company has moved to collaborate with other university in Bangkok in order to look for opportunity to conduct research and develop new product.

- **CH5.4: Bad Economy**

This challenge was mentioned by company 1-G founder. He explained that,

"When the economy is inactive, people want to save money and are not willing to spend money on unknown brand. Therefore, it is hard to sell both offline and online."

Even though this challenge was mentioned by one interviewee, it can be inferred that this challenge is the effect of Covid-19 which many cases found it as the problem they have faced.

4.3.5 Reflection and Learning from the Interview

The interview analysis led to identifying six key learnings.

1) Current Technique in Develop Technological Innovation

The interview led to understanding how the SMEs and start-ups in the program develop their innovations. Interviewees commonly sought opportunities by addressing challenges in people's everyday lives. However, diverse techniques were employed across different interviewee groups. PD (Platform developing) companies, which develops software product, utilized Lean Canvas, Business Model Canvas, and Design Thinking, employing these approaches to empathize, define problems, ideate, develop prototypes, and test them with customers. Conversely, TC (Technology commercializing) companies, that transfers research into products, focused on identifying current trends and customer needs before developing products, with limited mention of specific approaches or testing with expected customers for improvement.

2) Needs for More Specific Target Users

A majority of start-ups proposed segmenting ICAT into distinct business stages, such as the idea stage, set-up stage, and seed round stage. Start-ups with several years of business operation and stability perceived the current model as unsuitable for their needs, considering it more fitting for initial-stage start-ups. This perspective raised from the model's primary purpose of problem definition, which may not align with the high TIC levels already achieved by stable-stage start-ups. Conversely, start-ups in their initial stages also found the model less suitable for their needs, believing it catered more to businesses that have attained stability. Initial-stage companies often prioritize operational efficiency over improvement. In the case of SMEs, the mechanism was viewed as beneficial for understanding current capabilities and facilitating improvement. However, it was noted that the current model contains numerous technical terms, making it challenging for SMEs lacking technological and organizational backgrounds to understand. This learning underscores the need for tailoring the tool to specific business stages.

3) Needs for improving ICAT

Based on feedback received on the mock-up, a common need for improvement emerges across multiple cases. Several interviewees expressed a preference for a simpler mock-up, featuring more straightforward language and rating methods. Furthermore, they advocated for a more specific objective, targeting the right users. Participants expressed a desire for the tool to address specific challenges encountered in their businesses, such as achieving the lean canvas, implementing the business model canvas, or obtaining certification. A well-defined objective could also guide the inclusion of relevant perspectives and criteria. Moreover, many suggested that ICAT should not only focus on assessment but also provide actionable recommendations to attain the 'sustained' level. These recommendations should comprise manageable steps that users can easily follow. More details on the improvement opportunity will be explained in Section 4.4.

4) Challenge in NPD

The common challenge, encountered by the participating SMEs and start-ups in the development of their technological innovation, centers on NPD process. While most interviewees faced NPD challenges, the specific nature of these challenges varied. PD companies encountered issues in identifying customers' needs, such as customer bias during prototype testing. On the other hand, technology commercializing (TC) companies struggled with identifying target customers, as many had developed technologies and entered multiple markets before determining their actual customer base. Consequently, they needed to allocate more time and resources to marketing efforts rather than focusing on essential targets. Another common challenge related to producing prototypes and final products, with uncertainty about where to manufacture after completing the idea development in the laboratory.

5) Challenge in Collaboration with External

Interviewees faced challenges in collaborating with external entities, spanning areas such as establishing connections to sales and marketing, drafting contracts, adhering to standards, collaborating with research institutes, and seeking connections to prototype developers and product manufacturers. This collectively led to a clear desire for STeP support, emphasizing assistance in navigating these challenges and fostering beneficial collaborations.

6) Challenge in Government Funding

A recurring concern revolves around challenges associated with government funding. Most interviewees expressed a common need for funding from the government, though the specific challenges differed. Companies in the initial stage faced difficulties in securing funding for business operations or research and development, while more established companies required additional government funding for marketing and building customer awareness. Interviewees also perceived government support for funding as overly stringent. SMEs found the criteria for obtaining government funding too challenging, while start-ups experienced delays in receiving government funding.

4.4 Identifying Improvement Opportunities

While the mock-up was designed and several cycles of ADR were implemented and evaluated, the reflection and learning emerged in parallel through the studying. Sub-section 4.4.1 describes the evaluation of the mock-up against the design requirements, followed by the opportunities for improvement in Sub-section 4.4.2, Sub-section 4.4.3, Sub-section 4.4.4, and Sub-section 4.4.5.

4.4.1 Evaluating the Mock-up Against the Design Requirements

This sub-section evaluates the mock-up against the design requirements and discusses in relation to the literature and the evidence from the interview. Table 4.6 shows result of the evaluation.

Table 4.6 Evaluation the Design Against the Design Requirements

Design Requirement	Evaluation	Evidence
DR1: The tool supports users to understand their current TIC.	Partially meet	As mentioned in *OP4: Model objective*, the users recognized that the tool could support them to understand current capabilities. However, some interviewees thought that the objective of ICAT was not clear and specific enough to assess their capability. In addition, as mentioned in *OP3: Suitability*, if the tool separated into different types of business and stages of business, it could be more particular for the users to understand current TIC. In addition, comparing company profile in Table 3.2 and the results that the users got Table 4.3, the results are not relevant to the stages of the company. This leads to the conclusion that the tool does not thoroughly support users to understand their current TIC.
DR2: The TIC perspectives and criteria are suitable for the situation of users.	Partially meet	As mentioned in *OP1: Criteria*, the users would like the tool to include some perspectives and criteria, such as criteria relating to the challenges they faced, criteria from lean canvas and business model canvas.
DR3: The tool is easy to use.	Not meet	As mentioned in *OP2: Characteristic*, the users found that there were many confusing issues. For example, too many questions to assess, too detailed questions, complicated way to rate and confusing language.
DR4: The tool is suitable for self-assessment.	Partially meet	As mentioned in *OP4: Model objective*, some users were willing to use the mock-up. However, some users found that this tool did not meet their expectation owing to its broad scope. The users will use tool only when it is specific to solve their problems.

Table 4.6 Evaluation the Design Against the Design Requirements (Cont.)

Design Requirement	Evaluation	Evidence
DR5: The tool guides users to develop TIC.	Partially meet	As mentioned in *OP4: Model objective*, the tool leds to the users understanding where they are and developing capability to achieve level 5. However, the tool that supports users to assess the current capability is not enough, but it should also provide the guideline how to improve TIC and provide steps to follow.

DR1: The tool supports users to understand their current TIC.

The analysis revealed that this mock-up could assist users in comprehending their current potential and capabilities for developing innovation and competing in the market. Users were able to identify strengths and weaknesses and decide which capabilities to further improve, as mentioned in *OP4: Model objective*. The five maturity levels allowed them to see the overall picture of TIC development, understanding where they were and what steps they could take next. However, the mock-up only partially met DR1, as several interviewees recognized points that needed improvement. For example, some interviewees felt that the current objective of the tool was not clear and specific enough. Additionally, as mentioned in *OP3: Suitability*, users suggested that the tool, when separated into different types and stages of business, could be more specific for users to understand current TIC.

While SMEs and start-ups faced specific challenges and required specific tools to assess TIC and facilitate technological innovation development, this mock-up and previous ICMMs from the literature aimed to produce an assessment model for general company types. The models did not specify whether they were produced for companies like SMEs or start-ups. Therefore, ICAT should be developed separately into different versions.

Furthermore, interviewees were companies collaborating with STeP, indicating they might have already been interested in innovation and technology. Especially in the case of start-ups, their technological innovation might have already been integrated into the business model, and their TIC might have already been at a high level. So, the current concept of the mock-up and maturity level from the literature might not be applicable to the situation of Thai SMEs and start-ups collaborating with STeP. Consequently, the tool should specify the entry level of the target user, and the maturity level should be modified to be more appropriate to the situation.

Additionally, comparing the results of users using the mock-up to assess TIC in Table 4.3, it was found that the results users obtained were not relevant to the company profile inTable 3.2.. This might be because the way to rate is too complex and the questions are not clear, as mentioned in *OP2.3: Rating* and *OP2.5: Language*, respectively. Therefore, users might have been confused, leading to different results when using the tool. Moreover, users might have had bias when assessing their capabilities, resulting in significantly different results for the same stage of the company. For this reason, the tool did not thoroughly support users in understanding their current TIC.

DR2: The TIC perspectives and criteria are suitable for the situation of users.

The interview led to the learning that the mock-up partially met DR2, as current TIC perspectives and criteria from the literature were partly relevant to users (see *OP1: Criteria*). Some perspectives and criteria needed to be added, considering the different context between developing innovation capability in general technology-based companies and in Thai SMEs and start-ups. Therefore, there might be different influencers and restrictions. Other perspectives and criteria that interviewees wanted the model to include were NPD, production and operation management, resource management, and collaboration and support. The TIC perspectives and criteria should also be modified considering the interviewees' challenges. The aspects of Business Model Canvas and Lean Canvas can also be adopted. Moreover, as both approaches convey the idea without steps to achieve, this is an opportunity for ICAT to fill this gap.

DR3: The tool is easy to use.

It was found from the interview that the mock-up contained too many perspectives, criteria, and questions to assess, and each question was also too detailed (see *OP2: Characteristic*). There were also many confusing issues, such as the way to rate and language. This led to not meeting DR3. When the users were SMEs who might have had limited knowledge of technology and business, it might have been difficult for them to understand the specific words. This is similar to the literature on SMEs deploying ISO9001. SMEs faced obstacles in implementing ISO9001 due to insufficient knowledge. Hence, the model should be more user-friendly, improving aspects such as using general words, using software programs, or starting from simplicity and then continuing with more details later. The way to rate should be modified because the current assessment way made users confused and biased. The visualization of assessment result should be modified, and other chart types could be considered to show the result.

DR4: The tool is suitable for self-assessment.

The result showed that although SMEs were willing to use the mock-up as it could facilitate them to assess capability and develop to be sustained, the start-ups did not recognize the advantage of using this mock-up. Therefore, the mock-up partially achieved DR4. The evidence can be found in *OP4: Model objective*. Users used some tools only when they faced problems and wanted to solve them; however, they found that this assessment tool did not meet their expectations due to its broad scope. Tools that had specific objectives, such as supporting to get some standards, reducing some problems, or reducing some risks, were recognized as necessary tools. On the other hand, this mock-up was too general and did not guarantee that users would really have sustained capability when they achieved level 5. For this reason, the tool should have a more specific objective to have an effective benefit for the user.

DR5: The tool guides users to develop TIC.

The finding of the interview found out that the mock-up could facilitate the user in developing TIC as users could see their capability, know where they currently were, and develop capabilities from the starting point to sustain in level 5 (see *OP4: Model objective)*. It is particularly the case for SMEs, which might have limited business and technology knowledge; they could follow the criteria of the tool to develop their capabilities. Though, the mock-up partially achieved DR5, as many interviewees recognized some points that should be improved.

Both this mock-up and the previous ICMMs from the literature were tools to assess TIC level. Although the maturity level led to models showing where users were and where to go next, there was no suggestion for users to increase their capabilities. On the other hand, it was also found in *OP4: Model objective* that the tool for only assessing current capability is not enough. However, it should also guide users how to improve TIC and provide steps to follow to achieve level 5. As a result, the challenges of developing technological innovation should be further studied to develop mechanism to support the users to overcome that challenge and increase TIC.

4.4.2 Opportunities to Improve the Mock-up

Upon evaluating the mock-up against the DRs outlined in Sub-section 4.4.1, several opportunities for enhancing ICAT emerged to ensure its applicability and relevance to the target users. To address DR1, it is imperative to specify whether ICAT is designed for SMEs or start-ups. Additionally, determining the entry level of the target user is crucial. Subsequently, the maturity level should be adjusted to better align with the specific circumstances of the target user.

For DR2, the TIC perspective and criteria need refinement to better address the challenges faced by the target users. To fulfill DR3, emphasis should be placed on enhancing user-friendliness. The assessment process for TIC should be simplier, and the results should be presented in a clear and understandable manner.

Meeting DR4 involves ensuring that users comprehend the concept and importance of TIC. This, in turn, emphasizes the necessity of using ICAT as a self-assessment tool. Finally, addressing DR5 entails incorporating features in ICAT that not only guide users on improving TIC but also provide actionable steps to develop and sustain their TIC. Chapter 5 will delve into the proposed modifications and the renewed focus of the refined tool.

4.4.3 Opportunity to Improve TIC

Given the limited research on TIC within Thai SMEs and start-ups, this study offers an opportunity to propose TIC key perspectives tailored to the specific challenges faced by these stakeholders. The identified key perspectives, namely Innovation Decision Capability, Innovation Sourcing Capability, and NPD Capability, were adapted from an analysis of the challenges encountered during technological innovation endeavors. The details of each key perspective and the comparison to the previous perspectives and criteria from literature are shown in Table 4.7.

1) Innovation Decision Capability

The first key perspective, Innovation Decision Capability, pertains to the ability to execute technological innovation decisions (Wang et al., 2008). As highlighted in *CH1.1: Identifying target customers* and *CH1.4: Right Time*, cases in the study required decision and plan the technological innovation to meet market demand at the appropriate time. Furthermore, many companies adjusted their technological innovation decision during economic crisis to meet customers' need and survive in the market, as explained in *CH5.1: Covid-19* and *CH5.4: Bad Economy*. Strategic planning capability, risk management capability, and resource allocation capability constitute essential components of Innovation Decision Capability.

- **Strategic planning capability** involves formulating and adjusting innovation plans for effective implementation (Yam et al., 2004). Studies on TIC have consistently identified this capability as pivotal, with Liu, L. and Jiang (2016) underscoring its significant influence on TIC.
- **Risk management capability** entails assessing and taking risks associated with technological innovation adoption (Forsman, 2011; Sumrit and Anuntavoranich, 2013). While the latter study uniquely emphasizes this capability, it becomes apparent from interviews that cases faced

economic and pandemic challenges, necessitating a focus on managing and reducing risks.

- **Resource allocation capability** relates to acquiring and allocating capital, expertise, and technology in technological innovation projects (Yam et al., 2004). While Yam et al. emphasize the significance of this capability, Liu, L. and Jiang (2016) argue against the importance of FHM Resource (Finance, Human, Material). Interviews, however, reveal challenges in investment and people management, emphasizing the need for further development in this area (*CH3.1: Investment* and *CH3.2: People*).

2) Innovation Sourcing Capability

The second key perspective, Innovation Sourcing Capability, involves the ability to acquire and transmit internal and external technology, knowledge, and information. This capability, comprising technology acquisition and learning capabilities, is crucial for preventing companies from producing inappropriate products and hindering business expansion.

- **Technology acquisition capability** encompasses collaborating with external parties to acquire external technology, knowledge, and information (Herrmann et al., 2007; Sumrit and Anuntavoranich, 2013). While Sumrit and Anuntavoranich uniquely identify this capability, interviews reveal cases expressing the need for connections to research institutes and the acquisition of new technology and knowledge (*CH4.4: Research Institute* and *CH4.5: Other Collaborations and Supports from Incubator*).
- **Learning capability** involves identifying, assimilating, and exploiting knowledge and information from internal and external sources in technological innovation projects (Guan et al., 2006). This capability has been placed importance in many previous studies. For instance, Sumrit and Anuntavoranich (2013) identify collective learning capability as the top three TIC core perspectives and Liu, L. and Jiang (2016) indicate that knowledge resources is one of the main influence of NPD. However, Yam et al. (2004) argue that learning capability do not contribute as significantly as other TICs. Despite varying opinions on the significance of learning capability, interviews highlight challenges in acquiring technology and information, indicating the need for its development in target SMEs and start-ups. Challenges in identifying customer needs (*CH1.2: Identifying*

Customers' Need) further imply obstacles in learning and assimilating external information.

3) NPD Capability

The third key perspective, NPD Capability, encompasses the ability to design products that meet customer needs and efficiently manage both production processes and business operations. This capability includes design capability (formerly R&D capability), market capability, and production capability, (formerly manufacturing capability).

- **Design capability (R&D capability)** has been determined as TIC significance in literature of TIC (Guan et al., 2006; Liu, L. and Jiang, 2016; Sumrit and Anuntavoranich, 2013; Wang et al., 2008; Yam et al., 2004). R&D capability is the ability to expand existing technologies and establish novel technologies or improve R&D function (Wang et al., 2008). Yam et al. (2004) identify this capability as one of the two most influential TIC perspectives. Liu, L. and Jiang (2016) divide this capability into fundamental research and application R&D and indicate that both perspectives significantly affect NPD. The former brings about revolutionary products while the latter leads to developing R&D application that more suits to market demand. On the other hand, in case of the SMEs and start-ups in STeP, they are not only the technology commercializing companies, but also the PD companies who develop products and services. Through the interview analysis, it was found that product design and engineering were significant to the target SMEs and start-ups as they faced many difficulties, such as *CH1.1: Identifying target customers, CH1.2: Identifying Customers' Need, CH1.3: Testing Prototype* and *CH1.4: Right Time*. Therefore, this sub-perspective was re-determined to be '*Design capability*' where both product architecture and new technology are taken into account (Ulrich and Eppinger, 2016).
- **Market capability** relates to the ability to promote and sell products based on an understanding of customer demand (Yam et al., 2004). Challenges in entering new markets and increasing sales (*CH4.1: Sales and Marketing, CH5.1: Covid-19*, and *CH5.4: Bad Economy*) underscore the essential role of market capability for SMEs and start-ups.

- **Production capability (Manufacturing capability)** involves transforming R&D results into products, improving product quality, and encompasses designing product structure and processes (De Toni and Nassimbeni, 2001; Sumrit and Anuntavoranich, 2013; Wang et al., 2008) According to

CH2.2: Production and Operation, some cases have concern of producing product and operation after finishing the research stage, such as cannot find manufacturer or cannot estimate the number of customers. This emphasizes the importance of this capability. In addition, the products of many studied cases in this research are the software products. Therefore, this sub-perspective was re-determined to be '*Production capability'*. As a result, the term 'Production' in this research not only refers to the process of transforming R&D results into products, but also refers to the process of creating and delivering a final version of the software product. This involves coding, testing, and deployment processes, as well as ongoing maintenance and updates to ensure the platform remains effective and secure.

While this study proposes TIC perspectives based on challenges identified during technological innovation, the specific criteria for each perspective have not been established. Consequently, there is an opportunity for further research to identify these criteria. Additionally, the study highlights the need for further exploration on how users can determine which TIC aspect should be prioritized for development.

Table 4.7 Proposed TIC from the Interview Analysis vs. TIC from Literature

Proposed TIC Perspective		Definition	Other TIC Perspectives/Criteria from Literature				
Perspective	**Sub-perspective**		**Sumrit & Anuntavoranich (2013)**	**Yam et. al. (2004)**	**Guan et. al. (2006)**	**Wang et. al. (2008)**	**Liu & Jiang (2016)**
Innovation Decision Capability	Strategic planning capability	The ability to formulate innovation plans and adjusts them for implementation (Yam et al., 2004)	- Strategic Management Capability - Organization Capability	- Strategic Planning Capability - Organizing Capability	- Strategy Planning Capability - Organization innovating Capability	- Innovation Decision Capability	- Strategies Capability - Organizational Capability
	Risk Management Capability	The ability to assess and take the risk of technological innovation adoption (Forsman, 2011)	- Risk Management Capability				
	Resource Allocation Capability	The ability to acquire and allocate capital, expertise and technology in technological innovation projects (Yam et. al., 2004)	- Resource Allocation Capability	- Resource Allocation Capability	- Resource Allocating Capability	- Capital Capability	- FHM Resource (Finance, Human, Material)

Table 4.7 Proposed TIC from the Interview Analysis vs. TIC from Literature (Cont.)

Proposed TIC Perspective		Definition	Other TIC Perspectives/Criteria from Literature				
Perspective	Sub-perspective		Sumrit & Anuntavoranich (2013)	Yam et. al. (2004)	Guan et. al. (2006)	Wang et. al. (2008)	Liu & Jiang (2016)
Innovation Sourcing Capability	Technology Acquisition Capability	The ability to collaborate with external parties to acquire external technology, knowledge and information (Herrmann et al., 2007)	- Network Linkage Capability - Technology Acquisition Capability				
	Learning Capability	The ability to identify, assimilate, and exploit knowledge and information from internal and external in technological innovation projects (Guan et. al., 2006)	- Learning Capability - Absorptive Capacity - Knowledge Management Capability	- Learning Capability	- Learning Capability		- Knowledge Resource

Table 4.7 Proposed TIC from the Interview Analysis vs. TIC from Literature (Cont.)

Proposed TIC Perspective		**Definition**	**Other TIC Perspectives/Criteria from Literature**				
Perspective	**Sub-perspective**		**Sumrit & Anuntavoranich (2013)**	**Yam et. al. (2004)**	**Guan et. al. (2006)**	**Wang et. al. (2008)**	**Liu & Jiang (2016)**
NPD Capability	Design Capability	The ability to expand existing technologies, establish novel technologies (Wang et. al., 2008), and create products and services that solve problems or meet customer demands	- R&D Capability - Project Cross functional team integration capability - Technology Change Management Capability - Product Structural Design and Engineering Capability	- R&D Capability	- R&D Capability	- R&D Capability	- Fundamental Research - Application R&D
	Production Capability	The ability to produce and deliver a final version of product and service	- Process Design and Engineering Capability - Manufacturing Capability	- Manufacturing Capability	- Manufacturing Capability	- Manufacturing Capability	- Manufacturing Capability
	Market Capability	The ability to understand customer demands, promote and sell products (Yam et. al., 2004)	- Market Capability	- Market Capability	- Market Capability	- Market Capability	

4.4.4 Opportunity to Improve ICMM

An important finding in the study revealed that the ICMM cannot be developed for general use but should cater to specific target users. As referenced in *OP2.4 (Version), OP3.1 (Type of Business)*, and *OP3.2 (Stage of Business)*, different target users necessitated tools addressing distinct issues in developing technological innovation, along with varying maturity levels for measurement.

For instance, SMEs that have not previously applied technological innovation in their products may need to initiate their maturity journey from the initial level, gradually aiming to enhance their capabilities. Conversely, start-ups that have integrated technological innovation in their products or business models may commence from an intermediate level, working towards sustained capability. Consequently, there is an opportunity for further studies to tailor ICMM to specific users with different measurement objectives.

In the case of Thai start-ups and SMEs in the STeP program, several opportunities for improvement were identified:

- **Accuracy of Assessment Results:** Inconsistency were noted between assessment results and the actual organizational status. For instance, Company 1-C, with strong organizational management and revenue generation, received a lower assessment level (3), while Company 1-B, in the early stages, received a higher assessment level (4).
- **Definition Emphasis**: The definition placed excessive emphasis on producing an innovative product rather than focusing on developing capability. Level 1 was defined as having developed at least one successful innovation. This means the focus of maturity level is on one successful product, rather than the capability to produce it successfully. This potentially led to incorrect assessments for early-stage start-ups in ideation or market validation stages.
- **Rationalizing Level 1 and Level 2**: Levels 1 and 2 were not defined reasonably, both implying a lack of a structured plan for innovation. The modified maturity levels sought to address these issues by introducing a more nuanced and contextually relevant categorization.
- **Planning as a Foundation**: The interviews conducted during Phase 1 highlighted the significance of planning as a foundational step preceding doing. Therefore, planning should precede implementation, ensuring that the innovation process is strategically guided and systematically executed.

In response to these identified opportunities, new maturity levels were proposed to better suit the context of Thai start-ups and SMEs in the STeP program. These revised levels combined concepts from ICMM and Plan-Do-Check-Act (PDCA). PDCA is a structured methodology used for continuous improvement of processes. It was developed by quality management pioneer and is widely applied across various industries to enhance processes and drive organizational improvement. It involves four key stages:

- **Plan (P):** In the PDCA cycle, the first stage is *Plan*. During this phase, objectives and goals are established, and strategies to achieve them are developed. This involves identifying problems, analyzing root causes, setting targets, and formulating action plans. The emphasis is on thoughtful planning and laying out a clear roadmap for execution.
- **Do (D):** The *Do* phase involves implementing the planned actions. This stage is about executing the strategies and activities outlined in the planning phase. It is crucial to ensure that the actions are carried out effectively and efficiently according to the established plan.
- **Check (C):** Once the actions are implemented, the next step is to *Check* or evaluate the outcomes and results. This involves monitoring and assessing whether the objectives were met, measuring performance against predetermined targets, and gathering data to analyze the effectiveness of the implemented actions.
- **Action (A):** Based on the evaluation and analysis conducted in the Check phase, the final stage of the PDCA cycle is *Action*. In this phase, decisions are made to take corrective actions and make improvements based on the findings from the evaluation. This may involve refining strategies, adjusting processes, or implementing changes to address identified issues and enhance performance.

The decision to integrate the PDCA cycle within ICMM was driven by several key considerations. First, PDCA provides a systematic and structured approach to problem-solving and process improvement. It offers a logical sequence of steps that address challenges, evaluate outcomes, and implement effective solutions. By integrating PDCA, planning (Plan) is positioned as an essential precursor to subsequent phases of implementation (Do), evaluation (Check), and adjustment (Action). Second, the PDCA cycle embodies a continuous improvement mindset, aligning well with the iterative and evolving nature of innovation management. By incorporating PDCA into the maturity assessment, organizations are encouraged to continually refine their innovation processes and capabilities over time. Lastly, PDCA cycle is adaptable and flexible, making it suitable for diverse organizational contexts and innovation environments, especially in organizations with limited resources and skills. This accommodates the unique challenges of Thai SMEs and start-ups in the STeP program.

All in all, the PDCA cycle was selected for integration within the ICMM to foster continuous improvement in innovation processes. The refined ICMM aligns with the iterative nature of innovation management, enabling organizations to enhance their capabilities systematically over time. The focus of the assessment shifted towards emphasizing the techniques, approaches, or tools employed in each innovation process or activity, rather than solely on the development of a single product. By incorporating PDCA, the refined maturity levels emphasize not only the development of one innovative product but also the cultivation of structured and effective innovation processes.

The revised maturity levels align as follows:

- **Level 1 – Initial (Unstructured Plan and Do):** The innovation process or activity is performed without the structured technique, approach, or tool.
- **Level 2 – Plan and Do:** The innovation process or activity is planned and performed by adopting some techniques, approaches, or tools.
- **Level 3 – Plan, Do, and Check:** The innovation process or activity is planned and performed by adopting some techniques, approaches, or tools. The result of the innovation process or activity is reviewed, reflected, and adjusted.
- **Level 4 – Plan, Do, Check, and Action:** The innovation process or activity is planned and performed by adopting some techniques, approaches, or tools. The result of the innovation process or activity is regularly reviewed, reflected, and adjusted. The techniques, approached, or tools are continuously reviewed and improved according to the reflection.

For a clear distinction between existing ICMMs from the literature, the maturity levels of Essmann and Du Preez (2009) with three levels, Corsi and Neau (2015) with six levels, the mock-up of ICAT, and the proposed modification of ICAT, refer to Table 4.8. This comparison highlights the unique contributions and contextual relevance of the proposed modifications to ICMM.

Table 4.8 The Comparison between Maturity Level in the Literature and the Proposed Maturity Level Modification

Essmann and Du Preez (2009)	Level 1 (Innovation-related practices and procedures are limited in their ability)			Level 3 (Innovation-related best practices and procedures have been identified and deployed)		Level 5 (Innovation activities are natural behavior)
Corsi and Neau (2015)	Level 0 (Not innovate)	Level 1 (Do)	Level 2 (Repeat)	Level 3 (Coordinate)	Level 4 (Manage)	Level 5 (Sustain)
Mock-up of ICAT	Level 1 (Initial)		Level 2 (Repeatable)	Level 3 (Defined)	Level 4 (Managed)	Level 5 (Sustained)
Proposed Modification	**Level 1** **(Initial)** (Unstructured Plan and Do)			**Level 2** **(Plan and Do)**	**Level 3** **(Plan, Do, and Check)**	**Level 4** **(Plan, Do, Check, and Action)**

4.4.5 Opportunity to Improve the Users' Context

The interview analysis revealed challenges faced by Thai start-ups and SMEs in developing technological innovation. Opportunities for enhancing the users' context are categorized into two parts: opportunities for self-improvement and opportunities for government intervention.

4.4.5.1 Opportunity to Improve Themselves

According to the results of using the mock-up in Table 4.3, it was found that many companies performed better level of strategic management capability and organizational capability than resource allocation capability and risk management capability. The company that product was in ideating stage got Level 1 (Initial) of the first two criteria while the company did not perform the other criteria. Similarly, the companies in validating stage and scaling stage got higher level of the first two capabilities and got lower level of the last two. It can be assumed that Thai SMEs and start-ups placed importance on managing strategy and organization while they neglected to manage the resource and risk. This is supported by *CH3.1: Investment* and *CH3.2: People* that many interviewees faced challenge in investment and people management. The study of Rujirawanich et. al. (2011) also finds that Thai companies have high negative attitude to change. Due to the culture of unwillingness to take risk, they avoid uncertainty by producing simple products. This is also supported by the Global Entrepreneurship Index of Thailand, indicating risk acceptance score of 16.3 out of 100 (The Global Entrepreneurship and Development Institute, 2019). Hence, there is an opportunity to enhance innovation management capability by placing greater emphasis on resource allocation and risk management.

4.4.5.2 Opportunity that could be done by the government

The interview analysis led to identifying the missing supporting points that they have not yet achieved from the previous collaboration with Science and Technology Park nor from the government supports. Wonglimpiyarat (2016) suggests that company developing innovation capability themselves may be insufficient, government in national innovation system could facilitate the innovation capability.

Through the interview analysis, the Thai SMEs and start-ups need more support on connection to third parties, which include R&D institutes, laboratories, manufacturers, customers, and investors. According to *CH4.1: Sales and Marketing*, SMEs and start-ups need the connection to customers. This finding is supported by the study of Chaminade et. al. (2012) which found that there is insufficient policy to advocate customers to use innovative products and services. In addition, regarding *CH4.4: Research Institute* and *CH4.5: Other Collaborations and Supports from Incubator*, the SMEs and start-ups also need the connection to partners who have knowledges to support the business as it is difficult for them to directly access resources and information. This interview result confirms the study of Intarakumnerd (2019) that sources of information for innovation in Thailand are limited, emphasizing interactions with customers, parent firms, and suppliers. Munkongsujarit (2016) also found that the university business incubators are unable to find specialists and consultants to support and enhance incubatees' technical knowledge as well as find business partners to match the incubatees.

Funding emerged as a critical issue that can be advocated in the national innovation system, from the R&D process to the commercialization process, as discussed in *CH3.1: Investment* and *CH4.3: Government Funding*. Insufficient funding was evident in the mock-up results, where investment allocation capability for some cases was at a low level. The study of Intarakumnerd (2019) supports this finding, highlighting the high costs needed for innovation as a major problem for small companies with limited resources. Wonglimpiyarat (2016) further notes the scarcity of venture capital funds and private equity investments, leading to inadequate financial support for entrepreneurs. In addition, the interview led to recognizing that government and Science and Technology Parks could consider allocating more allowance for start-ups in the early stages, especially those that have not launched products or generated revenue.

Referring to *CH5.2 (Law)*, while the Thai government promoted an innovation-driven economic development model, the existing law did not adequately support start-ups, rapid technological change, and economic growth. Chaminade et al.'s study (2012) highlights the lack of policies supporting innovation, particularly those acknowledging the failure of innovative companies. Institutions, infrastructures, networking, and support services tend to target only research-based firms, leaving non-research-based firms without appropriated support.

The role of incubators is crucial in facilitating SMEs and start-ups in developing technological innovation. As mentioned in *CH2.1: Knowledge and Experience*, start-ups possessed technical backgrounds but lack real-business experience, while many SMEs lacked sufficient business knowledge. However, existing courses provided by STeP were too general, making practical application challenging. *CH4.2 (Contract and Standard)* and *CH5.2 (Law)* underscored the need for support in legal matters, standards, and contracts, indicating a gap in knowledge. The study of Munkongsujarit (2016) suggests that university business incubators, pressured to produce results by government KPIs, may prioritize generating revenue over fostering incubate growth.

Numerous opportunities for improvement within the users' context suggested a need for further exploration for the next phase, focusing on understanding what the Thai government and Science and Technology Parks can do to improve the SMEs and start-ups context. Particularly for start-ups, which context was not advocated appropriately.

4.5 Formalizing the Knowledge

In this phase, the mock-up of ICAT was designed and evaluated through interviews conducted with Thai SMEs and start-ups on STeP. The analysis of the interviews extends the existing literature on TIC in Thai SMEs and start-ups. The study contributed to formalizing the knowledge on key perspectives of TIC and key priority TIC that are relevant to Thai SMEs and start-ups in STeP.

4.5.1 Key Perspectives of TIC

From the literature review on TIC, there are many characteristics of TIC. For instance, the TIC frameworks of Yam et al. (2004), Guan et al. (2006), Wang et al. (2008), and Liu, L. and Jiang (2016). There is also a few TIC framework of Thai technology-based firms, proposed by Sumrit and Anuntavoranich (2013).

In this phase, interviews with target users were conducted to give a deeper understanding of the challenges that SMEs and start-ups on STeP face when developing technological innovation. Consequently, it led to the identification of TIC key perspectives to meet the challenges. The key TIC perspectives for Thai SMEs and start-ups for STeP were found to be:

- **Innovation decision capability**: The ability to execute technological innovation decisions. This capability includes strategic planning capability, resource allocation capability and risk management capability.

- **Innovation sourcing capability**: The ability to acquire and transmit internal and external technology, knowledge, and information. This capability includes technology acquisition capability and learning capability.
- **NPD capability**: The ability to design product that meets customers' needs and manage both production process and business operations. This capability includes design capability, production capability and market capability.

4.5.2 Key Priority TIC

The literature prioritized TIC as high priority capability in Thai SMEs and start-ups. Additionally, previous studies on TIC prioritized many TIC perspectives, such as innovation management capability (Sumrit and Anuntavoranich, 2013) and strategic capability (Liu, L. and Jiang, 2016)

From the finding in the interviews in this phase, TIC was not practically assessed in the target users. Through the analysis of the responses, the interviewees' concerns included such challenges as identifying target customer, identifying customers' needs, testing prototype, and producing products at the right time. These factors encapsulate a key concern about NPD. These challenges prevent the development of technological innovation, especially in cases of early-stage start-up. The obstacles led companies to not fully understanding markets and not enhancing their potential on commercializing products and expanding business growth.

4.6 Summary

A review of literature on innovation capability assessment led to the finding that several tools to assess innovation capability are available. These include ICMM which has been developed through a number of studies, for instance, Essmann (2009) and Corsi and Neau (2015).

However, the analysis of the interviews conducted in this phase identified two limitations in existing literature. Firstly, the models have strong theoretical foundations, but there is little emphasis on how such models might be implemented in practice. For instance, the key perspectives of the TIC and the maturity levels in existing models from the literature were found to be unsuitable for practical use by the target users. Analysis of the interviews revealed that the TIC perspective and criteria require refinement to better address the specific challenges faced by the target users. Furthermore, new maturity levels should be proposed to better align with operational realities of these organizations. This was particularly problematic for Thai SMEs and startups whose capacity to use such models is very limited.

Secondly, available models are wide-ranging in their scope but for participating SMEs and startups, the priority was maintaining and increasing the competitive position in the market through the delivery of better-quality products, more quickly, and less costly.

As a result, the focus of the research shifted to concentrate on NPD capability which is one aspect of TIC. In the next chapter, an approach is proposed to overcome ethe challenge on NPD and facilitate Thai start-ups to assess NPD capability.

Chapter 5 New Product Development Capability Assessment Method (NPDWise)

In Phase 1 study, several challenges affecting technological innovation development among Thai SMEs and start-ups at Science and Technology Park, Chiang Mai University (STeP) were identified. One of the primary concerns revolved around new product development (NPD). Consequently, this phase aimed to establish a method that facilitates early-stage start-ups in STeP to assess the NPD capability.

This chapter serves as an introduction to the “NPDWise”, a tailored method designed for assessing NPD capability of the early-stage start-ups engaged in STeP program. This name was chosen intentionally. In navigating the complex landscape of early-stage start-ups within the STeP program, the aim is to provide a method that is not just a tool but a wise guide. Therefore, the term “Wise” in NPDWise signifies that the method is intelligent and insightful. In providing insights into the NPD process and assessing the NPD capability. The objective of NPDWise is to introduce a structured approach that enables incubators and early-stage start-ups to understand the NPD process, evaluate their existing NPD capabilities, identify strengths and areas for improvement in their NPD processes, ultimately enhancing their opportunity for commercialization and market success.

The chapter begins with Action Design Research (ADR) Stage 1 of Sein et al. (2011) in Section 5.1, where the re-defined focus of NPDWise is proposed, tailored explicitly to suit the context of early-stage start-ups in the STeP program. This section includes an introduction to the DMADV (Define-Measure-Analyze-Design-Verify) methodology, clarifying the target users and design goals, and outlining the design requirements (DRs). Moving to ADR Stage 2, outlined in Section 5.2, the NPD process model is introduced. This model serves as a framework for comprehending the NPD process of early-stage start-ups in the STeP program, especially in the Define phase of the DMADV methodology. Section 5.3 presents the Measure phase of the DMADV methodology. The assessment sheet from Phase 1 was modified, enabling incubators and early-stage start-ups to evaluate the NPD capability across different stages and identify potential areas for improvement. Section 5.4 explains the visualizing result of using NPDWise to assess the NPD capability. Subsequently, in Section 5.5, an illustrative example of how NPDWise can be deployed to assess the NPD capabilities of a company is presented. The interview data of the company 2-A is provided, the NPD process is identified, and the NPD capability is assessed. Lastly, the summary of this chapter explains in Section 5.6.

5.1 Proposing New Research Focus

The need for enhancing NPD capability motivated the adoption of the DMADV methodology, incorporating Innovation Capability Maturity Model (ICMM) concept. This adaptation positions maturity level concept as an integral element of continuous improvement processes.

The DMADV methodology was selected to be a core of the method designed to assess NPD capability. DMADV, often used in the development of new products or processes, centers on aligning DRs with customer expectations requirements (Wang et al., 2016a). This methodology has been applied in various studies across different industrial projects, with variations in how the Define and Measure phases are executed, and the key metrics are assessed using specific techniques in various domains. For instance, Baptista et al. (2020), Mouaky et al. (2018), Wang et al. (2016a), and Huang et al. (2010).

- Baptista et al. (2020) implemented this framework to enhance components of air-conditioning systems for motor vehicles. In the Define and Measure phases, a prototype was developed using CAD software, and the project manager evaluated it based on quality, time, and cost considerations.
- Mouaky et al. (2018) utilized the framework to design a new inventory management system for the pharmaceutical supply chain. During the Define and Measure phases, questionnaires were employed to discern customer expectations regarding pharmaceutical features and to measure the importance of each feature, categorizing them as must-have or attractive features. Features included wait times for receiving treatment and safety.
- Wang et al. (2016a) adopted the framework to develop network devices for telephone exchanges. In the Define and Measure phases, Quality Function Deployment (QFD) was used to gauge the correlation between customer and DRs. The DRs focused on Critical-to-Quality (CTQ) factors such as waterproof and dustproof levels.
- Huang et al. (2010) applied the framework to improve the quality, reduce defects, and minimize the cost of surveillance cameras. During the Define and Measure phases, they measured CTQ factors, including solder joint quality and printed circuit board performance.

However, interviews conducted during Phase 1 revealed that the previously developed ICAT might not fully address the unique needs of early-stage start-ups. It was found that early-stage start-ups need an assessment tool that is easy and flexible to use, considering their limited resources, knowledge, and time to improve their capability. To bridge this gap, there is an opportunity to define NPD criteria, tailored to understand NPD process of the early-stage start-ups in Thailand during the Define phase. Subsequently, assessment sheet is introduced in the Measure phase of DMADV, to assess the NPD capabilities using maturity level system.

Therefore, NPDWise, encompassing the Define and Measure phases of DMADV methodology, was developed to comprehend the NPD process and assess NPD capability, with the overarching goal of facilitating the NPD, cultivating a culture of continuous improvement, and fostering technological innovation. The following sub-section outlines the new focus of the method, including the target users, the goals, and the design requirements.

5.1.1 Re-determining Target Users and Design Goal

The target users and design goal of NPDWise were re-defined, building upon the insights from ICAT in Phase 1. The comparison on the target users and goal between ICAT (Phase 1) and NPDWise (Phase 2) shows in Table 5.1.

Target users: NPDWise is specifically designed for incubators or any organization aiming to enhance the NPD capabilities of early-stage start-ups within their programs. This choice of target users is informed by a several rationales. First, this decision aligns with the findings from Sub-section 4.4.3 (Opportunity to Improve TIC). The study revealed that the studied cases did not perceive a need for self-assessment tools. Hence, the shift in target users from start-ups to incubators or other organizations seeking to understand and enhance the NPD capability of start-ups is a strategic move to offer more comprehensive support.

Moreover, as highlighted in Sub-section 4.4.2 (Opportunity to Improve the Mock-up), the mock-up of ICAT lacked clarity and specificity in its objectives, making it inadequate for assessing capability. Thus, NPDWise should be tailored to specific types and stages of businesses and provide more specific assessments for the users. Therefore, the method is intended to be used for assessing early-stage start-ups in the incubation program. This alignment with early-stage start-ups finds its foundation in the unique context of STeP, an incubator deeply committed to supporting student start-ups and alumni within the university. As the program comprises numerous ventures in their initial stages, STeP requires a mechanism to facilitate their growth and development, making these early-stage start-ups the target of this method’s user base.

Target goal: The method is expected to be an easy-to-use and useful tool for assessing NPD capability as part of the technological innovation capability (TIC) continuous improvement process. Addressing the opportunity for improvement noted in Section 4.4, it was evident that start-ups within the STeP program prioritized NPD over TIC development. Furthermore, while ICAT centers on assessing capability, insights from Phase 1 revealed that start-ups require a structured guideline for enhancing their NPD processes. Thus, the primary goal of this method has been modified to not only provide tailored NPD capability assessment but also encompass a structured guideline. This guideline supports early-stage start-ups in understanding their NPD processes, understanding their capabilities, highlighting their strengths and weaknesses, and facilitating the plan for process enhancement.

Table 5.1 The Re-determined Target Users and Design Goal for NPDWise

Version	ICAT (Phase1)	NPDWise (Phase2)
Target Users	(1) Companies that have already been stable in their existing market and would like to improve original products by adding technological innovation to explore new market (2) Startups in initial stage that want to create technological innovation and disrupt the market. The target users can be both business owners and department managers in such relate departments as NPD and marketing.	Incubators or any organization that need to understand and improve the NPD capability of early-stage start-up in the program.
Design Goal	to be an easy and useful tool that guides the users to assess their current capabilities and develop some priorities capabilities step-by-step.	To be an easy and useful tool to assess and improve NPD capability as part of TIC continuous improvement process.

5.1.2 Re-determining Design Requirements

The DRs of NPDWise were re-determined. The comparison on DRs between of ICAT (Phase 1) and NPDWise (Phase 2) shows in Table 5.2.

DR1: The method supports users to understand NPD capability of the early-stage start-up.

DR1 was modified based on the Phase 1 interviewees' feedback, indicating that the objectives and target users of the mock-up were not clear and specific. Therefore, for this method, DR1 needs to be more precise by emphasizing NPD capability and early-stage start-ups. Success in design will be evident when the target user group recognizes the tool's ability to showcase the extent of their NPD capability. A well-designed method will provide clear visualization of assessment results, covering wide range of NPD levels and accommodating users at various stages of NPD stage.

DR2: The NPD perspectives and criteria of the method are suitable for the situation of users.

DR2 was modified based on the findings from Phase 1, indicating that the perspectives and criteria in the mock-up were not applicable. The interviewees expressed the desire for the tool to include perspectives and criteria that are suitable for the situations and challenges they face when developing technological innovations, such as NPD and production and operation management. Therefore, NPDWise starts from Define stage, tailored to understand NPD process of different company. This DR is essential, emphasizing the necessity for the tool to possess relevant perspectives and criteria that align with the users' technological innovation development context. The design will achieve this requirement if the perspectives and criteria' relevance to their improvement needs. A well-designed method will incorporate perspectives and criteria that show significant to the users' situation.

DR3: The maturity levels of the method are suitable for the situation of users.

DR3 was added as the Phase 1 interviewees found the maturity levels of the ICAT mock-up to be irrelevant. Furthermore, when comparing the company profile with the self-assessment results, it was discovered that the results did not align with the company's stage or their actual performance. This indicates that the maturity levels of the mock-up were inappropriate for the users' situations. Therefore, it is necessary to re-define the maturity levels for the Measure phase. Success of design lies in the maturity levels being relevant to the users' context.

DR4: The method is easy to use.

DR4 of NPDWise emphasizes a principle carried over from DR3 of ICAT mock-up. The method should be easy to use. This originated from insight gained during Phase 1 mock-up testing that there were several confusing issues of the mock-up, such as an excessive number of assessment questions, overly detailed questions, a complicated rating system, and confusing language. To overcome these issues, DR4 accentuates the need for NPDWise to be user-friendly. The design will achieve this requirement if there is lack of confusion during use, and minimal resource and knowledge requirements.

DR5: The method creates awareness among early-stage start-ups about their NPD capability.

DR5 of ICA Method was modified from DR4 of ICAT. In Phase 1, the mock-up, which originally designed for self-assessment, revealed a realization that the users found the method challenging to use independently. This prompted a shift in the target users. NPDWise is now tailored for incubators or any organization seeking to understand the NPD capability of early-stage start-ups within the program. Despite this shift, the essence of the DR remained intact. NPDWise strives to ensure that early-stage start-ups, even if not the direct users, are aware of their NPD capability and facilitates their understanding of strengths and weaknesses. Success is evaluated by awareness of NPD continuous improvement.

DR5 of ICAT mock-up has been removed as the researcher aims for NPDWise to focus on assessing the capability rather than developing it. Nevertheless, the method can be used as part of DMADV and further advocate the users for analysing strengths and weaknesses (Analyze phase) and planning for improvement project for developing NPD (Design stage).

Table 5.2 The Re-determined DRs for NPDWise

Mock-up of ICAT (Phase1)	NPDWise (Phase2)
DR1: The tool supports users to understand their current TIC.	DR1: The method supports users to understand NPD capability of the early-stage start-up.
DR2: The TIC perspectives and criteria are suitable for the situation of users.	DR2: The NPD perspectives and criteria of the method are suitable for the situation of users.
	DR3: The maturity levels of the method are suitable for the situation of users.
DR3: The tool is easy to use.	DR4: The method is easy to use.
DR4: The tool is suitable for self-assessment.	DR5: The method creates awareness among early-stage start-ups about their NPD capability.
DR5: The tool guides users to develop TIC.	

5.2 The Overarching NPD Process Model

To assess NPD capability, it is essential to begin by understanding the current NPD process as Define phase of DMADV methodology. This section outlines the development of an overarching NPD process model, which serves as a foundational framework for NPDWise. The objective is to create a model that aligns with the NPD process in the literature, while addressing the specific needs of early-stage start-ups in the STeP program.

5.2.1 Aligning with Existing NPD Process Models

To meet DR2 (ensuring that the NPD perspectives and criteria of the tool are suitable for the situation of users), the overarching NPD process model was developed by aligning it with the NPD process models described in Section 2.4.1 of the literature, as well as considering the improvement opportunity identified in Phase 1. From Section 2.4.1, it can be observed that existing models have different starting and ending points for the NPD process and integrate three different aspects. For example, some models start with recognizing customer needs (Andreasen and Hein, 2000; Cagan et al., 2002; Cooper, R.G., 1990), while others begin with concept development (Wheelwright and Clark, 1992). Some models end at product launch (Andreasen and Hein, 2000; Cooper, R.G., 1990; Ulrich and Eppinger, 2016; Unger and Eppinger, 2011; Wheelwright and Clark, 1992), while others conclude at program approval (Cagan et al., 2002). Additionally, during the Phase 1 interviews, challenges related to identifying customer needs and accessing customers were reported in several cases. As a result, the overarching NPD process model was designed to start at “Opportunity recognition” and end at “Market introduction.” Overall, the process model consists of six stages as details following:

1) **Opportunity Recognition:** Opportunity recognition is the initial phase in the NPD process, where companies identify market opportunities and emerging technologies.
2) **Concept Development:** Concept development is the stage where companies work to refine and formalize ideas generated during the opportunity recognition phase.
3) **Early System Design:** In the early system design stage, companies begin to structure their product concepts further.
4) **Detail Design:** Detail design is where the early system design is translated into a detailed design plan.

5) **Commercial Preparation:** Commercial preparation is the stage in which companies prepare for the product's market rollout.
6) **Market Introduction:** Market introduction is the final phase in NPD, where the product is launched and introduced to the market.

5.2.2 Integrating Stage-gate

The stage-gate concept was incorporated, aligning it with the key stages defined in the NPD process. This approach draws inspiration from the work of Cooper, R.G. (1990), a pioneer in the field of NPD, who emphasized the importance of clear decision points throughout the innovation process. The stage-gate concept is a widely recognized framework that helps ensure that key decision points are clearly defined. It is important to note that Unger and Eppinger (2011) have highlighted a limitation of the stage-gate approach in terms of flexibility. This makes it more suitable for companies with stable product definitions and well-understood technologies. However, in dynamic markets, the stage-gate process may lack the flexibility. To address this, the stage-gate within NPDWise incorporates easy criteria, making it more adaptable for early-stage start-ups. The key stages and objectives set, explaining what needs to be achieved in each stage to move forward, are explained as Table 5.3.

Table 5.3 Stages and Objectives of NPD Process Model

NPD Stage	Objective
Opportunity Recognition	Identify and define promising market opportunities
Concept Development	Develop a viable product concept
Early System Design	Develop an early system prototype and production scheme
Detail Design	Develop product detail design, implement design changes, and define quality
Commercial Preparation	Prepare for market rollout, test pilot units, and build pilot units
Market Introduction	Successfully sell and promote the product, interact with customers, evaluate field experience with the product, and begin full operation of the production system

The details of stage-gate were set as follows:

Criteria for Advancement: The criteria for advancement to pass through each gate is to reach at least Level 1 (Unstructured Plan and Do) in NPDWise's maturity levels. The details on maturity level will be explain in Section 5.3.1 (Defining Maturity Levels for Assessing NPD Capability). This choice recognizes the developmental stage of early start-ups, acknowledging that they might not initially have highly structured plans. It signifies that they are actively engaged in the NPD process, even if the planning is not yet well-structured. This allows the start-ups to enhance their capabilities over time.

Gatekeepers and Decision-Makers: In our context, the gatekeepers are the incubators who oversee the development of early-stage start-ups within their programs. Their role is to assess the NPD capability of these start-ups and make informed decisions regarding advancement through the stages.

Documentation: As NPDWise is designed to be user-friendly and easy to use for early-stage start-ups, the extensive documentation is not required. This allows the companies to preserve their valuable resources while benefiting from structured guidance.

5.2.3 Integrating Key Aspects: Design, Market, and Production

The NPD process models described in the literature incorporate three major viewpoints: product, market, and production. For instance, the model by Andreasen and Hein (2000) encompasses product, market, and production aspects, while Ulrich and Eppinger (2016) integrates design, marketing, and manufacturing aspects. To meet DR2 (ensuring that the NPD perspectives and criteria of the tool are suitable for the users' situation), the proposed TIC perspectives of SMEs and start-ups in STeP, as presented in Section 4.4.3, were adopted. The three aspects considered are design, market, and production.

Design: The design aspect relates to product architecture and new technology (Ulrich and Eppinger, 2016).

Market: The market aspect relates to product concepts based on marketing criteria (Andreasen and Hein, 2000; Cagan et al., 2002; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992).

Production: The production aspect relates to production and supply chain systems (Andreasen and Hein, 2000; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992). Furthermore, since many of the studied cases in this research focused on software products, the term “Production” in this research also refers to the process of creating and delivering the final version of the software product.

5.2.4 Simplifying the NPD Process

Existing NPD process models in the literature consist of various NPD activities. For example, Ulrich and Eppinger (2016)’s model includes 10 activities in the market aspect, 18 activities in the design aspect, and 16 activities in the production aspect, totaling 44 activities. To meet DR4 (ensuring that the tool is easy to use for assessing NPD capability), the overarching NPD process should be simplified to include fewer activities, making it easier for users to assess and develop their NPD capability. To create a model suitable for early-stage start-ups in the STeP program, the resulting overarching NPD process model consists of 24 activities, details show in Table 5.4. The overarching process model is shown in Figure 5.1.

Table 5.4 NPD Activities and the Definitions

NPD Stage	NPD Aspect	NPD Activity	Activity Explanation
Opportunity recognition	Market	Articulate market opportunity	This activity involves clearly defining a potential market opportunity that aligns with a company's strategic objectives and identifies specific gaps or needs in the market.
	Design	Assess new technologies	In this activity, companies evaluate emerging technologies to determine their relevance and potential application in product development.
Concept Development	Market	Identify lead user	Identifying lead users refers to recognizing individuals or groups who are early adopters of innovative products and who face challenges or needs that could be addressed by NPD.
		Collect customer needs	Collecting customer needs involves systematically gathering information on what potential users require in terms of product features, performance, and functionality. It is essential for tailoring products to meet customer demands effectively.
	Design	Determine product type	This activity entails deciding the specific type or category of product or service that will address identified market needs and customer requirements.
		Investigate concept feasibility	Companies explore the feasibility of potential product concepts, evaluating their technical and market viability before moving forward with development.
	Production	Propose process concept	Proposing a process concept involves outlining the production processes required. It includes defining how the product will be manufactured or the software product will be created and delivered.

Table 5.4 NPD Activities and the Definitions (Cont.)

NPD Stage	NPD Aspect	NPD Activity	Activity Explanation
Early System Design	Market	Conduct customer tests of early system design	This activity focuses on early user testing of system designs to validate their effectiveness in meeting customer needs and expectations.
	Design	Develop early system prototype	Companies create early prototypes to provide a tangible representation of the early system design, allowing for practical testing and validation.
	Production	Determine production scheme	Determination of the production scheme involves planning and defining the production processes necessary for the manufacturing of the product or defining the software used for creating of the software product.
		Identify manufacturers and suppliers	This activity entails identifying and establishing relationships with manufacturers, suppliers, software houses who will contribute to the production and distribution of the product.

Table 5.4 NPD Activities and the Definitions (Cont.)

NPD Stage	NPD Aspect	NPD Activity	Activity Explanation
Detail Design	Market	Develop market rollout plan	Companies create a comprehensive plan for launching the product into the market. This plan outlines the strategies and activities required for a successful market introduction.
		Conduct customer tests of detail design	This activity focuses on testing the detailed product design with customers to ensure it aligns with their preferences and needs.
	Design	Develop product detail design	This involves creating a highly detailed product design that incorporates all technical specifications and requirements necessary for production.
		Implement design changes	In this activity, companies make necessary adjustments to the product design based on feedback from testing and evaluation.
	Production	Do process detail design	Companies develop detailed plans for the manufacturing processes or software developing processes.
		Define quality assurance processes	This activity involves establishing processes and protocols for ensuring the quality of the product during manufacturing or software creating and delivering.

Table 5.4 NPD Activities and the Definitions (Cont.)

NPD Stage	NPD Aspect	NPD Activity	Activity Explanation
Commercial Preparation	Market	Prepare for market rollout	Companies prepare all the necessary resources, materials, and strategies for the successful launch of the product.
	Design	Test pilot units	This activity involves testing a small number of pilot units to identify and address any production or performance issues before full-scale production.
	Production	Build pilot units	Companies create a limited number of pilot units that closely resemble the final product. These are used for testing and validation purposes.
Market Introduction	Market	Sell and promote	This includes activities related to marketing and selling the product, such as advertising, promotion, and distribution.
		Interact with customers	Engaging with customers to gather feedback, address concerns, and provide support for the product.
	Design	Evaluate field experience with product	Companies assess the real-world performance and reception of the product, considering feedback and experiences from customers in the field.
	Production	Begin full operation of production system	This marks the transition to full-scale production and operation of the product, where all production systems are fully engaged and operational.

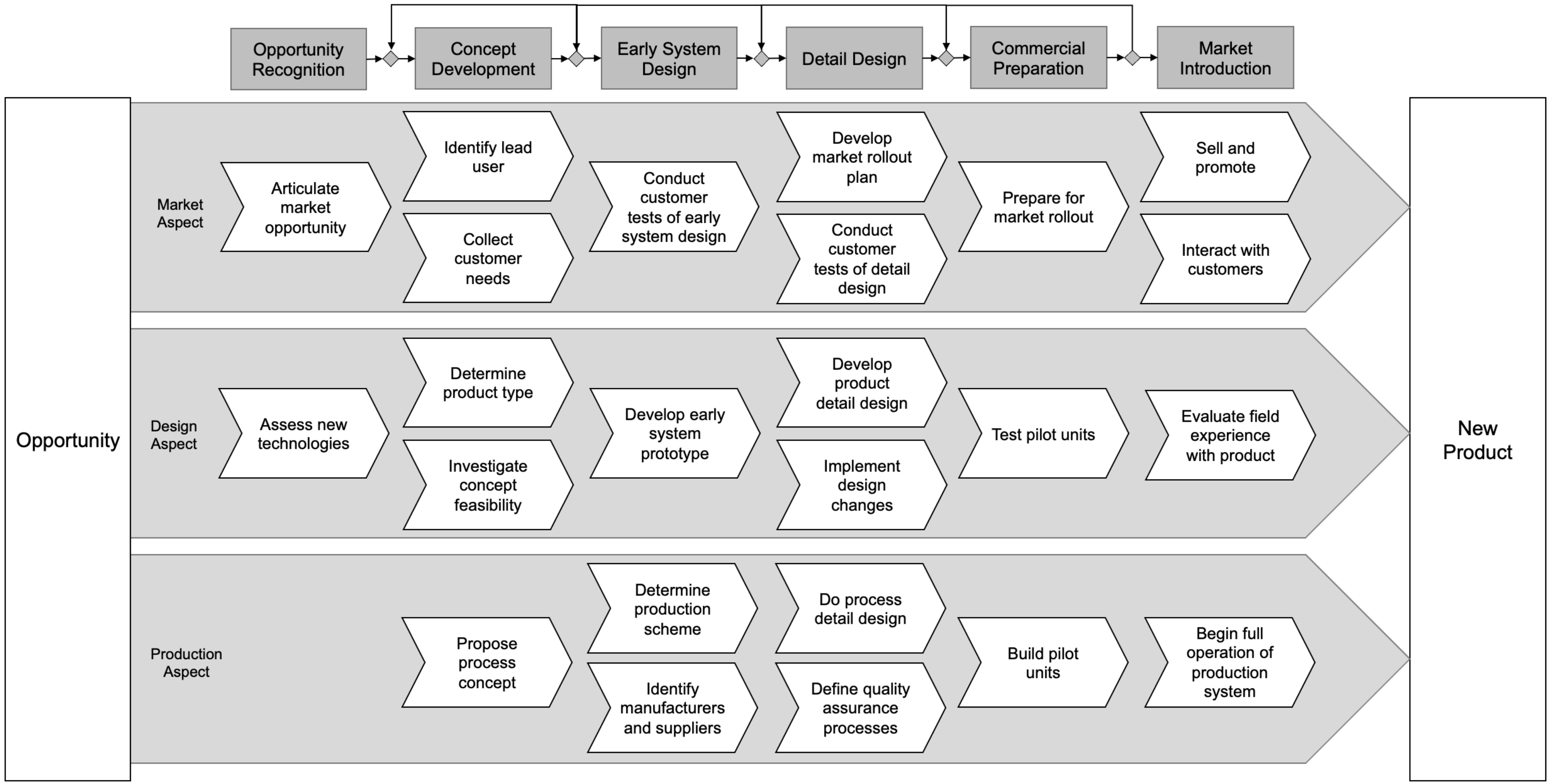


Figure 5.1 Overarching NPD Process Model

5.3 Assessing NPD Capability

This section delves into the heart of NPDWise, specifically focusing on the Measure phase of DMADV methodology. This phase is a pivotal component of the structured method, intended to evaluate the NPD capabilities of early-stage start-ups within the STeP program and empower them with the insights needed to understand and enhance their NPD processes.

5.3.1 Defining Maturity Levels for Assessing NPD Capability

One of the foundational elements in our NPDWise is the concept of maturity levels. These levels are a metric for evaluating the performance of companies in their NPD activities. The maturity levels in NPDWise were tailored to match the specific needs and challenges faced by Thai start-ups and SMEs within the STeP program to meet DR3 (ensuring that the maturity levels of the tool are suitable for the users' situation).

According to the finding in Phase 1, the initial assessment results using existing maturity levels did not accurately reflect the reality of NPD capability among Thai SMEs and start-ups in the STeP program. Therefore, the new maturity levels were proposed to meet the realities that the companies face. These new levels draw inspiration from two key concepts: Innovation Capability Maturity Levels (ICMM) and Plan-Do-Check-Action (PDCA). The incorporation of the PDCA concept was guided by insights from the interviews in Phase 1 (Explained in Section 4.4.4). These interviews revealed that effective planning should precede action in NPD processes. Notably, this stands in contrast to the initial design of the ICAT mock-up in Phase 1, which began with the “doing” phase while “defining the plan” was in Level 3. The revision aligns NPDWise with well-established frameworks, such as PDCA, where planning is an initiation of action. This redefinition allows for a more accurate assessment of NPD capability within the unique context of early-stage start-ups associated with STeP. Figure 5.2 illustrates the maturity levels used in this assessment stage.

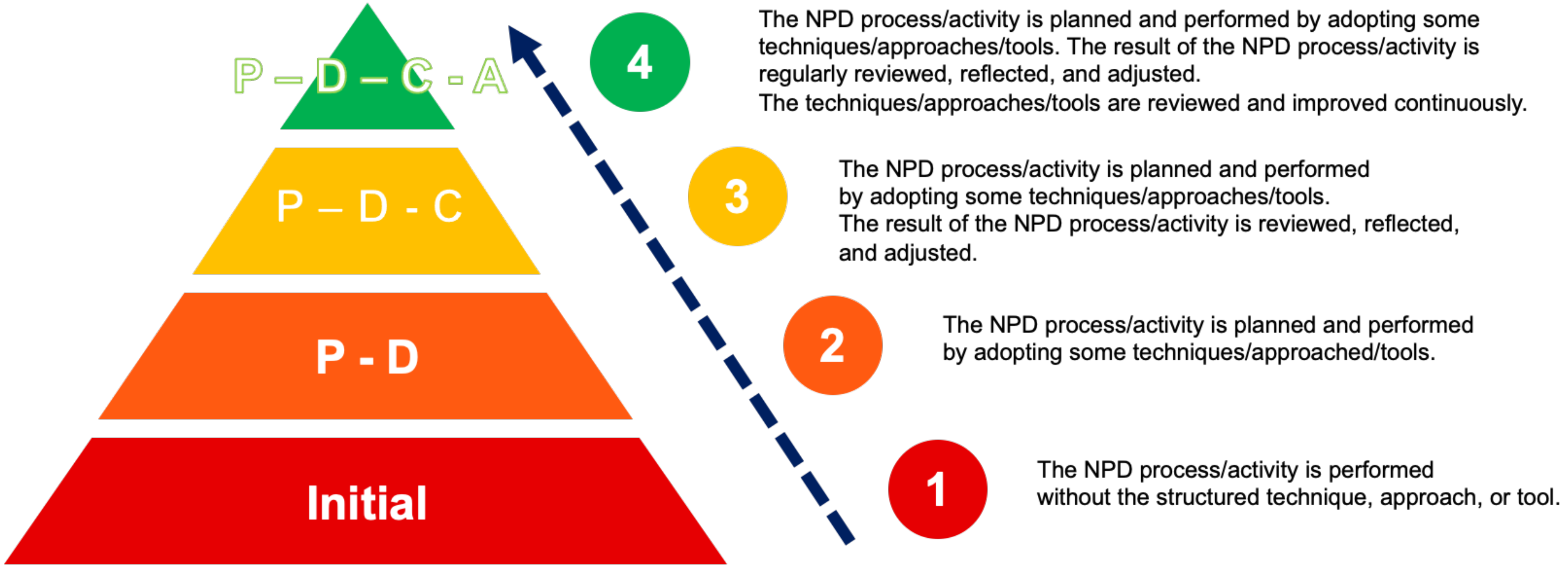


Figure 5.2 Maturity Levels to Measure the NPD Process and Activity

- **Level 1 – Initial (Unstructured Plan and Do):** The NPD process or activity is performed without a structured technique, approach, or tool.
- **Level 2 – Plan and Do:** The NPD process or activity is planned and performed by adopting some techniques, approaches, or tools.
- **Level 3 – Plan, Do, and Check:** The NPD process or activity is planned and performed by adopting some techniques, approaches, or tools. The results of the NPD process or activity are reviewed, reflected upon, and adjusted.
- **Level 4 – Plan, Do, Check, and Action:** The NPD process or activity is planned and performed by adopting some techniques, approaches, or tools. The results of the NPD process or activity are regularly reviewed, reflected upon, and adjusted. The techniques, approaches, or tools are continuously reviewed and improved based on feedback and reflection.

5.3.2 An Assessment Sheet

In this sub-section, ICAT from Phase 1 serves as the foundation to modify an assessment sheet of NPDWise. Six NPD stages and 24 activities determined in Section 5.2 are the key metrics for evaluating NPD capabilities. These stages and activities serve as guidelines for gathering relevant data or conducting open-ended question interviews to gain insights into how companies develop new products.

After the interview, the NPD process of each company is comprehended, adopting the overarching process. The interview data is then used to populate the key metrics assessment sheet, as shown in Table 5.5, and the maturity levels are used to grade the NPD stages. This enables understanding the current NPD capability and meet DR1 (The tool supports users to understand NPD capability of the early-stage start-up).

Table 5.5 Assessment Sheet of NPDWise

NPD Stage	Aspect	Does the organization …..(Activity)…..?		If yes to the previous question, continue to these questions.			Level
		Activity	Response (Yes/No)	Is the activity performed upon structured plan?	Is result of the activity regularly reviewed?	Is the activity improved according to the reflection?	
Opportunity recognition	Market	Articulate market opportunity					
	Design	Assess new technology					
Concept development	Market	Identify lead user					
		Collect customer needs					
	Design	Determine product type					
		Investigate concept feasibility					
	Production	Propose process concept					
Early system design	Market	Conduct customer tests of early system design					
	Design	Develop early system prototype					
	Production	Determine production scheme					
		Identify manufacturers and suppliers					
Detail design	Market	Develop market rollout plan					
		Conduct customer tests of detail design					
	Design	Develop product detail design					
		Implement design changes					
	Production	Do process detail design					
		Define quality assurance processes					
Commercial preparation	Market	Prepare for market rollout					
	Design	Test pilot units					
	Production	Build pilot units					
Market introduction	Market	Sell and promote					
	Design	Interact with customers					
	Production	Evaluate field experience with product					
		Begin full operation of production system					

5.4 Visualizing NPD Capability Levels

The NPD process model was outlined in Section 5.2 and the maturity level and assessment sheet was modified from Phase 1 ICAT in Section 5.3. This section delves into enhancing the usability of the NPDWise by introducing a visual representation of NPD capability levels within the NPD process.

One of the objectives of the NPDWise is to create awareness among early-stage start-ups about their NPD capability and facilitate their understanding of strengths and areas where improvement is required. To meet DR5, a colour visualization system is introduced to signify NPD capability levels within the NPD process.

- **Level 1 – Initial (Unstructured Plan and Do)**: Represented by the colour red.
- **Level 2 – Plan and Do**: Represented by the colour orange.
- **Level 3 – Plan, Do, and Check**: Represented by the colour yellow.
- **Level 4 – Plan, Do, Check, and Action**: Represented by the colour green.

Notably, Activities or stages not performed or not mentioned during the interview will be illustrated by the colour grey.

The implementation of this colour visualization aims to offer an intuitive presentation of NPD capability levels within the NPD process. This provides early-stage start-ups with a comprehension of stages or activities that operate at different capability levels, thereby creating a more user-friendly and actionable tool. Figure 5.3 provides an illustrative example of colour visualization. The example will demonstrate how the NPD process of an early-stage start-up is visualized with different colours, indicating various capability levels for each NPD activity and emphasizing the areas requiring attention and improvement.

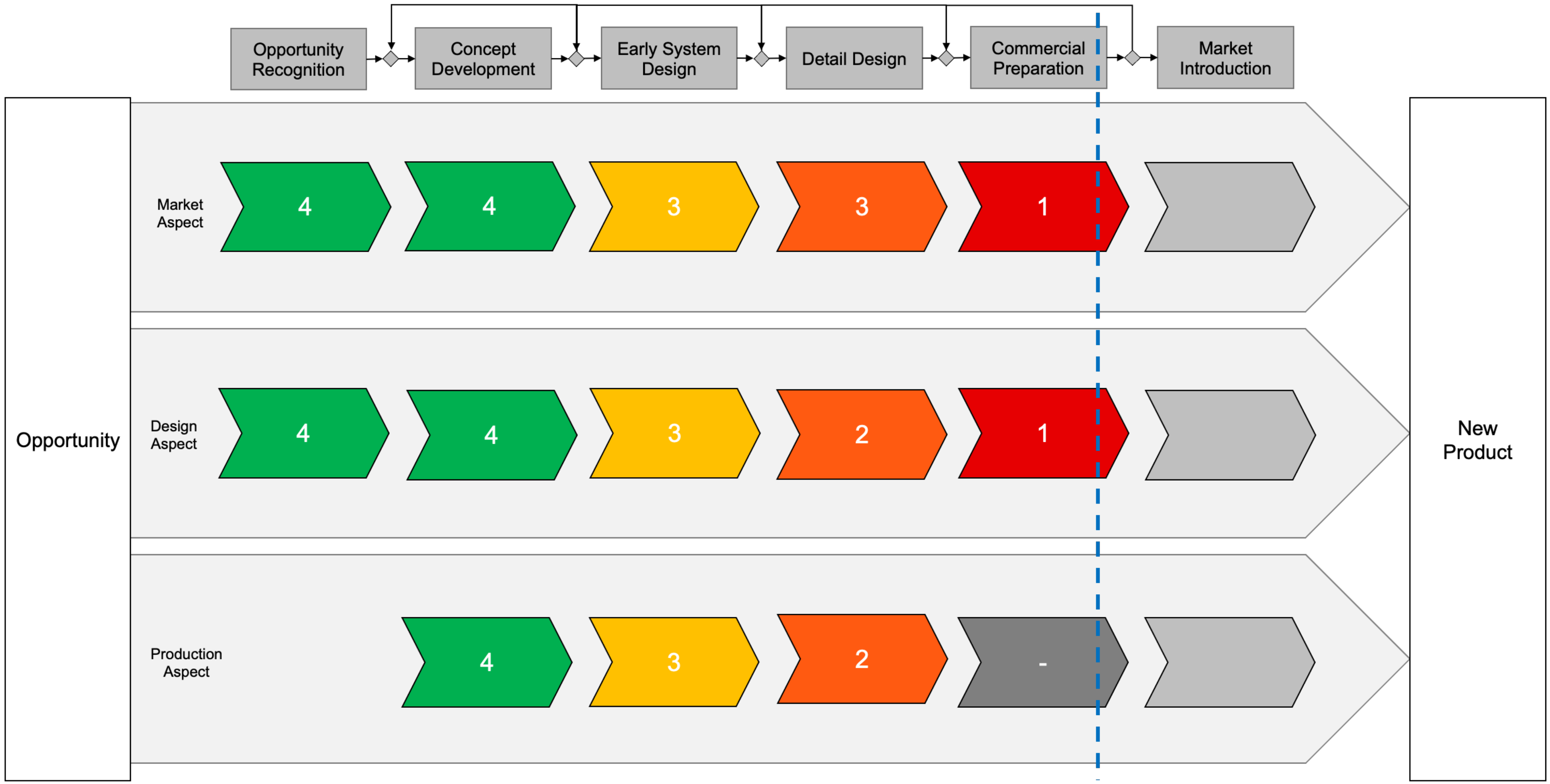


Figure 5.3 Example of Colour Visualization of Assessment Result Using NPDWise

It can be seen that the distinct colours represent the NPD capability levels associated with each aspect. For instance, in the ‘Opportunity Recognition’ and ‘Concept Development’ stages, the entire process is depicted in green, signifying that the company achieved level 4 in every aspect. However, in the ‘System Design’ stage, the colour changes to orange, reflecting a level 3 capability in each aspect. Moving on to the ‘Detail Design’ stage, the colour shifts to yellow, indicating a level 2 capability in all aspects. In the ‘Commercial Preparation’ stage, the colour visualization exhibits red for market and design aspects. This red shade conveys that the company attained only level 1 in these two aspects. Additionally, the production aspect is shown in grey, which signifies that the company did not perform this specific aspect of NPD. In addition, there is also a blue dashed line between the ‘Commercial Preparation’ stage and the ‘Market Introduction’ stage. This line serves as a visual indicator that the company is currently in the ‘Commercial Preparation’ stage and has not yet progressed through the stage-gate to the ‘Market Introduction’ stage.

5.5 Example of Using NPDWise

This section provides an illustrative example of how to use NPDWise to assess the NPD capability of Company 2-A. An interview was conducted with the founder of Company 2-A. The transcript is included in Appendix F. The company’s product is a platform that connects students studying automotive vocational courses with part-time job opportunities at garage owners. The platform offers students the chance to gain on-the-job training experience and earn income while still studying. Additionally, students receive a certificate that can enhance their job prospects with larger organizations. Garage owners benefit from access to flexible and affordable labor, as well as the opportunity to train and evaluate potential future employees. Company 2-A is currently in Camp 1 at STeP Basecamp24. The team started generating ideas and developing the concept while they were students at Chiang Mai University. After graduation, the company was registered, and the platform has been developed. The team consists of the interviewee and six friends who graduated from education, business administration, and computer engineering.

5.5.1 How Company Develops New Product

Based on the open-ended question interview, the process of how Company 2-A develops new products can be summarized as follows:

During the interviewee's time as a student at Chiang Mai University, she was passionate about supporting the environment and the community. She participated in hackathons and formed teams to develop several platforms related to environmental support. However, the team faced challenges such as high costs, funding issues, and limited market opportunities, which led to failures and the decision to abandon those products. Reflecting on this experience, the interviewee stated,

> *"This experience underscored the profound impact of education in nurturing individuals from a young age. Unlike environmental efforts, education has a lasting impact on societal attitudes. We also recognized the potential to incorporate environmental awareness into educational initiatives over time."*

Consequently, the team decided to develop a product focusing on education, leveraging the expertise of one of the co-founders who graduated from the Faculty of Education, had experience working with vocational students, and identified opportunities to facilitate their skills development.

During the planning stage, the team identified garages as the target customer and students as the supply. They conducted surveys and interviews with teachers from technical and polytechnic colleges, as well as garage owners, to understand the pain points in the industry. The team also conducted market testing by contacting garages and assessing their interest in hiring part-time students.

> *"We conducted surveys with teachers from technical and polytechnical colleges to gather insights on pain points for both garages and students. They recommended alumni who owned garages. We visited these garages to understand their hiring practices and pain points, such as technician absenteeism and lateness. We also obtained a list of garages from a magazine and contacted them directly to gauge interest in hiring part-time students. Additionally, colleges provided internship information to identify potential garage partners."*

Interviews and Google forms were used to collect data from students, enabling market validation and understanding of their needs. Findings revealed that approximately 80% of students were engaged in part-time jobs in the hospitality industry, which were unrelated to their studies but offered higher earnings. However, some students expressed their desire to work in garages to improve their skills.

> *"One student told us that he works at garage at 8:00 – 19:00 earning 150 THB, and works at the restaurant at 23:00 – 4:00 earning 500-1500 THB. However, he still wants to work at the garage because he wants to improve his skill."*

After extensive research to comprehend the challenges faced by vocational students and the job market, the company designed a platform to connect students with relevant job opportunities. Initially, the platform was launched on Facebook at the end of March 2022 to post new job opportunities. Students registered and filled out a Google form, which was used to create a resume showcasing their work experience and preferences. The team manually selected students to work with garage owners. Currently, the website is still under development and has not yet been tested with students.

> *“They fill out a Google form, which serves as their resume, detailing their past and intended work. We then forward these resumes to garage owners. At this early stage, we are managing all operations manually.*
>
> *We advertise job opportunities through Facebook groups, allowing students to apply for roles that suit their schedules and interests. This approach empowers students to choose jobs aligned with their expertise, avoiding mismatches common in automotive roles, such as painting or suspension work.”*

The company's current business model focuses on building a robust base and reputation by expanding the platform through word of mouth. Although the revenue model is not explicitly stated, the company plans to introduce a subscription model for garage owners and offer courses to students for skills development. They also aim to expand the platform to include other technicians, such as electrical technicians, and venture into other industries, such as food and travel. Eventually, the goal is to automate the matching process through their website. Overall, the company’s NPD process is at the early system design stage. The NPD process diagram, adopted from the overarching process, is shown in Figure 5.4.

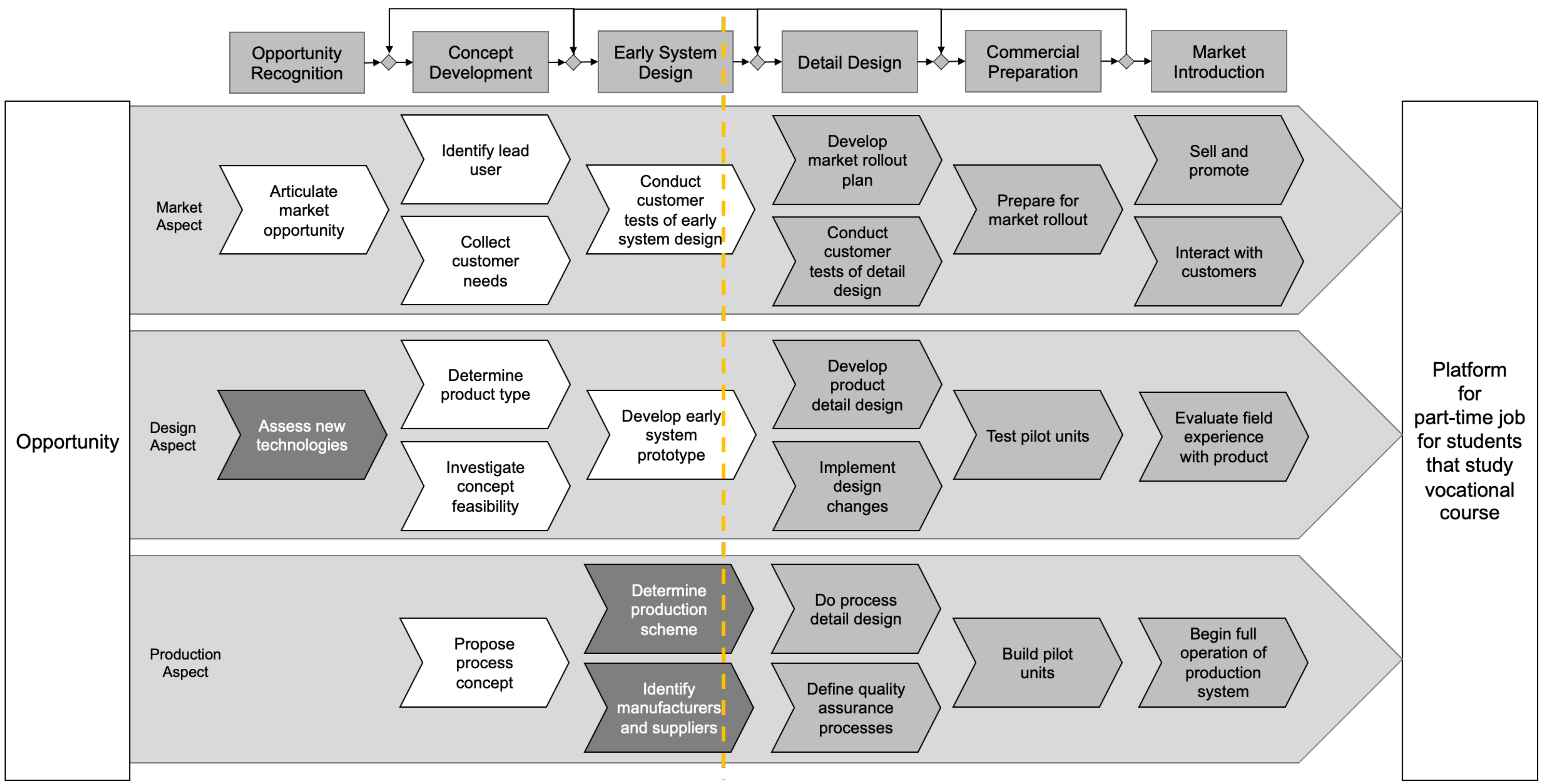


Figure 5.4 Diagram of NPD Process of Company 2-A

5.5.2 Assessing the Key Metrics

Based on the interview data, the key metrics of Opportunity recognition, Concept development, and Early system design are assessed in detail. The assessments are as follows:

1) Opportunity recognition

The interviewee mentioned actively searching for opportunities, engaging with customers and stakeholders, and gathering information to validate the potential of the opportunity. Previously, the interviewee worked on a platform related to the environment but shifted their focus to education after realizing the impact education can have on people. They believe that education has a greater influence in changing people's behavior and can serve as a foundation for addressing environmental issues in the future. It can be assumed that the company articulated the market opportunity; however, the activity was not performed according to a structured plan. Therefore, it can be summarized that the company's market aspect in opportunity recognition stage is at Level 1 (Initial). Next, the design aspect of this key metric, the founder did not mention assessing new technology. So, it cannot be summarized in which level the company's design aspect in opportunity recognition stage is. The sheet showing the measurement of the key metrics is shown in Table 5.6.

Table 5.6 Assessing Opportunity Recognition Key Metric of Company 2-A

NPD Stage	Aspect	Does the organization …..(Activity).....?		If yes to the previous question, continue to these questions.			Level
		Activity	Response (Yes/No)	Is the activity performed upon structured plan?	Is result of the activity regularly reviewed?	Is the activity improved according to the reflection?	
Opportunity recognition	Market	Articulate market opportunity	Yes	No	-	-	1
	Design	Assess new technology	No	-	-	-	-

2) Concept development

The interviewee mentioned developing concepts, planning user experience (UX) and user interface (UI) design, conducting market research to gather feedback on the proposed ideas, and investigating the feasibility of the concepts. However, the company faced several challenges during concept development, such as gaining the trust and participation of both students and garage owners. The company overcame these challenges by building strong relationships and providing support to the students. It can be summarized that there are activities in both the market aspect and design aspect, and those activities were planned and performed according to a structured plan. The company's market aspect and design aspect in concept development stage are at Level 2 (Plan and Do). On the other hand, for the production aspect, the founder mentioned using an in-house software developer but did not provide further details. It can be assumed that the company did not perform the production aspect according to a structured plan. Therefore, the company's production aspect in concept development stage is at Level 1 (Initial). The sheet showing the measurement of the key metrics is shown in Table 5.7

Table 5.7 Assessing Concept Development Key Metric of Company 2-A

NPD Stage	Aspect	Does the organization …..(Activity)…..?		If yes to the previous question, continue to these questions.			Level
		Activity	**Response** (Yes/No)	**Is the activity performed upon structured plan?**	**Is result of the activity regularly reviewed?**	**Is the activity improved according to the reflection?**	
Concept development	Market	Identify lead user	Yes	Yes	No	-	2
		Collect customer needs	Yes	Yes	No	-	
	Design	Determine product type	Yes	Yes	No	-	2
		Investigate concept feasibility	Yes	Yes	No	-	
	Production	Propose process concept	Yes	No	-	-	1

3) Early system design

After planning UX and UI and designing how the product will be, the interviewee emphasized executing the design plan, creating system architecture, developing early versions of the product or service, and making necessary adjustments based on user evaluations. The interviewee discussed the challenge of ensuring that the platform was user-friendly for students and garage owners. The company addressed this challenge by conducting user testing and collecting feedback to improve the platform's design and functionality. For example, the initial prototype involved sending student resumes to garage owners for their review and selection. However, the company learned that garage owners did not have time to perform the selection themselves, leading the company to select students and send them to the garage owners. It can be summarized that the activities in the market aspect and design aspect of this stage were planned and partially implemented. Both aspects in early system design stage are at Level 2 (Plan and Do). However, the interviewee did not mention the production aspect. As a result, the company's production aspect in early system design stage cannot be graded. The sheet showing the measurement of the key metrics is shown in Table 5.8.

Table 5.8 Assessing Early System Design Key Metric of Company 2-A

NPD Stage	Aspect	Does the organization .....(Activity).....?		If yes to the previous question, continue to these questions.			Level
		Activity	Response (Yes/No)	Is the activity performed upon structured plan?	Is result of the activity regularly reviewed?	Is the activity improved according to the reflection?	
Early system design	Market	Conduct customer tests of early system design	Yes	Yes	No	-	2
	Design	Develop early system prototype	Yes	Yes	No	-	2
	Production	Determine production scheme	No	-	-	-	-
		Identify manufacturers and suppliers	No	-	-	-	

The overall key metric assessment of Company 2-A using ICAT shows in Table 5.9.

Table 5.9 Assessing Key Metric of Company 2-A using Assessment Sheet of NPDWise

NPD Stage	Aspect	Does the organization …..(Activity)…..?		If yes to the first question, continue to these questions.			Level
		Activity	**Response** (Yes/No)	**Is the activity performed upon structured plan?**	**Is result of the activity regularly reviewed?**	**Is the activity improved according to the reflection?**	
Opportunity recognition	Market	Articulate market opportunity	Yes	No	-	-	1
	Design	Assess new technology	No	-	-	-	-
Concept development	Market	Identify lead user	Yes	Yes	No	-	2
		Collect customer needs	Yes	Yes	No	-	
	Design	Determine product type	Yes	Yes	No	-	2
		Investigate concept feasibility	Yes	Yes	No	-	
	Production	Propose process concept	Yes	No	-	-	1
Early system design	Market	Conduct customer tests of early system design	Yes	Yes	No	-	2
	Design	Develop early system prototype	Yes	Yes	No	-	2
	Production	Determine production scheme	No	-	-	-	-
		Identify manufacturers and suppliers	No	-	-	-	

5.5.3 Visualizing the Result

This section provides a practical example of how the colour visualization approach is applied within the NPDWise. It will illustrate how the NPD process of Company 2-A is visualized using different colours, indicating various capability levels for each NPD stage and activity. Figure 5.5 represents the visual representation of Company 2-A's NPD process, coloured to depict different NPD capability levels.

1) Opportunity Recognition

Market Aspect (Red): Company 2-A received a Level 1 rating in the market aspect, represented by the colour red in the visual representation. This signifies an initial, unstructured approach in this particular stage.

Design Aspect (Grey): The design aspect in the opportunity recognition stage is represented in grey, indicating that the interviewee did not mention activities related to assessing technology.

2) Concept Development

Market Aspect (Orange): In this stage, Company 2-A demonstrated a Level 2 capability in the market aspect, signified by the orange colour. This suggests a structured approach to product concept development.

Design Aspect (Orange): Similar to the market aspect, the design aspect also shows Level 2 capability, coloured orange, indicating a more organized approach to product design.

Production Aspect (Yellow): The production aspect, however, received a Level 1 rating, represented by the colour yellow, indicating room for improvement in this area.

3) Early System Design

Market Aspect (Orange): Company 2-A exhibited a Level 2 capability in the market aspect during early system design, depicted in orange.

Design Aspect (Orange): Like the market aspect, the design aspect also shows Level 2 capability, coloured orange, suggesting a structured approach to design.

Production Aspect (Grey): In this stage, the interviewee did not mention activities related to the production aspect, which is indicated by grey

For the remaining three NPD stages, Company 2-A did not perform these activities, represented by dark grey space in the visualization.

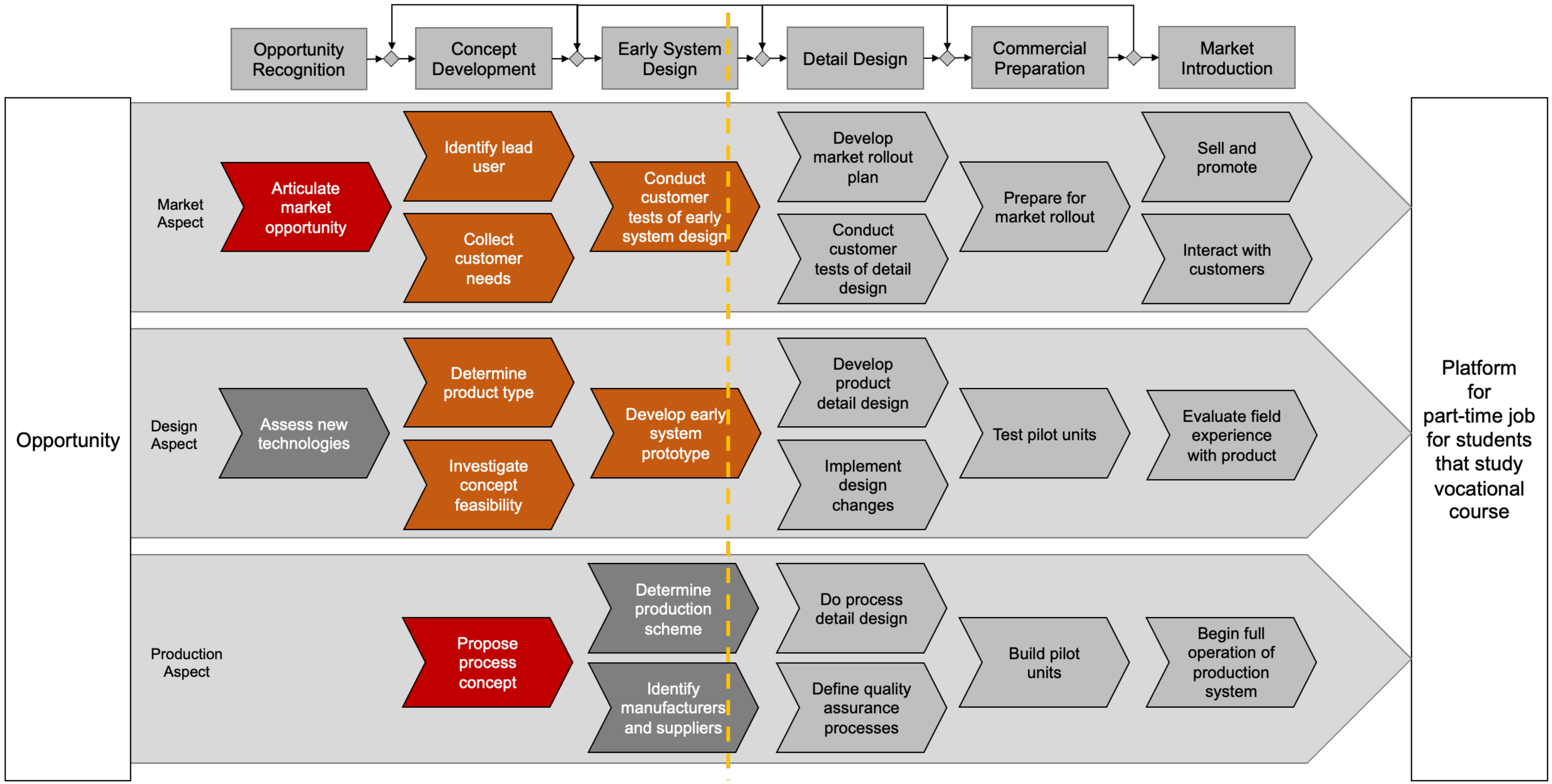


Figure 5.5 Virtualization of Assessment Result of Company 2-A

5.6 Summary

NPDWise was designed for the assessment of NPD capability in early-stage start-ups participating in incubation programs. The development of the method was catalyzed by the insights gained from the mock-up of ICAT during Phase 1. The DRs were formulated based on these opportunities and tailored to address the unique challenges faced by early-stage start-ups in the STeP program, which was the concern on NPD. The design requirements were modified to: DR1 emphasized on understanding NPD capability, DR2 underlined the alignment of perspectives and criteria with users' situation, DR3 prompted a redefinition of maturity levels, DR4 placed importance on the easiness of the tool, and DR5 shifted the tool's emphasis towards promoting user awareness. The subsequent development of NPDWise was centred on these DRs.

NPDWise serves as a Define and Measure Stages as part of the continuous improvement framework of DMADV. As the study recognized that DMADV framework has been applied in many studies, where key metrics have been evaluated using specific techniques. In contrast, the insights gained from interviews conducted during Phase 1 revealed a critical aspect. Early-stage start-ups, characterized by their limited resources, knowledge, and time constraints, need an assessment method that is not only user-friendly but also flexible. Recognizing this challenge, an opportunity emerged to leverage the NPDWise as part of the DMADV framework.

The method begins by understanding the current NPD process and developing the NPD process model of the company (Define phase). Following this, the method employs a maturity level system to assess NPD capability (Measure phase), inspired by Innovation Capability Maturity Model (ICMM) and Plan-Do-Check-Action (PDCA) cycle. These maturity levels encompass: Level 1 (Initial – Unstructured Plan and Do), Level 2 (Plan and Do), Level 3 (Plan, Do, and Check), and Level 4 (Plan, Do, Check, and Act).

Overall, this chapter has laid the foundation for assessing NPD capability in early-stage start-ups within the STeP program. The subsequent chapter will showcase the implementation of the NPDWise in the case study.

Chapter 6 Application of NPDWise to the Case Study

In the previous chapter, NPDWise, a framework designed to assess new product development (NPD) capability in early-stage start-ups within Science and Technology Park, Chiang Mai University (STeP) program, was introduced. Building upon the framework and insights established in the previous chapter, this chapter demonstrates the application of the method to the case study to represent an evaluation part of Action Design Research (ADR) stage 2 of Sein et al. (2011). By analyzing the data obtained from the case study, the chapter provides practical insights and recommendations to improve NPD capability within the STeP program.

This section provides a project overview, adopting NPDWise and illustrating how the Define and Measure phases of the DMADV (Define-Measure-Analyze-Design-Verify) process are applied to select case studies. The overarching goal of this application project is to enhance the success possibility of the NPD for early-stage start-ups within the STeP program. The aspiration is to understand the existing NPD process of the participating cases, assess the existing NPD capability, determine which elements of the NPD are closely linked to success, and propose improvement opportunities that STeP can implement to support these early-stage start-ups effectively. The project goal and scopes were outlined as Table 6.1. It is important to note that the case studies in this chapter were not taken through the complete DMADV process due to time constraints. However, they served as representative examples to illustrate the application of NPDWise.

Table 6.1 The Goal and Scopes of the Project of Application of NPDWise to the Early-stage Start-ups

Project name		Applying NPDWise to assess NPD capability of the early-stage start-ups in the STeP programs
Pain point		- Start-ups in STeP programs faced challenge when developing and commercializing products.
Desired outcome		- To determine which elements of the NPD are most closely associated with success. - To propose improvement opportunities that could be done by STeP to support early-stage start-ups in the programs.
Method	**Define**	- To conduct semi-structured interview with the early-stage start-ups in the STeP programs to understand the current NPD process. - To produce diagram of NPD process of each company, adopting the overarching NPD process model.
	Measure	- To evaluate the NPD capability, using assessment sheet
	Analyze	- To identify the strengths and weaknesses of the current NPD capability as a result of using assessment sheet. - To analyze NPD capability of Phase 2 cases and compare with Phase 1 cases. - To identify the best practices and determine which elements of the NPD are most closely associated with success in the context of the early-stage start-ups in the STeP programs. - To identify common challenges that the studied cases face in the NPD process, compare the challenges with the supports from STeP, and identify areas that require improvement.
	Design	- To propose improvement opportunities that could be done by STeP to support early-stage start-ups in the programs to overcome the challenge on NPD.
Stakeholder		- 7 early-stage start-ups in STeP program (Phase2 cases) - SMEs and start-ups in STeP program (Phase1 cases) - STeP members in Innovative Startup Development Department

The specific phases of this project include:

Define: Semi-structured interviews are conducted with early-stage start-ups in the STeP program to gain insights into their current NPD processes. Then, NPD process diagrams were produced for each company, based on the overarching NPD process outlined in Section 5.2. The interview results are shown in Appendix G.

Measure: The NPD process is evaluated using assessment sheet, as explained in Section 5.3. The detail of assessing Company 2-A capability was explained in the example of using ICAT in Section 5.5, whereas the other six companies' assessment results are presented in Appendix G.

Analyze: The strengths and weaknesses of NPD capability as a result of applying NPDWise assessment sheet were identified and discussed in Section 6.1. In addition, the interview data about how the company develop new product was analyzed. Within-case and cross-case analyses were performed, as proposed by Eisenhardt (1989). The within-case analysis led to identifying strengths and areas for improvement of each company. Based on the within-case analysis, the cross-case analysis was conducted to identify common strengths, and areas for improvement that are applicable across the early-stage start-ups in Phase 2.

Furthermore, as the interview questions in Phase 1 was about how the cases developed technological innovation, some answers were around how they develop their products. Therefore, the interview data of Phase 2 was also compared to the data of SMEs and start-ups in Phase 1 in order to understand the common NPD activities and challenges on developing new product. Details can be seen in Appendix H. The insights gained from the cross-case analysis between two phases were leveraged to identify the best practices and the elements for success, which can be seen in Section 6.2.

Lastly, common challenges faced by early-stage start-ups in the NPD process were identified, compared with STeP's support, and areas in need of improvement were pinpointed, as discussed in Section 6.3.

Design: The chapter concludes by proposing improvement opportunities for STeP to support early-stage start-ups in overcoming NPD challenges, outlined in Section 6.4.

In Section 6.1, a cross-case analysis was performed to identify similarities and differences across the participating start-ups in Phase 2. In Section 6.2, best practices were identified, and the elements of the NPD process that are most closely associated with success in the context of the early-stage start-ups in the

STeP programs were determined. In Section 6.3, an analysis was presented, comparing the challenges faced by the studied cases with the supports provided by STeP and highlighting gaps or areas where STeP could further enhance its support to address the specific NPD needs of early-stage start-ups. Section 6.4 proposes improvement opportunities for STeP. In Section 6.5, NPDWise evaluation was presented and reflected. Section 6.6 presents the key findings of Phase 2, which is ADR stage 4. Lastly, the summary of this chapter explains in Section 6.7.

6.1 Identifying Common Strengths and Areas for Improvement

The Analyze phase performed within-case analysis and cross-case analysis. The interview data about how the company develop new product was analyzed, which led to identifying strengths and areas for improvement of each company and providing valuable insights into their respective NPD processes. Table 6.2 and Table 6.3 show the summarized analysis of the identified strengths and areas for improvement.

Table 6.2 Within-case Analysis Identifying Strengths of Phase2 Cases

	Theme	Code	2-A	2-B	2-C	2-D	2-E	2-F	2-G
Strength	Customer focus	Customer focus	✓	✓	✓	✓	✓	✓	✓
	Continuous improvement	Continuous improvement	✓	✓	✓	✓	✓	✓	✓
	Team knowledge	Market			✓	✓	✓		✓
		Design			✓	✓	✓	✓	✓
	Market	Collaboration	✓		✓	✓	✓	✓	
		Agility	✓	✓					
	Design	Adjustment design based on feedback	✓	✓	✓	✓	✓	✓	✓
		Early system and detail design process plan and execution				✓	✓		
		Technology integration					✓	✓	✓
	Production	Safety and quality assurance							✓

Table 6.3 Within-case Analysis Identifying Areas for Improvement of Phase2 Cases

	Theme	Code	2-A	2-B	2-C	2-D	2-E	2-F	2-G
Area for Improvement	Team knowledge	Market						✓	
		Production	✓	✓		✓	✓		
	Market	Collaboration		✓					
		Scalability		✓	✓				✓
		Competitive market				✓	✓	✓	
		Market validation						✓	✓
	Design	Early system and detail design process plan and execution	✓	✓	✓			✓	✓
		Technology integration	✓	✓	✓	✓			
	Production	Software production	✓	✓	✓	✓	✓		
		Manufacturing						✓	✓

Drawing upon insights from within-case analyses and guided by established NPD models from the literature, this section identified shared strengths and areas for improvement across early-stage start-ups within the STeP program. The insights presented in this section were a direct outcome of the investigation facilitated by NPDWise, which enabled not only the gathering of data on capability maturity level, but also empowering the understanding and reflection on the realities faced by these entrepreneurs.

6.1.1 Customer Focus

Strength: Customer focus emerges as a strength among the studied companies. All companies emphasize understanding customer needs, conducting thorough research, and gathering feedback to align product development with customer preferences. By utilizing customer insights to guide product evolution, these companies align with the core principles advocated by the existing NPD models (Andreasen and Hein, 2000; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992).

Areas for Improvement: While many companies placed importance on customer-centric practices, their performance varied, particularly in market-related NPD activities. Notably, several companies received Level 1 and 2 in NPD capability assessment, indicating room for enhancement. To further strengthen their customer focus, companies can implement systematic mechanisms or continuous improvement processes, articulating market opportunities, gathering customer needs, and fostering long-term customer retention. Embracing mechanisms, such as NPDWise could serve as a robust framework for advancing NPD capabilities to higher maturity levels.

6.1.2 Continuous Improvement

Strength: Across the studied cases, a culture of iteration and refinement was evident. All companies demonstrated a commitment to enhancing their products through ongoing prototyping and user testing to refine their products based on customer feedback. The continuous improvement is another essential key of successful product development, as it was suggested by many existing NPD models (Ulrich and Eppinger, 2016; Unger and Eppinger, 2011).

Areas for Improvement: As indicated by the NPD capability assessment, many companies received Level 1 and 2 ratings, implying partial execution of NPD activities using structured techniques. This signals the potential for these companies to emphasize more on continuous improvement. Therefore, companies should establish systematic mechanisms or processes for continuous improvement, including regular evaluation of NPD processes, capturing lessons learned, and implementing feedback loops to drive innovation. Ulrich and Eppinger (2016) suggest several NPD processes for different types of products, such as the spiral process can be embraced by software development companies, executing iterative cycles of design, build, and test until not enough budget and times.

6.1.3 Team Knowledge

Strength: Many companies showcased expertise in marketing aspect and design aspect (Company 2-C, 2-D, 2-E, 2-G). A capable and experienced team can drive the company’s vision, make strategic decisions, and navigate challenges effectively. Some companies have their strong research background (Company 2-F, and 2-G), which allows them to develop innovative products based on scientific knowledge and expertise. Team composition and cross-functional team are critical factors influencing NPD outcomes (Andreasen and Hein, 2000; Cagan et al., 2002; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992).

Areas for Improvement: Some companies face challenges related to team knowledge and resource allocation, particularly in the areas of software development (Company 2-A, 2-B, 2-D, and 2-E). They do not have sufficient developer to produce software product. Some research-commercializing companies face challenges related to marketing expertise (Company 2-F). They should prioritize allocating adequate resources to hire skilled professionals and foster effective collaboration between different functional areas (Andreasen and Hein, 2000; Cagan et al., 2002; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992).

6.1.4 Market

Strength: Many companies have established partnerships with industry experts, government organizations, and academic institutions (Company 2-A, 2-C, 2-D, 2-E, and 2-F), providing collaborative opportunities for market penetration. Placing importance on marketing influences NPD results (Andreasen and Hein, 2000; Cagan et al., 2002; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992).

Areas for Improvement: A reliance on a single industry or marketing channel is apparent among some companies, which may lead to challenges related to market diversification (Company 2-B, 2-C, 2-D, 2-E, and 2-G). These companies can benefit from adopting continuous improvement processes, such as NPDWise, to enhance their market-related NPD activities. Developing market plans and exploring opportunities in other industries, regions, and marketing channels can broaden their customer base and mitigate market risks.

6.1.5 Design

Strength: All companies emphasize the importance of design, prototyping, testing, and refinement in their design stage. This approach aligns with the principles advocated by established NPD models (Andreasen and Hein, 2000; Cagan et al., 2002; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992).. Additionally, Company 2-D and 2-E focus on developing systematic design processes, including early system design and detailed design, echoing the NPD models of Ulrich and Eppinger (2016) and Wheelwright and Clark (1992). Furthermore, Company 2-E integrates technology into the product to improve functionality during detailed design stage. Company 2-F and 2-G also assess new technology during opportunity recognition stage, resonating the NPD model of Ulrich and Eppinger (2016).

Areas for Improvement: NPDWise reveals that Company 2-D and 2-E achieved Level 3 and 4 ratings respectively in design-related capabilities due to their systematic design process execution. However, most other start-ups received Level 1 and 2 ratings, indicating a lack of emphasis on early system design and detailed design planning and executing. Establishing systematic mechanisms or processes for these design stages, in line with the NPD models of Ulrich and Eppinger (2016) and Wheelwright and Clark (1992) can contribute to improved design outcomes. In addition, many companies did not emphasize integrating technology into the product, so that there is opportunity to acquire and adopt new technology to enhance product competitiveness.

6.1.6 Production

Strength: Only Company 2-G highlights the importance of ensuring the efficacy, quality, and safety of the product. This aligns with the quality assurance process suggested by Ulrich and Eppinger (2016).

Areas for Improvement: Based on the assessment of NPD capability, numerous software developing companies received Level 1 and 2 ratings, suggesting a partial plan and execution of the process of creating and delivering the software product. Similar to the cases of technology commercializing companies, the cases partially plan and execute the production process. To further strengthen their production-related capabilities, companies can adopt systematic mechanisms or continuous improvement processes as guidelines to plan and perform the production process.

6.2 Identifying Best Practices and Elements for Success

Since the Phase 1 interviews primarily focused on the process of technological innovation development, some responses delved into NPD process. Consequently, the Phase 2 interview data was compared with the data from both Phase 2 itself and cases in Phase 1. This comparison aimed to understand shared NPD activities and challenges in the context of product innovation. The specific information regarding this comparison is provided in Appendix H. The conclusions drawn from the cross-case analysis spanning both phases resulted in identifying best practices and factors contributing to the success of NPD process within the STeP program for start-ups.

6.2.1 Opportunity Recognition among Technology Commercializing Companies

Best Practice Example – Companies 1-E and 2-G: Building on findings from the literature, it is evident that university research often struggles to transition ideation to commercialization. Researchers typically have an interest in research itself rather than the commercialization aspects. This can create a challenge in successfully penetrating the market and commercializing their innovations, as documented by Wonglimpiyarat (2016). From the interview, Company 1-E and 2-G exemplify effective opportunity recognition among technology commercializing (TC) companies which lead to successful technology commercialization. However, it is not only their transition that is remarkable but also how they precisely identified these opportunities. As elaborated in Table H.1, these two companies receive better maturity level over other TC cases.

Company 1-E stands out for its unique approach. Transitioning from PhD research to a marketable fish farming solution, this company accentuates the significance of research, innovation, and engineering proficiency. What is particularly notable is their journey in understanding customers and developing products tailored to meet their needs. They tried using several frameworks before finally crafting their own. Regarding the assessment using ICAT, Company 1-E earned a Level 4 rating in both market aspects and design aspects of opportunity recognition. On the other hand, Company 2-G adopted an equally distinctive path to success. Comprising a diverse team with different backgrounds, they converged their skills to address a specific health issue and develop a novel nutraceutical product. Their opportunity recognition process was characterized by identifying common health problems, pinpointing the necessity for an alternative solution, and conducting market research to validate the opportunity. Their structured approach led to successful results. Company 2-G also secured a Level 4 rating in both market and design aspects of opportunity recognition.

Comparing to other TC companies, primarily led by researchers with knowledge of their products, their challenges primarily stem from their limited understanding of the market. These cases underscore the significance of a balance between robust research backgrounds (design aspect) and market insights (market aspect). The combination of these elements is importance within the context of Thai business environments.

6.2.2 Technology Assessment and Adoption among Platform Developing Companies

Best Practice Examples – Companies 1-B: This company excels in technology assessment and adoption among platform developing (PD) companies. Ulrich and Eppinger (2016) and Wheelwright and Clark (1992) emphasize the strategic importance of technology in the NPD process. Their research underscores the fact that active technology integration not only enhances product functionality but also ensures competitiveness in today’s dynamic market landscape. What sets Company 1-B apart from other PD companies is not only its commitment to technology integration but also its experience. This company’s entrepreneurial journey has been marked by several attempts, encompassing both successes and failures. Their current product, an application that matches landowners with farmers seeking agricultural land, has benefited from their hands-on experience. This practical exposure has equipped them with insights that inform their approach to technological integration.

Moreover, their ability to identify technology is strengthened by strategic collaborations facilitated by STeP. Through these collaborations, they gain access to partners with valuable technologies. For instance, they have partnered with Company X, utilizing their technology to enhance land management, including historical data and land health assessments. Additionally, they are exploring collaboration with Company Y, which has expertise in GIS, IT, and geography. This partnership not only expands their technology adoption but also helps them access a broader customer base through the partner's existing user network. Company 1-B received an impressive Level 4 rating in the design aspect of opportunity recognition and a Level 3 rating from concept development to detailed design. The elements driving these best practices encompass technology adoption, collaborative partnerships, and team experience which foster a ground for NPD and technological innovation.

6.2.3 Competence in Software Production among Platform Developing companies

Best Practice Examples – Companies 1-B, 1-C, and 1-D: The analysis identified two distinct groups among the participating companies: one group comprising co-founders with significant technology knowledge, particularly in software development, and another group characterized by co-founders with strong business knowledge but lacking technical expertise. Notably, it was found that companies with co-founders possessing software engineering backgrounds excelled in platform development, particularly in planning and executing software development processes. Company 1-B, 1-C, and 1-D serve as cases within this category. These companies received higher maturity levels in the production aspect compared to the others. These companies effectively plan and execute software development processes, ensuring the functionality and efficiency of their platforms. Furthermore, the co-founders' expertise in software development significantly contributed to their proactive product development and expansion.

Conversely, instances emerged during Phase 2 interviews where start-ups without co-founders skilled in software development struggled with this aspect. The lack of in-house technical knowledge led them to rely on external software developers and posed challenges in effectively managing the work of external developers which resulted in inefficiency of their platform development. The findings underscore the critical role of team's competence in software development; however, this factor not extensively emphasized in existing literature on NPD process process (Andreasen and Hein, 2000; Cagan et al., 2002; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992). While literature has outlined various aspects of NPD, the specific influence of co-founders' technical knowledge on software development in the early stages of start-ups needs further attention. On the other hand, while co-founders with software engineering backgrounds certainly have an advantage in platform development, they are not the only path to success. The data in Phase 2 suggested the importance of resource management and networking could be valuable for start-ups in this category.

6.2.4 Strong Market Rollout Strategy

Best Practice Examples – Companies 2-D and 2-E: This section delves into the domain of market rollout strategies, a critical aspect of NPD process (Andreasen and Hein, 2000; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992). The analysis identified two companies, 2-D and 2-E, which have excelled in this domain, securing higher maturity levels in the market aspect over the other companies. While other companies faced such challenges as market validation and market diversification, companies 2-D and 2-E demonstrate outstanding market rollout strategies that align with established marketing principles. Company 2-D emphasized effective marketing and product positioning strategies. They utilize channels, including digital marketing and social media, to create awareness and generate demand for their products. They understand the importance of building a strong brand and conveying their unique value proposition to customers. Moreover, they carefully positioned their products effectively to differentiate themselves from competitors and attract their target customers. This approach resonates with previous marketing research that highlights the significance of branding and differentiation strategies in new product introductions (Kotler et al., 2020). The work of Kotler et al. (2020) emphasizes the role of marketing and promotion in creating product awareness and generating consumer demand. Company 2-D's efforts mirror these established marketing practices and contribute to their success in the market rollout phase.

Differently, Company 2-E prioritized understanding the distinct needs of customers in different regional areas, aligning with the concept of market segmentation in marketing theory (Kotler et al., 2020). Their dedication to comprehending the unique demands of each market segment enables them to tailor their products to resonate with local customers. Furthermore, Company 2-E seeks strategic partnerships, including collaboration with STeP, to expand the market to northern area of Thailand. This partnership aligns with the recommendation of Munkongsujarit (2016) that the incubator in university should utilize its location and proximity for networking among local community. The element supporting these best practices includes market rollout strategy.

6.2.5 Concept Development and Product Design Iteration

Best Practice Example – Company 2-E: Company 2-E showcases a robust approach to concept development and product design through iterative refinement. As elaborated in Table H.1, this company received higher level in both market and design aspects in concept development, early system design and detail design. Their engagement in iterative development, involving concept, early system design, and detailed design, stands out whereas the other companies did not mention this way of design process. This systematic design processes resonate with the acclaimed NPD models proposed Ulrich and Eppinger (2016) and Wheelwright and Clark (1992). The elements contributing to this best practice include continuous improvement and systematic product development process.

6.2.6 Effective Overall NPD Process

Best Practice Example – Company 1-D: This company stands out for its effective overall NPD process. Starting with the development of a carpool app, Company 1-D swiftly identified new opportunities and adjusted their strategies and business model. The agile response to market changes (market and design aspects) and co-founders' expertise in software development (production aspect) contributed to their ability to seize new prospects and evolve into a venture builder investing in other software-based businesses. As illuminated in Table H.1, Company 1-D receives better maturity levels in every aspect and in every NPD stage, comparing to other companies. The company's agility in responding to market shifts played a role in its success. This trait proved particularly critical, as some Phase 1 interviewees who lacked such adaptability eventually encountered market failure when revisited in Phase 2. Furthermore, structured NPD processes and cross-functional teamwork contribute to their success in developing new product and survive in the market (Andreasen and Hein, 2000; Cagan et al., 2002; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992). The collaborative partnership strategy also enhances their capability to develop new products and enabled penetration into new markets. The elements contributing to this best practice include agility, cross-functional team, and collaborative partnerships.

6.3 Comparison on Challenges Faced by the Studied Cases with the Supports Provided by STeP

This sub-section presents the comparison between the four interviews with STeP members, where the supports from STeP were investigated (as explained in Appendix A) and the interview data in both phases, where the participating companies explained challenges on NPD as well as gave feedback on STeP support. In addition to the maturity level given, other interesting points from the interview were also identified. This can lead to identifying the areas that require further supports from STeP.

6.3.1 Workshop on Market Aspect

The support provided by STeP can link to the market aspect of the NPD process. STeP provides guidance on market research and analysis, as well as assistance with creating business plans and pitching to investors. This can help start-ups better understand their target customers and market demand for their product, which is a critical step in the marketing aspect of the NPD process.

The companies in Phase 2 discussed that the supports from STeP program have advocated their marketing and business management. For example, Company 2-B joined Big Brotherhood program where STeP provides Company 1-C to be their consultant. The interviewee explained that,

> *"It is beneficial. They are like big brothers who give suggestions to little sister, which is less formal."*

Company 2-F team, that consists of only researcher also viewed that STeP supports were helpful, especially in marketing training and mentorship session. The interviewee explained that,

> *"They give lectures on market adoption and revenue, teaching us to think about costs, revenue, profit, and basic principles."*

On the other hand, many companies in Phase 1 viewed the supports from STeP were generic and they need more hands-on guidance. Company 1-B said,

> *"While many programs, including STeP, offer fundamental knowledge and pitching techniques, we require more extensive assistance, particularly in navigating the VC landscape."*

This is same as Company 1-E, the interviewee also explained that,

> *"STeP provided training on how to plan business using Lean canvas. However, I found it did not work well with our business. I prefer read*

> *book to understand the steps to understand customer and develop new product."*

It is noticeable that the studied cases of Phase 2 are in early stage of business, such as ideation or market validation, whereas most studied cases in Phase 1 are in market expansion or market scale up stages. The Phase 1 cases may need more tailored supports that are applicable to the company stage and product. On the other hand, the Phase 2 cases may need fundamental knowledge during generating the idea and validating the market. In addition, it is possible that the interview in Phase 1 were conducted privately between the interviewee and the research; however, the interview in Phase 2 were conducted with STeP member observation. This observation could lead to bias as the interviewee in Phase 2 might not be comfortable to answer about STeP supports.

6.3.2 Workshop on Design Aspect

In terms of design, STeP provides support in the form of mentorship and workshops on NPD, design thinking, user experience design (UX), and interface design (UI). This helps start-ups better define their product and create an minimum viable product (MVP) that meets the needs of their target market. Additionally, STeP provides support for prototyping and testing, which are key steps in the design aspect of the NPD process. On the other hand, it is notable some challenges on case of TC company, Company 1-E explained that,

> *"STeP has many PD companies in the program which results in STeP has experience on advocating them. However, my innovation is different, and I need different supports."*

From his explanation, the reason can be because TC companies may require different types of support. Some may need more tailored support for their specific research and technology, or other aspects of launching a successful product.

6.3.3 The Need for Support on Manufacturing Aspect

There is no direct mention of manufacturing support which may be because manufacturing is often not relevant to start-ups in the early stages of development in Camp1 and Camp2. Nevertheless, many PD cases that the co-founders did not have software development knowledge mentioned that they have faced challenges on developing the platform. Differently, some TC companies have faced challenges on seeking the OEM for production. Company 1-E and 1-H mentioned that they need supports on the connection to OEM.

6.3.4 The Need for Support on Funding

Based on interview with STeP members who are responsible for Camp1 and Camp2, it appears that STeP supporting program is primarily focused on helping start-ups prepare their documentation and pitch their ideas to potential investors or funding sources rather than directly supporting product development. STeP member explained that,

> *"We help prepare the pitch deck for 7 minutes, starting from the presentation of the pre-seen materials, and then schedule a rehearsal to see if everything is okay. We rehearse answering questions from the small board round and use the comments from that round to help them prepare for the large board presentation."*

After the venture capital funding sources are accepted, STeP will support companies preparing the document. The interviewee explained that,

> *"Once they pass, we help prepare the documents and send them to the funding source. There will be milestone follow-ups for the 3 payment stages. We check the payment documents to see if they are correct."*

Comparing to the interview data of the studied case, Company 2-A viewed that they still need more support on funding issue; however, they need support in specific way rather than preparing documents. The interviewee mentioned that,

> *"It is hard to get the funding because of the process of applying for the funding. It takes time to approve the evidence, prepare the receipt."*

6.3.5 The Need for Networking and Collaboration

From the interview analysis, both cases in Phase 1 and Phase 2 need networking and opportunity to collaborate with other organizations for both marketing purpose and design purpose. For example, Company 2-A stated that,

> *"It is difficult to contact the big company directly to expand the customers or grow the business faster."*

Similarly, Company 2-E stated that,

> *"Incubator should support us by providing connection to partners who have new technology and knowledge."*

6.4 Aligning Challenges, Elements for Success, and STeP Supports

After an analysis was undertaken to assess the challenges faced by the cases examined in both phases and the corresponding support provided by STeP in Section 6.3, this section identifies opportunities through which STeP could offer assistance, adopting the elements for success, and empowering early-stage start-ups in addressing their NPD challenges.

6.4.1 Encouraging Culture of Entrepreneurship in Researcher

Building on findings from the literature, it is evident that there is limited R&D activity and university collaboration with small companies (Intarakumnerd, 2019). Wonglimpiyarat (2016) also found that university research often remains in an embryonic stage, failing to achieve commercialization. Furthermore, the lack of entrepreneurial skills among Thai start-ups has been highlighted by Munkongsujarit (2016). Given this context, it is clear that university incubators have not provided sufficient support for technology commercialization. Concurrently, insights derived from best practices, exemplified by Companies 1-E and 2-G (as explored in Section 6.2.1), emphasize the significance of robust research backgrounds and market insights. Consequently, STeP need to encourage the culture of entrepreneurship in the researcher in the university and support them on commercializing to the market.

6.4.2 Networking and Collaboration Opportunities

Building upon the highlighted area for improvement in technology integration (as discussed in Section 6.1.5), STeP can play a role in addressing this critical aspect. Drawing inspiration from the practices of Company 1-B in innovation and technological integration (as elaborated in Section 6.2.2), where this company has demonstrated a strong emphasis on collaborative partnerships and technology adoption, it becomes evident that these strategies hold significant potential. This correlation aligns with the findings of Munkongsujarit (2016) who underscored the importance of incubators providing technical support by linking companies with experts and specialists. Therefore, STeP could facilitate collaborations between the companies and innovation networks. This can provide the companies with access to technological advancements and further enriching the innovation landscape.

Taking cues from the accomplishments of Company 1-D in effective overall NPD process (as illuminated in Section 6.2.6), where the role of collaborative partnerships is demonstrated, it becomes evident that these strategies bear considerable potential in the NPD process. Considering this insight, STeP could facilitate networking that brings together entrepreneurs and industry experts.

6.4.3 Additional Supports for Production Aspect

In light of the identified challenges in team's knowledge and production (as discussed in Section 6.1.3 and 6.1.6 respectively), STeP's role could extend to encompass support for production aspects and resource access. Notably, PD companies faced challenge on the lack of in-house software development teams, while TC companies expressed their need for additional infrastructure and resources for production. This resonates with the findings of Munkongsujarit (2016), which highlighted insufficient specialized support systems for start-ups in Thailand. To address these challenges, Munkongsujarit suggested the incubator supports the 172ncubate with technical issue by connecting them to the specialists and organizing the seminars or public showcases. Therefore, STeP's intervention should extend to the production aspect, particularly addressing software development and infrastructure needs.

Leveraging insights from Company 1-D's best practice through their team's competence in software development (as explored in Section 6.2.3), STeP should advocate for an understanding of software development within the co-founders and teams, rather than relying on outsourced or part-time developers. STeP could organize networking events that foster knowledge exchange between start-ups with varying degrees of software development expertise. STeP can advocate collaboration and networking opportunities among the PD companies in BaseCamp24. This can include organizing regular networking events, and workshops where PD companies with less software developing knowledge can connect with those with more knowledge, share experiences, and explore potential partnerships. For TC cases, STeP can provide infrastructure and resources to the companies in the program. This includes well-equipped laboratories, prototyping facilities, and access to advanced technologies, equipment, and shared services.

6.4.4 Workshop on Market Aspect

In response to identified market improvement needs, such as collaboration, scalability, competitive positioning, and diversification (as presented in Table 6.3), STeP could strengthen its support in guiding early-stage start-ups through the marketing aspects of NPD process. This includes providing assistance with market research, market segmentation, product positioning, and facilitating access to valuable networks and potential investors, which align with the principles outlined by Kotler et al. (2020).

Furthermore, drawing insights from discussions with cases in both Phase 1 and Phase 2, as well as insights from Company 2-D and 2-E's best practice through strong market rollout strategy (as elaborated in Section 6.2.4) which highlight the significance of digital marketing and social media, STeP can extend its support by offering guidance on leveraging digital channels effectively.

Moreover, in alignment with Kotler et al. (2020), where global market expansion is strongly recommended, and considering the findings of Munkongsujarit (2016), which highlights the importance of incubators in fostering networking and international market promotion, STeP could further aid start-ups in accessing global markets. This expanded support might encompass conducting market research in target countries, providing guidance on international business development, and facilitating connections with international partners.

6.4.5 Workshop on Design Aspect

Considering the highlighted areas for enhancement in continuous improvement and design (as discussed in Section 6.1.2 and 6.1.5 respectively), STeP could advocate for workshops and mentorship sessions focused on design aspect together with market aspect. STeP could establish structured mechanisms that facilitate continuous improvement. For instance, using DMADV which is a framework that aims to create new products or processes by considering customers' expectation in the design requirements (Wang, F.-K. et al., 2016). STeP may use NPDWise to regular evaluation of NPD capability and processes, capturing lessons learned, and implementing feedback loops to drive innovation. Moreover, inspired by the success of Company 2-E's approach to systematic product development process (as detailed in Section 6.2.5), the facilitation of incubation programs could serve as a structured framework for conceptualization, early system design, and detailed design.

Moreover, drawing on insights from discussions with cases in both Phase 1 and Phase 2, STeP could further strengthen the design aspect of the NPD process by customizing incubation programs to cater to the specific needs of each company. These programs can provide a structured framework for the companies to develop their concepts, test and refine their products, and scale their businesses.

6.4.6 Workshop on Agility

As mentioned in Section 1.3 (Introduction of STeP) and Appendix A (Supports Program of STeP), the trajectory of STeP's support programs underwent a significant transformation, establishing Basecamp24 in March 2022. This enables university students and recent graduates to engage with the incubation program, which commences with the stage of opportunity recognition. This shift underscores the importance of recognizing opportunities at the initiation of the entrepreneurial journey. Drawing insights from the achievements of Company 1-D in effective overall NPD process (as expounded in Section 6.2.6), where an emphasis on agility has been instrumental, it becomes explicit that these strategies is potential. Therefore, STeP could organize workshops and training sessions that emphasize the importance of agility in recognizing and responding to evolving market opportunities. These sessions could involve real-world case studies and simulations to enhance start-ups' adaptability skills. Moreover, STeP could also organize workshops on market trend analyses and provide regular updates on market trend. This could empower entrepreneurs with data-driven insights, enabling them to proactively identify emerging trends and capitalize on novel opportunities.

6.4.7 Encouraging Cross-functional Collaboration

In addition to providing support for market, design, and production areas, STeP could consider organizing cross-disciplinary training sessions and workshops that unite professionals from diverse departments, including marketing, design, and production. Such initiatives can effectively foster understanding of each department's objectives and workflows, consequently enhancing interdepartmental collaboration. Drawing inspiration from the achievements of Company 1-D in effective overall NPD process (as highlighted in Section 6.2.6), where the role of cross-functional team is showcased, it becomes apparent that these strategies hold significant potential. This notion aligns with various established NPD models (Andreasen and Hein, 2000; Cagan et al., 2002; Ulrich and Eppinger, 2016; Wheelwright and Clark, 1992). Moreover, as suggested by the early-stage start-ups in Phase 2, STeP could explore the concept of an industry partnership program, establishing collaborations with start-ups in Camp3 or Camp4 that prioritize and value cross-functional collaboration. These partnerships can potentially inspire the early-stage start-ups to integrate and adopt similar effective practices.

6.4.8 Targeted Funding Support

Through conversations with the studied cases, they need STeP to assist the companies in accessing funding opportunities. However, discussions with STeP member revealed the inconsistency of government funding for supporting start-ups each year. This finding aligns with Munkongsujarit (2016), which identified the inadequacy of budget allocation for university business incubators and the limited availability of funding agencies. To address these challenges, STeP could play a role in connecting companies with investor networks. This would involve not only facilitating pitch sessions and offering guidance on funding applications, but also establishing partnerships with venture capital firms, angel investors, and other funding sources to enhance investment prospects. This approach mirrors Munkongsujarit (2016) proposal of connecting start-ups with business partners to overcome budgetary limitations.

6.5 Evaluating NPDWise Against the Design Requirements

While NPDWise was designed and applied to the case study, the reflection and learning emerged in parallel through the studying. This section describes the evaluation of NPDWise against the design requirements as showing in Table 6.4.

DR1: The method supports users to understand NPD capability of the early-stage start-up.

NPDWise meet DR1 as the tool supports early-stage start-ups in comprehending their NPD capability. As demonstrated in Appendix G, the method facilitates an assessment of NPD capability, providing insights into their strengths and areas for improvement. Moreover, the tool's ability to categorize companies into different maturity levels allows the incubator to tailor support to the specific needs of each start-up. This, in turn, empowers the incubator to offer targeted assistance to enhance the NPD capability of these dynamic enterprises.

DR2: The NPD perspectives and criteria of the method are suitable for the situation of users.

While existing tools in the literature may vary widely in their perspectives and criteria for assessing innovation capability and NPD capability, NPDWise's NPD perspectives and criteria were tailored to align with the needs and situations of early-stage start-ups within the STeP program. This alignment is rooted in the feedback obtained from users who interacted with the mock-up of ICAT. Moreover, as illustrated in Measure stage in Appendix G and Analyze stage in Section 6.1, Section 6.2, and Section 6.3, most NPD perspectives and criteria of the studied cases were suitable to measure the studied cases, analyze the strength and area for improvement, and lead to proposing the element for success. Furthermore, NPDWise's segmentation into three distinct aspects, which are market, design, and production, so that the method provides clarity in understanding each aspect's capability. On the other hand, there is opportunity for future research for pinpointing specific areas for development and enables a more targeted approach to fostering NPD capability of different product of the start-ups. For instant, different tools with specific perspectives and criteria relating to the PD company and TC company. The proposed future research will be explained in Chapter 7. Therefore, this can be summarized that NPDWise partially meets DR2.

DR3: The maturity levels of the tool are suitable for the situation of users.

There are different tools in literature determining different maturity levels. Differently, NPDWise's four progressive maturity levels have proven to be appropriated for assessing NPD capability within the context of early-stage start-ups, as it was developed based on the feedback gathered from the mock-up of ICAT users. These maturity levels resonate with the capability of the early-stage start-ups, as illustrate in Appendix G. Moreover, these maturity levels also offer a practical framework for identifying best practices, as evidenced in Section 6.2. By employing these maturity levels, the incubator can identify the elements contributing to the success of best practices and use this knowledge to guide other start-ups toward elevating their capability levels. As a result, it can be summarized that NPDWise meets DR3.

DR4: The method is easy to use.

Drawing from feedback received during the mock-up of ICAT in Phase 1, NPDWise was carefully designed to ensure ease of use, particularly for early-stage start-ups. As evidenced in Appendix G, NPDWise prioritizes user-friendliness and simplicity. It refrains from imposing the need for specialized knowledge, high costs, or extensive resources. Nonetheless, an opportunity for future research arises in further refining NPDWise, particularly in segmenting perspectives and criteria to better suit the unique needs of platform development and technology commercialization companies, making the method even more applicable to a wider range of enterprises. The proposed future research will be explained in Chapter 7. All in all, it can be summarized that NPDWise meets DR4.

DR5: The method creates awareness among early-stage start-ups about their NPD capability.

As of the current project timeline, NPDWise has not been applied to the studied cases in the Verify phase of DMADV. Consequently, it is not possible to definitively conclude whether the method effectively ensures early-stage start-ups' awareness and understanding of the NPD capability concept. However, this presents an avenue for future research, which will be proposed and discussed in Chapter 7.

Table 6.4 Evaluation NPDWise Against the Design Requirement

Modified DRs	Evaluation	Evidence
DR1: The method supports users to understand NPD capability of the early-stage start-up	Meet	According to the application of NPDWise to the participating cases illustrated in Appendix G, the method could support the user to understand NPD process as well as assess NPD capability by grading the maturity levels.
DR2: The NPD perspectives and criteria of the method are suitable for the situation of users.	Partially meet	According to the assessment in Appendix G and analysis in Section 6.1- 6.3, most NPD perspectives and criteria of the studied cases were suitable to measure the studied cases, analyze the strength and area for improvement, and lead to proposing the element for success. However, there is opportunity for future research. Some perspectives and criteria relating to the PD company and TC company should be divided to be applicable for the specific product of the company.
DR3: The maturity levels of the method are suitable for the situation of users.	Meet	According to assessment in Appendix G and assessment results in Section 6.2, the maturity levels were suitable to assess NPD capability and led to identifying best practices.
DR4: The method is easy to use.	Meet	According to assessment stage in Appendix G, NPDWise was easy to use for assessing NPD capability as the method was less complex and provided the visualized result.
DR5: The method creates awareness among early-stage start-ups about their NPD capability.	N/A	Due to the time limited during this project, the method has not been applied to the studied cases in Verify phase of DMADV. As a result, it cannot be concluded whether the method could ensure that the early-stage start-ups are aware of NPD capability and meet DR5.

6.6 Formalizing the Knowledge

With the identification of improvement opportunities in Phase 1, Phase 2 commenced by determining the research focus through prioritizing these opportunities. The research centered on NPD capability and selected early-stage start-ups within the STeP program as the case study. Building upon the Phase 1 ICAT, it was adapted into NPDWise, serving as an assessment method for NPD capability as part of the continuous improvement process. This adaptation facilitated formalizing the knowledge on developing the tailored assessment method for supporting NPD process and on applying the method to the case study.

6.6.1 Developing the Tailored Assessment Method for Supporting NPD Process

This phase has presented the development of tailored assessment method, NPDWise, designed for the assessment of NPD capability in early-stage start-ups participating in incubation programs. It introduces a structured approach that aims to support early-stage start-ups and incubators in understanding their NPD processes, identifying their current NPD capability levels, and pinpointing strengths and areas for improvement. Through interviews and feedback in Phase 1, NPDWise was refined to ensure ease of use, flexibility, and relevance to the unique challenges faced by these start-ups.

NPDWise was designed to use as part of the Define and Measure phases of DMADV process to structure the assessment of NPD capability. The overarching NPD process model consists of six stages: Opportunity recognition, Concept development, Early system design, Detail design, Commercial preparation, and Market introduction. This model integrated three major aspects of NPD: design, market, and production. The method also employs a maturity level system to assess NPD capability. This system, inspired by ICMM and PDCA cycle. The NPDWise framework introduces four progressive levels. Beginning at Level 1 (Initial), the NPD process or activity operates without structured plans. Advancing to Level 2 (Plan and Do), intentional planning and execution come into play. Level 3 (Plan, Do, and Check) introduces a reflective phase, reviewing and adjusting outcomes. At the highest level, Level 4 (Plan, Do, Check, and Action) embodies continuous improvement, with regular review, reflection, and refinement of techniques.

6.6.2 Application of the Tailored Assessment Method to the Case Study

NPDWise was applied in a case study involving early-stage start-ups in the STeP program. The application led to indicating that the method facilitated the understanding of NPD process and NPD capability. Furthermore, the application also resulted in identifying best practices and elements associated with success in the NPD process for early-stage start-ups in the STeP programs. Notable findings include:

- **Opportunity Recognition among TC Companies:** Best practices emphasize the balance between robust research backgrounds (design aspect) and market insights (market aspect).
- **Technology Adoption among PD Companies:** The success elements encompass technology adoption, collaborative partnerships, and team experience.
- **Competence in Software Production among PD Companies:** The best practice involves elements of knowledge in software development, resource management, and networking.
- **Strong Market Rollout Strategy:** The best practice emphasizes success elements in market rollout strategy.
- **Concept Development and Product Design Iteration:** Elements contributing to this best practice include continuous improvement and systematic product development processes.
- **Effective Overall NPD Process:** Success elements include agility, cross-functional teams, and collaborative partnerships.

The application brought to highlight the challenges associated with different developmental stages of NPD among companies. Phase 2 companies, primarily engaged in early business activities, involved in ideation or market validation, benefited from STeP's support in marketing and business management. In contrast, Phase 1 companies, largely involved in market expansion or scale-up, articulated the need for more specific supports. Participants expressed that STeP's training was overly broad, stressing the necessity for more targeted approaches. This distinction in requirements between the two phases suggests the importance for STeP to customize its supports in accordance with the unique challenges confronted by companies at different stages of development.

Moreover, the evaluation pinpointed challenges encountered by distinct types of products. TC companies underscored the potential for STeP to offer tailored support catering to various innovations. Additionally, STeP should foster an entrepreneurial culture among university researchers, support their journey in commercializing innovations to the market, and provide technical support by linking companies with experts and specialists. Challenges faced by PD companies, such as software development issues, emerged in the manufacturing domain. The companies expressed the need for STeP to organize networking events that facilitate the exchange of knowledge among companies with diverse expertise levels.

6.7 Summary

Building on insights gained from the application of NPDWise as well as the analysis of best practices and success elements, the key opportunities for STeP emerged. The analysis of best practices emphasizes the critical nature of identifying opportunities at the initiation of the entrepreneurial journey. To address this, STeP could organize sessions, stressing agility in responding to evolving market opportunities. Additionally, recognizing the importance of cross-functional collaboration highlighted in the best practice analysis, STeP could conduct cross-disciplinary sessions to foster the collaboration between marketing, design, and production. Furthermore, the analysis identified funding challenges expressed by several companies in both phases, reinforcing the role of STeP as a connector between companies and investor networks. STeP can expand its role beyond document preparation by establishing partnerships with funding sources to better support the varied funding needs of start-ups.

By implementing these improvements, STeP can foster an environment that empowers start-ups to overcome NPD challenges and increases their chances of success in developing and launching innovative products.

Chapter 7 Conclusion

It is recognized that in today's marketplace, the ability to innovate and leverage technology is essential to success and growth. Particularly in Thailand, the need to enhance Technological Innovation Capability (TIC) emerges as a necessity. The research journey has been emphasized TIC and New Product Development (NPD) capability assessment within the context of Thai SMEs and start-ups. This concluding chapter consolidates the insights gained through the journey of the PhD research and answering the research question (RQ) in Section 7.1. Section 7.2 identifies contribution with respect to the research objectives. The theoretical contributions of this research are explored in Section 7.3, where key findings are contextualized within existing theoretical frameworks. Section 7.4 delves into the practical implications, offering actionable insights for practitioners involved in fostering innovation and NPD among Thai SMEs and start-ups. In Section 7.5, limitations of the research are identified and the opportunities for future research are proposed in Section 7.6.

7.1 Research Journey and Answering RQ

The research journey embarked on a quest to address RQ aimed at advancing understanding of TIC and NPD capability within Thai SMEs and start-ups engaged with the Science and Technology Park, Chiang Mai University (STeP) program. This section summarizes the key insights gained through the journey of the PhD research and answering the research question:

RQ: *How can new product development capability (as an aspect of technological innovation capability) be assessed among Thai SMEs and start-ups?*

Initial insights from a literature review on innovation practices in Thailand revealed challenges in developing technological innovation in Thai SMEs and start-ups. Further literature on TIC in Thailand mainly explored factors and criteria of TIC rather than offering practical guidance on the assessment and development of TIC. In addition, subsequent interviews with twelve companies within Science and Technology Park, Chiang Mai University (STeP) highlighted TIC as critical to their ability to innovate. However, conversations with STeP members revealed that, despite TIC being a priority for SMEs and start-ups in the program, there was a lack of an assessment tools within the park for evaluating their capabilities. This realization led to the identification of improvement opportunities and paved the way for research aiming to explore how TIC could be assessed in this context.

The research was carried out in two phases. In Phase 1, the emphasis was on designing an easy-to-use and practical self-assessment tool for SMEs and start-ups within STeP. The mock-up of ICAT α version was based on Innovation Capability Maturity Model (ICMM) concepts and comprised five TIC perspectives. The mock-up was developed with ongoing evaluation against design requirements (DRs) as well as discussion with supervisors. Subsequent reflections and learnings from the mock-up α version led to the development of the mock-up β version: characterized by reduced complexity, an even number of rating scores, no need for evidence, the use of a heat map for or the visualization of assessment result, and a focus on a single perspective to reduce the time needed for mock-up testing. Interviews with eight SMEs and start-ups revealed that, while the tool was overly complex for practical use, it was acknowledged as valuable by participants in aiding the recognition and reflection of their strengths and weaknesses. Additionally, inconsistencies were observed between the assessment outcomes and the actual organizational circumstances. This underscored the need for proposing new maturity levels that accurately reflect the contexts of these studied cases. Furthermore, three key perspectives of TIC that are relevant to Thai SMEs and start-ups in STeP were identified: Innovation decision capability, Innovation sourcing capability, and NPD capability. This also led to a specific need for more targeted support in NPD capability being highlighted.

In response, the insights gained in Phase 1 informed the subsequent journey into Phase 2. The focus shifted to designing NPDWise, a method tailored for assessing NPD capability in early-stage start-ups in STeP. In Phase 2, the RQ was answered, developing NPDWise as an NPD capability assessment method for use as part of TIC continuous improvement processes and addressed two key design goals: the need for NPD capability assessment tools and suitability for use in target user companies. NPDWise includes an NPD process and a mean of assessing NPD capability. The NPD process comprises six NPD stages: Opportunity recognition, Concept development, Early system design, Detail design, Commercial preparation, and Market introduction. Each stage integrated three major aspects of NPD: design, market, and production. To address the inconsistancy observed in the maturity level assessment of ICAT, NPDWise employs a maturity level system inspired by ICMM and the Plan-Do-Check-Act (PDCA) cycle. Furthermore, to address the challenge of visual clarity noted with ICAT, NPDWise uses a colour visualization system to convey assessment results. Application of the method to seven early-stage start-ups within STeP indicated that the method facilitated an understanding of current NPD capability and facilitated the identification of improvement opportunities.

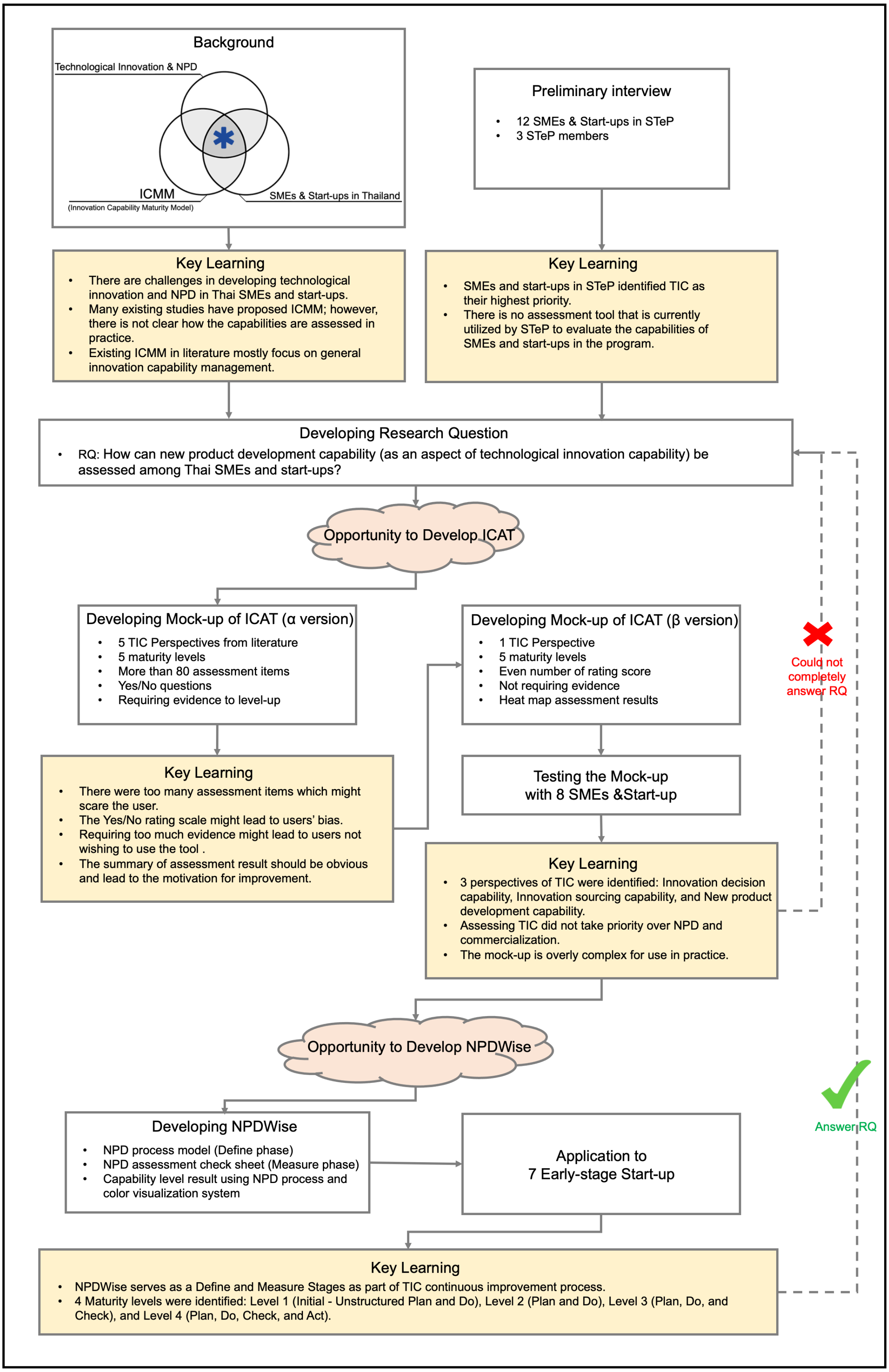


Figure 7.1 Research Journey

In summary, this research journey underscores the critical importance of TIC and NPD capability assessment within the context of Thai SMEs and start-ups. The insights gained contribute to fostering technological innovation and NPD processes, ultimately driving economic progress within Thailand’s business landscape. The entire research journey is shown in Figure 7.1.

7.2 Contributions with Respect to the Research Objectives

The research built on previous knowledge that was adapted to the specific needs of Thai SMEs and start-ups in their quest to improve TIC. In response to the research objectives, the following contributions to knowledge were made.

Objective 1: To elicit stakeholder needs for TIC assessment and development methods from a review of literature and in conjunction with STeP member companies.

Based on the literature review and interviews with twelve STeP member companies, several key findings emerged.

- The literature review highlighted that the development of TIC is considered a high priority for SMEs and start-ups in Thailand. This finding was consistent with discussions held with SMEs and start-ups at STeP.
- Opportunities for research were identified in the existing ICMMs. While these models proposed concepts theoretically, there was an opportunity to improve the understanding of how these capabilities are assessed and developed in practice.
- Various scholars have proposed ICMMs (Arends, 2018; Corsi and Neau, 2015; Essmann and Du Preez, 2009; Narcizo et al., 2019), but existing models lacked specificity when it came to addressing TIC. The need for a more specific approach to TIC assessment became evident.
- Drawing parallels between ISO9001 and TIC development, it was observed that both emphasize leadership, management, organizational learning, improvement, and network linkage. However, challenges faced by SMEs in implementing ISO9001, such as complexities in grasping organizational knowledge, as well as resource limitations, should be taken into account when developing a TIC assessment method.
- Previous studies on TIC in Thailand primarily focused on factors and criteria of TIC, rather than practical assessment and development (Sumrit

and Anuntavoranich, 2013). Interviews with STeP members further revealed the absence of a capability assessment tool.

These findings underscored a need for a TIC assessment tool within the context of STeP's SMEs and start-ups. Addressing knowledge, cost, and resource constraints in stakeholders were key considerations in the development of such a tool.

Objective 2: To evaluate selected TIC assessment methods through application to STeP member companies.

Phase 1 of the research introduced a mock-up of ICAT for assessing TIC, utilizing the ICMM concept and TIC perspectives from Sumrit and Anuntavoranich (2013). Following interviews with eight SMEs and start-ups in Phase 1, three TIC perspectives suitable for the target users were identified: innovation decision capability, innovation sourcing capability, and NPD capability. The first perspective, innovation decision capability, explains how businesses make critical choices related to innovation. This includes strategic planning capability, resource allocation capability and risk management capability. The second perspective, innovation sourcing capability, examines how these enterprises identify and access the internal and external knowledge and technologies necessary for their growth. This capability includes technology acquisition capability and learning capability. The last perspective, NPD, explains how these businesses design product to meets customers' needs. This capability includes design capability, production capability and market capability. Furthermore, the interview highlighted the significance of this specific capability, NPD capability, for the early-stage start-ups. The study also acknowledged that while TIC assessment remained an essential focus, the mock-up of ICAT was not well suited for use by the target users due to its complexity for use in practice.

Objective 3: To identify design goals and requirements for TIC assessment methods in STeP member companies.

The evaluation of the mock-up of ICAT resulted in identifying design goals to create tools that are straight forward to use and focus on high priority aspects of TIC. The first design goal is a need for NPD capability assessment as part of TIC development. The research thus emphasized on a more tailored solution, NPDWise, which aligns more closely with the challenges of early-stage start-ups in STeP. To overcome the challenge on the tool's complexity for use in practice, the second design goal is the suitability for use in target user companies.

Subsequently, five design requirements were identified:

- The method supports users to understand NPD capability of the early-stage start-up.
- The NPD perspectives and criteria of the method are suitable for the situation of users.
- The maturity levels of the method are suitable for the situation of users.
- The method is easy to use.
- The method creates awareness among early-stage start-ups about their NPD capability.

These design requirements provided a structured foundation for the subsequent development of NPDWise.

Objective 4: To propose a TIC assessment method in response to the design goals.

In many organizations, capability assessment serves as a component of continuous improvement journeys. Recognizing this, NPDWise, specifically designed for assessing the NPD capabilities of early-stage start-ups, not only aligns itself as an assessment tool but also adds value to the Define and Measure phases within continuous improvement frameworks. The method provides insights into defining NPD process and assessing NPD capability by using the maturity level system.

In the Define Phase, the method begins by enabling understanding of the current NPD process within the company and developing the NPD process model of the company. NPDWise encompasses a range of NPD metrics that span the entire NPD cycle. NPD capability perspectives were determined into six distinct perspectives according to the NPD cycle. Firstly, in opportunity recognition, companies excel in identifying market opportunities and emerging technologies, emphasizing articulate market opportunities, and assessing new technologies. Subsequently, during concept development, efforts focus on refining and formalizing ideas generated in the opportunity recognition phase. Key sub-metrics include identifying lead users, collecting customer needs, determining product types, investigating concept feasibility, and proposing process concepts. As companies progress into early system design, further structuring of product concepts takes place, incorporating sub-metrics such as conducting customer tests of early system design, developing early system prototypes, determining production schemes, and identifying manufacturers and suppliers. The subsequent stage, detail design, involves translating early system design into a detailed plan, encompassing tasks like developing market rollout plans, conducting customer tests of detail design, developing product detail design, implementing design changes, formulating process detail designs, and defining quality assurance processes. As the product matures, commercial preparation becomes pivotal, with sub-metrics including preparing for market rollout, testing pilot units, and building pilot units. Finally, market introduction marks the product's official launch, emphasizing interactions with customers, evaluation of field experiences with the product, and the initiation of full-scale production system operations. This allows companies to tailor NPDWise to their specific NPD stage, emphasizing NPD activities or NPD aspects at each stage.

In the Measure Phase, the maturity levels incorporated within NPDWise align with the PDCA cycle, emphasizing a structured approach that supports both assessment and action. Level 1 represents a phase where NPD process or activity is performed without predefined framework. Level 2 signifies a more intentional approach. The NPD process or activity is planned and executed by incorporating selected techniques, approaches, or tools. This level infuse structure into the innovation process. Level 3 integrates a reflective dimension into the NPD process. It involves planning and execution, coupled with a subsequent review, reflection, and adjustment of the results. This level emphasizes learning from the outcomes and refining the approach accordingly. Level 4 embodies a continuous improvement mindset. The NPD process or activity is not only planned, executed, and reviewed but also subjected to regular reflection and adjustment. Moreover, the techniques, approaches, or tools employed undergo continuous enhancement based on feedback and reflective insights. This contribution offers a path for these companies to recognize their NPD strengths and weaknesses, implement changes, and steadily progress through maturity levels. In doing so, NPDWise evolves from a static assessment tool into a dynamic driver of continuous improvement for NPD, enhancing the competitiveness and innovative capabilities of Thai early-stage start-ups in technology change market.

Objective 5: To evaluate the efficacy of the developed method with respect to the stakeholder needs.

NPDWise was evaluated through its application in a case study involving seven early-stage start-ups enrolled in the STeP program. This facilitated a deeper understanding of the NPD process and capability of the participating companies, identified best practices, and revealed improvement opportunities for STeP to better support early-stage start-ups in their NPD processes. The assessment uncovered challenges faced by different NPD stages and types of companies, highlighting the need for different supports.

The identification of distinct challenges encountered by varying NPD developmental stages of the companies underscores the need for tailored support strategies. Early-stage start-ups found value in foundational knowledge during idea generation and market validation. In contrast, start-ups in market expansion or scale-up stages indicated a requirement for more specific training. This insight directs STeP to consider a hybrid approach, offering both foundational training and specialized support.

Challenges specific to product types, such as companies commercializing technology and companies developing software platform, further emphasize the need for targeted supports. Technology commercializing (TC) companies needed more specialized assistance, related to their research and technology-specific areas. STeP can address this by fostering an entrepreneurial culture among university researchers, support their journey in commercializing the research, and linking companies with technical specialists. Challenges for platform developing (PD) companies, such as facing software development issues. STeP can address this by organizing networking events that facilitate knowledge exchange between PD companies with varying expertise levels.

In summary, the results indicated that the NPDWise not only provides insights into the existing NPD process of companies but also assesses NPD capability. This represents a contribution to the field by addressing the practical needs of SMEs and start-ups and a contribution to a more flexible innovation assessment method. Moreover, the developed method contributes valuable insights to STeP, guiding it to adapt its support mechanisms based on the specific challenges, various developmental stages, and different products of the start-ups within its program.

Table 7.1 is structured around the research objectives, as outlined in Chapter 1, and illustrates the accomplishment of these objectives and the contributions to knowledge. The chapter in which findings are presented is also indicated.

Table 7.1 Summary of Research Objectives and Contributions

Research objectives	Chapter	Contributions
1) To elicit stakeholder needs for TIC assessment and development methods from a review of literature and in conjunction with STeP member companies.	2	- An initial literature review, coupled with the interviews with members of STeP, identified TIC development as a high priority. - This research identified a need for practical TIC assessment within the context of STeP's SMEs and start-ups.
2) To evaluate selected TIC assessment methods through application to STeP member companies.	4	- Three TIC perspectives suitable for the target users were identified: Innovation decision capability, Innovation sourcing capability, and NPD capability. - A need for more specific support in NPD capability was identified. - The mock-up of ICAT was overly complex for use in practice.
3) To identify design goals and requirements for TIC assessment methods in STeP member companies.	5	- The first design goal is a need for NPD capability assessment tools. - The second design goal is the suitability for use in target user companies. - Five design requirements were identified: to provide users with insights into understanding NPD capability in the early-stage start-up, to align NPD perspectives and criteria with the user's context, to tailor the maturity levels to suit the user's situation, to be user-friendliness, and to ensure that early-stage start-ups are aware of the NPD capability.

Table 7.1 Summary of Research Objectives and Contributions (Cont.)

Research objectives	Chapter	Contributions
4) To propose a TIC assessment method in response to the design goals.	5	- NPDWise was proposed as a method for assessing NPD capability in early-stage start-ups in Thailand. It serves as a Define and Measure Stages as part of continuous improvement process. - In Define stage, the NPD process comprises six NPD stages: Opportunity recognition, Concept development, Early system design, Detail design, Commercial preparation, and Market introduction. Each stage integrated three major aspects of NPD: design, market, and production. - In Measure stage, NPDWise employs a maturity level system inspired by ICMM and PDCA cycle: Level 1 (Initial), Level 2 (Plan and Do), Level 3 (Plan, Do, and Check), and Level 4 (Plan, Do, Check, and Action).
5) To evaluate the efficacy of the developed method with respect to the stakeholder needs.	6	- The application of NPDWise to seven early-stage start-ups led to indicating that the method facilitated the understanding of NPD process and assessing NPD capability. - The application resulted in opportunities for STeP to better support start-ups in the program, addressing specific needs based on the developmental stage of each company. - The evaluation highlighted specific challenges faced different types of companies: TC companies indicated challenges in technology-specific areas and PD companies identified challenges in software development.

7.3 Contribution to Theory

The theoretical underpinnings of this research are rooted in the broader context of TIC and NPD capability and innovation capability assessment and its application within the unique landscape of Thai SMEs and start-ups. This section outlines the specific contributions made to theory, building upon research background explained in Section 1.1.

Advancing Understanding of TIC and NPD Capability: Previous studies, including those by Sumrit and Anuntavoranich (2013), emphasized the importance of TIC for economic growth in Thailand. However, the focus has predominantly been on identifying factors and criteria, rather than practical methodologies for assessment and development. This research bridges the gap by identifying TIC key perspectives: Innovation decision capability, Innovation sourcing capability, and NPD capability. Additionally, during Phase 1 interview, which involved gathering challenges faced by the studied cases in developing technological innovation, it became evident that NPD emerged as a primary challenge for SMEs and start-ups in STeP. This insight underscores the critical need to develop tailored method to assess NPD capability within this context.

Practical Innovation Capability Assessment: Existing innovation capability assessment models, such as ICMM from Essmann and Du Preez (2009) and Corsi and Neau (2015), have provided insights globally. However, their applicability to specific contexts, particularly in Thailand's SME and start-up ecosystem, remains underexplored. This study contributes by customizing assessment method to suit the unique needs of TIC development in the Thai context, offering practical tools for TIC assessment. Based on interviews conducted to gather opinions on the mock-up of ICAT in Phase 1, it was evident that this assessment tool has strong theoretical foundations but lack emphasis on practical implementation. This limitation poses challenges for Thai SMEs and start-ups, whose capacity to use such tool is often limited. This finding led to the design goal of creating assessment methods that is practical for early-stage start-ups and focus on high-priority aspects of TIC, particularly NPD. NPDWise, developed as part of this research, represents a tailored method to understand NPD process and assess NPD capability within the early-stage start-ups in Thailand. It features a two-phase approach: the Define phase encompasses a structured NPD process comprising six distinct stages, while the Measure phase incorporates a maturity level system integrated with PDCA. The integration with PDCA was driven by the recognition that previous maturity levels were not entirely suitable for the studied companies. By aligning with PDCA principles, NPDWise offers a more actionable and iterative approach to NPD capability assessment, thereby facilitating continuous improvement.

7.4 Contribution to Practice

The practical implications of this research are grounded in addressing the identified needs and challenges of Thai SMEs and start-ups within the STeP program, as explained in Section 1.1. The findings and method developed contribute to enhancing TIC assessment and supporting NPD process in this specific context.

Tailored Assessment Method for SMEs and Start-ups in STeP Program: Through the interview with STeP members during the preliminary phase, the absence of an assessment tool to evaluate the capabilities of SMEs and start-ups participating in STeP program was identified. By designing and implementing assessment method specifically tailored for Thai SMEs and start-ups, this research fills a gap in practical tools available for capability evaluation within the STeP program. The development of user-friendly assessment method, such as NPDWise, addresses the need for accessible and targeted approaches to TIC and NPD capability assessment.

Practical Insights from NPDWise Application: This research facilitates the translation of theoretical insights into actionable roadmap for organizations to improve NPD capability as part of TIC continuous improvement. Through the application of NPDWise, the research not only assesses NPD capability but also identifies areas for improvement and best practices among early-stage start-ups in STeP. The application of NPDWise, coupled with a cross-case analysis between Phase 1 and Phase 2 cases, provided insights into the challenges associated with different developmental stages of NPD among companies. Companies primarily engaged in early business activities indicated a need for fundamental knowledge during the idea generation and market validation stages. Companies involved in market expansion or scale-up articulated the need for more specific and tailored supports that are applicable to their company stage and product. TC companies underscored the potential for STeP to offer tailored support catering to various innovations, while PD companies emphasized the importance of knowledge exchange among companies with diverse expertise levels.

Addressing Industry Challenges: The emphasis on developing TIC and NPD capability aligns with the priorities of Thai SMEs and start-ups, fostering a culture of product innovation and technology adoption and improvement. The tailored method developed in this research empower organizations to navigate industry challenges and drive sustainable growth through innovation.

7.5 Limitations of the Research

While this study has made contributions to the assessment of NPD capability and TIC within the context of Thai SMEs and start-ups participating in the STeP program, it is essential to acknowledge limitations that accompany the research findings and methodologies employed. Firstly, the focus of NPDWise was in the context of NPD capability. Its application to other aspects of TIC within SMEs or start-ups was not fully explored in this research. Additionally, the case studies presented in Chapter 6 were not taken through the complete DMADV (Define-Measure-Analyze-Design-Verify) process, primarily due to time constraints. Future research may be required to adapt NPDWise for broader TIC assessments while incorporating the complete DMADV framework. Moreover, while NPDWise provides a comprehensive assessment method for NPD capability, a notable limitation exists in its current application across diverse product types. The existing perspectives and criteria within NPDWise are formulated to address a broad scope of products. However, in practice, companies within the STeP program may exhibit varied product types, ranging from platform development to technology commercialization. This diversity raises a challenge as different products often demand distinct key metrics for accurate assessment. The current NPD perspectives and criteria might not be aligned with the requirements of various product categories. Additionally, the current visualization of capability results, manually crafted for the NPD process, stands as a limitation. The absence of an automated interface means that each visualization was individually curated. This method may lack scalability and real-time adaptability for different companies. Future research is warranted to explore the development of an interface that allows incubators and companies to dynamically visualize their own processes, ensuring a more user-friendly and adaptable method for NPD capability assessment.

Secondly, while NPDWise uses semi-structured interviews to acquire input data, there were instances where not all questions could be answered. This limitation stems from the nature of the interview process, which may not cover every key metric of the assessment tool. The restricted time allocated for interviews may have hindered the depth of responses, impacting the comprehensiveness of data collection. Furthermore, the data collected through interviews might be influenced by subjectivity, recall bias, or personal interpretations. Moreover, it is noteworthy that the ongoing COVID-19 pandemic impacted travel, leading to the decision to conduct video interviews with participants as opposed to in-person meetings. This adaptation could have influenced the quality of the interview process. While efforts were made to ensure data reliability and accuracy, these limitations are inherent in the data collected through interviews. Additionally, the involvement of STeP members in selecting participating companies could potentially introduce bias in the selection process and impact the precision of interview outcomes.

Finally, the research focused on the context of Thai SMEs and start-ups within the STeP program. While the findings and NPDWise provide insights in this specific context, it is important to recognize that the applicability of these findings and the method may be constrained when transferred to industries or regions with different technological, economic, and cultural backgrounds. In addition, the research was conducted within the specific environment of STeP, which, as outlined in Chapter 1, was subject to change as the research progressed. During the research process, STeP underwent significant changes in its program support structures. The researcher aimed to conduct three interviews with participating start-ups in 2019, 2020, and 2022, coinciding with the rollout of the new support program of STeP, BaseCamp24, in March 2022. However, this transition necessitated an initial round of interviews with STeP members to understand the new support framework before proceeding with the third interviews of start-ups. Furthermore, as this thesis was written in 2023, it is noteworthy that STeP has introduced a new program, Builds, launched in August 2023, aimed at guiding current university students in their journey toward entrepreneurship. Although this new program, targeting students starting the business, align with the decision of this study to focus on early-stage start-ups, the continual evolution accentuates the complexity and dynamism of the case study environment. Nevertheless, this recent development underscores the dynamic nature of STeP, indicating ongoing adaptations to better serve the entrepreneurial ecosystem.

7.6 Opportunities for Future Research

In the short term, there is an opportunity to embark on a detailed exploration to tailor NPDWise for specific product contexts. From the identified limitation regarding the generalization of NPD key metrics across different product types, a targeted approach can pinpoint specific areas for development within NPDWise. This involves tailoring the method to cater to the unique needs of different product contexts. For instance, specific methods with perspectives and criteria tailored for platform development companies, including metrics to account for software production, platform scalability and user engagement. Future work could also revolve around customizing NPDWise to suit the distinctive context of technology commercialization companies, such as identifying key metrics related to intellectual property management, market penetration strategies, and technology transfer efficiency. Another short-term opportunity involves explicit define and measure phase of NPD application. To address the limitations in the semi-structured nature of the questions leading to incomplete responses, future research can recommend a more extended timeframe for interviews. This allows for more explicit and thorough questioning, ensuring all aspects of the NPDWise are adequately covered. Further refinement of interview questions can also be implemented to ensure clarity and specificity.

There is opportunity to undertake a medium-term exploration to implement the comprehensive DMADV including the verification. While this research laid the foundation for using the Define and Measure phases, future studies can delve into the practical implementation of the entire DMADV process. This entails defining NPD process, measuring and analyzing existing capabilities, designing improvement initiatives, and verifying their effectiveness through implementation and evaluation. Further future research could develop an interactive interface for visualizing NPD capability results. As presented in this research, the manual crafting of visualizations for NPD capability results signifies a current limitation. To address this, future research can explore creating a tool that involve an interactive interface tailored for individual companies. For example, a system that adapts to changes in a company’s NPD processes over time and offers real-time insights for ongoing improvement or a web-based solution that ensures accessibility from various devices and fosters engagement among both incubator and start-up. Developing such an interface not only addresses the current manual crafting limitation but also aligns with the objective of empowering companies to actively participate in the assessment and continuous improvement of their NPD capabilities.

In the long-term, a more comprehensive TIC assessment and development method could be developed. While NPDWise primarily explored in the context of NPD capability, it has the potential for broader applications within the TIC scope. Future research can explore how the method can be customized to evaluate various dimensions of TIC, such as innovation decision capability and innovation sourcing capability. This exploration can further enrich the utility for SMEs and start-ups seeking a comprehensive assessment of their TIC. Such research can provide a systematic roadmap for SMEs and start-ups to enhance their innovation capabilities, offering an actionable approach for improvement. This future research may include the long-term organizational adaptation studies. STeP can evolve and refine their support structures, including conducting long-term studies on how these adaptations impact SMEs and start-ups over time. Continuous evaluations can help identify the long-term effects of program changes on TIC and offer actionable guidance for program development. Another proposed long-term future research is the validation and adaptation of NPDWise in diverse technological, economic, and cultural contexts. While this study provides insights into the context of Thai SMEs and start-ups within the STeP program, extending this research to different industries, regions, or countries can help assess the cross-contextual validity. This cross-validation can reveal the flexibility and capacity of the method to address varying TIC requirements in different settings.

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Appendix A
Support Programs from STeP

Science and Technology Park Chiang Mai University (STeP) plays a pivotal role in supporting entrepreneurs within the Northern region of Thailand. STeP offers multifaceted support, catering to various segments of the entrepreneurial ecosystem. Its functions span across eight different departments, but the primary focus is on fostering innovation and assisting start-ups and SMEs. This support extends to students, alumni, researchers, and local businesses. The following sub-sections detail the distinctions between pre-incubation and TBI and Basecamp24. Furthermore, two additional interviews were conducted with STeP members responsible for supporting student start-ups and SMEs within the Camp2, which were explained in the following sub-section.

A.1 Pre-incubation and Technology Business Incubation (TBI)

The initial STeP support programs are divided into two distinct stages: pre-incubation and TBI (incubation). The **Pre-incubation Phase** is a critical early step that progresses from the problem/solution fit to the product/market fit. Problem/solution fit represents the initial stage where companies explore ideas to address specific pain points, while product/market fit characterizes the subsequent phase, in which companies attain revenue traction and their target customers start buying their products. This stage emphasizes the cultivation of an entrepreneurial mindset and equips participants with essential tools such as idea generation, design thinking, lean canvas development, team building, pitching, market entry, and prototype testing. Within this pre-incubation stage, a diverse array of programs with varying objectives are offered. For instance, the **Entrepreneurial Ecosystem Development Program** caters to students and alumni, guiding them from team formation and idea generation to prototype development. The **Research 2 Market Program** is tailored for students seeking to transform existing university research into viable business plans, ultimately presenting their ideas in pitch competitions. The **Startup Thailand League Program**, on the other hand, is designed for existing start-ups looking to secure funding. It is noteworthy that participants in these programs can include individual students, groups of students, or registered companies. It can be seen that there are both programs that are intended to encourage students to adopt entrepreneurial thinking, and programs that are specifically designed for alumni who are already engaged in start-ups and seek to enhance their business growth.

Nevertheless, the availability of these programs can fluctuate each year, contingent upon government budget allocations, as explained by the interviewee,

> *"There was government funding last year, but this year, there is none. Relying on government projects to incubate entrepreneurs is challenging. To overcome this, we tailor-make our programs by adapting to budget constraints and sometimes seek funding from alternative sources."*

While the majority of programs are geared toward students and alumni, there is one program that welcomes SMEs known as **Startup's Guide**. This program serves as a precursor to TBI, open to students, alumni, and SMEs. The Startup's Guide program begins with an initial cohort of 70 teams/companies, engaging in a two-month training program. Following this, 35 teams/companies are selected to advance to a four-month training and consulting phase, culminating in a pitching competition where the top 12 teams/companies are chosen to enter the TBI program. TBI, which extends over two years, focuses on nurturing businesses that have already achieved product/market fit. The primary training within this incubation program centers on topics such as team management, innovation management, fundraising, investor engagement, financial management, and intellectual property management. In addition to these training elements, TBI offers supplementary support, including international networking opportunities and business matching. It is worth noting that while TBI is open to businesses of all types, the majority of its participants tend to be students and alumni who are more extensively prepared for the program. As the interviewee elaborated,

> *"Student start-ups are generally better prepared, having undergone the pre-incubation program and spent 1-2 years developing their ideas. In contrast, SMEs, often well-established with existing products, may not possess the mindset to modify their business models or incorporate innovation."*

Since its inception, STeP has supported and incubated 56 companies within the TBI program.

A.2 Basecamp24

A transformative shift occurred in STeP support paradigm with the inception of 'Basecamp24' on March 31, 2022. The interviewee explained that,

> *"The term 'Basecamp24' takes its name from its around-the-clock availability, symbolizing its continuous support. This rebranding aimed to address a prevalent issue regarding the misperception and misunderstanding of STeP incubation process. The traditional view of*

> *incubation often misconstrued it as a source of free support from universities or the government, leading to misguided expectations and incomplete actions. While STeP objective is to foster start-ups, the precise manner of assistance remained ambiguous. Therefore, the decision was made to redefine this process by adopting a more private enterprise-oriented identity."*

This pivotal change entailed a comprehensive reorganization of start-ups into five distinctive camps: Basecamp (Inspiration), Camp1 (Ideation), Camp2 (Market validation), Camp3 (Market expansion), and Camp4 (Market scale-up). The basecamp journey shows in Figure A.1

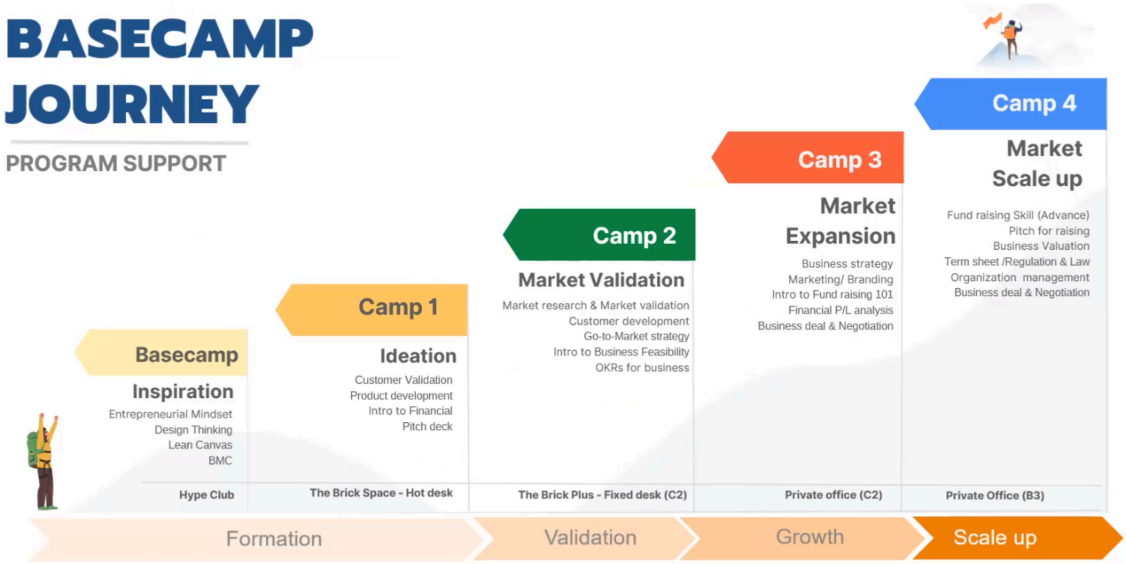

Figure A.1 STeP Basecamp24 (Sources: STeP)

Basecamp and Camp1 serve as platforms akin to entrepreneurial university programs, instilling inspiration and knowledge within university settings. Individuals who have engaged with the project find their place in **Basecamp**, which remains open to all, offering spaces for activities like the annual workshop and hackathons, accessible to everyone. Transitioning into Camp1 is contingent upon the number of teams displaying commitment. This means that, while there might be around 3000 participants in Basecamp, Camp1 typically hosts a more focused group of 30 to 50 ideation teams. **Camp1** centers its efforts on the crucial phases of Problem/Solution fit and Vision/Founder fit. Teams or companies aspiring to join Camp1 need to have a well-defined idea in place, have assembled a dedicated team, and their concept should have undergone rigorous market research. They must exhibit a clear direction for their business and a strong grasp of where their solution is heading. In **Camp2**, the emphasis shifts to market validation, still within the ambit of Problem/Solution fit. As this stage culminates, teams or companies are expected to introduce their prototype or Minimum Viable Product (MVP) to the actual market, engage in field tests, and conduct comprehensive market research. The primary objective is to secure the first dollar of revenue, substantiating that the solution they have conceived aligns with market demand, and customers are willing to pay for it. At this juncture, the business is deemed ready to take off. **Camp3** centers its attention on expanding the customer base, targeting companies that already possess a comprehensive understanding of their customer demographics. The focus pivots to profit/loss and financial aspects, delving deeper into the market to acquire substantial monetary traction and data-driven insights. This readiness enables companies to grow further and actively engage with venture capitalists. Market expansion signifies not only the expansion of the existing customer base but also venturing into new markets while maintaining the same product or service. In **Camp4**, the trajectory follows the S-curve. Companies at this stage might introduce new features or entirely new product lines, running in parallel with their existing offerings. They dive deeper into their current market or explore novel markets for expansion.

In contrast to the previous program structure of Pre-incubation and TBI, which extended over three years, STeP has ingeniously restructured it into three distinct camps within Basecamp24: Camp2 equates to TBI year 1, Camp3 aligns with TBI year 2, and Camp4 mirrors TBI year 3. In the transition from Camp2 to Camp3, a pivotal pitching event occurs, offering multiple funding opportunities. This serves as the selection process for teams aspiring to join TBI in Camp3 and Camp4. In essence, STeP has condensed the duration of TBI; what was once a three-year program has been streamlined into a comprehensive pre-incubation, laying the groundwork for teams to compete for entry into TBI, a two-year program supporting 12 teams annually.

A.3 Insights from STeP Members: Fostering Entrepreneurship with Camp2

In this sub-section, key insights gained from interviews with two STeP members responsible for the Camp2 program were presented, which plays a pivotal role in supporting entrepreneurship in northern Thailand. Camp2 focuses on nurturing startups and SMEs, guiding them through various stages of development, and assisting them in their quest for innovation and growth.

Diverse Mix of Entrepreneurs: One of the most prominent observations is the diversity within Camp2 participants. The interviewed members noted a broad mix of entrepreneurs, ranging from startups to SMEs. These participants encompass businesses within various sectors, including food, cosmetics, coffee, and even medical services.

Startups' Technology Orientation: While the focus within Camp2 is diverse, a significant portion is dedicated to tech-oriented startups. These startups typically emphasize innovation, digital platforms, and the application of technology to differentiate their products or services. The emphasis on technology-driven innovation is seen as a key factor in stimulating business growth and offering unique value to consumers.

Market Validation and Business Consulting: The program places significant importance on market validation and business consulting. Startups are coached on how to accurately assess their target markets, gather customer feedback, and fine-tune their value propositions. The goal is to help these businesses transition from the ideation stage to a more solid, market-ready position.

Mentorship and Consultation: Besides external experts, internal teams within STeP play a substantial role in mentoring and consulting with the participants. This dual approach ensures that the startups and SMEs receive well-rounded guidance. The importance of mentorship and consultation extends to facilitating interactions and collaborations between startups themselves.

Support Services at Camp2: The incubator offers comprehensive support services for startups. These services include access to office space, essential equipment, mentorship, and training to help startups develop robust business plans and strategies. Legal and accounting services are also provided to assist with navigating Thailand complex regulatory requirements for business setup.

Networking and Funding: Camp2 facilitates networking opportunities and offers mentorship on effective pitching to connect startups with potential investors and partners. Their network aids startups in securing the necessary funds for growth and development. The goal is not just to help startups survive but to enable them to thrive and grow into successful, sustainable businesses.

Sustainability and Social Impact: Notably, Camp2 has a keen focus on sustainability and social impact. They prioritize startups that incorporate environmentally and socially responsible practices into their business models. This emphasis has helped their startups stand out and attract investors and customers who share these values.

Early stage of NPD: Camp2 focuses more on the early stages of the NPD process, particularly on the planning and concept development stages. The incubator provides resources and guidance to help start-ups prepare documents and pitch their ideas to potential investors. However, there is less emphasis on the later stages of the NPD process, such as detail design and testing and refinement. Therefore, there is a difference between the support provided by the incubator and the NPD process models proposed by Ulrich and Eppinger (2016) and Wheelwright and Clark (1992).

NPD Aspect: The support provided by the incubator can link to the market and design aspects of the NPD process of Ulrich and Eppinger (2016). In terms of marketing, the incubator provides guidance on market research and analysis, as well as assistance with creating business plans and pitching to investors. This can help startups better understand their target customers and market demand for their product or service. In terms of design, the incubator provides support in the form of mentorship and workshops on product development and design thinking. Camp2 also provides some resources and guidance on product design and development, prototyping, and testing. However, they also mentioned that they can connect startups with manufacturers and suppliers, which could potentially link to the manufacturing aspect of the NPD process.

Appendix B Examination of Existing ICMMs

This appendix presents a comprehensive analysis of 30 Innovation Capability Maturity Models (ICMMs) identified and reviewed from 2009 to 2024, as showed in Table B.1. The sample encompasses a range of models, not limited to innovation, but also including Technological Innovation Capability (TIC), New Product Development (NPD) capability, New Service Development (NSD) capability, as well as other models relevant to organizational capabilities such as digital transformation or Information Technology (IT) and sustain-oriented innovation/NPD.

As illustrated in Table B.1, each ICMM within this sample is examined based on critical criteria including assessment focus, maturity level depiction, and the extent of model validation. Key findings from this examination reveal a diverse landscape of ICMMs, with specific focuses distributed as follows: 9 models on general innovation, 3 on technological innovation, 9 on NPD/NSD, 6 on digital transformation or IT, and 3 on sustain-oriented innovation/NPD.

Table B.1 Examination of Existing ICMMs

Model Name	Focus of the Model	Assessment Metric	Level						Validation
			Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	
Innovation Capability Maturity Model (Essmann, 2009)	General innovation	- Innovation Process (Explore & Converge, Portfolio Management, Consolidate & Exploit, Process Control & Risk Management) - Knowledge & Competency (Discover, Absorb & Consolidate, Core Competency & Technology) - Organisational Support (Innovation Strategy & Leadership, Structure & Infrastructure, Environment & Climate, Resources & Measurement)	-	Ad hoc & Limited	-	Formalisation & Predictability	-	Integration, Synergy & Autonomy	Validation (6 Case Studies)
I²MM Integrated Innovation Maturity Model for Lean Assessment of Innovation Capability (Müller-Prothmann and Stein, 2011)	General innovation	- Ideation & Product Development - Innovation Management - Requirements Engineering - Quality Management	-	Chaotic	Organised	Standardised	Predictable	Innovation 'Black Belt'	-
Innovation Capability Maturity Model (Corsi and Neau, 2015)	General innovation	-	Not innovate	Do	Repeat	Coordinate	Manage	Sustain	-
InnoMM Innovation Maturity Matrix (El Bassiti, 2018)	General innovation	- Knowledge Scale (Core-Idea, Behavior, Process, Class) - Actor Scale (Individual, Organization, Community) - Context Scale (Resources, Policies, Capabilities)	-	Awareness	Defined	Linked	Managed	Sustained	-
Firm-level Innovation Capability Maturity Model (Arends, 2018)	General innovation	- Innovation Strategy - Innovation Ecosystem - Process & Governance - Organizational Learning - Innovation Culture - Technology - Knowledge Management	-	Ad-hoc	Low	Intermediate	High	Excellent	Validation (Delphi study with 9 experts & Survey)
S3M-I Strategic Management Maturity Model for Innovation (Demir, 2018)	General innovation	- Leadership - Planning & Executing - Processes & Tools - Structure & Model - People & Culture - Performance Management - Innovation	Undefined	Initial	Planned	Performed	Optimized	Excellent	-

Table B.1 Examination of Existing ICMMs (Cont.)

Model Name	Focus of the Model	Assessment Metric	Level						Validation
			Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	
Innovation capability maturity in Non-R&D performers (Narcizo et al., 2019)	General innovation	- Input (Data and information on the market and technology, new knowledge, opportunities, and ideas) - Organizational dimension (Learning, Culture, Strategy, Structure, Leadership, Marketing, Processes, People, Resourses, and Relationships) - Output (Product innovation, Process innovation, Marketing innovation, organizational innovation) - Performance perspectives (Operational, Customer satisfaction, HR, Financial)	-	Revealed innovation	Experimental innovation	Achieved innovation	Improved innovation	Mature innovation	Validation (Consulting specialists during the model development)
OI-CMM Open Innovation Capability Maturity Model (Podmetina et al., 2019)	General innovation	- Knowledge transfer (Internal process, Collaboration process) - Open innovation (Human resource process, Structures and tools)	-	Initial	Repeatable	Defined	Managed	Optimizing	Validation (Factor analysis)
Innovation Project Management Maturity Assessment in Industrial Enterprises (Honorato and de Melo, 2023)	General innovation	- Strategy (Guidelines deployment process, Analysis of enterprise ecosystem, Portfolio management, Knowledge management, Technological roadmap) - Product Development Process (Systematized process, Interactive development, Product engineering, Process engineering, Quality engineering, Scope management, Cost management, Risk management) - Project Management (Quality management, Schedule management, Resource management, Communications management, Acquisition management, Stakeholder management, Integration management) - Innovation Environment (Governance, Organizational structure, Culture directed to innovation, Driven open innovation, Qualification and training) - Results and Metrics (Strategy performance evaluation, Performance evaluation of people, Performance evaluation of projects, Product performance evaluation)	-	Initial	Standardised	Detailed	Managed	Continuous Improvement	Validation (2 Case Studies)

Table B.1 Examination of Existing ICMMs (Cont.)

Model Name	Focus of the Model	Assessment Metric	Level						Validation
			Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	
Technology Management Maturity Model for Healthcare Organizations (Shaygan and Daim, 2019)	Technological innovation	- Technology (Data management, Supporting infrastructure, Real-time knowledge access and sharing) - Social (Stakeholder trust, Accessibility, Stakeholder engagement, Talent acquisition) - Organizational (Leadership, Strategic management, Organizational culture, Wuality improvement) - Regulatory (Standard compliance, Regulative influence, Governance)	-	Mission	Perspectives	Criteria	Outcomes	-	-
Practice-based Maturity Model for TTO Performance Management (Kreiling and Bounfour, 2020)	Technological innovation	- TTO (Technology Transfer Organization) Intelligence - Cross-fertilizing - Matching - Platformic Bundling - Changing the Mindset - Managing the Knowledge Base	Initial (Not done)	Managed (Experimentation phase)	Defined (Done in minority of transfer projects/organisation)	Generalised (Done in majority of transfer projects/organisation)	Advanced (Fully deployed)	-	Validation (4 cycles of survey and revision)
Management and Technological Maturity Levels (Shpak et al., 2022)	Technological innovation	Assessment metrics are different based on each level and each technology group	-	Initial	Cyclic	Process	Progressive	Dynamic	Validation (Tests with 7 enterprises)
Lean Product Development Maturity Model (Viklander and Möller, 2011)	NPD	- Establish custom-defined value - Front-load the product development process - Create a leveled product development process flow - Utilize rigorous standardization to reduce variation and to create flexibility and predictable outcomes - Develop a chief engineer system to integrate development from start to finish - Organize to balance functional expertise and cross-functional integration - Develop towering technical competence in all engineers - Fully integrate suppliers into the product development system - Build in Learning and Continuous Improvement - Build a culture to support excellence and relentless improvement - Adapt technology to fit your people and processes - Align your organization through simple, visual communication - Use powerful tools for standardization and organizational learning	No effort at all has been made in the area of the principle	-	-	-	-	This principle is completely practiced in a lean way	Validation (Interviews and Survey)

Table B.1 Examination of Existing ICMMs (Cont.)

Model Name	Focus of the Model	Assessment Metric	Level						Validation
			Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	
CMM-IPD Capability Maturity Model for Industrial Products Development (Wei et al., 2013)	NPD	- Organizational Support Capability - Technology Development Capability - Project Management Capability	Has completely failed to carry out any mission industrial products development.	Business success depends on individual skills and experience, management is reactive.	Business process has been institutionalized, disciplined and repeatable.	With standard procedures, the development process will be equipped with standardized.	Business products and processes to establish quantitative quality goals.	Industrial products development process quantitative feedback and new ideas & technology for the process of continuous improvement.	-
CLIMB Model (Rossi and Terzi, 2017)	NPD	- Activities & Flow - Decision Making - Training - Roles and Collaboration - Knowledge Management Process - Knowledge Management Techniques - Methods - Computerization and Software	-	Chaos	Low	Intermediate	Mature	Best Practice	Validation (Interviewing 103 Companies)
Maturity Model for Effective Additive Manufacturing Integration in the Product Development Process (Lamontagne, 2016)	NPD	- AM Uses (Prototyping, Tooling, Production parts) - Product Development Process	-	Occasional	Formalized	Controlled	Optimized	Innovative	Validation (Quantitative method)
DEEP 1.0 Product Roadmap Maturity Model (Münch et al., 2019)	NPD	- Items to be found on the product roadmap - Adequacy of item detailing based on the timeline - Reliabilty - Confidence - Discovery - Responsible for placing items on the roadmap - Prioritization of product roadmap items - Extent of Alignment - Ownership of the product roadmap	-	N/A	N/A	N/A	N/A	N/A	-

Table B.1 Examination of Existing ICMMs (Cont.)

Model Name	Focus of the Model	Assessment Metric	Level						Validation
			Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	
MM for NSD Maturity Levels of New Service Development (NSD) Processes (Rapaccini et al., 2013)	Service Innovation, NSD	- Organizational approach (Relevance of NSD, Roles, Management practices) - Resources (Budget, Tools and methods, Skills) - Stakeholders (Customers, Suppliers and other stakeholders) - Performance management (Feedback systems, KPIs)	-	Initial	Repeatable	Defined	Managed	Optimized	Validation (6 Case Studies)
NSDMM New Service Development Maturity Model (Jin et al., 2014)	Service Innovation, NSD	- Strategy management (Goals and objectives, Arenas of focus, Resource allocation0 - Process formalization (Systematic behavior, Documentation, Assignment of responsibilities) - Knowledge management (Culture, Process, Technology) - Customer involvement (Customer role of involvement, Stage of involvement, Method of involvement)	-	N/A	N/A	N/A	N/A	N/A	-
SCSM Service Capability Sourcing Model (Carroll and Helfert, 2015)	Service Innovation, NSD	- Volume - Velocity - Variety - Value of the service lifecycle	-	Initial	Repeatable	Defined	Managed	Optimized	-
CMMI-SVC Maturity Level 2 for Start-up Firms (Wang, K. et al., 2016)	Service Innovation, NSD	- Measurement analysis - Work planning - Supplier agreement management - Work monitoring and control - Requirements managemen - Service delivery	-	Initial	Managed	Defined	Quantitatively managed	Optimizing	Validation (Case study)
Industry 4.0 Maturity Model of Manufacturing Enterprises (Schumacher et al., 2016)	Digital transformation, IT	- Strategy - Leadership - Customers - Products - Operations - Culture - People - Governance - Technology	-	A complete lack of attributes supporting the concepts of Industry 4.0	N/A	N/A	N/A	The state-of-the-art of required attributes	Validation (Case study)

Table B.1 Examination of Existing ICMMs (Cont.)

Model Name	Focus of the Model	Assessment Metric	Level						Validation
			Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	
PAM Process Assessment Model for Digital Transformation (Aguiar et al., 2019)	Digital transformation, IT	- Customer - Value proposition - Organiztion - Data - Operations - Transformation Management	Incomplete process	Performed process	Managed process	Established process	Predictable process	Innovating process	-
Capability and Maturity Model for Collaborative SaaS (Software-as-a-Service) (Cancian et al., 2020)	Digital transformation, IT	- Collaborative process - SaaS process	Incomplete	Performed	Managed	Established	Predicable	Optimizing	Validation (Expert evaluation)
Maturity Model for Assessing the Product Lifecycle (Pfenning et al., 2020)	Digital transformation, IT	- Process - Organization - Collaboration - Data - Application - Technology	-	Reactive	Repeatable	Integrated	Collaborative	Adaptive	-
Digitalcheck Mittelstand Digital Transformation Maturity Model for SMEs (Petzolt et al., 2022)	Digital transformation, IT	- Strategy - Customers - Products and Services - Processes - Organization - IT-Infrastructure/Technology - Environment	N/A	N/A	N/A	N/A	N/A	N/A	Validation (Interview) and Application
Digital Business Transformation Maturity Model for Micro Enterprises in Developing Countries (Sukrat and Leeraphong, 2024)	Digital transformation, IT	- Strategy - Process - Technology - People	-	Beginner	Intermediate	Experimenced	Leader	-	-

Table B.1 Examination of Existing ICMMs (Cont.)

Model Name	Focus of the Model	Assessment Metric	Level						Validation
			Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	
IRI Sustainability Tool (Hynds et al., 2014)	Sustain-oriented Innovation	- Strategy Dimensions (Corporate Sustainability Policy, Overall Sustainability Strategy, Government Policy & Regulation, Impact of Trends, Supply Chain, Green labeling, Sustainability Design for Environment) - Design Tools Dimensions (Specifications/Customer Insights, Life Cycle Assessment (LCA) Process, DfE–Material and Part Selection, DfE–Supply Chain, DfE–Manufacturing Impact, DfE–Use Phase Impact, DfE–End of Life Impact)	-	Beginning	Improving	Succeeding	Leading	-	Validation (Quantitative method)
Responsible Research and Innovation (RRI) Maturity Model (Stahl et al., 2017)	Sustain-oriented Innovation	- Purpose (Motivation for doing the research, Motivation for engaging with RRI, Ethics) - Process (Anticipation, Engagement, Reflection, Governance, Ethics, Responsiveness) - Product (Gender/equality and diversity Open access, Social justice/inclusion, Sustainability, Science education)	-	Unaware	Exploratory/Reactive	Defined	Proactive	Strategic	Validation (3 Case Studies)
Eco-Mi Eco-Innovation Maturity Model (Xavier et al., 2020)	Sustain-oriented Innovation	- Strategy - Structure - Resources - Culture	-	Incompete	Ad-hoc	Operational	Strategic	Holistic	Validation (Expert evaluation & Case study)

Appendix C The Mock-up of ICAT Alpha (α) Version

The mock-up of ICAT alpha (α) version shows in Figure C.1, Figure C.2, and Figure C.3. It can be seen that there are some opportunities to improve this version. For example, there is yes/no question. However, the answer could not be 0% performed or 100% performed. This design requires supporting material as the evidence. However, the users might think the tool was too difficult to use and did not want to spend many resources. The mock-up consists of six TIC perspectives with over 80 items to assess. It was possible that it might take long time to interview the users and resulted in users' bias.

Level	Perspective	Question	Criteria	Sub-criteria	Example of evidence	Score (Weight)	Evaluation (Yes/No)	Result
Level 1 Initial	Innovation Management Capability	Does initial innovation management exist?	Strategic Management Capability	Innovation topic is not priority, but is sparked by crisis/customer/supplier/etc.	- Initial plan to produce and manage innovation	20	Yes	
			Organization Capability	Innovation projects are planned and executed in isolation		20	Yes	
				Infrastructures, systems &tools are insufficient to support innovation activities		20	Yes	100
	Technology Commercialization Capability	Have at least one technology been developed and commercialized successfully?	Manufacturing Capability	Company has already developed at least one successful innovation and improve incrementally	- Report of at least one successful innovation (e.g. sales report, customer list)	20	Yes	
			Market Capability	Company keeps revenue from main product		20	Yes	
Level 2 Repeatable	Innovation Management Capability	Is innovation management based on successful practice in the past?	Strategic Management Capability	A strategic innovation plan is present and focused on the short-term	- Short-term innovation management plan - Innovation project management based on successful project in the past	10	Yes	
				Employees are partly aware of innovation strategy		10	Yes	
			Organization Capability	Project tasks & schedule are based on successful project in the past		10	Yes	
				Infrastructures, systems &tools to support innovation activities that work well in the past are reused and function as separate system		10	Yes	
			Resource Allocation Capability	The resources are allocated by focusing on maintaining most profitable product		10	No	
			Risk Management Capability	Project uncertainties are reduced based on past experience		10	No	60
	Technology Commercialization Capability	Have successful products been reproduced to explore main market?	Manufacturing Capability	Company develops other products by reproducing successful practice	- Initial result of reproducing successful practice (e.g. increase production volume and sales)	10	Yes	
			Market Capability	Company explores main market & focus on customer loyalty		10	Yes	
	Innovation Sourcing Capability	Have information, skill and technology been sourced from external occasionally?	Network Linkage Capability	Information and skill transfer across boundaries (e.g. customers, suppliers, consultants) takes place occasionally	- Initial result of sourcing information, skill and knowledge across boundaries (e.g. initial collaboration with research institute, science and technology park)	10	No	
			Technology Acquisition Capability	Technology acquisition across boundaries (e.g. Intellectual Property (IP), research institutions) takes place occasionally		10	No	
Level 3 Defined	Innovation Management Capability	Have innovation management been defined?	Strategic Management Capability	A long-term innovation vision, mission, strategy and objectives are presented.	- Innovation vision, mission, strategy and objectives			
			Organization Capability	Projects tasks & schedules are planned & coordinated	- Projects tasks - Projects schedules			
				Infrastructures, systems &tools to support innovation activities are defined	- Infrastructures list - Infrastructure usage plan			
			Resource Allocation Capability	Procedures/plans to allocate resource are defined	- Procedures to allocate resource - Plan to allocate resource			
			Risk Management Capability	Procedures/plans to reduce project uncertainty & imitate risk are defined	- Procedures to imitate risk - Plans to imitate risk			
	Technology Commercialization Capability	Have technology commercialization process been planned?	Manufacturing Capability	Procedures/plans to improve R&D result and transform into products are defined	- Procedures to transform R&D result into products - Plans to transform R&D result into products			
			Market Capability	Procedures/plans to probe market are defined	- Procedures to probe market - Plans to probe market			
	Innovation Sourcing Capability	Have procedure to source information, skill and technology been established?	Network Linkage Capability	Procedures/plans to network and facilitate collaboration with external parties has been defined and deployed	- Procedures to network - Plans to network			
				Procedures/plans to transfer information and skill across boundaries are defined	- Procedures to transfer information - Plans to transfer information			
			Technology Acquisition Capability	Procedures/plans to acquire technology across boundaries are defined (e.g. technique to protect IP)	- Procedures to acquire technology - Plans to acquire technology			
	Collective Learning Capability	Have collective learning procedure been established?	Learning Capability	Employees responsible for knowledge sharing are selected	- List of employees responsible for knowledge sharing			
				Procedures/plans to internally share knowledge/arrange training are defined	- Procedure to internally share knowledge - Training plans			
			Absorptive Capacity	Procedures/plans to bring idea forward are defined	- Guideline on how to bring idea forward			
			Knowledge Management Capability	Procedures/plans to measure, store and share innovation project metrics are defined	- Procedures to measure and store knowledge - Plans to measure and store knowledge			

Figure C.1 Mock-up of ICAT α Version

Level	Perspective	Question	Criteria	Sub-criteria	Example of evidence	Score (Weight)	Evaluation (Yes/No)	Result
Level 4 Managed	Innovation Management Capability	Have innovation management been performed?	Strategic Management Capability	A long-term innovation vision, mission, strategy and objectives are translated into actionable goals and KPIs	- Regular activity report			
				Employees are fully aware of the content of the innovation strategy and act in the day-to-day operations.				
			Organization Capability	Project tasks & schedules are managed	- Project tasks report			
				Management monitor innovation closely	- Internal audit report			
				Infrastructures, systems &tools to support innovation activities are deployed and integrated	- Infrastructure usage report			
			Resource Allocation Capability	Resources are managed and allocated to meet innovation objectives	- Resource usage report			
			Risk Management Capability	Project uncertainty is reduced and risk is imitated	- Risk management report			
	Technology Commercialization Capability	Have new products been developed to enter new market?	Manufacturing Capability	Second and third generation of successful products are developed	- Report of transforming R&D result into products - Product portfolio			
				Company develops new line and product families				
			Market Capability	Company enters new market and explores other niche	- Report of probing market - Sales report			
				There is a significantly increase in sale volume and profit				
	Innovation Sourcing Capability	Have information, skill and technology from external parties been acquired and adopted?	Network Linkage Capability	External parties (e.g. customers and suppliers) are consulted at various stage throughout the innovation process	- Consulting report - Networking report			
				Potential innovation partners are regularly scanned and selected for collaboration				
			Technology Acquisition Capability	Technology is acquired, sold and used properly (e.g.)	- IP usage report			
	Collective Learning Capability	Have knowledge from both internal and external been exploited, evaluated, stored and shared?	Learning Capability	Employees actively pursues internal knowledge sharing	- Training material - Training result			
				Knowledge sharing support tools are offered	- Knowledge sharing support tools			
			Absorptive Capability	Employees actively identify opportunities from external information	- Conceptualizing idea from external information report			
				Conceptualizing ideas from external information are well managed to achieve the target				
			Knowledge Management Capability	Innovation project metrics are measured and stored in an integrated database	- Database with evaluation of innovation project - Database usage report			
				Documentation is accessible and used by employees for learning purposes				
	Technology Development Capability	Have technology been developed properly?	R&D Capability	Individuals and teams have empowerment to manage own research and freedom to experiment and seek new solution	- Innovation project plan - Innovation activity result			
			Project Cross functional team integration capability	Innovation teams are made up of individuals of functional divisions with diverse skills				
				Company can create internal source for innovation				
			Technology Change Management Capability	A diverse range of trends is pro-actively scanned	- Analysis of new technology trend - Analysis of customer needs			
				Complex customer needs are analyzed and understood				

Figure C.2 Mock- of ICAT α Version

Level	Perspective	Question	Criteria	Sub-criteria	Example of evidence	Score (Weight)	Evaluation (Yes/No)	Result
Level 5 Sustained	Innovation Management Capability	Have innovation management been evaluated and improved continuously?	Strategic Management Capability	Innovation strategy plan, goal and KPI is continuously evaluated and improved	- KPIs evaluation			
			Organization Capability	Project schedule and cost are managed as an integrated whole within the innovation portfolio	- Project task evaluation and improvement activity			
				Management supports and coordinates individuals' activities				
				Infrastructures, systems &tools to support innovation activities are evaluated & improved constantly	- Infrastructure usage evaluation and improvement activity			
			Resource Allocation Capability	Resources are pooled to the alignment and integration of the project tasks	- Resource allocation evaluation and improvement activity			
			Risk Management Capability	Project uncertainties and risks are identified, managed balanced, and reduced as an integrated whole within innovation portfolio	- Risk management evaluation and improvement activity			
	Technology Commercialization Capability	Do products have competitive advantage and strengthen market position?	Manufacturing Capability	New lines/ product families are frequently developed to meet market need	- Product portfolio evaluation and improvement activity - Sales report (e.g. sales growth, price/cost, net income) evaluation and improvement activity - Benchmarking analysis and improvement activity			
				Products have competitive advantage				
			Market Capability	There is business diversification of market position				
				Financial performance is strong				
	Innovation Sourcing Capability	Have external parties played essential role throughout innovation process?	Network Linkage Capability	Customers and suppliers play an essential role throughout the innovation process& consistent involvement in activities and at key decision points	- Networking evaluation and improvement activity			
				Company is skilled in deploying a diverse range of existing relations and initiating new relations for innovation purposes				
				Company consistently evaluates and revises innovation partnerships				
			Technology Acquisition Capability	Strategy of IP protection is evaluated and improved	- IP usage evaluation and improvement activity			
	Collective Learning Capability	Have collective learning process been continuously improved?	Learning Capability	Employees know where to find the right people for the right information	- Knowledge sharing support tool evaluation and improvement activity			
				A knowledge sharing support tool is frequently used and constantly improved				
			Absorptive Capability	Identifying opportunity and bringing them forward is natural behavior	- Conceptualizing idea from external information evaluation and improvement activity			
				Concept develops are modular and flexible, enabling multiple opportunities to be addressed				
			Knowledge Management Capability	The organization continuously reflects and updates the innovation project metrics defined as relevant	- Database with evaluation of innovation project and employee feedback			
				The formal evaluation process is constantly improved by integrating employee feedback into its development				
	Technology Development Capability	Have technology development process been continuously improved?	R&D Capability	Research and experiment is evaluated and improved continuously by individuals and teams	- Innovation project evaluation and improvement activity			
			Project Cross functional team integration capability	Innovation is integrated with all function				
				Teams and individuals naturally involve the knowledge and skill of others				
			Technology Change Management Capability	All employees are encouraged to participate in environmental scanning	- Revise version of innovation strategy regarding new technology trend			
				High potential trends are selected and incorporated in the innovation strategy				
	Robustness Product and Process Design Capability	Have robustness product and process design been continuously improved?	Product Structural Design and Engineering Capability	Product structure design is continuously improved e.g. product simplification, modularization activities, component selection	- Product structure design evaluation and improvement activity			
			Process Design and Engineering Capability	Process design is continuously improved e.g. DFM (design for manufacturing) activity, process engineering equipment	- Process design evaluation and improvement activity			

Figure C.3 Mock-up of ICAT α Version

Appendix D The Mock-up of ICAT Beta (β) Version

The reflection and learning from the development of mock-up alpha (α) version informed the creation of mock-up beta (β) version by introducing even-numbered scales to minimize user bias, avoiding the need for users to provide extensive evidence to conserve resources during assessment, implementing a heat map for user-friendly visualization of strengths and weaknesses, and focusing on a single perspective to streamline the interview process and reduce time requirements. The assessment check sheet of mock-up beta (β) version shows in Figure D.1 and the assessment result shows in Figure D.2.

Criteria	Questions	Response (Yes/No)	If yes to the first question, please continue to these question.	Level 1: Initial			Level 2: Repeatable			Level 3: Defined			Level 4: Managed			Level 5: Sustained		
				Please rate whether the following answers describe your company. (4 = always true, 3 = often true, 2 = sometimes true, 1 = never true)	Rating	Percentage	If yes to the first question, please rate whether the following sentences describe your company.	Rating	Percentage	If yes to the first question, please rate whether the following sentences describe your company.	Rating	Percentage	If yes to the first question, please rate whether the following sentences describe your company.	Rating	Percentage	If yes to the first question, please rate whether the following sentences describe your company.	Rating	Percentage
Strategic Management Capability	Does your organisation have a documented innovation strategy?	Yes	How explicit has innovation strategy been?	Innovation vision, mission or strategy has been initially mentioned.	4	100%	Innovation strategy has presented and focused at least on the short-term.	4	100%	Innovation strategy has focused on the long-term	4	100%	An innovation vision, mission, strategy and objectives have been translated into actionable goals and KPIs.	3	67%	Goals and KPIs of innovation vision, mission, strategy and objectives have been continuously evaluated.	2	33%
													An innovation vision, mission, strategy and objectives have been well managed.	3		The evaluation result of goals and KPIs have been taken action and improved.	2	
			How important have innovation activities been?	Innovation topic has been sparked, at least by crisis/customer/supplier/etc.	4	100%	Company has already developed at least one successful innovation and seek to produce other.	4	100%	Innovation activities are prioritized	3	67%	Innovation is driving force of company.	3	67%	Innovation and business strategies are synconized.	2	33%
				Innovation activities have had at least some priority in company.	4		Innovation activities have been emphasized based on successful project in the past.	4								Innovation model of company is subject to continuous improvement.	2	
			How well innovation strategy has been communicated within company?	Innovation strategy has been initially communicated within company.	4	100%	Innovation strategy has been communicated within related departments.	3	67%	Innovation strategy has been planned to communicate within company.	3	67%	Innovation strategy has been clearly communicated within company.	2	33%	Innovation strategy and objectives are fully and regularly communicated within company.	2	33%
			How aware are the employees of your innovation strategy?	Employees have been at least initially aware of innovation strategy.	4	100%	Employees in related departments have been aware of innovation strategy.	3	67%	Company has planned to increase employee awareness of innovation.	2	33%	Employees have been fully aware of the content of the innovation strategy.	2	33%	Full awareness of the innovation strategy has been presented among all employees, day-to-day operations and decision-making processes.	1	0%
Organizational Capability	Does your organisation have a documented organizational management for innovation?	Yes	How well have innovation projects been planned and exacuted?	Innovation projects have been planned and executed at least in isolation.	4	100%	Project tasks & schedule have been presented based on successful project in the past.	4	100%	Projects tasks & schedules have been planned & coordinated.	3	67%	Project tasks & schedules have been managed according to the plan.	2	33%	Project schedule and cost are managed as an integrated whole within the innovation portfolio.	1	0%
			How well have managers encouraged employees in innovation activities?	Innovation projects have been emphasized by managers.	4	100%	Managers have at least occationally encouraged innovation activities.	3	67%	Management inspiration programs have been defined.	3	44%	Management inspiration programs have been deployed according to the plan	2	22%	Outcomes of management inspiration programs are evaluated and improved continuously.	1	0%
							Managers have actively exposed innovation success to employees.	3		Managers have regularly encouraged innovation activities	2		Managers have monitored innovation closely.	2		Manager have established culture that links departments and managed multidiscipline processes.	1	
										Managers have regularly selected important innovation success stories and shares them among employees.	2		Managers have actively stimulated innovation activities on all levels.	1		Employees on all levels continuously inspire and stimulate each other to innovate.	1	
			How sufficient have infrastructures/systems/tools been assigned to support innovation activities?	Infrastructures/systems/tools have been managed to support at least at hoc innovation activities.	4	100%	Infrastructures/systems/tools to support innovation activities that work well in the past have been reused and functioned based on successful project in the past.	3	67%	Lists of infrastructures/systems/tools to support innovation activities have been established.	2	33%	Infrastructures/systems/tools to support innovation activities have been deployed and integrated.	1	0%	Infrastructures/systems/tools to support innovation activities have been evaluated & improved constantly.	1	0%
										Usage plans of infrastructures/systems/tools to support innovation activities have been defined.	2		Employees are actively encouraged to use infrastructures/systems/tools to support innovation activities.	1		Infrastructures/systems/tools to support innovation activities have been integrated to project tasks.	1	
																Infrastructures/systems/tools to support innovation activities are available to all employees when require.	1	
Resource Allocation Capability	Does your organisation have a documented resource allocation plan?	Yes	How sufficient have material resources been allocated to innovation activities?	Material resources for innovation projects have been allocated in at least an ad hoc innovation activities.	4	100%	Material resources for innovation projects have been allocated based on successful practice in the past?	3	67%	Procedures/plans to allocate material resource have been defined.	3	67%	Physical resources have been managed and allocated to meet innovation objectives.	2	33%	Physical resources allocation result has been evaluated and improved.	1	0%
										Physical resources for innovation projects are consistent.	3		Employees are actively encouraged to use physical resources for innovation activities.	2		Physical resources are pooled to the alignment and integration of the project tasks.	1	
			How sufficient has investment been allocated in innovation activities?	Investment in innovation projects has been allocated in at least an ad hoc innovation activities.	3	67%	Investment in innovation projects has been allocated based on successful practice in the past?	2	33%	Procedures/plans to allocate investment have been defined.	1	0%	Investment has been managed and allocated to meet innovation objectives.	1	0%	Investment allocation result has been evaluated and improved.	1	0%
										Investment in innovation projects is consistent.	1		Employees are actively encouraged to allocate budget for innovation activities.	1		Investment quantity and structure provide sufficient slack and freedom for activities when require.	1	
			How sufficient has human resource been allocated in innovation activities?	Human resource in innovation projects has been allocated in at least an ad hoc innovation activities.	3	67%	Human resource in innovation projects has been allocated based on successful practice in the past?	2	33%	Procedures/plans to allocate human resource have been defined.	2	33%	human resource have been managed and allocated to meet innovation objectives.	1	0%	Human resource allocation result has been evaluated and improved.	1	0%
										Innovation project teams are dedicated and carefully selected.	2		Number of employees that are responsible for innovation has been increased.	1		Number of employees provide sufficient slack and freedom for activities when require.	1	
Risk Management Capability	Does your organisation have a documented risk management plan?	Yes	How well has risk torelance been determined?	Willingness to take risk has been determined at least an ad hoc innovation activities.	3	56%	Willingness to take risk has been determined based on past experience.	3	44%	Procedures/plans to determine willingness to take risk have been defined.	2	22%	Willingness to take risk has been determined according to the plan	1	0%	Willingness to take risk has been determined as an integrated whole within innovation portfolio.	1	0%
				Ability to take risk has been determined at least an ad hoc innovation activities.	3		Ability to take risk has been determined based on past experience.	2		Procedures/plans to determine ability to take risk have been defined.	2		Ability to take risk has been determined according to the plan	1		Ability to take risk has been determined as an integrated whole within innovation portfolio.	1	
				Risk tolerance has been determined at least an ad hoc innovation activities.	2		Risk tolerance risk has been determined based on past experience.	2		Procedures/plans to determine risk tolerance have been defined.	1		Risk tolerance has been determined according to the plan	1		Risk tolerance has been determined as an integrated whole within innovation portfolio.	1	
			How well has company managed the tolerance of failure?	Failure of innovation results have been estimated, at least an ad hoc innovation activities.	2	33%	Failure of innovation results have been estimated based on past experience.	2	33%	Procedures/plans to estimate failure of innovation results have been defined.	2	17%	Failure of innovation results have been estimated according to the plan	1	0%	Failure of innovation results have been determined as an integrated whole within innovation portfolio.	1	0%
										Usage plans of infrastructures/systems/tools to switch from failure to learning have been defined.	1		Managers accept occasional innovation failures as being normal.	1		Employees have been encouraged to take the risk of pursuing innovation.	1	
													Infrastructures/systems/tools to switch from failure to learning have been deployed according to the plan.	1		Infrastructures/systems/tools to switch from failure to learning have been evaluated and improved.	1	
			How well have project risks been reduced?	Project risks have been identified at least occationally.	3	44%	Project risks have been identified based on past experience.	2	11%	Procedures/plans to identify project risk have been defined.	2	11%	Project risks have been identified according to the plan.	1	0%	Project uncertainties have been identified, evaluated and imitated as an integrated whole within innovation portfolio.	1	0%
				Project risks have been evaluated at least occationally.	2		Project risks have been evaluated based on past experience.	1		Procedures/plans to evaluate project risk have been defined.	1		Project risks have been evaluated according to the plan.	1				
				Project risks have been imitated at least occationally.	2		Project risks have been imitated based on past experience.	1		Procedures/plans to imitate project risk have been defined.	1		Project risks have been imitated according to the plan.	1				

Figure D.1 Assessment Sheet of Mock-up of ICAT β Version

Criteria	Topic	Level 1: Initial		Level 2: Repeatable		Level 3: Defined		Level 4: Managed		Level 5: Sustained	
		Percentage	Average percentage	Percentage	Average percentage	Percentage	Average percentage	Percentage	Average percentage	Percentage	Average percentage
Strategic Management Capability	Explicitness of innovation strategy	100%	100%	100%	83%	100%	67%	67%	50%	33%	25%
	Importance of innovation activities	100%		100%		67%		67%		33%	
	Communication about innovation strategy within company	100%		67%		67%		33%		33%	
	Employee awareness of innovation strategy	100%		67%		33%		33%		0%	
Organization Capability	Innovation project plan	100%	100%	100%	78%	67%	48%	33%	19%	0%	0%
	Management encouragement of innovation activities	100%		67%		44%		22%		0%	
	Infrastructures/systems/tools to support innovation activities	100%		67%		33%		0%		0%	
Resource Allocation Capability	Physical resources allocation	100%	78%	67%	44%	67%	33%	33%	11%	0%	0%
	Investment allocation	67%		33%		0%		0%		0%	
	Human resource allocation	67%		33%		33%		0%		0%	
Risk Management Capability	Willingness to take risk	56%	44%	44%	30%	22%	17%	0%	0%	0%	0%
	Tolerance of failure	33%		33%		17%		0%		0%	
	Project uncertainties management	44%		11%		11%		0%		0%	
Total		**81%**		**59%**		**41%**		**20%**		**6%**	

Figure D.2 Visualization of Assessment Result of Mock-up of ICAT β Version

Appendix E Example of an English Transcript from Phase 1

This appendix presents English transcripts of interviews conducted with Company 1-B’s co-founder during Phase 1 of the research. The selected transcripts encompass discussions on Company 1-B’s overview, its current business model, products, challenges encountered during development, and opinions on the mock-up of ICAT.

E.1 Company Overview

Can you provide an overview of your company?

The current model of our company has evolved since the last time we spoke. Our current product, Farmmate, facilitates connections between farmers seeking to rent land and landowners interested in agricultural use. Previously, our focus was on farm record-keeping and management, but we’ve shifted towards farm rental and management. This move represents a shift to the upstream of the supply chain, starting from the land. Our co-founder structure has also evolved; there are now three co-founders, with myself being the only remaining original member. We currently employ one staff member and occasionally host trainees. While the company name remains the same, our product has transitioned to Farmmate, offering a new platform and service suite. We provide website services, sales, and coordination. Currently, we have secured income from two customers totaling approximately 50,000 Baht. The idea generation phase began around January to March, but progress was halted for three months due to the COVID-19 lockdown. We have been actively operating for the past six months but have not yet turned a profit.

What stage is your company in?

We are currently at the product-market fit stage, which is the phase prior to scaling. Last October, we joined the STeP incubation program. During your previous interview with us, we were part of the Brotherhood program. The incubation program is a three-year commitment from STeP, providing us with 150,000 Baht annually for marketing purposes, crucial for sustaining our operations.

E.2 Technological innovation

How does your company approach technological innovation?

While deep technology is not our specialty, we collaborate with Partner X, whom I mentioned in our previous interview. Our partnership extends beyond mere matchmaking; we also integrate features related to land history and land health assessments into our platform. We adapt their technology to enhance our platform's capabilities, offering insights on suitable crops for specific lands, displaying historical images, and indicating vegetation levels (e.g., green denotes abundance).

Additionally, we are exploring a collaboration with Partner Y, a company with a mapping app boasting over two million users. This company champions open innovation, fostering connections between stakeholders. The app provides land size information, and its user base predominantly comprises farmers. Although this company is not currently profitable, I have faith in their technical expertise in GIS, IT, and geography. Originally, they planned to develop a farmmate platform too. STeP facilitated our partnership discussions, enabling revenue-sharing opportunities. This collaboration will enable us to commence operations seamlessly, starting in Chiang Mai and Lumphun. If successful, we plan to expand nationwide

What strategies does your company employ for technological innovation?

We utilize milestone planning and OKR (Objectives and Key Results) frameworks. For instance, to test our marketing hypothesis, we set OKRs like acquiring 100 landowners with 1,000 units and achieving a one-third rental match rate. Our foundational knowledge aligns with that of other STeP program participants, involving lean canvas and business model canvas methodologies. We adhere to these approaches, ensuring clarity in each canvas element. OKR is an evolution from KPIs, emphasizing objective-driven approaches. For instance, this quarter's target is 500,000 Baht; therefore, our objective is achieving this revenue goal, with corresponding KRs such as securing ten land matches, ensuring bug-free platform usability, and receiving payments within three days. Subsequently, these KRs inform subsequent objectives. For instance, the technical team's objective is to ensure a bug-free platform, with KRs including website speed optimization and addressing user complaints.

What challenges have you faced in developing technological innovations?

Since the inception of our company, we have encountered significant turnover among co-founders. The previous leader, whom you interviewed previously, decided to step down. I assumed leadership because I believed in the potential of agricultural work. However, when I attempted to recruit two individuals as co-founders, the COVID-19 situation forced them to resign. I've come to realize that the traditional approach of offering equity to co-founders may not be effective for us, given that our equity currently holds little value. Consequently, I opted to hire employees to sustain our operations. The challenges with changing co-founders stem from the startup's financial constraints and time limitations. Presently, our team comprises three co-founders: myself as CEO, one specializing in law, and one in development. We've hired one marketing employee and outsourced sales to freelance personnel. STeP provides office support for us.

Another challenge is ensuring the business's survival. While collaborating extensively with STeP and participating in their programs, we sense a pressure to scale up, which concerns us. Additionally, understanding customer needs has proven challenging. Although we developed our products based on theory, customer feedback has been unexpected. We marketed our products as time-saving solutions, but customers prioritized cost savings, particularly Thai farmers who value frugality. In the customer view, they are willing to spend more time if they can save a little money. Despite our efforts to emphasize our product's value and its role in facilitating interactions with landowners, customers perceive us as mere land agents rather than a comprehensive platform or supporter.

Initially, from January to March, we conducted market research on Facebook and identified a higher demand for rented lands than available supply. Following our partnership with Partner Y, we plan to evaluate user adoption. If users from Partner Y do not engage with our services, we'll assess whether our value proposition resonates with Thai consumers.

Technology from Partner X assists us in determining suitable crops for specific areas using satellite data and agricultural insights from various countries. However, farmers often have predetermined preferences for crops and rely less on our data.

Although our company is during researching stage, we might face operation problem when the application starts to use. This is because we cannot estimate the future customer, so that we might face problems, such as application error. In addition, because our company is going to be partner with other platform which is possible to increase the number of users. So, we might need to prepare the operation in case of overload of users. On the other hand, if we spend the money on developing this operation while there is no new user, the investment is wasted.

Despite these challenges, we see opportunities in assisting landowners who lack the resources to manage their properties effectively. Our future plans include expanding our services to include activities like land mowing, thereby extending our reach beyond the upstream supply chain.

Another hurdle is our geographical location; our office in Chiang Mai limits our access to networking events typically held in Bangkok, which offers more extensive connections and seminars.

If there were a model to support your business, what aspects would you want it to address?

We are seeking a model that goes beyond the basics of pitching and provides guidance on venture capital (VC) support. While many programs, including STeP, offer fundamental knowledge and pitching techniques, we require more extensive assistance, particularly in navigating the VC landscape.

E.3 Mock-up Opinion

What are your thoughts on this mock-up?

It appears intriguing. However, I recommend segmenting it by user type, such as co-founders and employees, to accommodate different perspectives. Additionally, consider dividing it by stages, like ideation and company setup. We faced numerous challenges during the setup phase, such as learning to navigate legal requirements like contract drafting—an area where Thai law presents unique obstacles. Despite having acquired basic knowledge, we often had to find solutions independently. For instance, learning how to draft contracts presented a significant challenge. Moreover, Thai law doesn’t adequately support startups. We want incubator, like STeP support for contract drafting. The incubator should offer sample contracts tailored for startups, enabling incubatees to adapt them to their businesses.

You may separate into start-up version, SMEs version, and large company version. This is because there are different points for different types of business to focus on.

You may separate into different stage. For example, level 1 is start-ups in idea seeking stage and level 2 is start-ups that is setting up the company.

Another valuable addition would be guidance on company setup procedures, defining authorities, and understanding financial laws.

In terms of targets, incorporating a timeline, like an 18-month plan, could enhance clarity and goal-setting.

Managing people, especially for us who are new graduated startups lacking professional experience, often involves trial and error. Consider incorporating strategies to facilitate effective team management.

Will you use this mock-up?

If this mock-up serves as a guideline, a corresponding solution guide would be essential. For instance, if the mock-up indicates a red area, suggest methods to transition it to green or yellow. The tool should help us to follow the plan, such as providing timeline to achieve target.

Is the detail suitable for startups?

Regarding the level, I suggest placing "*Initial*," "*Defined*," and "*Managed*" on the same level, as they often occur simultaneously. Subsequently, incorporate "*Repeatable*" and "*Sustained*." Ensure that "*Defined*" and "*Managed*" are addressed at all levels.

Startup stages typically include ideation, product-market fit, scaling, and sustainability. Align the mock-up accordingly, prioritizing team-building and ideation in the initial stages and employee management during scaling.

Consider revising the question "*Company has at least 1 idea*" to "*What are your plans for the next 18 months?"* to enhance clarity.

Any additional thoughts?

People will get confused with your questions.

This question here, “*Company has at least 1 idea*” may change to be “*next 18 months, do you know what you are going to do?*”. You may ask people part from co-founder “*Do you know the organization start to emphasize on innovation?”.* You should ask not only co-founder, but also employee and customer.

Here, “*How important are the innovation activities*?” Start-ups usually think innovation is important to them. So, it is bias to answer 100% important. In practical, start-up need to response to customers. So, they may use innovation as a part of solution, not the main. We are not large company that use innovation to compete with the disruptive innovation. So, you may also separate into start-up version, SME version and large company version.

The criteria of team, you may have questions, such as “*how the team place importance to each other*”, “*how often you meet*”. This is because, I want the tool that could support the business to manage employees because many start-ups are new graduate and do not have working experience. Therefore, it is difficult to manage team."

Regarding language, using English instead of Thai would eliminate translation confusion. For example, this question is not clear, "*innovation awareness*". People don't understand what it is. Instead of "*Have employees been aware of innovation strategy?",* You may change to "*Do the employees often find new solution? Do the employees often generate idea?*" I think we can't measure how people are aware of innovation, so your question should be changed. This is similar to the personality test. The question isn't "*Do you work carefully*?" but ask "You view the work as big or small picture?".

You may develop 2 opposite sites and ask where between these sites they are at.

Overall, this mock-up seems most beneficial for SMEs venturing into innovation rather than those well-versed in the field.

Appendix F Example of an English Transcript from Phase 2

This appendix presents English transcripts of interviews conducted with Company 2-A's co-founder during Phase 2 of the research. The selected transcripts encompass discussions on Company 2-A's overview, process to develop new product, and challenges faced and supports from STeP that could facilitate NPD.

F.1 Company Overview

Can you provide an overview of your company?

I recently graduated with a bachelor's degree in accounting from Chiang Mai University in March 2022. Currently, I am developing a platform for part-time job opportunities tailored to students studying vocational courses, such as automotive and electrical technicians. Our primary focus initially is on auto technicians. The concept for this platform originated during my time as a student at CMU. We conducted extensive research and continued development, but the company's activities intensified after my graduation, including registering the business, launching our product, and initiating sales. Initially, the platform was designed for employee training, with research refining our direction just before my graduation, ultimately shaping it into a platform for part-time job placement.

I am collaborating on this venture with friends who have backgrounds in education. Our motivation stems from a shared belief in the transformative power of education as a catalyst for opportunities, particularly for children. Education is fundamental to personal development. My friend brings valuable insights from her internships and related experiences in the field.

What was your previous platform about?

In the early stages, my focus was on environmental initiatives. At that time, I was deeply passionate about environmental issues despite limited knowledge of startups. I received a scholarship related to the environment and participated in a Hackathon, a pivotal moment that altered my perspective. Initially, I believed training alone could effect change within communities. However, I realized that sustainable impact requires financial stability to support both societal and business needs. The Hackathon experience introduced me to like-minded individuals from Bangkok who interested in the intersection of environment and business. Although our team did not win the competition, we received a special prize for social impact. This event marked my realization that I could contribute to societal change through business initiatives, leading me to pursue additional programs and opportunities.

Subsequent endeavors included launching a platform focused on combating wildfires alongside community members. Unfortunately, our team disbanded due to full-time job commitments. Following this, I ventured into a refill station business selling natural products, which earned me recognition in pitching competitions. However, due to challenges related to high costs, funding issues, and limited market opportunities, we eventually discontinued this venture.

F.2 Developing the Company Product

How did you decide to focus on education?

The decision to shift our focus toward education was influenced by several factors. Our initial funding of 45,000 THB provided a solid foundation. Additionally, during the Hackathon, we observed that the winning projects were centered around educational innovation. This experience underscored the profound impact of education in nurturing individuals from a young age. Unlike environmental efforts, education has a lasting impact on societal attitudes. We also recognized the potential to incorporate environmental awareness into educational initiatives over time.

The pivotal moment occurred after conducting three workshops for vocational students, a demographic often overlooked. These workshops aimed to enhance soft skills among vocational students, revealing the transformative impact of our efforts. This positive reception inspired us to concentrate our efforts in this direction. Participating in programs like the Thailand Startup Club introduced us to mentors and judges whose feedback was invaluable. We received constructive criticism, such as the need for greater sustainability and technological integration. This feedback guided our product development journey, incorporating advanced technologies to maximize impact.

Why did you decide to focus on vocational students initially?

A friend who studied education interned at a technical college and shared the challenges she observed. She highlighted various areas needing improvement, such as outdated equipment and facilities. We conducted workshops and identified significant issues affecting vocational students. Compared to universities like Chiang Mai University, vocational colleges lacked resources and support. Recognizing this gap, we decided to take action to improve opportunities for vocational students.

Can you descript about your current platform?

Our platform is currently in its nascent stages. Students provide their information and indicate job preferences, allowing us to match them with suitable garage placements. Moving forward, our platform will facilitate continuous part-time employment opportunities for students. Upon completion of assignments, students receive certificates bearing the signature of the garage owners. These certificates validate students' experiences, addressing common challenges faced by large organizations when hiring students.

Presently, we utilize a Facebook group as our primary platform, but envision expanding and enhancing our technology to provide a more robust and scalable solution.

You mentioned that you personally choose the students for placements. Could you elaborate on that process?

Yes, originally, our plan was to have garage owners select students themselves. However, we found that they preferred us to make the selections. After matching students with placements and receiving positive feedback, the garage owners returned to use our service.

Regarding product details, we conducted extensive fieldwork. Currently, we are developing and testing the website. On the website, students can register, specify preferred dates and times, and indicate whether they prefer part-time or full-time work. We already have 140 registered students. They fill out a Google form, which serves as their resume, detailing their past and intended work. We then forward these resumes to garage owners. At this early stage, we are managing all operations manually.

We advertise job opportunities through Facebook groups, allowing students to apply for roles that suit their schedules and interests. This approach empowers students to choose jobs aligned with their expertise, avoiding mismatches common in automotive roles, such as painting or suspension work.

We've received positive feedback from garage owners. Many expressed frustration with Jobnorththailand.com, where they paid a monthly fee of 400 THB but struggled to find suitable technicians.

When do you expect the website to be operational?

The design phase is complete, and we are now structuring the development process, which is quite complex. The section for garage owners is still under construction, so we are using Google forms for now. Our main challenge is securing funding, which is why we are minimizing costs by handling job postings and promotions ourselves.

Toyota Lanna has shown interest in investing with us. In our last meeting, they requested financial projections before our next discussion. However, we aim to solidify our product before that meeting to strengthen our company's value. Without a robust platform, Toyota Lanna might view us as high-risk and demand a larger equity stake

How does your platform generate revenue? Do you earn from garages or students?

We generate revenue from garages, based on a percentage model.

How long has your platform been active on Facebook?

We launched at the end of March 2022, just after I graduated. We anticipate transitioning to the website in the next 2-3 months once we complete student testing. Currently, simplicity is acceptable. The primary customer need is to hire students, not cutting-edge technology. Therefore, we're focused on building a strong foundation and reputation. Despite having only a few garages in our system initially, growth has been organic through word of mouth. Major brands like Isuzu and Toyota have joined because our initial customers spread the word. We believe that a strong foundation will justify our investment upon the website launch. Conversely, launching a website prematurely could necessitate costly adjustments later, so we're prioritizing a robust foundation.

Have you started testing the website?

No, our developers are currently refining the registration process and modifying code. Other components are in place but progressing slowly because our team members graduated a year before me and now work full-time elsewhere and part-time on our platform.

How many team members do you have?

We have four members in business administration and initially five in development, now three due to one member focusing on their full-time job and another pursuing a master's degree.

How did you design the website interface?

A friend who is passionate about learning, despite having a medical technology degree, handles UX/UI design for us. We invested just 3,000 THB in a course to develop her skills. Our developers, who have engineering backgrounds, also trained her in design. We prioritize continuous learning together as a cost-saving strategy.

How did you plan the platform initially? Was the customer primarily the garage or the student?

Our primary customer is the garage, representing the demand side, while students represent the supply side. Currently, there is a greater demand than supply of students, so we need to incentivize students to join our platform. Many students prefer ride-sharing or food delivery services like Grab due to higher earnings.

How did you understand student interest in part-time work?

We conducted surveys with teachers from technical and polytechnical colleges to gather insights on pain points for both garages and students. They recommended alumni who owned garages. We visited these garages to understand their hiring practices and pain points, such as technician absenteeism and lateness. We also obtained a list of garages from a magazine and contacted them directly to gauge interest in hiring part-time students. Additionally, colleges provided internship information to identify potential garage partners.

How did you identify student interest in part-time work related to their studies?

During workshops and interviews with college students, we asked about their needs and aspirations. Market validation involved encouraging interested students to fill out our Google form, which received substantial responses. We discovered that many students were already working part-time but in unrelated fields like food service. They expressed difficulty in finding industry-relevant work.

One student told us that he works at garage at 8:00 – 19:00 earning 150 THB, and works at the restaurant at 23:00 – 4:00 earning 500-1500 THB. However, he still wants to work at the garage because he wants to improve his skill.

How did you handle student concerns about low wages?

Initially, students earned 150 THB during a trial period, increasing to 300 THB per month if the garage decided to continue employing them. We emphasized the value of retaining experienced students over hiring new, inexperienced ones. We negotiated higher wages based on students' skills and experience, ensuring a fair compensation model to incentivize retention.

Some garages continued to offer 150 THB wages, but we advised them on the benefits of retaining experienced students. We emphasized the negative impact on company reputation through word-of-mouth if students were dissatisfied. Managing public perception is critical, as negative feedback could tarnish a garage's image despite social media presence.

Do you have employer reviews, such as star ratings?

We currently have a manual feedback system where students provide written feedback on their experiences. For example, they might mention positive aspects of the employer but note that the owner is overly emotional. After collecting reviews from multiple students at a garage, I summarize and analyze the feedback. Although this process is currently manual, we plan to integrate it into our website later. Our goal is to emphasize transparency and provide a platform where both students and garages can share their experiences. Positive feedback helps attract and retain talent.

How did you develop your website and platform? Did you adapt existing models?

We occasionally study competitors and similar platforms to understand market dynamics. We also explore tools like career assessments (e.g., SDS) to gather insights and refine our approach.

Have you conducted surveys to understand garage and student needs?

We haven't conducted specific surveys yet due to our current focus on website development. We've discussed this with our developers and aim to integrate survey functionalities into our platform to streamline the matching process and improve overall user experience.

What do you plan to expand in the future?

We're currently expanding into Lamphun province due to higher wages in the industrial estate there, which makes it an attractive market. One prominent garage in Lamphun has reached out to us, presenting an opportunity for growth.

Additionally, we're considering expanding beyond automotive technicians to include electrical technicians. Looking further ahead, we're exploring entry into the food industry, offering opportunities in roles like waitstaff and cashier. The potential to develop soft skills in the food sector, particularly in tourist-heavy areas like Chiang Mai, presents a compelling opportunity.

When the platform grows larger, do you plan to use technology to facilitate matching?

Our immediate focus is on completing the student-facing aspects of the platform. Once that's established, we'll develop the employer interface, allowing them to register, specify their student requirements, view student profiles, and make selections. We've noticed strong positivity among students towards our platform, likely due to our novelty and perceived support.

We're contemplating a subscription model where employers and students can autonomously match. The current recruitment services could transition to a premium feature within this model.

How will payments be handled in the future? Who pays if you implement a subscription model?

In a subscription model, the primary paying customers will remain employers. For students, we envision additional revenue streams through skills development services. As competition among students grows, some may opt for paid courses that include on-the-job training with partnering garages. We've engaged with government labor departments in Lamphun to explore course opportunities that generate revenue for us. We're also considering freelance technician services based on student interest and market feedback. This concept aligns with shifting employment trends where graduates pursue freelance roles, offering specific skills to garages without full-time commitments.

F.3 Challenges Faced and STeP Support

Do you face any challenges when developing your product?

In Thailand, I believe funding and connections are major challenges. There's a lack of support for the new generation of startups, and many aspiring entrepreneurs give up due to limited resources. Those who persist are often driven by sheer passion, but this survival mentality shouldn't be the only way forward. I've discussed this with a friend in Singapore who highlighted the extensive support available there, including funding and networking opportunities. I wonder if the situation would be different if I were based in Bangkok rather than Chiang Mai.

Securing funding in Thailand is particularly challenging due to the lengthy application and approval process. It takes time to compile the necessary evidence and paperwork, which can be discouraging for startups needing quick access to funds.

Have the coaching programs you've attended provided sufficient support?

The coaching we receive through various programs is beneficial, but it's usually delivered periodically, often once a month. While this coaching is helpful for incubating ideas and concepts, real-life situations and customer interactions require a deeper level of understanding. For instance, managing accounts, registering a business, and handling equity distribution are critical skills that many young entrepreneurs lack. This is where ongoing coaching and mentorship play a crucial role in bridging the knowledge gap.

How have you managed to address these challenges?

We're fortunate to have supportive partners who offer valuable recommendations, especially when it comes to pitching and business essentials. Our partners, who previously served as pitching judges, have shared insights into what makes a compelling pitch.

Navigating the complexities of company registration was initially challenging, and we were even rejected at first. Eventually, we enlisted the help of an accounting firm to guide us through the process.

Regarding funding, many startups we know are in constant need of financial support. When a startup mentions having only a few months of runway left, it underscores the urgency of securing funding to sustain operations.

Have you encountered any specific challenges in developing your product? How is everything working on Facebook platform?

One of our main challenges lies in deciding how to proceed with the development of our website. We've received several offers and opportunities, but choosing one means forgoing others. This decision-making process is crucial for the future direction of our platform.

In terms of technology, like many startups, we face the challenge of sourcing skilled developers. Hiring external developers can be costly, but fortunately, we've received interest from several individuals willing to contribute. Now, our focus is on selecting the most suitable partner to ensure our tech development aligns with our vision.

Are there other areas where you're encountering challenges, such as planning, growth, or revenue generation?

One of our primary challenges is how to accelerate our growth trajectory. Initially, establishing credibility and gaining recognition was difficult without existing connections. It's not easy to directly contact large companies or influential figures like Toyota without established credibility. However, as we've become more recognized and built relationships with reputable partners, such as the garages we work with and the support of individuals like Toyota Lanna, the head of the Chiang Mai Automotive Club, our network and credibility have improved significantly.

How has STeP supported you?

The funding support from STeP, particularly the initial 45,000 THB, has been instrumental in driving our business forward. While it may seem like a modest amount, it has significantly contributed to our operations.

Regarding coaching, I found the workshops conducted by lecturers from Bangkok particularly valuable. These sessions expanded my perspective and prompted me to consider various aspects I hadn't previously explored. The fact that these workshops are offered free of charge is also highly beneficial.

Are there any additional forms of support you require from STeP to further develop your platform or address specific challenges?

Certainly, continued funding support remains a priority for us. Additionally, access to facilities such as office space is crucial. Currently, we utilize the co-working space provided by STeP for conducting meetings and interviews with students. Having a dedicated space facilitates our operations, and additional support in this regard would be greatly appreciated.

Appendix G How the Cases in Phase 2 Develop New Product

In this stage, the interview with the early-stage start-ups in the STeP programs was conducted according to the defined metrics. This phase also performed within-case analysis. The interview data about how the company develop new product was analyzed Notable, the activities that the interviewee did not mention during the interview were assumed that the company did not conduct those activities. Those activities are in grey colour in the diagram.

G.1 Company 2-B

Company 2-B's product is an online platform that aims to be a community hub for creators and crafters to showcase their products and offer online courses to interested customers. Buyers can easily browse and purchase products or enroll in courses, while sellers can easily post their products and manage their online courses. The company is in Camp 2 in STeP Basecamp24. The team consists of three co-founders who are marketing expert, with four developers on contract.

G.1.1 How Company Develops New Product

The company started as a mental health tour company in 2019 as the co-founders have experiences in this field. The interviewee was psychologist, one co-founder was tour guide, and the other one co-founder is marketing expert. Nevertheless, due to the pandemic, they shifted their focus to crafting platform because they found the opportunity to develop online platform. Moreover, they could focus on the same target customer as the mental health tour customer which they had some research data about. Therefore, they decided to establish a platform for crafting that includes a crafting course, an online crafting marketplace, and a crafting community.

The company received funding from TED Fund to develop a prototype, which they have been working on for a year since June 2021. The company's development process started with planning UX and UI design process and generating customer journey. The team conducted a survey to understand features that customers were looking for in an online course platform. Based on the survey results, competitor’s product analysis, and their own background in marketing, the team started from developing the main model with general features, such as separating course syllabus and providing a review system. After that, they identified the essential features required in their platform.

Currently, they are using Facebook as their MVP and studying the market to make decisions about their platform. The team also conducted customer journey testing with both buyers and sellers to ensure that the platform is user-friendly and easy to navigate. Currently, they are developing their website, but it has not yet launched because they are working on payment and PDPA law. In addition to product development, the company also worked on developing their revenue model, with plans to use a commission-based model and gather feedback from potential customers to determine the appropriate percentage they should charge. Overall, the company's NPD process is at detail design stage.

G.1.2 Assessing the Key Metrics

From the interview data, the NPD diagram was produced in Figure G.1 and the key metrics were assessed as details as following.

1) Opportunity recognition

Company 2-B identified the opportunity to establish a platform for crafting activities when their mental health tour business was impacted by the COVID-19 pandemic. They recognized that there was a demand for teaching and selling crafting products online, especially among individuals unable to conduct in-person classes. This can be summarized that the company's opportunity recognition stage is at Level 1 (Initial).

2) Concept development

Company 2-B defined their concept as a crafting platform that includes crafting courses, an online crafting marketplace, and a community. The company planned the design process using UX and UI and generating customer journey. They considered various approaches for the online course model, such as having external providers or creating their own course content. This can be summarized that the activity was planned and undertaken, so that the company's concept development stage is at Level 2 (P – D) in market and design aspects. On the other hand, the company faced challenge on production, assuming Level 1 (Initial) in production aspect.

3) Early system design

After planning UX and UI and generating customer journey, they conducted a survey to understand the customers' needs before developing the main model. Nevertheless, Company 2-B faced challenges on lacking technical expertise. As none of the co-founders were developers, they had to rely on contracted developers to build their platform. This led to issues with coding and language preferences when one of the developers left the team, resulting in delays and the need for a second prototype. Although the company planned the customer journey, they did not plan on technical team, so that it can be assumed that the company's early system design stage is at Level 2 (P – D) in market aspect and Level 1 (Initial) in design and production aspects.

4) Detail design

After developing main model with general features, they identified the essential features required in their platform. However, Company faced challenge on determining the appropriate revenue model, as the company had to consider the balance between attracting users with low fees and generating enough revenue to sustain the platform. Another challenge was the uncertainty of doing business when they made decision. The interviewee explained that,

"An uncertainty is the challenge. We won't know if it is right or wrong."

To overcome this challenge, the company sought support from STeP and joined Basecamp24 and Big Brotherhood programs to gain access to experienced consultants and mentors. Through these programs, they were able to participate in workshops and receive guidance from experienced professionals to help them overcome the challenges they faced in product development and revenue model planning. This can be summarized that the company's detail design stage is at Level 2 (P – D) in market and design aspects.

The assessment check sheet shows in Table G.1 and the visualized assessment result shows in Figure G.2.

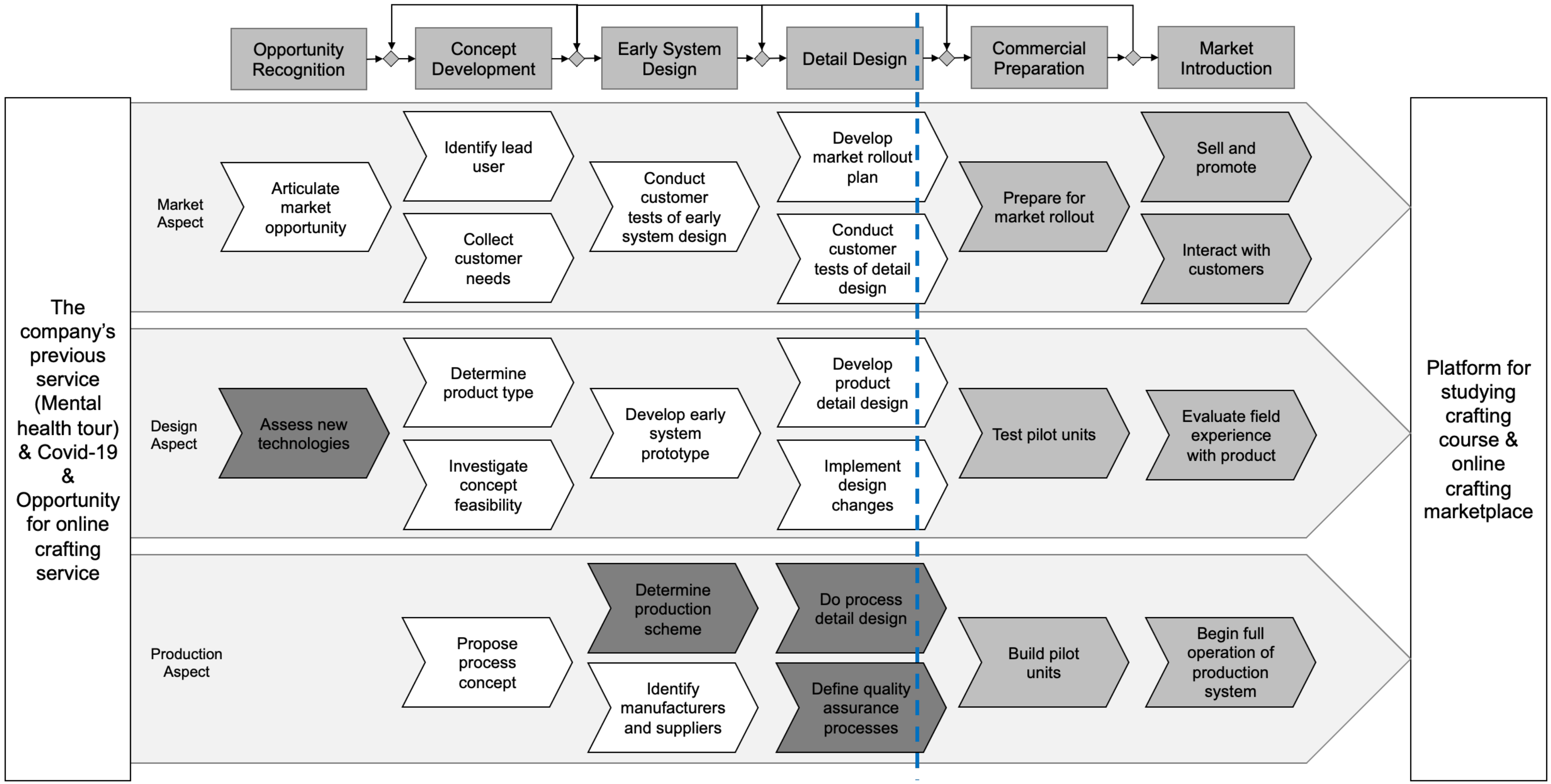

Figure G.1 Diagram of NPD Process of Company 2-B

Table G.1 Assessing Key Metric of Company 2-B Using Assessment Sheet of NPDWise

NPD Stage	Aspect	Does the organization …..(Activity)…..?		If yes to the first question, continue to these questions.			Level
		Activity	**Response** (Yes/No)	**Is the activity performed upon structured plan?**	**Is result of the activity regularly reviewed?**	**Is the activity improved according to the reflection?**	
Opportunity recognition	Market	Articulate market opportunity	Yes	No	-	-	1
	Design	Assess new technology	No	-	-	-	-
Concept development	Market	Identify lead user	Yes	Yes	No	-	2
		Collect customer needs	Yes	Yes	No	-	
	Design	Determine product type	Yes	Yes	No	-	2
		Investigate concept feasibility	Yes	Yes	No	-	
	Production	Propose process concept	Yes	No	-	-	1
Early system design	Market	Conduct customer tests of early system design	Yes	Yes	No	-	2
	Design	Develop early system prototype	Yes	No	-	-	1
	Production	Determine production scheme	No	-	-	-	1
		Identify manufacturers and suppliers	Yes	No	-	-	
Detail design	Market	Develop market rollout plan	Yes	No	-	-	2
		Conduct customer tests of detail design	Yes	Yes	No	-	
	Design	Develop product detail design	Yes	Yes	No	-	2
		Implement design changes	Yes	No	-	-	
	Production	Do process detail design	No	-	-	-	-
		Define quality assurance processes	No	-	-	-	

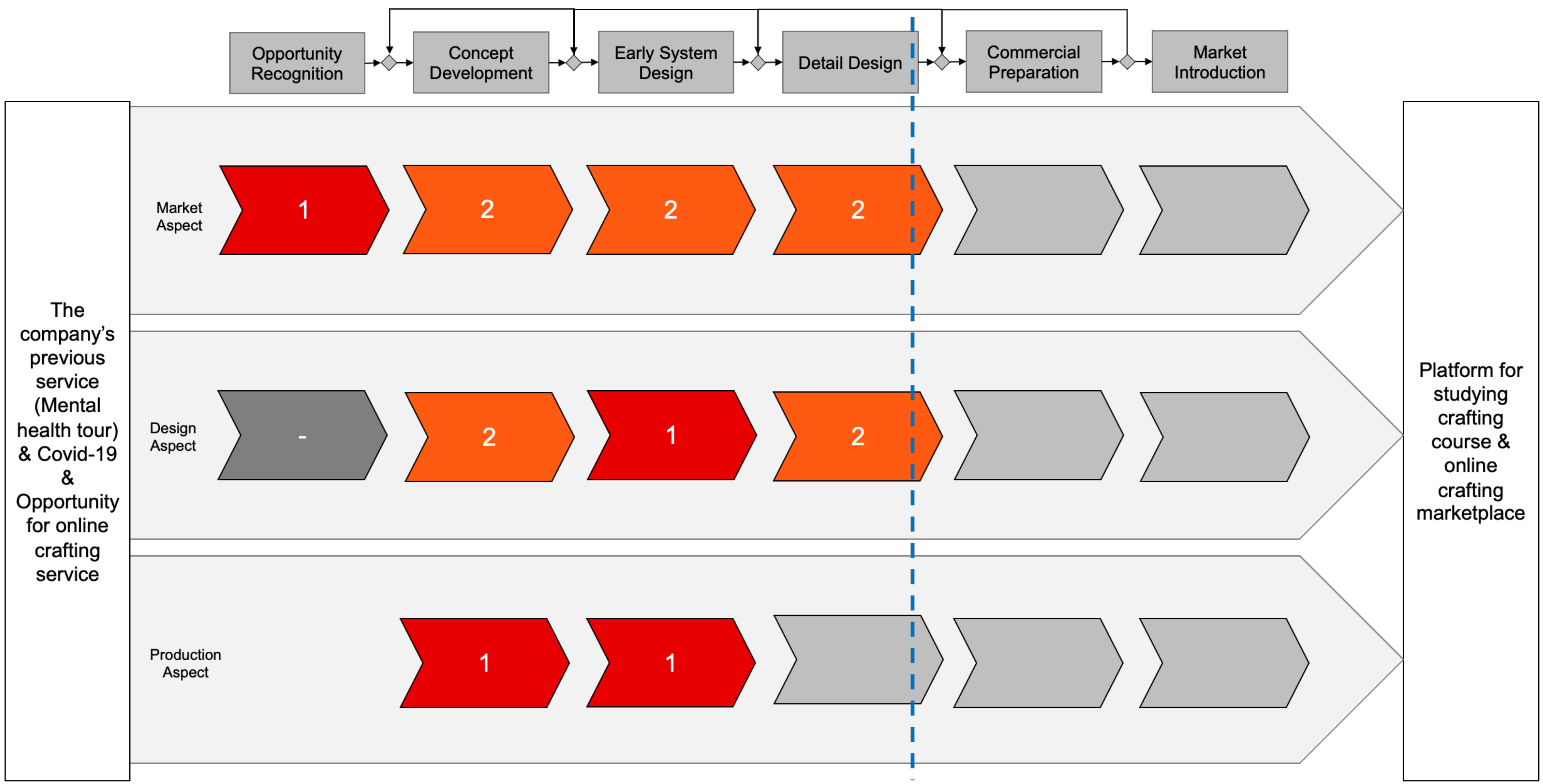

Figure G.2 Assessment Result of Company 2-B

G.2 Company 2-C

The company provides sensory testing services to organizations that want to gain customers' insights and improve their products before launching them in the market. The service involves testing prototypes with a target group, including focus group and in-dev services, and analyzing the results to identify areas where improvements can be made. By providing this service, the company aim to helps organizations ensure that their products are not only safe and meet regulatory standards but also appeal to their intended customer base. The company has started this business one year and 1 month ago and is currently in Camp 2 in STeP Basecamp24. The team consists of three co-founders. This includes the interviewee who is specialist in R&D and had working experience in sensory organization and another co-founder who is specialist in marketing.

G.2.1 How Company Develops New Product

The interviewee had worked in organization in Chiang Mai University that works around sensory, including sensory testing service. She found that the service requires high cost and takes long time. As the organization is part of university, the majority is on teaching. Moreover, that organization tested the sample by randomly giving the product to someone without screening the profile. From this opportunity, she decided to start this business and aims to reduce the R&D process and increase its efficiency. The team joined EED program of STeP, which is the program supporting to generate idea, and received the fund to prove the idea.

After that, they received another fund to develop prototype. Currently the company develops platform on 'Line OA' application for the experimental groups to join. The company screens experimental participants' behaviour, sends the sample to the participants that meet criteria, collects data, and follows up the result. Apart from providing the service of testing sample, the company also provides focus group and in-dev services, and initially analyzing the data before sending the customer a report.

They initially targeted government organizations, as these groups have a lot of research and need to prove whether people need their products. The interviewee explains that,

> *"Me and that organization that I had worked are not the competitor; however, it is both our partner and customer. That organization test*

> *something in the lab, but we test the product with target customer. We both help each other."*

The company plans to have government organizations as customer to build their reputation. In the future they plan to expand to private organizations, such as SME that produces the product with OEM (Original equipment manufacturer) and needs to test the product before the mass production. Overall, the company's NPD process is at detail design stage.

G.2.2 Assessing the Key Metrics

From the interview data, the NPD diagram was produced in Figure G.3 and the key metrics were assessed as details as following.

1) Opportunity recognition

The company identified the opportunity to generate revenue from sensory testing services. They recognized the importance of testing products and understanding customers' needs. This can be summarized that the company's opportunity recognition stage is at Level 1 (Initial) in market aspect.

2) Concept development

The company planned to focus on government organizations as both customers and partners in the first year to increase their reputation as they recognized that government organizations had research needs that required testing. Then, they target private organizations, both SMEs and new generation entrepreneurs. This can be summarized that the company's concept development stage is at Level 2 (P – D) in market aspect.

3) Early system design

They developed a prototype and improved the system based on customer feedback. The company aimed to refine and enhance their online platform, focusing on user experience and user interface. They requested a workshop on UX and UI from STeP to improve their platform. This can be assumed that the company planned, managed, and controlled the activity, so that their early system design stage is at Level 3 (P – D - C) in market and design aspects.

4) Detail design

The company identified the effective way to test the behavior of its customers' target audience and collect data after testing the sample. Initially, the company used Facebook and Google Forms, but this process was found to be complicated, and they eventually changed to an online platform to collect data. In addition, the company also improved the testing process itself. The company had faced issues such as delivering the sample, managing the experimental group, experimental group not testing, and notification. Then, the company addressed to improve the process and develop a platform that provides badges to experimental groups once they have tested the product. This can be summarized that the activity in this stage was planned, managed, and controlled, so that their detail design stage is at Level 3 (P – D - C) in market and design aspects.

The assessment check sheet shows in Table G.2 and the visualized assessment result shows in Figure G.4.

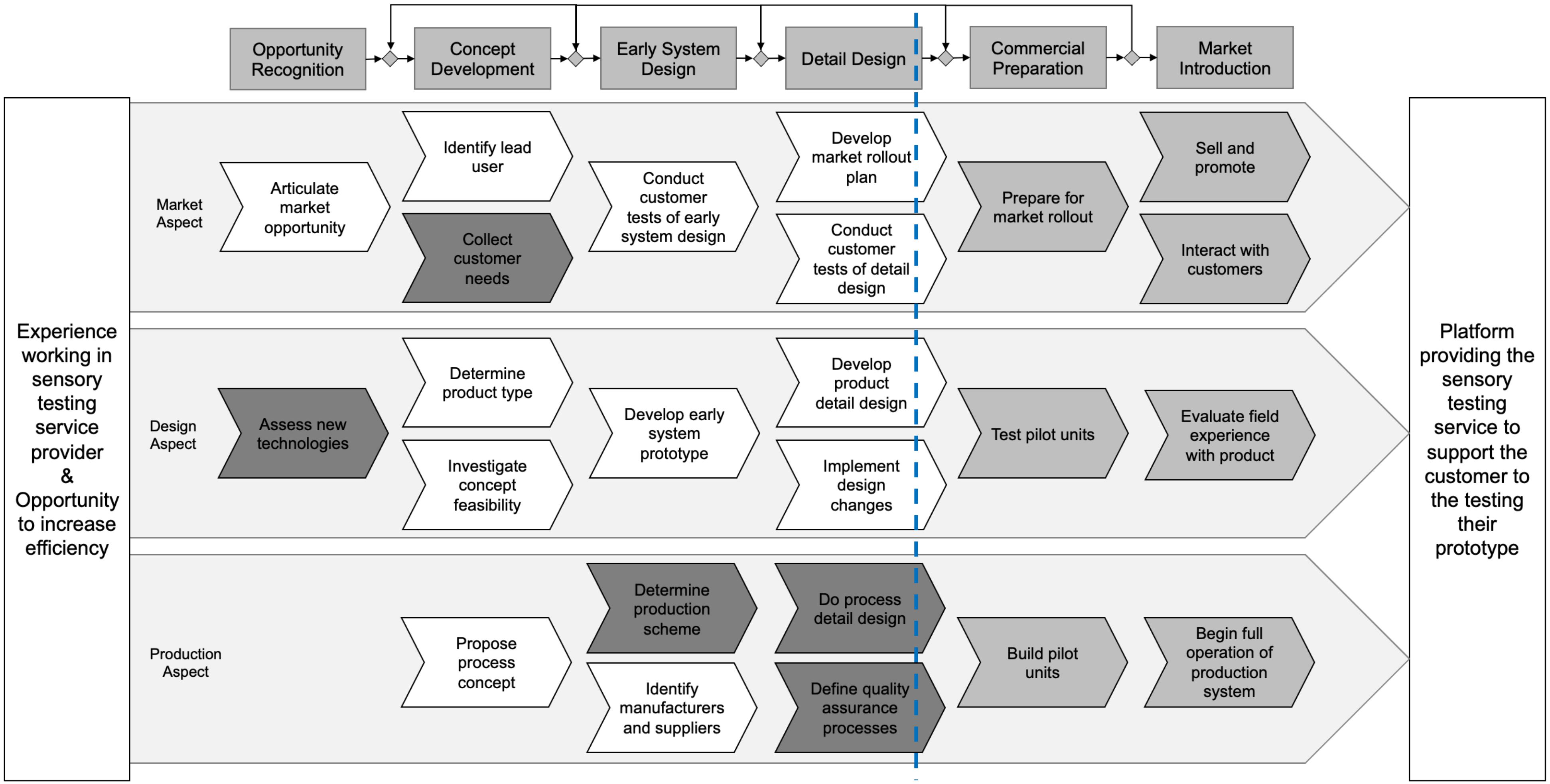

Figure G.3 Diagram of NPD Process of Company 2-C

Table G.2 Assessing Key Metric of Company 2-C Using Assessment Sheet of NPDWise

NPD Stage	Aspect	Does the organization …..(Activity)…..?		If yes to the first question, continue to these questions.			Level
		Activity	Response (Yes/No)	Is the activity performed upon structured plan?	Is result of the activity regularly reviewed?	Is the activity improved according to the reflection?	
Opportunity recognition	Market	Articulate market opportunity	Yes	No	-	-	1
	Design	Assess new technology	No	-	-	-	-
Concept development	Market	Identify lead user	Yes	Yes	No	-	2
		Collect customer needs	No	-	-	-	
	Design	Determine product type	Yes	No	-	-	1
		Investigate concept feasibility	Yes	No	-	-	
	Production	Propose process concept	Yes	No	-	-	1
Early system design	Market	Conduct customer tests of early system design	Yes	Yes	Yes	No	3
	Design	Develop early system prototype	Yes	Yes	Yes	No	3
	Production	Determine production scheme	No	-	-	-	1
		Identify manufacturers and suppliers	Yes	No	-	-	
Detail design	Market	Develop market rollout plan	Yes	Yes	Yes	No	3
		Conduct customer tests of detail design	Yes	Yes	Yes	No	
	Design	Develop product detail design	Yes	Yes	Yes	No	3
		Implement design changes	Yes	Yes	Yes	No	
	Production	Do process detail design	No	-	-	-	-
		Define quality assurance processes	No	-	-	-	

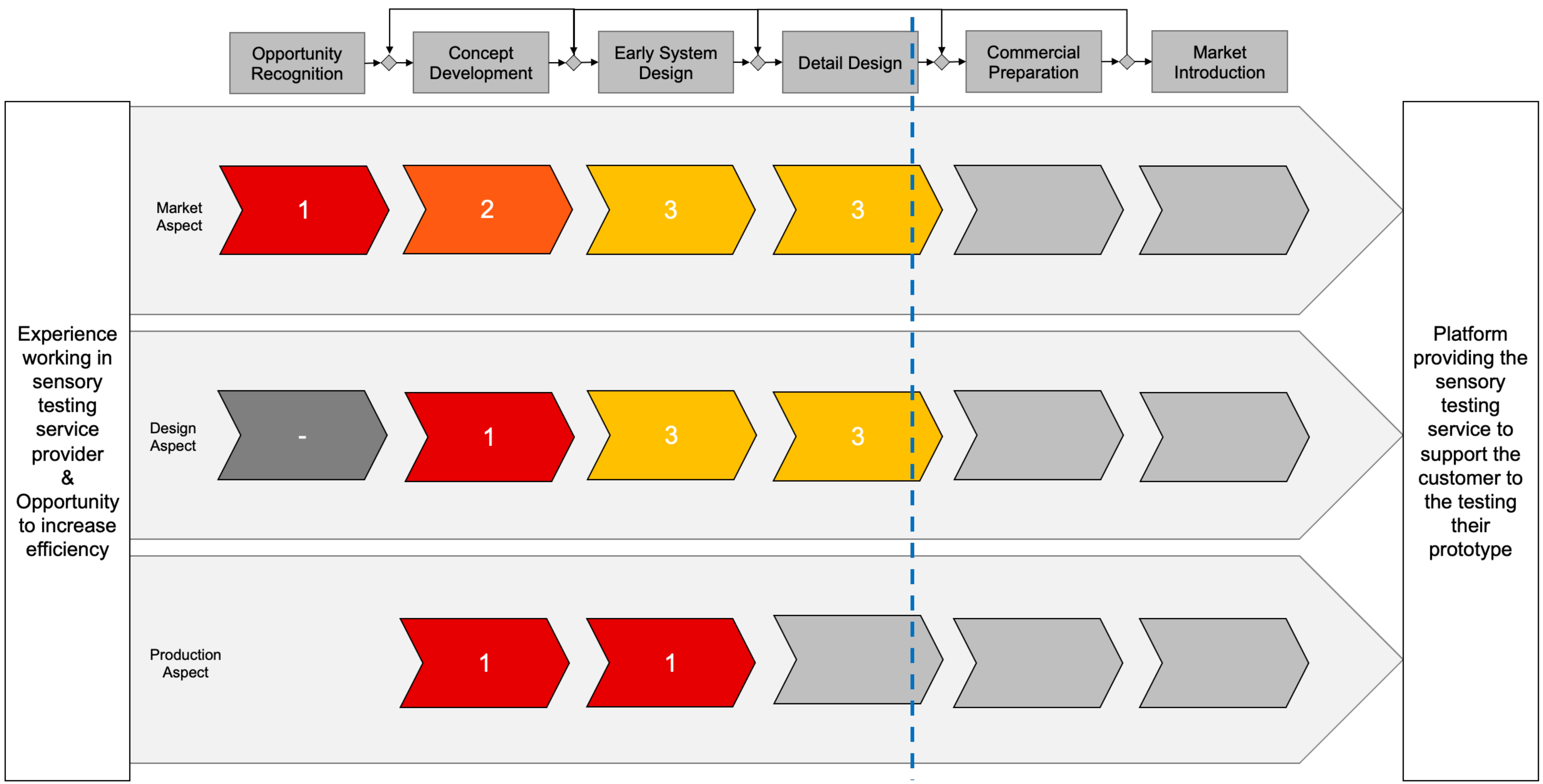

Figure G.4 Assessment Result of Company 2-C

G.3 Company 2-D

Company 2-D developed a construction platform that connects homeowners with contractors. Its target is small-scale projects such as designing, home renovations and construction. The company offers a comprehensive service that includes educating clients on how to hire the right contractor, design assistance, contract preparation, finding a contractor, and project inspections. They also offer a comparison service where they provide a list of contractors and their history and allow the customer to analyze their profiles and prices. The platform acts as a consultant and helps with everything except for being a contractor itself. The founder was a civil engineer and working on large-scale projects involves a complex process that includes an owner, a consultant, and many stakeholders. However, when he purchased his own apartment and hired a contractor himself, he was defrauded by a small contractor. This resulted in idea to start the business focusing on small project management for homeowners. The founder currently works alone and holds 100% of the shares. The company is in Camp 1 in STeP Basecamp24.

G.3.1 How Company Develops New Product

When the founder bought his own apartment, he fell victim to a small contractor who scammed him because he was not familiar with the tricks used by small contractors. He found that this problem is widespread, particularly for online building and home renovation projects. This was the opportunity to start the business. After being scammed, he joined the STeP project under the YFS (TED Youth Startup Fund) and conducted a survey to identify the problem and its causes. After that, the team designed the product to address the root of the problem.

The company works closely with its customers to understand their requirements, gather feedback, and incorporate it into the product development cycle. The MVP was developed in five months after studying the pain points of homeowners and contractors. The first MVP was to match the homeowners with the designers manually, without a design plan. The company provided the concept to the customer and then found a designer. The feedback was that designers did not accept small or renovation projects, and they didn't like the bidding or price comparison system. In second MVP, the company separates into several parts as well as offers different service packages. They have packages for those who have no concept or design, and packages for those who already have a design and want help with managing and supervising the construction work. In the design part, the company changed the bidding system to a partner system. This allowed the first part of the job to be completed more quickly. In consultant part, the company offers a comparison service where they provide a list of contractors and their history and allow the customer to analyze their profiles and prices. The company also added the consultant part as they had tested by providing consultation services to the pilot customers and found that the customers trusted them and wanted them to take care of this part. Therefore, the company added a consultation service package.

The current MVP is in use although the platform is not yet finished. The company is using Google Forms to collect information, but the backend system is now complete with a membership registration system. The current MVP had 2-3 projects completed. He stated that,

> *"If you look at the website's footnote, you'll see that more than 1000 people have signed up for the service, both for free and paid projects, with 240 projects providing construction budget details worth approximately 300 million baht."*

The current revenue model has two parts, which are providing consultation and from the platform itself. This was from what the company surveyed from the beginning about the cost of service from both customer site and contractor site. In the future, the company also plans to develop the payment system in the platform as well. For the market roll out strategy, the company has been expanding its customer base through social media platforms, such as Facebook, and recently started shooting ads to get more customers. For expanding plan, the company is going to partner with another startup that helps with small-scale fraud cases about legal. Overall, the company's NPD process is at commercial preparation stage.

G.3.2 Assessing the Key Metrics

From the interview data, the NPD diagram was produced in Figure G.5 and the key metrics were assessed as details as following.

1) Opportunity recognition

The founder recognized the problem of fraud in the construction industry based on personal experience and conducted market research through surveys to identify the pain points and causes of contractor scams. This can be summarized that the company's opportunity recognition stage is at Level 3 (P – D – C).

2) Concept development

They conducted research to understand the market and business model, and later developed an app with UX/UI design. Nevertheless, before he developed this concept, the company had faced challenge on team direction does not match to one another and led to splitting the business. When he firstly entered the YFS project with STeP, there were three software developers and interviewee who came up with an idea. However, once the idea was complete, the software developers focused solely on developing the system, even though the business model was not clear. This led them to lose direction as they developed the app and its UX/UI, but the product was still unclear. After that, the interviewee left the team, started new concept with same idea, and focused more on the market and business model rather than just developing the app. This can be summarized that the activity in this stage was planned, managed, and controlled, so that their concept development stage is at Level 3 (P – D - C) in market and design aspects.

3) Early system design

The company developed the MVP using UX/UI design. The company gathered customer feedback and understood pain points related to design and price comparison. Feedback from initial customers highlighted issues with the bidding system and the need for a partner system for faster job completion. This can be summarized that the company planned, performed, and controlled the activity, so that their early system design stage is at Level 3 (P – D - C) in market and design aspects.

4) Detail design

The company developed the MVP2 using UX/UI design and feedback from MVP1. They pivoted to a partner system, refined the concept, and added consultation services based on customer demand. They also planned to develop a new payment system. Nevertheless, the founder currently hires app platform developers who have just graduated which he finds that they are relatively new and inexperienced. Therefore, the company currently need a CTO. All in all, it can be summarized that their detail design stage is at Level 3 (P – D - C) in market aspect, Level 2 (P – D) in design aspect, and Level 1 in production aspect.

5) Commercial preparation

The company had tested pilot units. The current MVP had several projects completed. For market rollout, they focused on expanding the customer base through organic growth, content creation, and targeted ads. The founder created a Facebook page to educate people about contractor scams and gained followers, reaching millions of people through content. He also aimed to shoot more ads for further expansion. For financial planning, it is still the challenge for the company. Although STeP provides training in this topic, the founder found that it is not enough. He needs to consult with experts or look for CFO to work for the company. Similar to detail design stage, NPD activity in commercial preparation stage was planned and partially performed and evaluated, so that this stage is at Level 3 (P – D - C) in market aspect, Level 2 (P – D) in design aspect, and Level 1 in production aspect.

The assessment check sheet shows in Table G.3 and the visualized assessment result shows in Figure G.6.

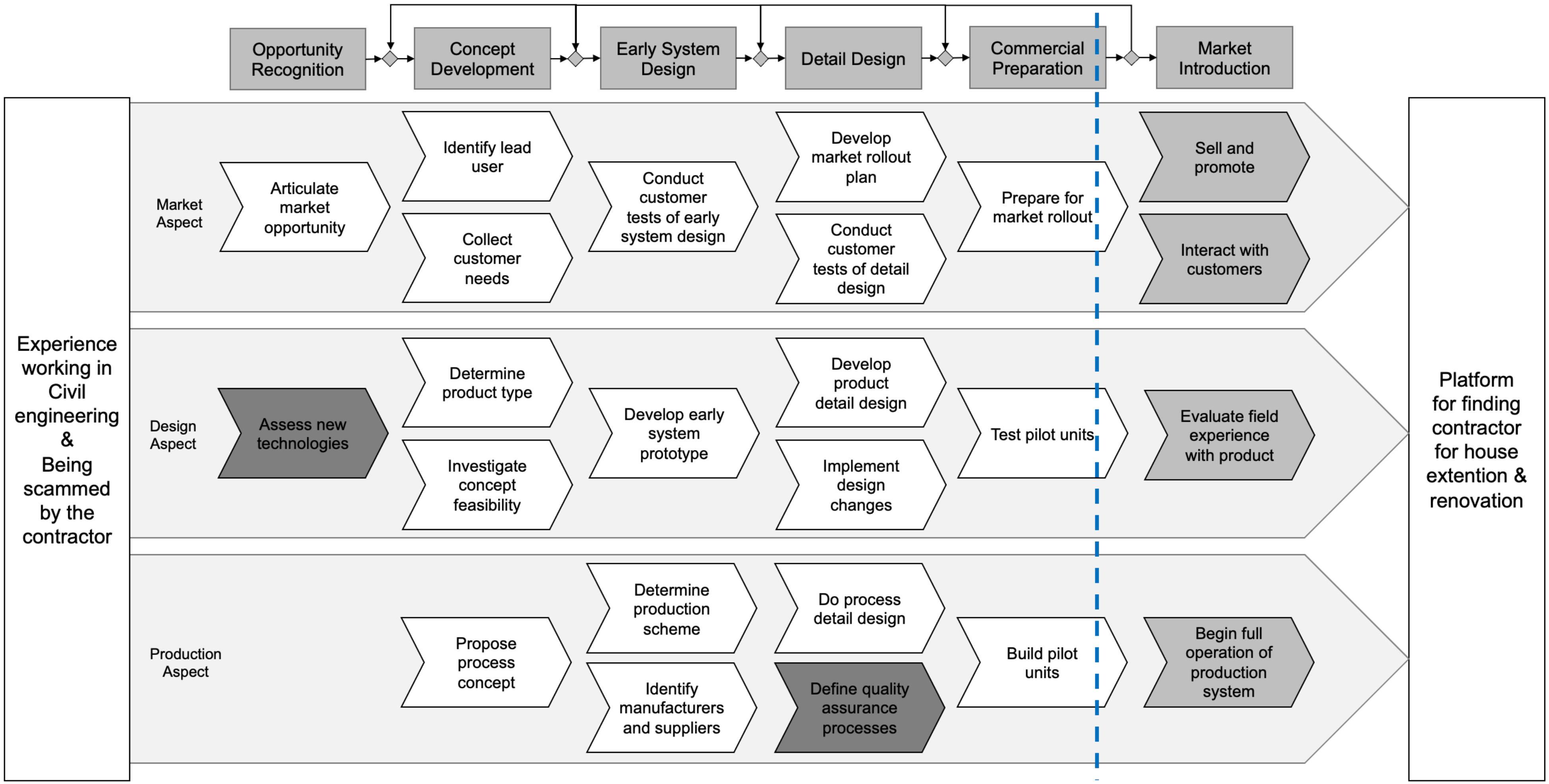

Figure G.5 Diagram of NPD Process of Company 2-D

Table G.3 Assessing Key Metric of Company 2-D Using Assessment Sheet of NPDWise

NPD Stage	Aspect	Does the organization …..(Activity)…..?		If yes to the first question, continue to these questions.			Level
		Activity	Response (Yes/No)	Is the activity performed upon structured plan?	Is result of the activity regularly reviewed?	Is the activity improved according to the reflection?	
Opportunity recognition	Market	Articulate market opportunity	Yes	Yes	Yes	No	3
	Design	Assess new technology	No	-	-	-	-
Concept development	Market	Identify lead user	Yes	Yes	Yes	No	3
		Collect customer needs	Yes	Yes	Yes	No	
	Design	Determine product type	Yes	Yes	Yes	No	3
		Investigate concept feasibility	Yes	Yes	Yes	No	
	Production	Propose process concept	Yes	No	-	-	1
Early system design	Market	Conduct customer tests of early system design	Yes	Yes	Yes	No	3
	Design	Develop early system prototype	Yes	Yes	Yes	No	3
	Production	Determine production scheme	Yes	No	-	-	1
		Identify manufacturers and suppliers	Yes	No	-	-	
Detail design	Market	Develop market rollout plan	Yes	Yes	Yes	No	3
		Conduct customer tests of detail design	Yes	Yes	Yes	No	
	Design	Develop product detail design	Yes	Yes	No	-	2
		Implement design changes	Yes	Yes	No	-	
	Production	Do process detail design	Yes	No	-	-	1
		Define quality assurance processes	No	-	-	-	
Commercial preparation	Market	Prepare for market rollout	Yes	Yes	Yes	No	3
	Design	Test pilot units	Yes	Yes	No	-	2
	Production	Build pilot units	Yes	No	-	-	1

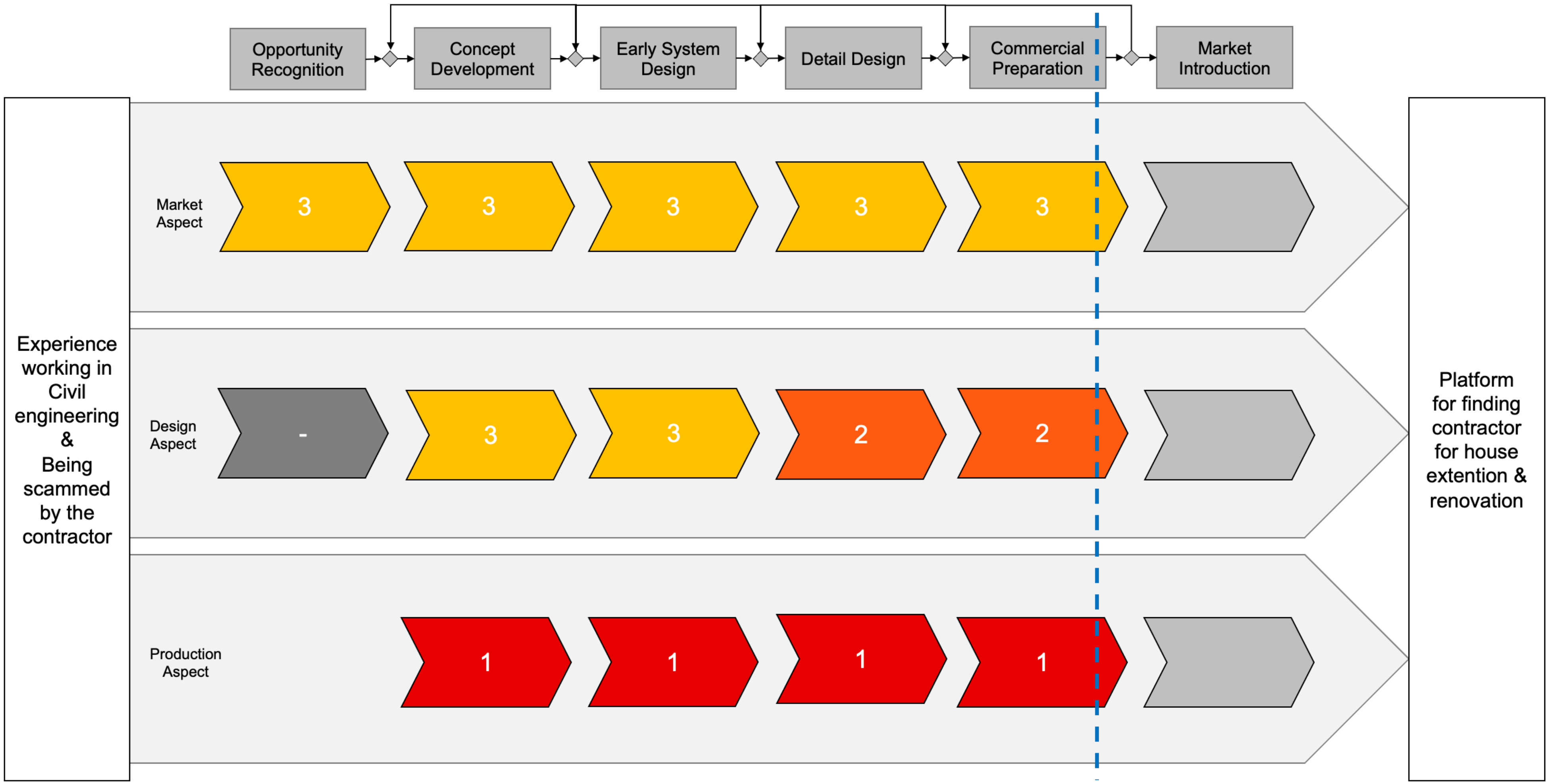

Figure G.6 Assessment Result of Company 2-D

G.4 Company 2-E

The company provides a service management platform that aims to improve the appointment process for service providers. The platform currently focuses on dental clinics to support both clinic owners and dentists to increase their revenue by maximizing capacity through appointment scheduling. It was started in 2017 by the founder, who has both engineering and technology management background and saw the inefficiencies of the appointment process in his wife's dental clinic. The company has joined STeP Basecamp24 since March 2022 and is currently in Camp 2.

G.4.1 How Company Develops New Product

The idea for the platform came from the founder's wife, who is a dentist, and the founder's desire to improve the appointment scheduling process in clinics as he found that there is the need for improvement in the punctuality of appointments in the dental industry. The company started in 2017 as a hobby, but the founder began to focus on it in 2019. The product development process involves a few key stages. First, he conducted market research to identify pain points and gaps in the market that the software could address. This resulted in he deciding to develop platform to support the service providers' revenue management and appointment system management, aiming to reduce costs, increase revenue, and minimize human error.

In design stage, he developed the platform using a deep and systematic design process, which involved creating initial design and inputting the options. Features were also designed based on feedback from users and the market in Thailand. Some software and technologies were also added to make the platform work effectively. The platform was continuously tested and improved to meet the needs of the major users. The founder explained that,

> *"This app interface finished in the middle of 2020. Then, we upgraded the features until the middle of 2021, which is this current interface. We also continuously do the minor change."*

The founder also used change management techniques to ensure the platform can compete with a time. The company's MVP product is currently in phase 1, which focuses on making the process of appointment management more comfortable for the person who is responsible for managing appointments. The platform also includes tools for managing the service provider's business, such as opening-closing time, the services they provide, the number of dentists available. For the current revenue model, the company earns money from both clinics and advertising on the app. The platform currently offers services for clinics and shops, with more than 70 clinics registered and 20 shops paying since the company started to charge for their services in March 2022. The company also joined STeP to gain market penetration in the northern part of Thailand and is currently being supported in this regard. STeP has introduced them to clinics and helped answer questions about local people's behaviors.

In phase 2, the company plans to replace the need for some personnel in appointment management by expanding to target service providers in various fields. The company also continuously upgrading the features of the app and plan to use AI in the future to assist with appointment scheduling, improve punctuality, and replace unnecessary employees. The next phase of the platform aims to introduce an automotive or vending machine system that allows customers to pay via the platform so that the money comes directly to the owner and leads to preventing any missing money issues. Overall, the company's NPD process is at market introduction stage.

G.4.2 Assessing the Key Metrics

From the interview data, the NPD diagram was produced in Figure G.7 and the key metrics were assessed as details as following.

1) Opportunity recognition

The company recognized the opportunity to improve the appointment management process in dental clinics and similar service providers. The founder identified pain points related to appointment management, revenue commitment, and the need for a more efficient system. The opportunity was identified based on personal experience and observations, following by market research. It can be assumed that the company's market aspect in opportunity recognition stage is at Level 3 (P – D - C). In addition, company assessed new technology and utilized in product design. This can be summarized that the company's design aspect in opportunity recognition stage is at Level 2 (P - D).

2) Concept development

The concept development stage involved planning and designing the platform to address the identified opportunity. The founder used knowledge from the "Service Design and Delivery" course to analyze the service, identify the parties involved, determine delivery channels and tools, and plan for change management. The initial concept focused on re-designing the appointment process to make it more streamlined and efficient. This can be seen that the activity in this stage was planned, managed, controlled, and adjusted, so that the company's concept development stage is at Level 4 (P – D – C - A) in market and design aspects.

3) Early system design

During this stage, the company developed the minimum viable product (MVP) and implemented the initial system design. The MVP aimed to support the people working in dental clinics to be more comfortable, with a focus on appointment management. The founder planned to replace unnecessary staff positions in the future to further optimize the process. This can be summarized that the company regularly planned, performed, reviewed and adjusted the activity, so that their early system design stage is at Level 4 (P – D – C - A) in market and design aspects.

4) Detail design

The detail design stage involved refining and upgrading the features of the platform. The company continuously made minor changes and improvements based on user feedback and requirements. The founder mentioned the deep design and systematic design aspects, ensuring the database checks and fine-tuning for efficient appointment scheduling and avoiding double bookings. Nevertheless, one of the key challenges that the company faces is managing the scope of its projects. The interviewee noted that the target users often request additional features during the development process; however, after the company spent time developing those features, the customers finally said that they did not want to use. This can result in wasting time developing unclear requirements. The company has also faced challenges in finding skilled developers who can work systematically. The founder explained that the developers claimed that they had worked with Bitkub (Unicorn startup in Thailand) and asked for high salary; however, he finally found that they weren't that skilled. This led to delay of introducing platform or releasing. All in all, it can be summarized that the company planned, managed, controlled, and improved the activity, so that their detail design stage is at Level 4 (P – D – C - A) in market and design aspects.

5) Commercial preparation

In this stage, the company prepared for commercialization and revenue generation. They started charging for the platform's usage from March 2022 and focused on converting users to paying customers. The company also explored additional revenue streams, such as advertising on the platform. It can be summarized that the NPD activity in commercial preparation stage was planned, undertaken, and controlled, so that this stage is at Level 3 (P – D – C) in market and design aspects.

6) Market introduction

The market introduction stage involved promoting the platform and expanding the user base. The company had more than 70 clinics registered, with 20 of them paying for the service. They actively engaged in promotional activities, such as participating in events and acquiring new registrations. The founder mentioned the need to penetrate the existing market and communicate the value proposition to potential users. It can be summarized that the NPD activity in market introduction stage was planned and undertaken, so that this stage is at Level 2 (P - D) in market and design aspects.

The assessment check sheet shows in Table G.4 and the visualized assessment result shows in Figure G.8.

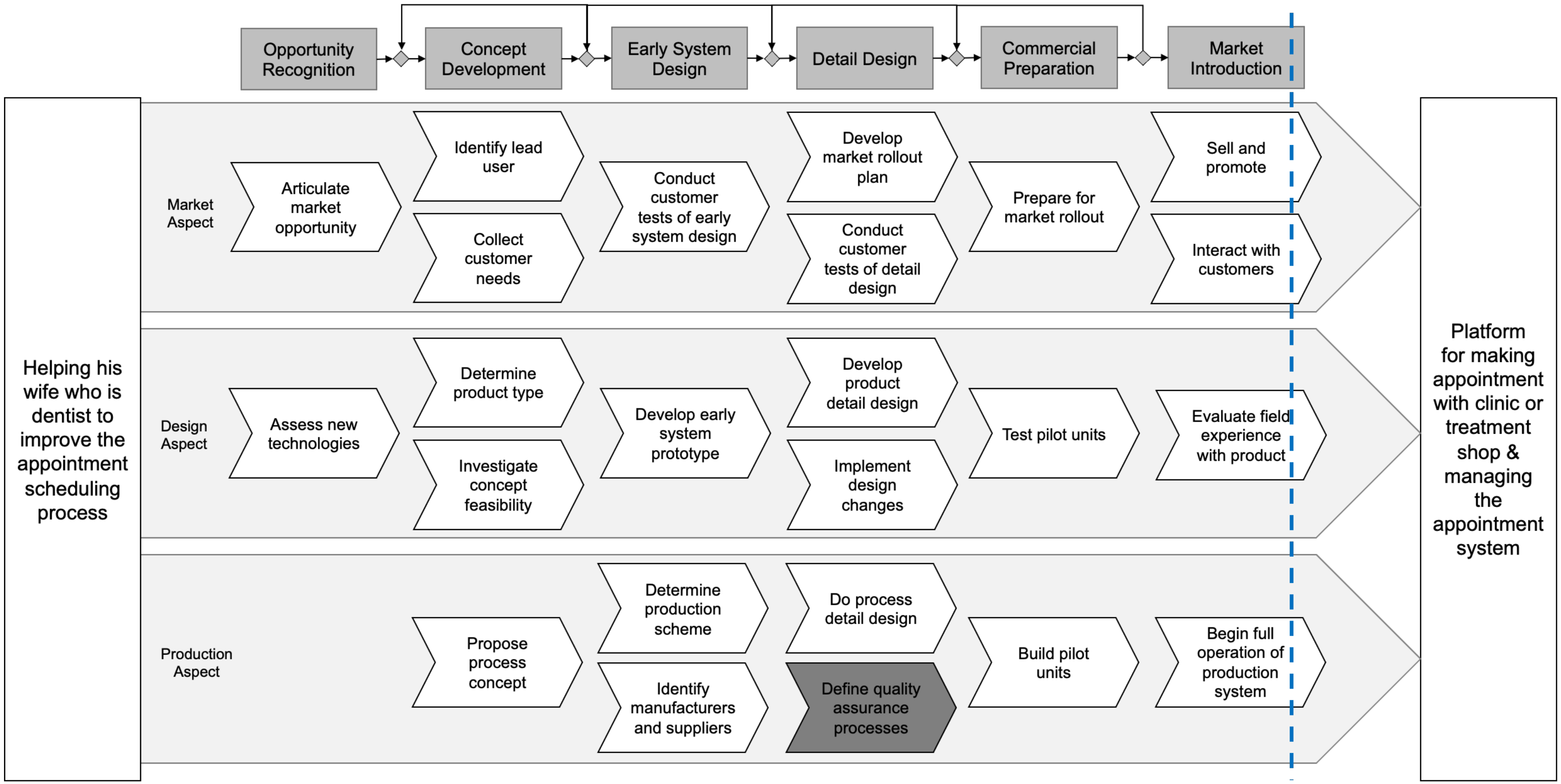

Figure G.7 Diagram of NPD Process of Company 2-E

Table G.4 Assessing Key Metric of Company 2-E Using Assessment Sheet of NPDWise

NPD Stage	Aspect	Does the organization …..(Activity)…..?		If yes to the first question, continue to these questions.			Level
		Activity	Response (Yes/No)	Is the activity performed upon structured plan?	Is result of the activity regularly reviewed?	Is the activity improved according to the reflection?	
Opportunity recognition	Market	Articulate market opportunity	Yes	Yes	Yes	No	3
	Design	Assess new technology	Yes	Yes	No	-	2
Concept development	Market	Identify lead user	Yes	Yes	Yes	Yes	4
		Collect customer needs	Yes	Yes	Yes	Yes	
	Design	Determine product type	Yes	Yes	Yes	Yes	4
		Investigate concept feasibility	Yes	Yes	Yes	Yes	
	Production	Propose process concept	Yes	No	-	-	1
Early system design	Market	Conduct customer tests of early system design	Yes	Yes	Yes	Yes	4
	Design	Develop early system prototype	Yes	Yes	Yes	Yes	4
	Production	Determine production scheme	Yes	No	-	-	1
		Identify manufacturers and suppliers	Yes	No	-	-	
Detail design	Market	Develop market rollout plan	Yes	Yes	Yes	Yes	4
		Conduct customer tests of detail design	Yes	Yes	Yes	Yes	
	Design	Develop product detail design	Yes	Yes	Yes	Yes	4
		Implement design changes	Yes	Yes	Yes	Yes	
	Production	Do process detail design	Yes	No	-	-	1
		Define quality assurance processes	No	-	-	-	
Commercial preparation	Market	Prepare for market rollout	Yes	Yes	Yes	No	3
	Design	Test pilot units	Yes	Yes	Yes	No	3
	Production	Build pilot units	Yes	No	-	-	1
Market introduction	Market	Sell and promote	Yes	Yes	No	-	2
	Design	Interact with customers	Yes	Yes	No	-	2
	Production	Evaluate field experience with product	Yes	No	-	-	1
		Begin full operation of production system	Yes	No	-	-	

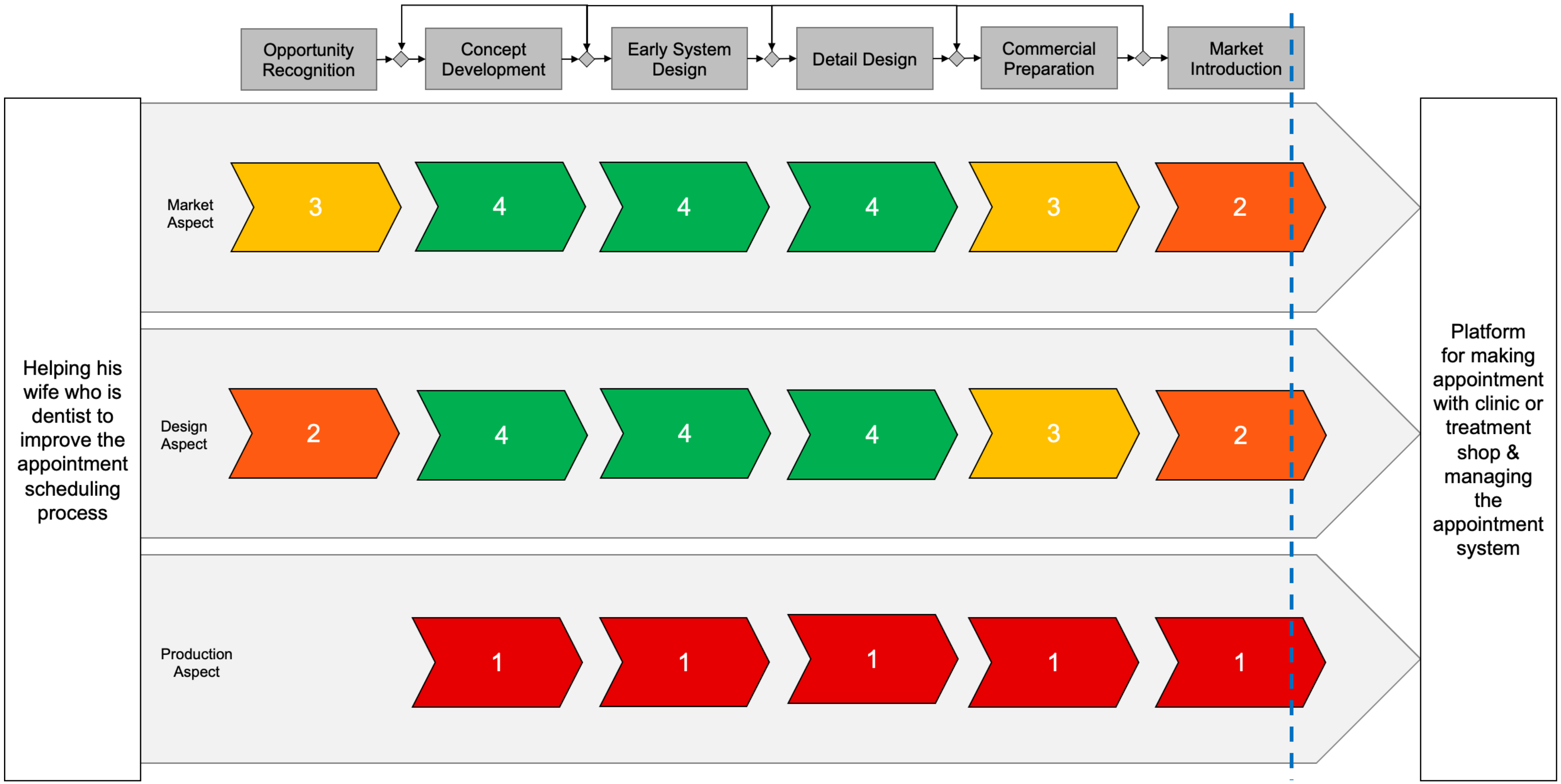

Figure G.8 Assessment Result of Company 2-E

G.5 Company 2-F

The research team is the professor, students, and research assistants from faculty of veterinary medicine. The team developed cream to heal the wound in small animals, such as dog and cat. Currently, the team is Camp 2 in STeP Basecamp24.

G.5.1 How Company Develops New Product

At the beginning, they had developed the first product was to be used in cow. The first project was when we joined EED program of STeP last year, which was a starting point for people who wanted to create products. STeP consulted and held workshops to see how they could find a market, what the customer base would be, and whether the product they would make would reach the customer and be sellable.

The product is currently in research stage, and they continuously test the product. The first product targets to be used in cow and the target customer was the farmer. After testing, they found that it was hard to heal, so that it had not made to the market. Then, the team moved to target small animals. They conducted another R&D, such as making it gentler. In the testing process, the prototype was tested in the animal lab, and in farms. The interviewees explained that,

> *"We asked for the feedback, such as a clinic that said the cream did not absorb well into wounds and was not suitable for wounds that have a lot of discharge. We used this feedback to further develop the product and added a note that it's not suitable for wounds of this type."*

The team also conducted research on how to make it easier for customers to use, improve performance, and use it on a variety of wounds. The product is currently in research stage.

At the same time, they are also in the trial marketing and copyright application stage. They approach veterinary clinics and pet stores to let them try it out and then sell it on consignment. They also continuously follow up with customers to see if they are interested in buying more. Another market approach is online promotion. They have Facebook and Shopee, where they promote with ads and promotions. Nevertheless, the team consists of students and research assistants who are not familiar with marketing. The interviewees stated that,

> *"Our team are not familiar with running ads. We tried doing it ourselves, but it didn't work."*

In addition, they are currently building a factory and applying for permission to produce medical equipment and products. Overall, the company’s NPD process is at detail design stage.

G.5.2 Assessing the Key Metrics

From the interview data, the NPD diagram was produced in Figure G.9 and the key metrics were assessed as details as following.

1) Opportunity recognition

Company F are researcher team who recognized an opportunity to commercialize their research work and joined the STeP's T1 project. They have had their core technology and product; however, they have not mentioned how they articulated the market opportunity. This can be assumed that the company’s opportunity recognition stage is at Level 1 (Initial) in design aspect while market aspect could not be graded.

2) Concept development

STeP program mentors provided lectures and guidance on market adoption, revenue, costs, and profit to help the teams think through their product concepts. Company 2-F evaluated the feasibility of their product entering the market. They developed and refined their product concepts based on mentor feedback and market analysis. This can be assumed that the company’s concept development stage is at Level 1 (Initial) in all aspects.

3) Early system design

The first product targets to be used in cow and the target customer was the farmer. However, after testing, the result was ineffective. The team shifted to target small animals. Nevertheless, one challenge that they faced was about how to make customers accept the new product concept. As the product is related to animal health and was sold online, customers hesitated to buy it because it involves the health of their pets. At the same time, there have already been well-known commercial wound care products in the market, which have already had a customer base. The team tried to overcome the challenge by partnering with veterinarians to provide consultations and follow-ups to build trust in the product. In manufacturing aspect, they are currently building a factory in order to producing the product by themselves. All in all, this can be assumed that the company’s early system design stage is at Level 1 (Initial) in all aspects.

4) Detail design

The team conducted research on how to make it easier for customers to use, improve performance, and use it on a variety of wounds. They also engaged in trial marketing, monitored the response to the trial marketing, gathered feedback from customers. Nevertheless, there was the challenge as the team consists of students and research assistants who are not familiar with running ads. To address this challenge, the team hired an external team to do content creation, posting, ad targeting, and follow-up. The team also joins STeP program where there is a training or mentorship session. It can be assumed that the company's detail design stage is at Level 1 (Initial) in market and design aspects.

The assessment check sheet shows in Table G.5 and the visualized assessment result shows in Figure G.10.

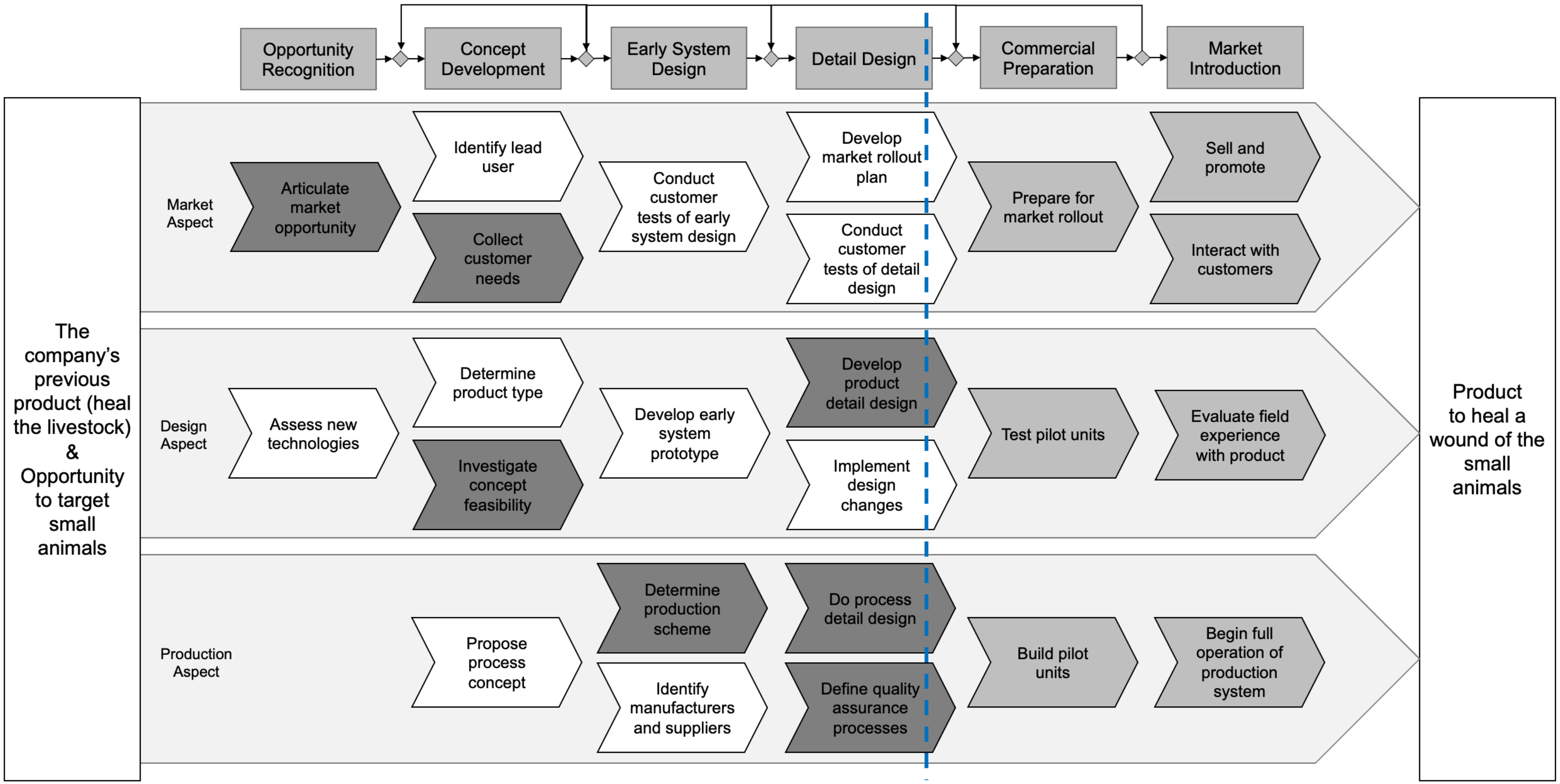

Figure G.9 Diagram of NPD Process of Company 2-F

Table G.5 Assessing Key Metric of Company 2-F Using Assessment Sheet of NPDWise

NPD Stage	Aspect	Does the organization …..(Activity)…..?		If yes to the first question, continue to these questions.			Level
		Activity	Response (Yes/No)	Is the activity performed upon structured plan?	Is result of the activity regularly reviewed?	Is the activity improved according to the reflection?	
Opportunity recognition	Market	Articulate market opportunity	No	-	-	-	-
	Design	Assess new technology	Yes	No	-	-	1
Concept development	Market	Identify lead user	Yes	No	-	-	1
		Collect customer needs	No	-	-	-	
	Design	Determine product type	Yes	No	-	-	1
		Investigate concept feasibility	No	-	-	-	
	Production	Propose process concept	Yes	No	-	-	1
Early system design	Market	Conduct customer tests of early system design	Yes	No	-	-	1
	Design	Develop early system prototype	Yes	No	-	-	1
	Production	Determine production scheme	No	-	-	-	1
		Identify manufacturers and suppliers	Yes	No	-	-	
Detail design	Market	Develop market rollout plan	Yes	No	-	-	1
		Conduct customer tests of detail design	Yes	No	-	-	
	Design	Develop product detail design	No	-	-	-	1
		Implement design changes	Yes	No	-	-	
	Production	Do process detail design	No	-	-	-	-
		Define quality assurance processes	No	-	-	-	

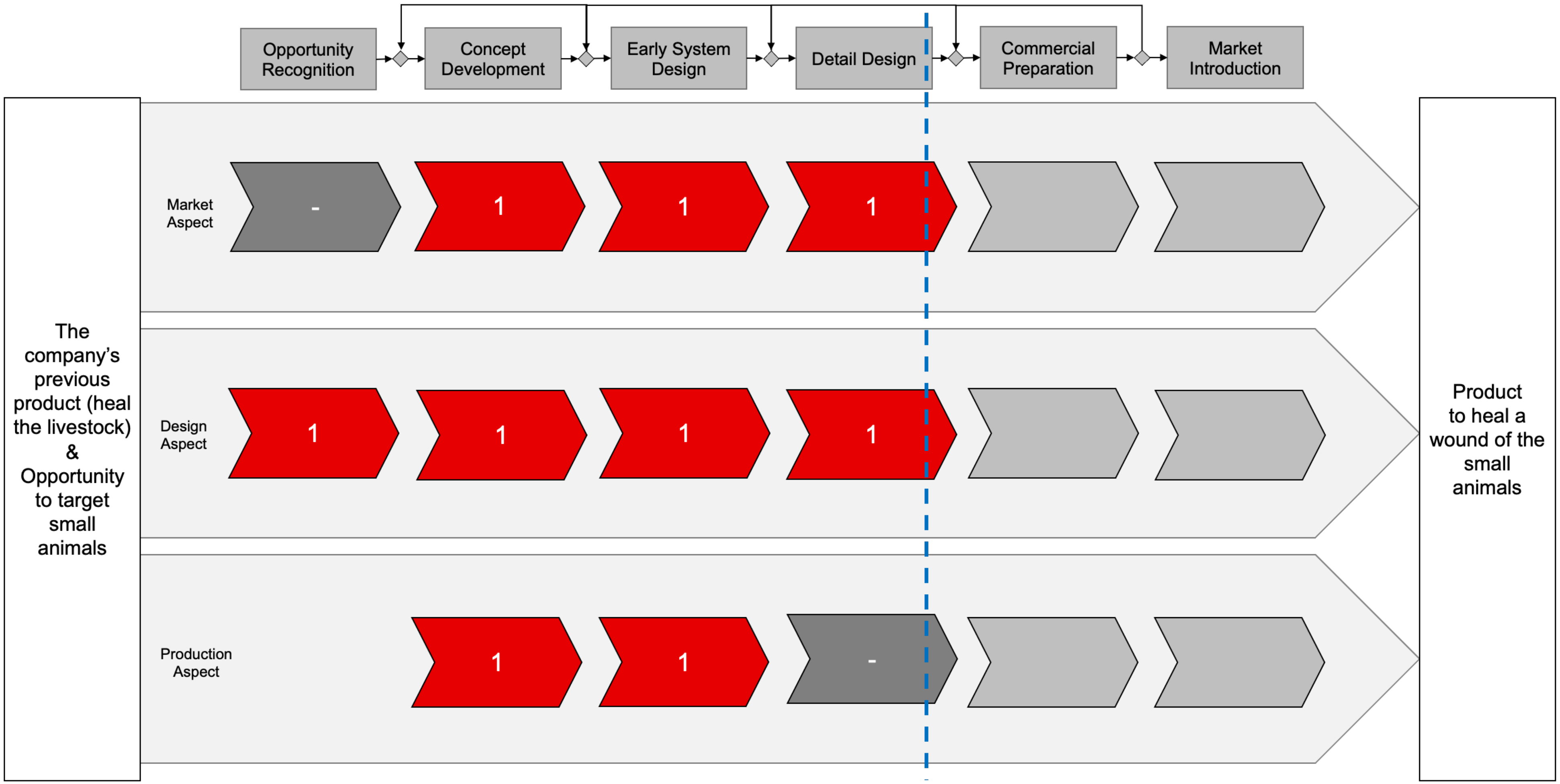

Figure G.10 Assessment Result of Company 2-F

G.6 Company 2-G

The company developed a health product that helps prevent and treat high blood cholesterol. The founder is a doctor specializing cancer from the Faculty of Medicine, Chiang Mai University. He has a research background in natural products and studying the effects of important substances on health when he was studying PhD. Before he finished his PhD, he had entered the startup industry and joined STeP program. The interviewee formed a team with others who had a researching background and a management background. They involved in STeP's Business Brotherhood for two years and received funding in July 2021 for product development and conducted market research with TED Fund and Youth Startup Fund, with STeP as the incubator. Currently, the company is in Camp 2 in STeP Basecamp24.

G.6.1 How Company Develops New Product

Initially, the interviewee wanted to build the product based on the PhD research project, but he was afraid of conflicts with the university and decided to form the team and develop new product by himself. As a medical professional, he noticed that many people have high blood cholesterol levels due to genetics, unhealthy diets, sedentary lifestyles, and behaviors that promote obesity and hypertension. Then, his team conducted a survey to confirm this hypothesis. In addition, the company found that hospital treatments often use conventional methods, such as Statin drugs, but some patients dislike the long-term use of chemicals due to side effects. This leaded them to consider alternative medicine or nutraceuticals, that is the use of food as medicine. The interviewee stated that,

> *"We must try to find out what the real problems and needs of consumers are, not just producing what we think is needed. Market validation is crucial to find out what problems consumers want us to solve."*

Therefore, the company wants to solve the problems of their target market by using this alternative product that is a safer and side effect-free option.

To develop the product, the formula was developed by conducting a literature review to find what substance had good efficacy. The interviewee explained that,

> *"We found three substances from critical trial paper that have only been tested individually, so we have to combine them to create a new formula. Then we have to look at the dosage, the amount of important substance, and choose substances that complement each other"*

The formula was tested on volunteers to see if it was effective and if there were any side effects over a period of 2, 3, and 6 months. Once accurate results were obtained, they registered for intellectual property, created a prototype, and sent it to an OEM factory for production. To ensure the quality and stability of the product, they checked the product's shelf life for 3 and 6 months before proceeding to mass production.

They are currently producing the product for market research purposes. For example, they give it to people and collect data, such as feedback on the product's effectiveness, whether customer would buy it again, and whether it is worth the cost. After that, they use the data to improve the product. During this time, they have also started selling products both online and offline. He explained that "*We sold through various channels such as Inno Store of STeP, organic product exhibitions, and we conducted digital marketing through our website, Facebook, and Line OA*". Overall, the company's NPD process is at commercial preparation stage.

G.6.2 Assessing the Key Metrics

From the interview data, the NPD diagram was produced in Figure G.11 and the key metrics were assessed as details as following.

1) Opportunity recognition

The interviewee identified the common health problems in Thailand, specifically focusing on high blood cholesterol levels. They recognized the need for an alternative solution to conventional treatments and saw potential in nutraceutical products. After that, they conducted market research to confirm the opportunity. This can be assumed that the company's opportunity recognition stage is at Level 2 (Plan and Do) in market and design aspects.

2) Concept development

The company conducted surveys and observed the prevalence of high cholesterol levels in the target market and validated the problem by confirming the hypothesis through surveys and personal observations. This can be assumed that the company's concept development stage is at Level 2 (Plan and Do) in market and design aspects.

3) Early system design

They conducted literature reviews and clinical testing to identify and evaluate potential substances and their efficacy. Then, they developed the formula based on the combination of substances with complementary functions. They evaluated the formula's effectiveness in reducing fat and blocking external and internal factors and evaluated the side effects of the product through rigorous testing. In early system design of manufacturing, the company planned to produce with OEM. Overall, it can be assumed that the company's early system design stage is at Level 1 (Initial) in all aspects.

4) Detail design

In this stage, the company repeated testing and ddjusted the ratios of the main ingredients in the formula based on feedback and analysis. The interviewee mentioned challenge on developing a formula that there were problems in testing with real volunteers, as the results were not as expected. The company expected better results or a shorter treatment time, so they needed to adjust the formula to be as effective and safe as possible. This led to delay of the development. In detail design of manufacturing, the company defined the quality assurance process to test whether the prototype from OEM had the amount of active ingredients that met the company's standards. All in all, it can be assumed that the company's detail design stage is at Level 1 (Initial) in all aspects.

5) Commercial preparation

In commercial preparation of design and manufacturing, the company sent product to an OEM factory for production. To ensure the quality and stability of the product, they checked the product's shelf life for 3 and 6 months before proceeding to mass production. The data collected was used to improve product and prepare for mass production. In commercial preparation of marketing, the company sold the product through various channels, both online and offline, and collected feedback and data on effectiveness and market acceptance. Nevertheless, the company encountered obstacles in targeting the right group. The interviewee explained that they got positive feedback and a lot of interests during market validation. However, when it came to actual sales, there was a problem of less customers willing to pay than during market validation. It can be assumed that the company's commercial preparation stage is at Level 1 (Initial) in all aspects.

The assessment check sheet shows in Table G.6 and the visualized assessment result shows in Figure G.12.

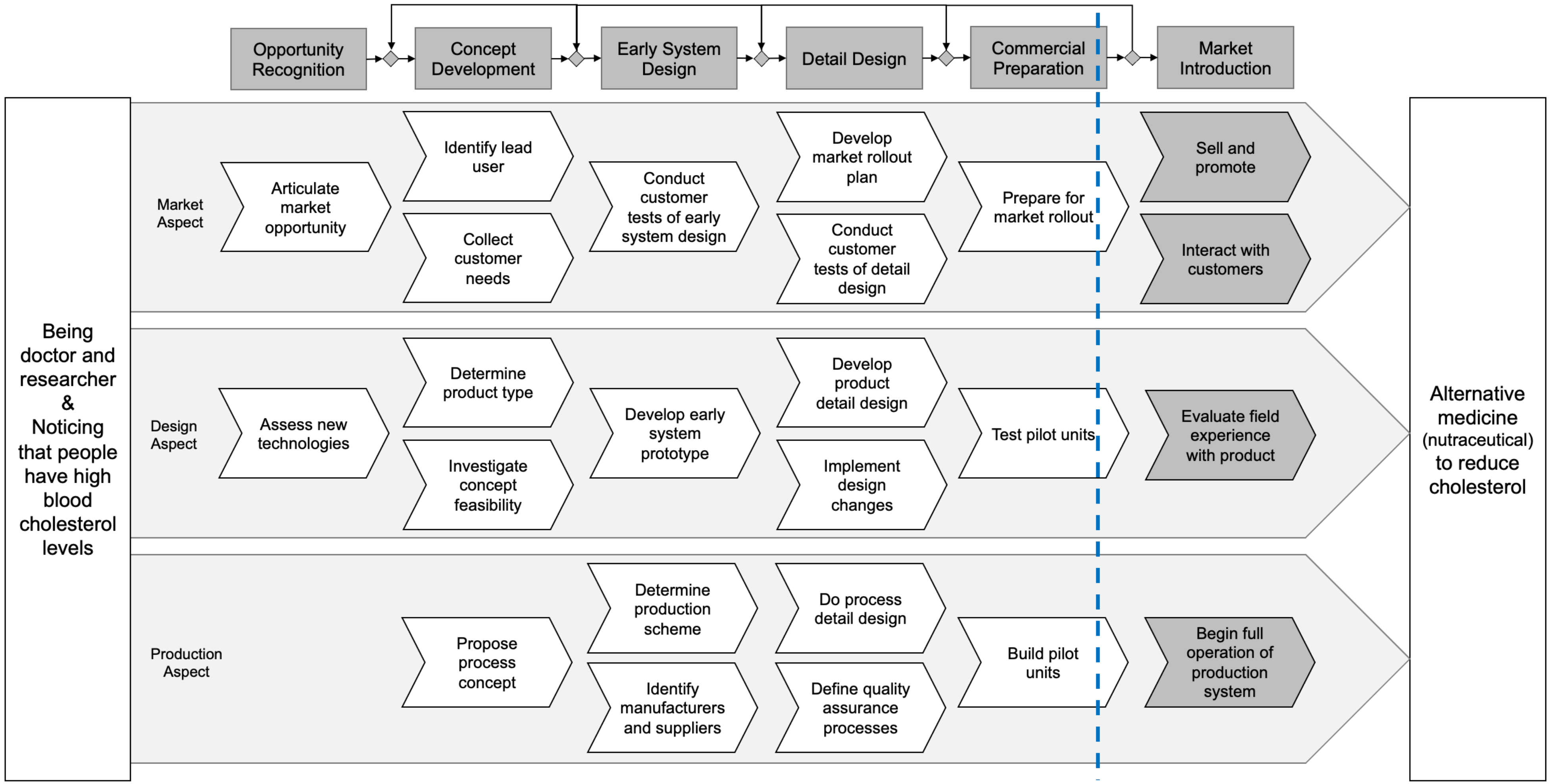

Figure G.11 Diagram of NPD Process of Company 2-G

Table G.6 Assessing Key Metric of Company 2-G Using Assessment Sheet of NPDWise

NPD Stage	Aspect	Does the organization …..(Activity)…..?		If yes to the first question, continue to these questions.			Level
		Activity	Response (Yes/No)	Is the activity performed upon structured plan?	Is result of the activity regularly reviewed?	Is the activity improved according to the reflection?	
Opportunity recognition	Market	Articulate market opportunity	Yes	Yes	No	-	2
	Design	Assess new technology	Yes	No	No	-	2
Concept development	Market	Identify lead user	Yes	No	-	-	2
		Collect customer needs	Yes	Yes	No	-	
	Design	Determine product type	Yes	Yes	No	-	2
		Investigate concept feasibility	Yes	Yes	No	-	
	Production	Propose process concept	Yes	No	-	-	1
Early system design	Market	Conduct customer tests of early system design	Yes	No	-	-	1
	Design	Develop early system prototype	Yes	No	-	-	1
	Production	Determine production scheme	Yes	No	-	-	1
		Identify manufacturers and suppliers	Yes	No	-	-	
Detail design	Market	Develop market rollout plan	Yes	No	-	-	1
		Conduct customer tests of detail design	Yes	No	-	-	
	Design	Develop product detail design	Yes	No	-	-	1
		Implement design changes	Yes	No	-	-	
	Production	Do process detail design	Yes	No	-	-	1
		Define quality assurance processes	Yes	No	-	-	
Commercial preparation	Market	Prepare for market rollout	Yes	No	-	-	1
	Design	Test pilot units	Yes	No	-	-	1
	Production	Build pilot units	Yes	No	-	-	1

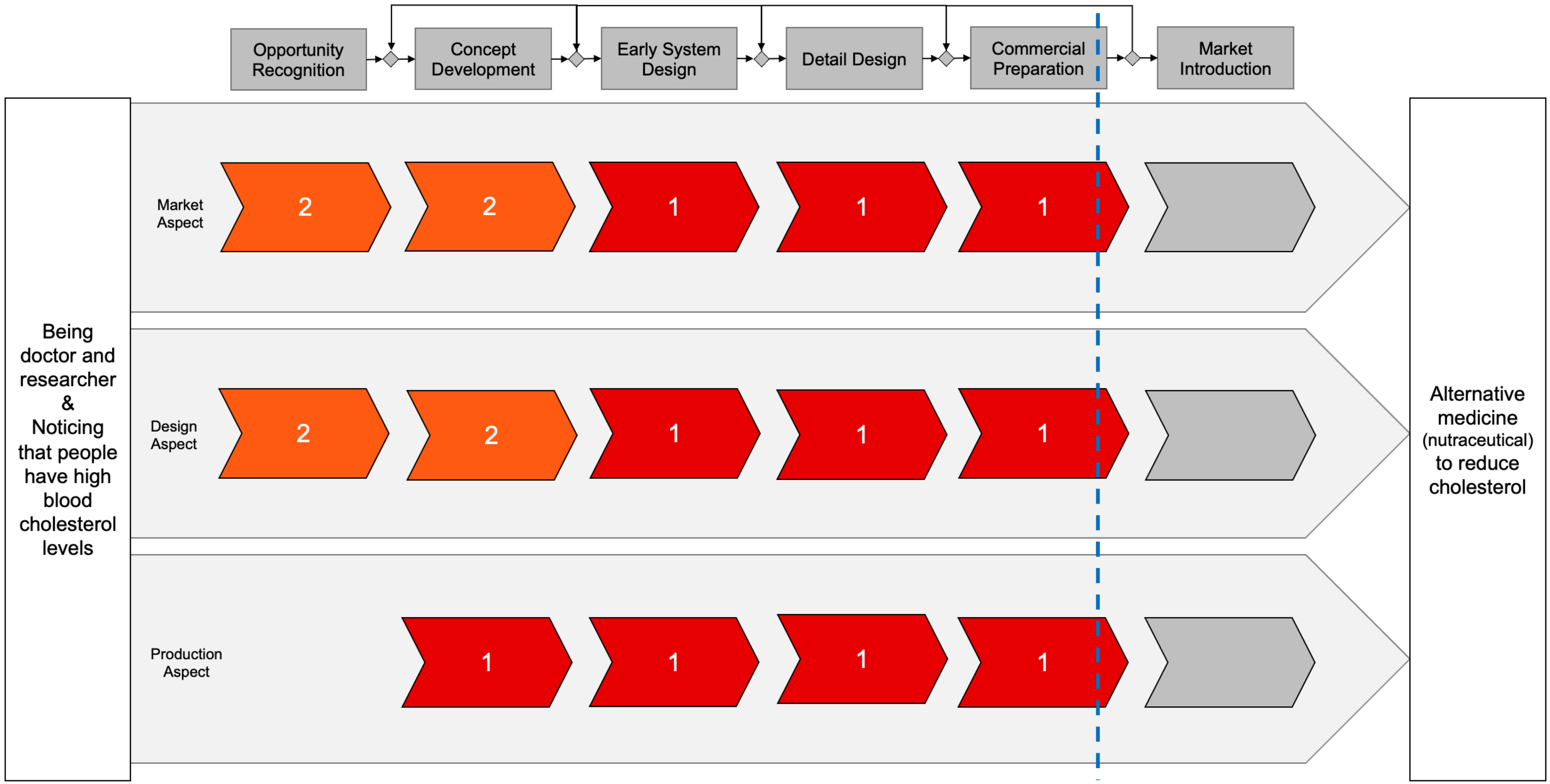

Figure G.12 Assessment Result of Company 2-G

Appendix H Cross-case Analysis of NPD Key Metrics and Maturity Level Between the Cases in Phase 1 and Phase 2

In addition to the cross-case analysis of the common strengths and areas for improvement, it is also valuable to consider the overall maturity level of each company's NPD process. This appendix describes the key metric analysis, which are six NPD stages, together with three aspects of NPD process and NPD activities of the interviewed cases. In addition, as the interview questions in Phase 1 was about how the cases developed technological innovation, some answers were around how they develop their products. In this sub-section, the interview data from Phase 1 was re-analyzed. The interview data of Phase 2 was not only compared between the early-stage start-ups themselves, but it was also compared to the data of start-up and SME cases in Phase 1. Result of assessing NPD stages using maturity levels shows in Table H.1. It is important to note that there might be some answers of Phase 1 data that could not be re-analyzed, these assessment results were written in N/A.

For the cases of Phase 1, 8 cases were both start-ups and SMEs from different business sectors. The first 4 cases were start-ups that develop software platforms. The researcher will use PD to refer to platform developing cases. The next 2 cases were start-ups that commercializing technology from the research. The other 2 cases were small enterprises that commercializing technology from the research. The researcher will use TC to refer to technology commercializing cases. For the cases of phase 2, they were all early-stage start-ups that have just started the business and joined STeP program. 5 cases were PD, and 2 cases were TC.

Table H.1 Result of Assessing NPD Capability of Phase 1 and Phase 2 Cases Using NPDWIse

NPD Phase	Aspect	Phase 1								Phase 2						
		1-A	1-B	1-C	1-D	1-E	1-F	1-G	1-H	2-A	2-B	2-C	2-D	2-E	2-F	2-G
Opportunity recognition	Market	2	4	3	4	4	1	1	1	1	1	1	3	3	-	2
	Design	N/A	4	N/A	N/A	4	1	1	1	-	-	-	-	2	1	2
Concept Development	Market	2	3	3	3	4	1	1	1	2	2	2	3	4	1	2
	Design	2	3	3	3	4	1	1	1	2	2	1	3	4	1	2
	Production	3	1	1	3	1	1	1	1	1	1	1	1	1	1	1
Early system design	Market	2	3	3	3	2	-	-	-	2	2	3	3	4	1	1
	Design	2	3	3	3	2	1	1	-	2	1	3	3	4	1	1
	Production	3	1	1	3	1	1	1	-	-	1	1	1	1	1	1

Table H.1 Result of Assessing NPD Capability of Phase 1 and Phase 2 Cases Using NPDWise (Cont.)

NPD Phase	Aspect	Phase 1								Phase 2						
		1-A	1-B	1-C	1-D	1-E	1-F	1-G	1-H	2-A	2-B	2-C	2-D	2-E	2-F	2-G
Detail design	Market	2	3	3	3	2	-	-	-	-	2	3	3	4	1	1
	Design	2	3	3	3	2	1	1	-	-	2	3	2	4	1	1
	Production	3	1	1	3	1	1	1	-	-	-	-	1	1	-	1
Commercial preparation	Market	N/A	3	3	N/A	-	N/A	N/A	-	-	-	-	3	3	-	1
	Design	N/A	3	3	N/A	-	N/A	N/A	-	-	-	-	2	3	-	1
	Production	3	N/A	N/A	N/A	-	N/A	N/A	-	-	-	-	1	1	-	1
Market introduction	Market	-	-	3	N/A	-	N/A	N/A	-	-	-	-	-	2	-	-
	Design	-	-	3	N/A	-	N/A	N/A	-	-	-	-	-	2	-	-
	Production	-	-	N/A	N/A	-	N/A	N/A	-	-	-	-	-	1	-	-

1) Opportunity Recognition Stage

Marketing aspect: To **articulate the market opportunities,** all PD cases, have identified opportunity from people's pain points. Interestingly, 6 out of 9 PD companies are the student and newly graduated start-ups, and 5 companies (Company 1-A, 1-B, 1-D, 2-A, and 2-B) in this group have identified improvement opportunities from their previous unsuccessful products in order to develop new product. On the other hand, 3 companies whose co-founders have had experience related to the product (Company 2-C, 2-D, and 2-E) have not mentioned about their previous unsuccessful product. This can be assumed that the latter group have specific knowledge of their product. Another assumption is that they have more concern on financial sustainability and are more careful to develop the concept and plan the product. Differently, the student and newly graduated start-ups are more confident to compete in uncertainty and accept the risk to fail. In case of the TC companies, they have looked for the current trends and used their specific knowledge that they have had to develop the product.

Design Aspect: Only a few PD cases have **assessed new technology** in order to develop the concept. One case (Company 1-B) has collaborated with the partner that has specific technology. Another case (Company 1-C) has analyzed new technology of similar product in other countries. On the other hand, the co-founder of company 1-D view that technology is not the most important factor as he stated that,

> *"The most modern technology may not be the one that customers need. The solution can be anything rather than technology. So, the most importance is to understand users".*

A few TC cases have also mentioned about assessing technology. Some companies (Company 1-F, 2-F, and 2-G) have reviewed literature to find new knowhow. One company (Company 1-G) sees the importance of technology; however, the co-founder viewed that technologies were costly, so that the company needed to use ones that were seasonable. Nevertheless, many TC cases are researchers or students from Chiang Mai University (Company 1-E, 2-F, and 2-G), and they mentioned that they generated the concept from their research or core technology they had. This can be assumed that they also assessed new technology.

2) Concept Development Stage

Marketing aspect: After articulating the opportunities, the next process is to **identify lead user** and **collect customer needs,** All PD companies, have firstly defined market segment, followed by conducting market research to prove whether the pain points are worth to solve and whether the concepts are feasible.

These activities have been executed continuously as cycles until the concepts being proved. In addition, some companies have also analyzed the competitors and differentiated by focusing on different target customer. For the TC cases, half of the cases in both phases (Company 1-E, 1-G, and 2-G) have not mentioned clearly about how they define market segment and collect customer needs. One case (Company 1-G) said they collected customer need, which led to positioning and developing product regarding each target group. Differently, another case (Company 1-E), firstly identified several target groups and developing product to solve different problems for customers. Nevertheless, company finally found that focusing only one target group and developing one product for them was more appropriate.

Design aspect: For concept development in design aspect, there is interesting point of the PD cases. Cases in Phase 1 mentioned using diverse approaches during **determining product type** and **investigating concept feasibility**. Company 1-A utilized the milestone and OKR (Objective and Key Result), Company 1-B built hypothesis and tested, Company 1-C used Design thinking, and Company 1-D used Design thinking and Lean process. Differently, in Phase 2 cases, 4 out of 5 PD cases utilized UX and UI to develop the product concept (Company 2-A, 2-B, 2-C, and 2-D). Only Company 2-E that used Service design and delivery and Change management approaches.

Manufacturing aspect: Some TC cases have mentioned about **proposing the process concept**. Half of the cases in both phases (Company 1-E, 1-H, 2-G) have planned to produce products with OEM (original equipment manufacturer), while the other haft (Company 1-F, 1-G, and 2-F) built or planned to build their own manufacturing plants. 2 out of 3 cases (Company 1-E and 1-H) that planned to OEM faced challenge on finding OEM to produce prototype and product. In case of PD companies, the interviewed cases did not explicitly mention about the planning the production. However, it was noticed that there is some difference between Phase 1 and Phase 2. The co-founders in Phase 1 cases (Company 1-A, 1-B, 1-C, and 1-D) have knowledge in software development, which can be assumed that they proposed the process concept and planned to develop software by themselves. On the other hand, the co-founders in Phase 2 cases (Company 2-A, 2-B, 2-C, 2-D, 2-E) hire or plan to hire outsource developer team, which can be assumed that the cases in Phase 2 proposed the process concept by using manufacturers.

3) Design Stage (Early System Design and Detail Design)

Marketing aspect: The cases in both phases emphasized the importance of customer feedback and engagement in their marketing strategies. They all use various methods to gather feedback from customers during **conducting customer tests of prototype**, such as surveys and social media interactions. Cases in Phase 2 mentioned about **developing market rollout plan**. There are differences in their marketing approaches. For example, Company 2-A uses an organic marketing approach and relies heavily on word-of-mouth marketing and referrals from satisfied customers. Many companies focus on partnership strategy, such as Company 2-C builds partnerships with government organization, Company 2-E builds partnerships with dental clinics and organizations in different areas in Thailand. Company 2-A plans to build partnership with larger automotive organization and chamber of commerce in Northern part area. Some companies (Company 2-B, 2-D, 2-F, and 2-G) use digital marketing channels to reach their target customers. They have websites and social media accounts to promote their products and services, as well as to engage with their customers. On the other hand, for Phase 1 cases, they did not discuss on this activity which might be because of the different interview question when interview conducted.

Design aspect: All PD cases have **developed early system prototype or MVP**, tested with customers, got feedback, **developed product detail design**, and **implemented design changes**. The student and newly graduated start-ups (Company 1-A, 1-B, 1-C, 1-D, 2-A, and 2-B) have explained how they defined major subsystems and interfaces in similar way; developing prototype based on customer survey, their background, and adapted from other platforms. Interestingly, two cases (Company 2-D and 2-E), whose founders have engineering and management working experience (and are not at young age), have explained different way of developing prototype. They both explained that they firstly designed the system-level and later designed the detail-level. Another interesting point is that many PD cases have faced challenges during period of developing prototype, such as customer bias, during interview, burning money without gaining revenue, and taking time to test and modify which led to competitors coming to the market. TC cases have developed prototype, tested with customers, and got feedback. Comparing the expertise of the co-founder during developing prototype, the PD companies can be divided into two groups; those whose co-founders are the software developer, and those whose co-founders are not. All cases in Phase 1 have not faced challenge on developing software whereas 4 out of 5 cases in Phase 2 (Company 2-A, 2-B, 2-D and 2-E) have mentioned that they faced this challenge. In case of TC companies, many cases (Company 1-E, 1-G, 2-F, and 2-G) have specific knowledge of their products, such as engineer, researcher, and professor, leading to not facing much challenge on product design. In case of TC cases, some companies (Company 1-F, 1-G) have explained that they not only improved design change but have also expand the target customers and developed other products using the company's core technology.

Manufacturing aspect: Both PD and TC cases did neither mention explicitly how they **determine production scheme** nor **do process detail design**. This might be because of the open-ended questions during the interview were about how they developed the product or technological innovation. This led to them discussing about marketing and design aspects. In case of TC companies, only some cases, that is during production stage, have mentioned about **identifying manufacturers or suppliers** that are qualified. Company 1-F has purchased material from qualified suppliers who have certificates in order to build confidence to the customers. Company 2-G has produced product using OEMs that have been approved by GMP, HACCP. In addition, the company has also **defined the quality assurance process** and assessed the prototypes produced by the OEM. Other TC cases have not mentioned about identifying manufacturers or suppliers. This might be because they are during early stage, so that they might focus on conducting research and producing in lab-scale. In case of PD companies, the Phase 1 cases created and delivered a software product by themselves, which means they identified themselves as the manufacturer. Some cases also used some techniques in the production process. For example, Company 1-A planned the milestone and OKR (Objective and Key Result) to determine the objective and achieve it, and Company 1-D used Agile method and time sprint to produce the product success within the time. On the other hand, PD cases of Phase 2 hired outsource developer team, which can be assumed that they identified manufacturers. This was except of Company 2-A that was in early market validation stage and have not hired the developer yet. Another interesting issue is from the explanation of the founder of Company 2-B about the contracted developers leaving the team which resulted in delays and the need for a new prototype. This can be assumed that some PD cases, that the founders do not have software knowledge, do not clearly determine production scheme.

4) Commercial Stage (Commercial Preparation and Market Introduction)

Marketing aspect and Design aspect: For Phase 1, it is same as the previous stage. Most cases did not mention about **preparing for market rollout** or **testing pilot units** due to the different interview question. Excepting of Company 1-B, they found that they did things according to the theory; however, their target customers did not use their product. This is similar to Company 2-G, they got a lot of interests during market validation; however, the customers were not willing to pay when starting to sell. Several cases in this stage have started **selling and promoting** (Company 1-C, 1-D, 2-F, and 2-G), but only some cases have mentioned about the **interaction with customers** and **evaluating field experience with product**. Company 1-C co-founder said they have produced the product 5 years ago, but it is known and used thoroughly today. He said that it might be because it didn’t come at the right time. Many cases in phase 2 are during design stage, so that they have not launched the product yet. Only Company 2-E has started selling and promoting.

Manufacturing aspect: Only Company 1-A mentioned about **building pilot units**. The company faced challenge on app operation after launching as more customers used the platform than the operation during testing prototype. No case has mentioned about **beginning of full operation of production system**. Most cases in Phase 2 are during design, testing, and refinement stage whereas the cases in Phase 1 did not mention due to the different interview question.

Appendix I Research Ethics Approval

This research has received approval from the EPS Faculty Research Ethics Committee. The university research ethics application form (Version 1) was submitted on June 1, 2020, under the ethics reference number MEEC 19-035. Copies of the ethics approval documents from the EPS Faculty Research Ethics Committee are included in Figures I.1 and Figure I.2.

Additionally, an amendment to the research ethics application was submitted on May 3, 2024, following feedback from viva examiners requesting the inclusion of one anonymized transcript from each phase of the research in the thesis appendices. Figure I.3 contains a copy of the amendment approval from the EPS Faculty Research Ethics Committee.

Subject: MEEC 19-035 - Conditional Approval
Date: Monday, 6 July BE 2563 15:55:43 British Summer Time
From: Kaye Beaumont on behalf of EPSResearchEthics
To: Nattida Tachaboon
CC: Alison McKay, Gerard Duff

Dear Nattida

MEEC 19-035 - The Development of Innovation Capability in Thai SMEs

NB: All approvals/comments are subject to compliance with current University of Leeds and UK Government advice regarding the Covid-19 pandemic.

I am pleased to inform you that the above research ethics application has been reviewed by the Engineering and Physical Sciences Research Ethics Committee and on behalf of the Chair, I can confirm a conditional favourable ethical opinion based on the documentation received at date of this email and *subject to the following condition/s which must be fulfilled prior to the study commencing:*

1. C19. How anonymity of videos will be handled? How they will be stored and after how long it will be destroyed.

The study documentation must be amended where required to meet the above conditions and submitted for file and possible future audit.

Once you have addressed the conditions and submitted for file/future audit, you may commence the study and further confirmation of approval is not provided.

Please note, failure to comply with the above conditions will be considered a breach of ethics approval and may result in disciplinary action.

Please retain this email as evidence of conditional approval in your study file.

Please notify the committee if you intend to make any amendments to the original research as submitted and approved to date. This includes recruitment methodology; all changes must receive ethical approval prior to implementation. Please see https://leeds365.sharepoint.com/sites/ResearchandInnovationService/SitePages/Amendments.aspx or contact the Research Ethics & Governance Administrator for further information on epsresearchethic@leeds.ac.uk if required.

Ethics approval does not infer you have the right of access to any member of staff or student or documents and the premises of the University of Leeds. Nor does it imply any right of access to the premises of any other organisation, including clinical areas. The committee takes no responsibility for you gaining access to staff, students and/or premises prior to, during or following your research activities.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, risk assessments and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited.

It is our policy to remind everyone that it is your responsibility to comply with Health and Safety,

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Figure I.1 A Copy of Ethics Approval by the EPS Faculty Research Ethics Committee (1/2)

Data Protection and any other legal and/or professional guidelines there may be.

I hope the study goes well.

Best regards
Kaye
On behalf of EPS/FREC

From: Nattida Tachaboon <mnnta@leeds.ac.uk>
Sent: 01 June 2020 09:07
To: EPSResearchEthics <EPSResearchEthics@leeds.ac.uk>
Cc: Alison McKay <A.McKay@leeds.ac.uk>; Gerard Duff <G.Duff@leeds.ac.uk>
Subject: Apply for the Ethical Review

Dear Rachel de Souza,

I am Nattida Tachaboon, PhD student in the school of Mechanical Engineering.

I am conducting the research about The Development of Innovation Capability in Thai SMEs and would like to apply for the ethical review. Kindly find the application form and relevant supporting material as files enclosed;
1. MEEC Submission Checklist
2. Ethical Review Form v1
3. Participant Consent Form v1
4. Participant Information Sheet v1
5. Example of Recruitment Email

Best regards,
Nattida Tachaboon

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Figure I.2 A Copy of Ethics Approval by the EPS Faculty Research Ethics Committee (2/2)

Subject:	MEEC 19-035 Amendment 1 May 2024 - study Approval Confirmation
Date:	Friday, 3 May BE 2567 15:36:35 British Summer Time
From:	EPSResearchEthics
To:	Nattida Tachaboon
Attachments:	image001.gif

Dear Nattida,

MEEC 19-035 Amendment 1 May 2024 – An Innovation Capability Assessment Method for Early-Stage Start-ups in Thailand

I am pleased to inform you that your amendment to your research ethics application has been reviewed by the Faculty of Engineering and Physical Sciences Research Ethics Committee (EPS FREC) and on behalf of the Chair, I can confirm a favourable ethical opinion based on the documentation received at date of this email.

Please retain this email as evidence of approval in your study file.

Please notify the committee if you intend to make any amendments to the original research as submitted and approved to date. This includes recruitment methodology; all changes must receive ethical approval prior to implementation. Please see https://secretariat.leeds.ac.uk/research-ethics/how-to-apply-for-research-ethics-amendment/ or contact the Research Ethics & Governance Administrator for further information (epsresearchethics@leeds.ac.uk) if required.

Ethics approval does not infer you have the right of access to any member of staff or student or documents and the premises of the University of Leeds. Nor does it imply any right of access to the premises of any other organisation, including clinical areas. The committee takes no responsibility for you gaining access to staff, students and/or premises prior to, during or following your research activities.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, risk assessments and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited.

If you require this confirmation in letter form, for example to show to external funders, then please do email me. I am happy to provide this if required.

It is our policy to remind everyone that it is your responsibility to comply with Health and Safety, Data Protection and any other legal and/or professional guidelines there may be.

I hope the study goes well.

Very best wishes,

Taylor Haworth, Research Ethics Administrator, Secretariat
On behalf of Dr Virginia Pensabene, Chair, EPS Faculty Research Ethics Committee

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Figure I.3 A copy of Amendment Approval by the EPS Faculty Research Ethics Committee