DEVELOPING A COMMERCIALIZATION MODEL FOR INNOVATIVE PRODUCTS AND PROCESSES IN A PETROLEUM FIRM

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สรนาถ งามขจรกุลกิจ : การพัฒนาแบบจำลองการค้าสำหรับผลิตภัณฑ์และกระบวนการเชิงนวัตกรรมของบริษัทปิโตรเลี่ยม (DEVELOPING A COMMERCIALIZATION MODEL FOR INNOVATIVE PRODUCTS AND PROCESSES IN A PETROLEUM FIRM) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ศ. ดร. ปารเมศ ชุติมา, 113 หน้า.

อุตสาหกรรมปิโตรเลียมมีบทบาทสำคัญกับเศรษฐกิจในประเทศไทยในการเป็นผู้ผลิตผลิตภัณฑ์ปิโตรเลียม เนื่องจากความเอื้ออำนวยทางด้านสถานที่จึงทำให้บริษัทต่างชาติได้เข้ามาลงทุนในอุตสาหกรรมปิโตรเลียมในประเทศไทย และด้วยเหตุผลนี้จึงทำให้บริษัทที่ก่อตั้งภายในประเทศไทยต้องมีกลยุทธ์ที่ใช้นวัตกรรมเป็นหลัก ในการคิดค้นนวัตกรรมที่จะนำไปใช้มีกระบวนการที่สำคัญที่เรียกว่า กระบวนการการพัฒนาสินค้าในรูปแบบของเชิงพาณิชย์ ซึ่งเป็นกระบวนการที่สำคัญที่จะทำให้เกิดผลกำไรและได้รับความร่วมมือจากหน่วยงานอื่น ๆ

โดยงานวิจัยนี้คือการพัฒนาแบบจำลองการค้าสำหรับผลิตภัณฑ์และกระบวนการเชิงนวัตกรรมของบริษัทปิโตรเลียม มีจุดประสงค์หลักเพื่อสนับสนุนกระบวนการภายในองค์กรในเชิงพาณิชย์และทำให้พนักงานภายในองค์กรสามารถเข้าถึงการพัฒนาในรูปแบบนี้ได้ด้วย

การพัฒนาแบบจำลองการค้าสำหรับผลิตภัณฑ์และกระบวนการเชิงนวัตกรรมของบริษัทปิโตรเลียมนั้นถูกแบ่งกระบวนการเป็นสามขั้นตอน ซึ่งได้แก่ ขั้นแรกคือการสอบถามข้อมูลเบื้องต้นจากผู้ทำงานจริงมาทำเป็นแบบจำลองเบื้องต้น ขั้นที่สองคือการนำข้อมูลและแบบจำลองจากขั้นตอนที่หนึ่งมาวิเคราะห์ว่ามีหลักการที่เหมาะสมกับอุตสาหกรรมปิโตรเลียมหรือไม่ ขั้นตอนที่สามคือการนำแบบจำลองไปทดสอบการใช้งานในบริษัท

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In Thailand, the petroleum industry is a major contributor to the economy as a supplier of crucial petroleum products. Due to its geographical location, multinational oil & gas companies have established their operations in Thailand. For Thai petroleum firms to remain competitive in the industry, innovation can be used as a strategy. Specifically, commercialization of inventions can bring firms competitive advantages in terms of financial returns, and business opportunities for partnerships.

The objective of this research is to develop a commercialization model for inventions in Thailand's petroleum industry. The model is aimed to serve as a roadmap of essential activities for individual work functions throughout the stages of the commercialization process. Additionally, the model will provide an overview of the relationships between work functions and their responsibilities.

The methodology used in this research consists of three stages. The first stage is developing a preliminary commercialization model by integrating data from literature and data from interviews of industry experts in Thailand. The second stage is refinement of the model through evaluating the preliminary model on commercialization experts. Finally, the last stage uses a Thai petroleum firm as a case study to adapt the model for use at company-level. As a result, this research has developed 2 commercialization models, namely an industrial commercialization model, and a company commercialization model.

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Chapter 1: Introduction

In this chapter, the basis for conducting this study is firstly established. This will be through explaining the general research area, followed by a background of the company and their operations, and research overview covering the problem statement, research question, research objective, hypothesis, assumptions in the research, scope of research, expected benefits and outcomes of the study, and finally the research structure.

1.1 Description of General Research Area

In the current age, petroleum has become an essential material for every country due to its significant applications. For example, petroleum products such as petrol, diesel fuel, and jet fuel are commodities required for transportation. Additionally, petroleum is used as feedstock for the petrochemical industry to produce plastics, rubber, solvents, and many more products (EIA, 2015). According to CIA, 2017, petroleum was responsible for roughly 2.5% of the World's Gross Domestic Product (GDP) in 2016. Furthermore, CIA, 2017 reported that petroleum products accounted for 38.2% of the world's energy consumption in 2016, making it the world's leading fuel and BP, 2016 forecasts that it will remain the leading fuel source for many decades despite the continuous developments and increasing use of alternative fuel sources.

Due to the importance of petroleum products in the economy, such as driving recessions, fluctuations in the price are carefully monitored by economists as well as the government (Deloitte, 2015). As a result of its driving role in the global economy,

countries are significantly affected by fluctuations and developments in the petroleum market, either as producers, consumers, or both. The phrase “Oil is wealth” is commonly used to summarize its importance. Therefore, as a provider of crucial petroleum products, the petroleum industry plays an important role as a driver of both a nation’s economy as well as the global economy.

According to CIA, 2017, the petroleum industry is one of the major contributors to Thailand’s economy, and is ranked as the ninth largest industry in Thailand as of 2016. Due its geographical location, numerous multinational oil & gas companies use Thailand as a base for oil refineries and petrochemical plants. This makes the petroleum industry challenging and difficult to compete for smaller Thai firms. Nonetheless, through innovations, Thai firms have been able to sustain their businesses and compete with multinational competitors. To remain competitive, and maintain their position and sustainability, Thai petroleum refineries must continuously advance the state of their innovative technologies and commercialization processes in the industry.

Developments in technological innovations are commonly regarded among industries as a major source of competitive advantage (McCoy, Thabet, and Badinelli, 2008). Due to the competitive environment of many industries, companies are forced to continuously expand and improve the portfolio of their products and processes through innovation. Most innovations in the field of petroleum are process innovations rather than product innovations (Anbardan, 2013). This is because the petroleum

industry competes in terms of efficiency of their operations and processes. Thus, innovations which improve process efficiency, or incremental innovations, have become the main driving force of the industry's development (Lei et al., 2016). However, before an innovation can be realized it must firstly start as an invention. As an opportunity, commercialization of inventions to innovations can be utilized to provide firms with another source of revenue as well as strategic business opportunities.

Commercialization is a complex process which involves multiple stages to complete. When successful, commercialization can bring about competitive advantages in terms of economic returns and also create opportunities such as partnerships between companies leading to knowledge sharing (Rosa and Rose, 2007). However, developing inventions and successfully moving them into the marketplace, or commercializing, is becoming increasingly difficult due to global competition. Commercializing an invention requires more than just developing a product or process which functions. The invention must also address and meet the demands of the market (USDOE, 2000). In this respect, the commercialization process must link the technical, marketing, and business aspects of a firm (Goldsmith, 2016).

Furthermore, in the petroleum industry, there are many challenges and barriers in commercializing innovative products and processes. These challenges are mostly related to the complex characteristics of technology and processes in the industry. Some examples of these challenges and barriers include:

1. The petroleum industry involves the use of a wide range of processes and technology such as drilling, ground engineering, petrochemical refining technology, automation controls, and other assistive technology (Lei et al., 2016). Therefore, the commercialization process becomes increasingly complex and is subject to varying.

2. Innovative products and processes are sensitive to laws & regulations, such as environmental regulations on the emission of greenhouse gases (Anbardan, 2013), and must also comply with local standards such as the Thai Industrial Standard Institute (TISI).

3. Due to the high amount of uncertainties and resources involved, firms are discouraged to commercialize inventions if there is a lack of tools or model (USDOE, 2000).

To address these challenges, a commercialization model can be used to serve as a roadmap and provide a list of activities to be completed throughout the commercialization process. According to Lei et al., 2016, the use of a commercialization model assists by providing an overview of the entire commercialization process, therefore allowing firms to plan their technical, marketing, and business activities more efficiently resulting in higher rates of successful commercialization. However, there is currently no commercialization model for the petroleum industry in literature.

Against this background, this study contributes to the research area of innovation and commercialization by proposing a model to effectively commercialize product and process inventions in the studied petroleum firm.

1.2 Company Background

1.2.1 Company Introduction

The studied company, or hereafter referred in this study as The Company, was established in Thailand, and has over 50 years of experience competing in the petroleum industry. Currently headquartered in Bangkok, Thailand, The Company operates one of Thailand's largest oil refineries and contributes to approximately 21% of the Nation's refining capacity. Their main products are separated into three groups which include:

1. Light Products: Gasoline, LPG, Mixed Xylene
2. Middle Distillates: Diesel and Jet Fuels
3. Heavy Distillates: Bitumen and Fuel oil

Furthermore, The Company constitutes as the core business of a Group, and provides feedstock to its subsidiaries operating in related businesses to the petroleum industry such as petrochemicals, solvents & chemical products, lubricants, marine transportation, and ethanol production.

Although The Company's oil refinery is considered one of the largest in Thailand, neighboring countries in the Association of Southeast Asian Nations (ASEAN) operate much larger and complex refineries. For example, in 2016, Singapore's largest refinery

owned by Exxon Mobil had a refining capacity of 605,000 barrels-per-day which is nearly triple the capacity of The Company's. Furthermore, the complexity of The Company's refinery is second-rate in terms of technology and process efficiency.

As a strategy to improve its operations to compete on the ASEAN scale, The Company has future plans to increase the size and complexity of its oil refinery such that it reduces the production of low demand products, such as heavy fuel oils or residue, and increases the production of higher demand products such as diesel and jet fuel. The Company also has goals to improve their production processes to use less energy and emission of gasses. In addition, they are finding new ways to compete due to threats such from advancements in alternative energy sources, and EV vehicles. Through successful commercialization and innovation, The Company can explore new products and processes to address these threats, as well as improve their current operations, and generate new revenue streams.

1.2.2 Company Strategies & Operations

1.2.2.1 Corporate Strategy & Structure

As an industry competing on key commodity products required by the general public, the prices of products are regulated by the government and are priced similarly throughout competitors in the petroleum industry. Therefore, importance is given to the improvement of process and operational efficiency to drive down costs. By reducing their operation costs, this increases the margin of their petroleum products. Additionally, The Company gives high importance to creating new revenue streams to

address the predicted future issues of alternative energy sources, such as solar energy. By applying Porter's Generic Strategies (Porter, 1980), The Company uses a cost leadership strategy.

For the corporate structure, The Company currently operates using a functional organization structure and facilitates cross-departmental communication through an established multi-discipline committee of Directors. As a functional structure, The Company's departments are operated as separate silos with communication only through each department's Director. This is meant to drive performance and efficiency within individual work functions, and also ensure systematic decision-making. However, The Company has future plans to change to a cross-functional structure to support a culture of integration to promote effective collaboration in the organization, as well as between subsidiaries and business partners.

1.2.2.2 Innovation Strategy & Culture

With alignment to the corporate strategy, The Company's innovation strategy is to identify and generate new revenue streams through IP management and business development. As a result, The Company uses a mix between an incubative strategy and acquisitive strategy. For the incubative strategy, innovations are developed internally or through strategic partnerships. However, developing innovations internally requires The Company to have necessary capabilities, knowledge, and know-how. Hence, the acquisitive strategy is employed as a supporting strategy to acquire

innovations by other companies through acquisitions and licensing to cultivate such capabilities while also improving their current operations.

Furthermore, The Company's innovation culture is to continuously improve the way they are working to achieve the best efficiency and performance in petroleum production. This is maintained through a proactive culture which focuses on monitoring and measurements, management reviews, and diagnosing why errors or inefficiencies occur.

1.2.2.3 Commercialization Strategy

Linking to the innovation strategy, the commercialization strategy for The Company is separated into two categories which are called as 'external applications', and 'internal applications'. For external applications, the commercialization strategy is to form strategic partnerships to share knowledge, capabilities, and also risks between partners in commercializing inventions using an 'outside-in' or demand-pull approach. This strategy is frequently utilized as commercializing inventions in the petroleum industry is complex and involves high risks & uncertainties. Therefore, by including partners in the process, the risks are shared. In contrast, the internal application strategy refers to an 'inside-out' or supply-push approach using licensing as the main method of generating revenue from innovations developed from internal processes such as R&D.

1.2.2.4 Current Commercialization Process

Currently, The Company lacks a formalized and documented commercialization process. Hence, planning the process from the start is required in each project. Moreover without documentation, planning and management of the project is based on employee experience and is difficult to review and advise new employees. Nonetheless, The Company's commercialization process has some regularity in the stages of commercializing throughout each project.

During the early stages, an 'End Game' is defined to clearly identify the value proposition, and the value delivered to consumers as either a solution or an improvement. Using this as a basis, a plan of activities is created to achieve the End Game. Furthermore, each path of action taken throughout the commercialization process is chosen to reflect the End Game. The criteria for identifying the End Game depends on the level of technology and market potential of the invention.

In the intermediate stages, the project is reviewed against the initial plan and adjustments are made to key aspects such as resource allocation, financing, and personnel. In addition, the immediate internal and external environment is monitored for changes such as new laws & regulations, or trends of future recessions and the plan is adjusted accordingly.

Finally, in the last stages of the commercialization process, the project's progress is reviewed once more against the plan for the objectives set and End Game.

Additionally, potential customers or new partnership opportunities are identified and engaged.

1.3 Statement of Problem

In the context of the petroleum industry, competitive advantages are gained through improvements in process efficiency from inventions and innovations. However, keeping an invention strictly for internal applications is an example of inefficient use assets since many resources were used for processes such as intellectual property (IP). To maximize the benefits from an invention, companies should aim to commercialize it to generate new revenue streams, form new business partnerships, and also improve the company's reputation. However as mentioned previously, commercialization is becoming increasingly difficult due to global competition and changing demands of stakeholders (USDOE, 2000). According to Lei et al., 2016, companies with documented plans or a roadmap for commercialization lead to better chances of success.

This research aims to study and improve The Company's commercialization process through the development of a commercialization model and identifying important activities in the petroleum industry. In this context, the commercialization process includes all stages from moving an invention to successful market entry into a revenue-generating position. In doing so, the following problem statements of The Company will be addressed.

1.3.1 No Standard Process for Commercialization

Currently, The Company's inventions stop at the IP stage, and do not continue onto commercialization. This is due to The Company's current situation of not having a standard process or procedure to follow when commercializing new products and processes. As a result, each new innovation project requires developing a new set of plans. Due to the complex nature of the petroleum industry, different projects may require distinct aspects to consider such as the material requirements, regulatory compliances, manufacturing requirements, marketing, and financial details. Furthermore, there are many uncertainties which may occur throughout the commercialization process. By failing to address a certain aspect, the success rate of commercializing a product or process will decrease.

Therefore, developing a new commercialization plan for every project is both difficult and inefficient. Without standard procedures, there are higher risks involved in commercializing products and processes in the petroleum industry. This causes discouragement of commercialization for senior management which is reflected onto their teams, and ultimately the firm too.

1.3.2 Commercialization Activities are operated as Separate Silos

As the current situation in The Company, the corporate structure makes it so each work-function manages an individual part in the commercialization process. However in reality, many stages in the process require the coordination of activities between different work-functions. For example, the marketing team must rely on coordinating

with R&D and business development for information before developing their marketing strategy. Without clearly communicating a commercialization plan, it is challenging for employees to comprehend how different work-functions operate together. Consequently, this obscures the relationship between activities and the importance of working across work-functions. As a result of this, the firm's current commercialization activities are conducted as separate silos. This causes resources wasted trying to link each part of the project together which is both ineffective and inefficient.

1.4 Research Question

In this study, the research question is:

"How can The Company effectively plan and manage the commercialization process of a product or process invention in the petroleum industry?"

1.5 Research Objective

The objective of this study is to develop a model for effectively commercializing inventions as products or processes in a petroleum firm.

1.6 Research Hypothesis

To address the research question, this study's hypothesis is:

"The Company can effectively plan and manage its commercialization process of a product or process invention in the petroleum industry through developing a formalized and documented commercialization model."

1.7 Assumptions in the Research

1. An invention is defined as the introduction of a product, process, or method which is created to improve or replace an existing way of doing things. Inventions are used internally and may or may not have commercial potential
2. An innovation is defined as a product, process, or method which improves or replaces an existing way of doing things, and has successfully entered the marketplace.
3. The commercialization process starts with an invention and ends when the invention enters the market into a revenue-generating position where it is then called an innovation.
4. Due to the rare occurrence of disruptive innovations in the petroleum industry, innovations are assumed to be only incremental and radical innovation.
5. Commercializing supply-push inventions is an extension of demand-pull inventions, and therefore undergoes similar processes.

1.8 Scope of Research

Firstly, in this research, the development of the model will be designed for commercializing product and process inventions in the context of Thailand's petroleum industry, or specifically The Company. The model is intended for use from taking an invention to successful market entry only, and does not consider aspects of scaling-up products after market entry.

Secondly, the model is designed as a roadmap or checklist of activities which need to be completed throughout each stage of the commercialization process. However, this excludes in-depth details of *how* to complete an activity, for example the process in developing a business plan.

1.9 Significance and Expected Benefits of the Research

1. A comprehensive model for commercializing inventions as products and processes which is specific to The Company, and the petroleum industry.
2. An improved commercialization process at The Company through more efficient planning and management of the process.
3. Support and encouragement from senior management of The Company for commercializing inventions in the firm.
4. A greater understanding from employees of how separate departmental activities in the commercialization process are interrelated.
5. Academic contribution of a commercialization model for the petroleum industry to literature.

1.10 Thesis Structure

To achieve this study's objectives, the research will be structured into five chapters which are described as follows:

Chapter 1: Introduction will describe this study's general research area and its significance, the studied company's background, statement of problem, research

question, hypothesis, research objective, assumptions in the study, scope of the project, and expected outcomes from this study.

Chapter 2: Literature Review will investigate previous studies in the fields of innovation theory and strategy, the commercialization process, existing commercialization models, and corporate model to support innovation.

Chapter 3: Research Methodology describes the proposed action plan of achieving the research objectives. This will be done through developing a preliminary model, refining the model, and finally adapting the model to fit the studied company.

Chapter 4: Results & Discussion presents the findings from the research. This is structure according to the research methodology under headings of the preliminary model, refined model, and company commercialization model.

Chapter 5: Conclusion summarizes the study in terms of the findings from the research, limitations, research contributions, and further research.

Chapter 2: Literature Review

2.1 Innovation

Innovation is commonly viewed by organizations as a key activity which provides competitive advantages, and can ultimately determine an organization's success and sustainability (Isabelle, 2004). In industries, innovation has the ability to create new opportunities and also transform markets. For example, innovation played a substantial role in the petroleum industry during the transition from a coal-based to a petrochemical-based industry (Hassani et al.,, 2017). As a source of competitiveness in terms of operational effectiveness and efficiency, organizations which continuously innovate will become sustainable industry leaders (McCoy, Thabet, and Badinelli, 2008).

2.1.1 Background of Innovation in the Petroleum Industry

According to Mcgrath, 2011, the first innovation for the petroleum industry was the rotary drill which was developed in the 1880s for improving oil drilling. Following this, remotely operated vehicles, surface mining, synthetic zeolites in petrochemicals, and microwave and radio technology for discovery and extraction of petroleum were important innovations in the petroleum industry (Mcgrath, 2011).

However, a recent trend of innovation in the petroleum industry is based on information technology such as Internet of Things (IoT) and Big Data. According to Mills, 2013, innovations as information technology started in the petroleum industry with

innovations such as seismic mapping, surface rock formation, and magnetic field analysis.

As a newly emerging technological trend, Big Data has vast potential in the petroleum industry. For example, Seshadri, 2013, suggested that Big Data can be employed to improve the reliability of oil drilling processes through anticipating problems. Furthermore, Leber, 2012 extends this by finding applications for Big Data in terms of monitoring and tuning drilling operations for unconventional oil reserves.

From the discussion of the background in the petroleum industry, it can be observed that the nature of key technological innovations in the petroleum industry are majorly used for process improvement.

2.1.2 Definition of Innovation

As previously mentioned, the scope of this study will be dominantly on the concept of innovation. Thus, it would be useful to elaborate on the definition of innovation. According to Porter, 1990, the term innovation was used to describe processes which exploited new technology and knowledge to create new or improved products. Similarly, Acton, 2016 defines innovation as the introduction of a product which is entirely new or an improvement of products available in the past. Additionally, OECD, 1997 defines innovation as the adoption of technologically enhanced or new production methods. Extending upon OECD, 1997's definition, Isabelle, 2004 defines innovation as the utilization of knowledge or techniques to develop new solutions for problems. McCoy, Thabet, and Badinelli, 2008 defines innovation broadly as "novel

products whose inherent criteria define significant change in an institution's process." From the common concepts of the definitions, innovation is defined in this study as a product, process, or method which serves as a new and more effective solution for dealing with existing problems or needs. Furthermore, adding to this definition, it should be noted that innovations can be classified according to the significance of a change which an innovation brings to a company, industry, or market.

2.1.3 Models of Innovation

The earliest viewpoint of innovation in literature dated back to 1934 by Schumpeter, 1934. According to Schumpeter, 1934, innovation was historically regarded as a linear process for the creation of products and processes which started with research followed by technology development and then finally diffusion. The conclusion made from Schumpeter, 1934's linear model was that companies with better research and development resources had greater outputs of new technology. This viewpoint concurs with the traditional concept of closed innovation where organizations relied solely on its internal resources and operations for innovation processes (Huff, M ö slein, and Reichwald, 2013). The rationale behind closed innovation was to protect valuable information and knowledge-based competencies, and also be the sole beneficiary by being the first to market new technology (Chesbrough, 2003).

However, the simplicity of the linear model led to skepticism among authors (Sekhar and Dismukes, 2009). Additionally, closed innovation was believed to inhibit

an organization's innovation capabilities by not considering external pressures such as globalization (Chesbrough, 2003). As a result, innovation was subsequently viewed contrastingly in a non-linear approach (Hanna et al., 2015). For example, Yin, 1994 viewed innovation from a demand-pull perspective and speculated that the consumer's demands played a dominant role in creating inventions as opposed to advances in knowledge by research as proposed by Schumpeter, 1934.

Furthermore, another non-linear approach to address the limitations of the traditional approaches was the concept of open innovation (Westerlund and Leminen, 2011). The term 'open innovation' was first coined by Chesbrough, 2003 as "organisations innovating through integrating external ideas from stakeholders, customers, and even competitors with an organisation's internal ideas." Nonetheless, both the supply-focused perspective by Schumpeter, 1934 and the demand-pull perspective by Yin, 1994 are commonly accepted in industries as important concepts (Nemet, 2007), although more significance is given to the latter (Hanna et al., 2015). A summary of the views of innovation is illustrated in **Table 1**.

Table 1: Summary of Views of Innovation

Name	Approach	Reference
Supply-push Innovation	Linear	Schumpeter, 1934
Closed Innovation	Linear	Huff, M ö slein, and Reichwald, 2013
Demand-pull Innovation	Non-linear	Yin, 1994
Open Innovation	Non-linear	Chesbrough, 2003; Westerlund and Leminen 2011

2.1.4 Stages of Innovation

Innovation may come to an organization in two ways, namely by generation or adoption. According to Hassani et al., 2017, innovations that are generated in an organization are usually for its own use or for sale to other organizations and the generation of innovation is process which results in an outcome of a new or improved product, process, or technology. Adoption occurs if this outcome is then acquired by another organization (Rosa and Rose, 2007). For the generating organization, it must go through the stages of innovation. In literature, innovation typically consists of 4-5 stages depending on the industry (Hassani et al., 2017).

Nonetheless, the stages of innovation proposed are consistent. These stages are:

1. Idea Generation: The idea regarding a new product, process, service, or method is conceptualized
2. Proposal: The idea or concept is transformed into a business plan or proposal for official acceptance
3. Adoption or acceptance: The proposed idea or concept is accepted and planning of resource allocation occurs. Adoption is for internal use by the organization whereas acceptance is the market.
4. Implementation or commercialization: The new 'invention' is utilized by organizational members as they perform their tasks (implementation) or commercialized into the market and transformed into an 'innovation'.

In this study, the focus will be on the generation of innovation, or more specifically the commercialization stage.

2.1.5 Classification of Innovations

The path of commercializing an invention into an innovation is dependent on its classification, and thus it would be impossible to use a single commercialization model for every innovation. There are many arguments from literature on how to classify innovations (Hassani et al., 2017). For example, (Dismukes, 2005) classifies innovation as incremental innovation (continuous), radical innovation (discontinuous), and disruptive innovation.

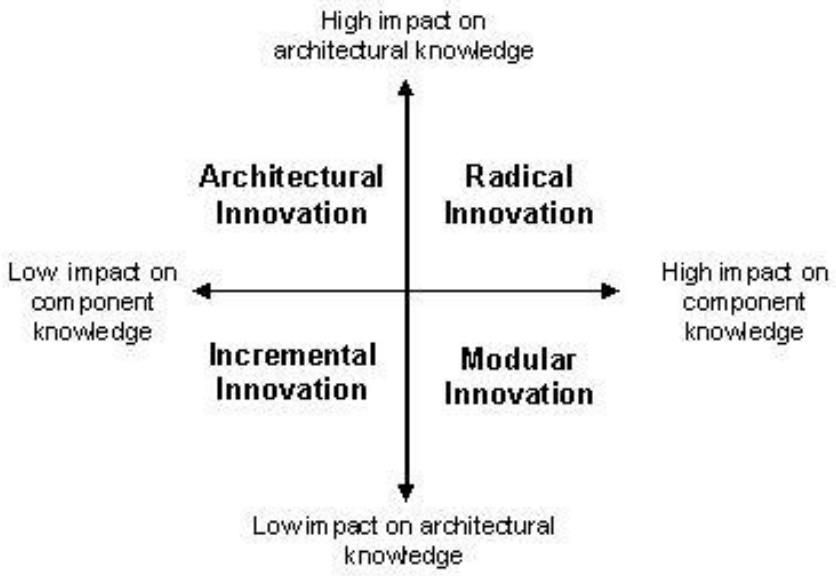

Figure 1: Classification of Innovations

(Source: Henderson and Clark, 1990)

With respect to the petroleum industry, innovations are mostly in the form of incremental and radical innovation (Gaubinger, 2012). Hence, in this study, the focus will be mainly on incremental and radical innovations. Incremental and radical innovations are commonly referred to as classifications with the majority of innovations.

2.1.6 Invention vs. Innovation

The concepts of invention and innovation are commonly misunderstood and used erroneously. To prevent misunderstanding of the scope of study, it is important to firstly define and distinguish between the concepts of invention and innovation, the latter which this study will focus on. In literature, the concepts of invention and innovation have been discussed to great lengths. However, according to Porter, and Cunningham, 2005, due to the extremely complicated nature of innovation, such as industry-specific limitations, it is challenging for authors to present a general theory.

It should be noted that in most definitions, the two concepts of invention and innovation are interlinked. For example, Jessua et al., 2006 defines innovation as the "process of transforming a new idea invention into a commercially viable product or service".

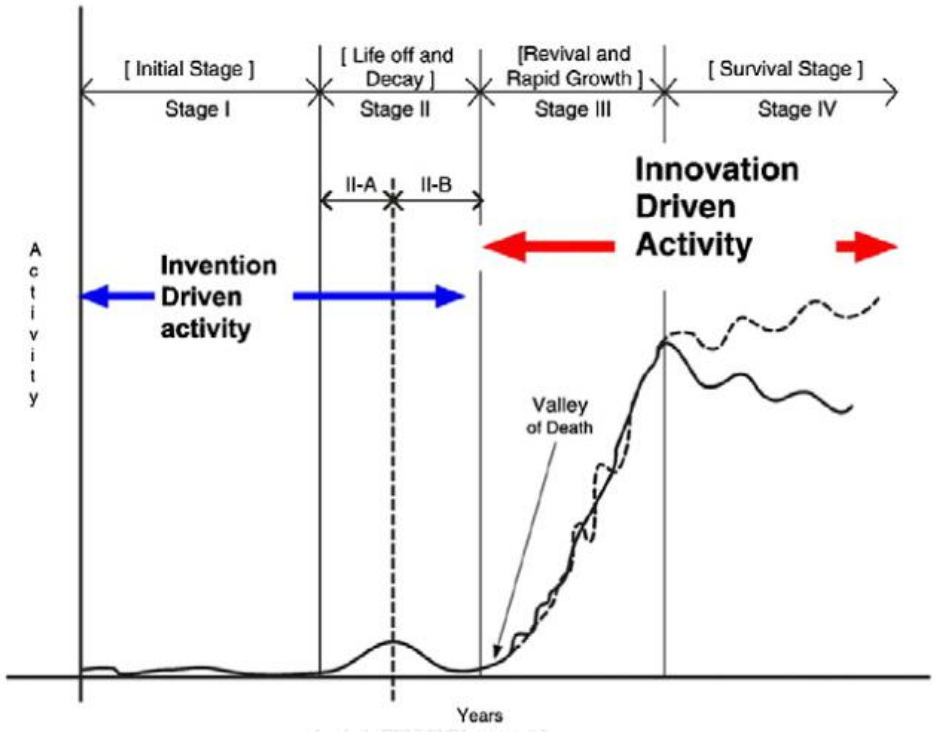

Figure 2: Life Cycle Model of an Innovation

(Source: Sekhar and Dismukes, 2009)

To further clarify between the concepts of invention and innovation, the life cycle model of an innovation reported by Sekhar and Dismukes, 2009 is illustrated in **Figure 2**. From the figure, it can be observed that Stage I (initial stage) and Stage II (life off and decay) are the invention stages, whereas the subsequent Stage III (revival and rapid growth) and Stage IV (survival stage) are the innovation stages. According to Connelly and Sekhar, 2012, the invention stages are technically driven as the invention is being developed into a market innovation. In contrast, the innovation stages are driven by market, teaming, and financial factors.

2.1.7 Role of Innovation in the Petroleum Industry

It is important to understand what fuels the continued importance of innovation in the petroleum industry. Innovation is needed in the industry for:

1. Petroleum Production;
2. Cross-industry Competition;
3. Addressing Problems of Fluctuating Oil Price;
4. Access to Future Oil Reserves.

2.1.7.1 Petroleum Production

A major reason for companies operating in the petroleum industry to innovate and develop new technologies was due to external pressure from laws and regulations (Hassani et al., 2017). However, Al-Sharrah et al., 2010 viewed this external pressure as a business opportunity for innovation rather than an obstacle for the petroleum industry. It was stated by Al-Sharrah et al., 2010 that more innovative firms in the industry would gain competitive advantages through exploiting their capabilities.

2.1.7.2 Cross-industry Competition

Another reason for companies in the petroleum industry to innovate is due to competition from other industries. According to Al-Sharrah et al., 2010, innovation plays a vital strategic role in the petroleum industry's overall strategy. For example, the advancements in alternative energy sources and EV vehicles have been a threat to the petroleum industry as they could someday replace the industry. In this respect, if the

petroleum industry fails to innovate and improve their technologies for sourcing, producing and transporting oil and gas, then the industry is likely to find itself going out of business as demand could drop rapidly owing to successes in innovation and technology in competing industries.

2.1.7.3 Addressing Problems of Fluctuating Oil Price

Another major problem for the petroleum industry is the depressed price of oil. However, several literature argue that depressed oil price is good for the petroleum industry in terms of innovation. For example, Meehan and Hughes, 2015 argue that firms have their assets tied in operations during oil price peaks, and therefore have lower priority and time for innovation.

2.1.7.4 Access to Future Oil Reserves

Another issue which the petroleum industry must address is the difficult in finding oil reserves. According to Demirbas et al., 2016, 53.3% of the world's oil reserves are in the form of restorable oil such as heavy oil, extra heavy oil, oil sand, tar sands, oil shale, and bitumen. As a solution, innovation such as Big Data analytics can be employed.

2.2 Commercialization

As the simplest definition, commercialization is the process of developing and launching a new product into the market (Isabelle, 2004). However, this definition can also be misinterpreted as the process of new product introduction, and therefore does not clarify the term 'commercialization'.

Commercialization is a complex process which consists of multiple components. According to USDOE, 2000, commercialization is defined as the “activities required for moving a product or process from its conceptual stage to the marketplace”. The Canadian Panel of Experts (CPE) defines commercialization as a “series of activities taken to transform knowledge and technology into new processes, products, or services in response to market opportunities”. Similarly, another definition of commercialization is the process of “translating knowledge into new or improved products or technology, and successfully moving them into a position to generate economic benefits in the marketplace”, emphasizing that commercialization is an essential part of the innovation process (Isabelle, 2004).

The definitions previously mentioned view the commercialization process from a broad business view. As a comparison, and to narrow the scope specifically for commercialization within the petrochemical industry, Lei et al., 2016 defines commercialization in the industry as successfully developing innovative technologies with market potential, and moving them into the market to ultimately generate profit, or simply as “the process from idea to technology development to large-scale applications”.

Although studies have defined commercialization in many ways, the common focus of each definition remains similar in the aspects of moving a new product, process, or service into the marketplace, and generating economic returns. Therefore, this research defines commercialization in the petrochemical industry as the process

of moving a product or process from the idea stage to a profit-making position in the marketplace. This involves activities from the concept definition stage through to feasibility, design, production, manufacturing, and marketing. Hence, this model is intended for use at any point until the product or process successfully enters the marketplace and generates revenue.

2.2.1 The Commercialization Process

In developing our preliminary commercialization model, a breakdown of the commercialization process into smaller stages is necessary. This will allow us to better separate activities for each work-function and will also allow us to evaluate the developed preliminary model against the opinion of industry experts and project case studies. Clear stage names and descriptions must be determined to prevent confusion of each stage. Note that these stage names and description are only a basis for the preliminary model and will be adjusted later to accommodate Thai Oil's actual commercialization process. A summary of stages in the commercialization process from studies is shown in *Table 2*.

From this summary, there are several similarities in terms of stage names and their position in the commercialization process, as well as repetition of important stages. In the early stages, market assessment, concept development, and feasibility study are present in all reviewed literatures and suggest the importance of these stages.

In the middle stages, product prototyping, product development, and production planning are commonly seen. As a difference seen in Dehghani, 2015 and McCoy,

Thabet, and Badinelli, 2008, there are reviewing processes which provide the organization with feedback. These reviews better help identify potential problems and support organizations by allowing them to improve their product to better fit with market needs. By doing this, it helps decrease the amount of risks involved when commercializing the product. Additionally, this reviewing stage can potentially stop projects which are not wanted by the market, therefore reducing the amount of wasted resources. Hence, during the middle stage of the commercialization process there should be a reviewing stage.

Finally, in the last stages of the commercialization process, IP protection, marketing, and standardization are common. However, another important stage is the review of process for product improvement. By introducing a stage for reviewing the entire commercialization process, specific problems to the product or process can be improved to better fit market needs. Additionally, organizations can evaluate their commercialization process for improvements. Furthermore, if a project fails to commercialize, the reviewing stage will serve as an evaluation of why the product failed.

Table 2: Summary of Stages in the Commercialization Process

Steps	Dehghani, 2015	Nevens, 1990	Isabelle, 2004	Lei et al., 2016	McCoy, Thabet, and Badinelli, 2008
1	Idea Generation	Identify Market Needs	Market Assessment	Market Needs Assessment	Concept Design
2	Idea Development	Conceptualize Product	Feasibility Study	Feasibility Study	Feasibility Study
3	Feasibility Study	Feasibility Study	Business Management	Research & Development	Planning
4	Product Prototyping	Product Prototyping	Product Design & Development	Product Testing & Demonstration	Review of Planning
5	Initial Assessment & Review	Product Development	Management of IP Rights	Standardization of Processes	Early Production

6	Production Planning	Product Manufacturing	Product Manufacturing	Product Manufacturing	Review of Early Production
7	IP Protection	Marketing	Marketing Strategy Development	Marketing Strategy Development	Standardization
8	Product Manufacturing	Market Release	Market Release	Market Release	Market Release
9	Customer Feedback	Review of Process	Review of Process		
10	Marketing				
11	Market Release				
12	Product Improvement				

2.2.2 Commercialization Strategies

According to Isabelle, 2004, the term commercialization strategy is defined as the form or process of financing option a firm chooses when moving an idea or invention into the marketplace. This can be done through directly moving the invention through internal processes and development or through strategic partnerships using licensing,

and alliances. On the one hand, developing a value chain from scratch allows the innovator to enter the product market and compete directly with more established players (Hassani, 2017). Therefore, choosing an appropriate commercialization strategy is a major decision which firms must make to ultimately determine the profitability from its innovations.

While each of the firms is focusing on innovation and developing innovative products for the petroleum industry, they differ in how they define and choose the most appropriate strategy that fits both their short- and long-term intentions.

According to Isabelle, 2004, two commonly observed commercialization strategies in the petroleum industry are:

1. Develop an invention, commercialize and exit
2. Develop an invention, commercialize and provide

With respect to The Company, the second strategy is more suitable as this strategy is meant to accumulate all the necessary resources for a sharp start and to stay, so as to become a sustainable game changer. This strategy also requires a considerable amount of resources, both financial and organizational. Additionally, high uncertainty is involved in commercializing inventions in the petroleum industry.

In the petroleum industry, the most commonly employed commercialization strategies are licensing and strategic alliances. Normally companies which are able to commercialize first are able to reap the full benefits from the marketplace. However, in a technology-dependent industry with high uncertainty and risks, commercialization

in the petroleum industry is typically in the form of partnerships because the risks and uncertainty are shared.

2.2.2.1 Commercialization Strategy 1: Licensing

In many firms, licensing is the commercialization strategy of choice. Using this strategy, the innovating firm gets financial returns from the licensee firms throughout the agreed period. As a result, the licensee gains permission to legally utilize the innovation and learn its know-how.

2.2.2.2 Commercialization Strategy 2: Strategic Alliances

The strategic alliance strategy is when a firm forms a partnership with another firm for strategic purposes such as sharing know-how. Additionally, a strategic alliance may be formed to exploit a firm's capabilities as well as share risks involved.

2.2.3 Commercialization Models

Currently, the petrochemical industry has no commercialization model. This is due to the complex nature of the industry combined with different approaches to commercialization which vary throughout each organization. Therefore, no single commercialization model or framework alone is suitable for commercialization in the petrochemical industry. Nonetheless, organizations can develop a commercialization model and adapt it to its industry by analysing the basic components of models from other industries. By understanding the basic elements of commercialization, a comprehensive commercialization model can be formulated through integrating relevant key aspects applicable to a specific industry (Rosa and Rose, 2007). Hence, in

the process of developing a preliminary commercialization model for the petrochemical industry, firstly an appreciation of other industry models is important.

In the literature, there are various commercialization models from multiple industries. To narrow the scope of the literature review, only commercialization models which seem applicable to the petrochemical industry's characteristics were reviewed. This section seeks to explore viable options of commercialization models from other industries. This review will firstly begin with generic theoretical-based commercialization models before moving onto industry-based models.

2.2.4 Generic Commercialization Models

Generic commercialization models are commonly used as a foundation for developing industry-specific commercialization models (McCoy, Thabet, and Badinelli, 2008). This is due to their broad description of stages in the commercialization process and the activities required. Furthermore, certain stages proposed in the generic models may be omitted or expanded depending on the importance to a certain industry.

One of the most commonly used generic commercialization models is Goldsmith's model. According to Goldsmith, 2016, the objective of Goldsmith's commercialization model is to serve as a 'roadmap' for enabling organizations to develop plans relating to commercialization. The model provides a strategic framework for sets of actions or "best practices" required for successfully commercializing advanced technologies (Rose and Rose, 2007). Furthermore, Goldsmith's model can be used as a checklist for

tracking progress throughout the different stages in the commercialization process (Isabelle, 2004).

In Goldsmith's model, the commercialization process is broken down into a sequence of 18 steps that are segmented as three main phases: the concept phase, the development, and the commercial phase. For each phase, Goldsmith proposes three types of decisions or activities which must be considered throughout the commercialization process, namely technical, marketing, and business activities. This is displayed in **Figure 3**.

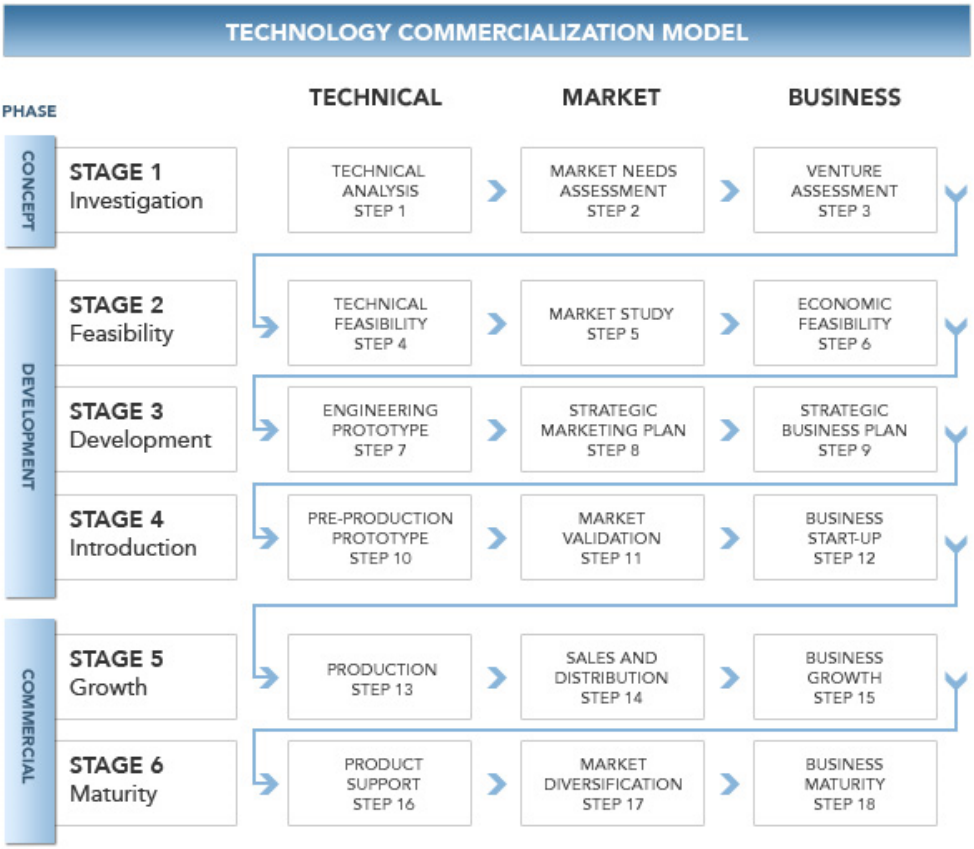

Figure 3: Goldsmith's Model

(Source: Adapted from Goldsmith, 2016)

However, Goldsmith's model was designed as a market-push framework for the successful commercialization of new products, processes, and ideas or only for emerging and disruptive technologies (Goldsmith, 2016). According to Isabelle, 2004, emerging and disruptive technologies only account for a very small percentage of total innovation, whereas the bulk of innovations are market-pull technologies. Hence, a limitation of Goldsmith's model is that it is suitable only for commercializing new technology and not incremental innovation (Rosa and Rose, 2007). Moreover, Goldsmith's model is a linear framework and therefore lacks the flexibility regarding feedback of information throughout the commercialization process.

Similarly to Goldsmith's model, the USDOE model (sometimes referred as Rourke Model) serves as a guide to show major obstacles in the commercialization process by breaking down obstacles into smaller components which are then translated into a set of actions required to overcome them. The activities in the USDOE model are segmented into three functions and three stages **(Figure 3)**. Compared to Goldsmith's model, the stages and activities based on technical, marketing, and business decisions are analogous. Moreover, the USDOE model is also a linear model and lacks the ability for reviewing information in the commercialization process.

A major take-away from the generic models described in this section is the appreciation of similar key stages and activities required for commercialization, along with distinguished key aspects in terms of technical, marketing, and business decisions. In contrast, Shaw, O'Loughlin, and McFadzean, 2005's model offers a more collective

description of the distinct phases in the commercialization process as discovery, opportunity, finding, application, and adoption & diffusion **(Figure 4)**. However, Shaw, O'Loughlin, and McFadzean, 2005's method of describing the commercialization processes makes it difficult to separate activities for each work function, and thus diminishes the transparency of a linkage between all commercialization decisions within an organization.

Stage	Step	#	Action
Innovation *Product definition to engineering prototype*	Technical	1	Product Definition
		2	Working Model
		3	Engineering Prototype/Test & Refine
	Marketing	1	Preliminary Market Definition
		2	Market Analysis
		3	Identify Market Barriers
	Business	1	Define Development and Intellectual Property Strategy
		2	Find Money, File Patents
		3	Establish Intellectual Property, License Plan
Entrepreneurial *Prototype to production*	Technical	1	Production Prototype
		2	Limited Production
		3	Full Production Initial Growth
	Marketing	1	Full Market Analysis and Plan
		2	Establish: Customers, Distribution, and Endorsements. Publish
		3	Expand: Distribution, Competitor Analysis, Response Increasingly Complex
	Business	1	Find Big Money, Complete Business Plan, Form Business, Meet regulations, Arrange Insurance
		2	Find Big, Big Money, Start-up Business, Build Plant, Buy Equipment, HR Training, Arrange: Record Keeping, Purchasing, Transportation
		3	Monitor Costs, Finance Cash Flow, Refine Production Increasingly Complex
Managerial *Production for major market penetration*	Technical		Product Improvement, New Products
	Marketing		Complexities Intensify
	Business		Complexities Intensify

Figure 4: USDOE Model

(Source: USDOE, 2000)

Gaubinger, Schweitzer, and Zweimuller, 2012 states that a well-defined commercialization process should provide transparency for all departments within an organization. This is to effectively communicate the progress of the commercialization

process, and also communicates how the product fits with the organization's overall goals (McCoy, Thabet, and Badinelli, 2008). Furthermore, Isabelle, 2004's study

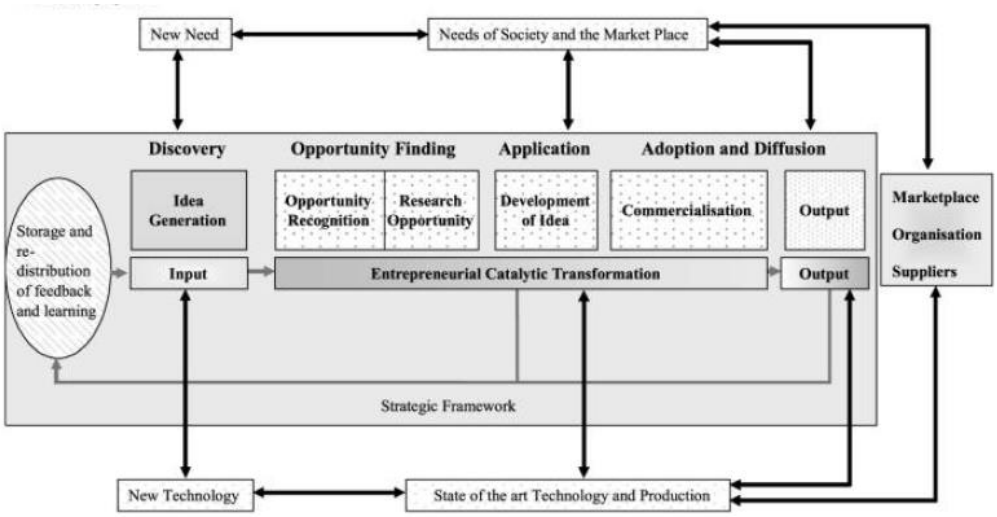

Figure 5: Shaw, O'Loughlin, and McFadzean, 2005's Model

(Source: Shaw, O'Loughlin, and McFadzean, 2005)

concludes that businesses using a well-defined commercialization process which link decisions between departments within an organization are more successful at commercializing products.

From the review of generic commercialization models, Goldsmith's model and the USDOE model are suitable for incorporating into developing our commercialization model for the following reasons:

1. Generic models are commonly used to provide a foundation for industry-specific commercialization models. Stages and activities proposed by the models can be overlooked, replaced, or expanded depending on the importance of a certain stage for an industry. Additionally, the models are flexible to change, thus combining other commercialization models is possible.

Due to the absence of a commercialization model in the petrochemical industry, the integration of other models is important since no single model alone is suitable for direct application.

2. Although the USDOE model is a commonly used generic model, it was designed for the energy industry. In many aspects, the petrochemical industry has key similarities with the energy industry in terms of the complexity of the technology, the uncertainties and risks involved, the sensitivity of technology to laws & regulations, and the large-scale and costs involved in commercializing technology (USDOE, 2000). Hence, the USDOE should provide several stages and activities which are important and relevant to developing a commercialization model for the petrochemical industry. Additionally, Goldsmith's model was designed for commercializing advanced technologies which is also present in the petrochemical industry.
3. The models provide a rather complete and detailed list of commonly used stages and activities for the commercialization process. Additionally, the activities are linked through technical, marketing, and business decisions. This addresses the issue of having well-defined and linked processes within an organization as previously mentioned (Gaubinger, Schweitzer, and Zweimuller, 2012; Isabelle 2004).

However, despite the suitability of incorporating the generic models for the development of our commercialization model, the models were designed as market-

push and linear frameworks. Due to the high costs and risks involved, most products and technologies in the petrochemical industry are based on in incremental innovation or are market-pull in nature. Additionally, the petrochemical industry is competitive in terms of efficiency, thus feedback of information is important to continuously improve the product or process. Therefore, other commercialization models must be integrated to eliminate these limitations of the generic models. The next section will expand the review to industry-based commercialization models.

2.2.5 Industry-based Commercialization Models

Although the previously mentioned generic models provide a good basis for developing our commercialization model, they are primarily based on theory and have limitations. Therefore, they lack certain practicalities which are required for application in the petrochemical industry, such as its lack of ability to review information. To compensate for such limitations and to further expand the understanding for developing a suitable commercialization model, a review of practical industry-based models is necessary. This section will be split into four sub-sections according to important factors which should be considered in developing our commercialization model.

2.2.5.1 Early Stages of Commercialization are Important

In many industry-based models, the central theme was major problems could be avoided if the early stages of the commercialization process are completed strongly. Casto, 1994's model highlights a process at the early stages of the commercialization

process called “concept definition”, and argues it as a highly important process which should be a part of *any* commercialization model **(Figure 6)**. Isabelle, 2004 extends this argument and states that concept definition should not only be used exclusively for the product, but rather focused by the entire organization to better understand how the product fits with the organization’s objectives.

Furthermore, the Australian Commercial Progression (ACP) model emphasizes incorporating a process called “rapid risk reduction” as a review of the early stages to increase the success rate of commercialization (Isabelle, 2004). As an example, McCoy, Thabet, and Badinelli, 2008’s study of commercialization in the residential industry concluded that the majority of actions viewed as “key activities to successful commercialization” by expert opinions mainly occurred at the early stages of the commercialization process.

From these studies, it can be concluded that high importance should be placed on the early stages of the process to ensure successful commercialization (Casto 1994, Isabelle 2004, McCoy, Thabet, and Badinelli, 2008). Additionally, there should be a review stage, as stated by the ACP model, to reduce the amount of uncertainties involved, and fix problems during the early stages where not many resources have been consumed yet.

In the development of our commercialization model, importance will be placed on the early stages such as market assessment, concept development, and feasibility studies, and also and their corresponding activities. There will also be an additional

stage to perform a review and provide feedback through activities such as product prototyping, and process reviewing.

2.2.5.2 Feedback of Information and Linkage of Activities are Important

Alongside the importance of the early stages in commercialization, Casto, 1994's study of Concept Definition: A New Model, also identified three other major problems in the commercialization process as:

1. The rather linear approach which was present in many commercialization models,
2. The failure of models to explain the relationship between all activities in an organization during the commercialization process,
3. Problems and barriers caused by organizational structure.

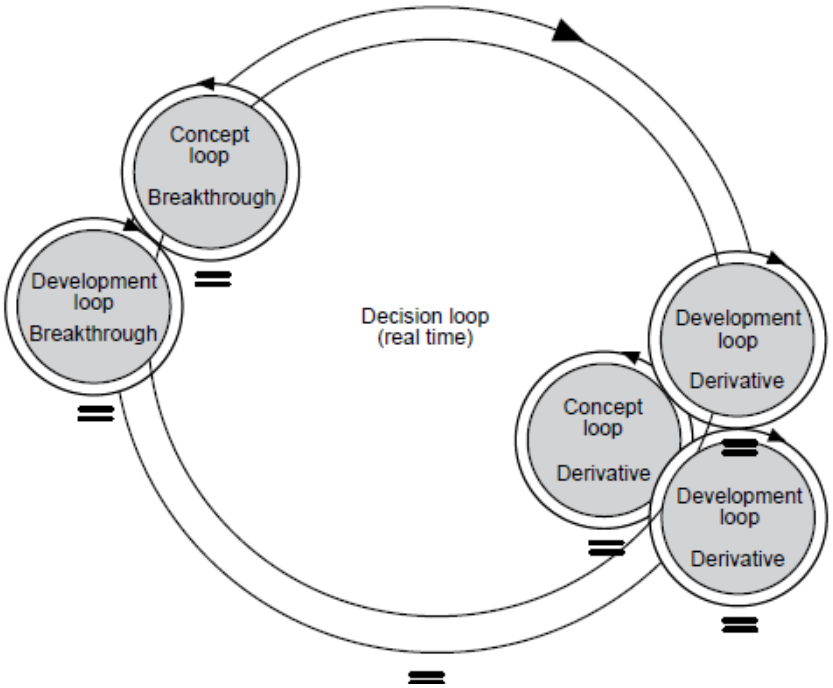

Figure 6: Casto's Model

(Source: Casto, 1994)

Problems one and two can be solved by the commercialization model, and therefore must be focused on. In addressing the first problem, Casto, 1994's model proposes that while the concept definition process should be connected to the other commercialization activities, concept definition should additionally operate concurrently in a reiterative loop **(Figure 6)**. This allows the model to provide feedback of information to the organization where there is a review stage. Likewise, Shaw, O'Loughlin, and McFadzean, 2005 further emphasizes the importance of concurrent actions and a reiterative loop with her framework **(Figure 5)**.

In addressing the second problem, Casto, 1994 emphasizes the importance of breaking down the commercialization process into distinct components to provide an overview of the commercialization process. Good examples of this are the generic models mentioned in section 4.4. However, the activities detailed in Goldsmith's model and the USDOE model must firstly be segmented into separate work-functions. This will provide a visual representation of the relationship between activities in an organization and provide a holistic view of the overall commercialization process.

Concluding this sub-section, Casto, 1994's model and Shaw, O'Loughlin, and McFadzean, 2005's model provided insight to the importance of having a commercialization model being looped in nature. The flexibility provided with these looped models allows necessary feedback of data, and therefore offers organizations

the ability to review their commercialization process. In practice, a stage for reviewing the processes is ideal as it allows integration of new information to improve the product or process, or even the current commercialization process. Furthermore, the second problem of having linked activities within an organization is addressed by incorporating Goldsmith's model and the USDOE model which distinctly describe the stages and activities to be completed.

In the development of our commercialization model, importance will be placed on separating activities into their respective work-functions to provide a visual overview of the commercialization process and its relationship network. Additionally, the developed model will provide organizations with the ability to review information.

2.2.5.3 Protection of Intellectual Property is Important

In other literature of industry-based models, great emphasis is put to illustrate the importance of intellectual rights. Isabelle, 2004 states that the majority of innovative projects are unsuccessful due problems with IP. Similarly, Gaubinger, Schweitzer, and Zweimuller, 2012 associated IP with challenges in successfully commercializing products and processes in the petrochemical industry. Gully, 2004's model incorporates a vast amount of legal considerations into the commercialization process. Furthermore, similarly to the models mentioned previously, Gully, 2004's model focuses on the early stages of the commercialization process and uses a reiterative loop diagram with a breakdown of the process into stages. Likewise, the ACP model

integrates activities regarding IP throughout each activity in the commercialization process (Isabelle, 2004).

Gully, 2004's model is suitable for integrating into the development of our preliminary commercialization model as it addresses the problems with IP, and reinforces our preliminary model in legal aspects which are required for successful commercialization.

2.2.6 Practical Examples of Commercialization Models

An example of a commercialization model which incorporates several key factors mentioned in the previous sections is McCoy, Thabet, and Badinelli, 2008's model for the residential industry which is displayed in **Figure 7**. The residential industry shares several similarities with the petrochemical industry in terms of the nature of products and processes such as:

1. The products or technology is usually large-scale and involves high costs. Thus, the key considerations for firms will be the uncertainties and risks involved, as well as the firm's perceived benefits.

2. Products and processes are prone to be sensitive and may be inhibited by certain laws & regulations such as environmental regulations.

3. Process innovation is usually in the form of incremental innovation to improve the efficiency of operations

4. Products and processes used in the industry may be the ideal technology for one plant but incompatible with another plan due to site variability.

Although McCoy, Thabet, and Badinelli, 2008's model was designed in different context, certain aspects can be used to adapt and incorporate into our preliminary model due to the similarities in the application and intended use of the model. For example, a key characteristic of the model is that it expands business-related activities in the commercialization process to incorporate all relevant work functions in an organization. This modification provides more practicality as it details the work functions and their respective activities, which occur concurrently, to complete for each stage in the commercialization process. Additionally, this provides an overview of the commercialization process in an organization, thus relationships of each activity can be established. Organizations which are more successful with commercialization view the process as overlapping phases that involve many work functions simultaneously (Nevens, 1990).

Expanding on McCoy, Thabet, and Badinelli, 2008's model, Gaubinger, Schweitzer, and Zweimuller, 2012's model includes other useful aspects such as the integration of KPIs and management tools which are specifically chosen for a stage in the commercialization process. However, the limitation of this model is that it combines all activities into a single set. This model is displayed in **Figure 8**.

		Phases							
		Concept	Feasibility	Planning	Review Planning	Early Production	Review Early Production	Standardization	Market Release
		1	2	3	4	5	6	7	8
Functional Areas	Definitions	Specifying conceptual design of product & business	Assessing feasibility of product & viability of business	Designing the product and the business plan	Testing product design and business plan	Initial product release	Evaluate initial release and revise product design and business plan	Standardize product design and business plan	Ongoing product/process improvement
Product Design	Specifying the technical design of a product.	PD1: Technical Research	PD2: Conceptual Design	PD3:Detailed Design	PD4: Test Prototype	PD5: Initial Product Release, Test in Field	PD6: Field Testing Results, Redesign	PD7: Standardized Product	PD8: Next Generation of Product Designs
Process Planning	Establishing the needed production capability and capacity	PP1: Process Research	PP2: Select Processes	PP3: Design Processes	PP4: Test, Review Processes	PP5: Measure Process Times, Quality, Costs	PP6: Early Production Results, Redesign	PP7: Standardized Process	PP8: Process Improvement Design
Marketing	Identifying the requirements of available markets for a product.	M1: Market Research	M2: Market Fit & Segmentation	M3: Forecast Demand & Marketing Plan	M4: Review Marketing Plan	M5: Test Market through Production Run	M6: Revise Marketing Plan	M7: Manage Sales	M8: Discover New Markets
Supply Chain Management	Establishing the chain of business entities for manufacture and distribution	SCM1: Identify Sourcing & Outsourcing Options	SCM2: Configure Supply Chain	SCM3: Detailed Design of Supply Chain	SCM4: Model Supply Chain Performance	SCM5: Execute Production Run	SCM6: Adjust Supply Chain	SCM7: Standardize Sourcing & Outsourcing	SCM8: Improve Supply Chain Management, Discover New Sources
Human Resources	Defining the personnel requirements for the supply chain and acquiring human resources	HR1: Identify Project Leaders & Responsibilities	HR2: Create Leader Positions, Other Labor Roles & Responsibilities	HR3: Create Hiring, Firing, & Promotion Plan	HR4: Review Labor Costs, Reassign or Dissolve Labor. Decide to Outsource?	HR5: Recruit, Create, Train, & Supervise for Production Run	HR6: Review Staff Costs, Reassign or Dissolve Labor. Decide to Outsource?	HR7: Manage Human Resources.	HR8: Review Human Resources for New Generation Product
Accounting & Information Systems	Implementing the AIS system for all business functions	AIS1: Includes: Research Information Technology	AIS2:Includes: Design Accounting & Other Information Systems	AIS3: Includes: Plan & Acquire IS Implementation	AIS4: Includes: Install & Test IS	AIS5: Includes: Audit IS through Production Run	AIS6: Includes: Revise from Audit	AIS7: Includes: Support & Standardize IS	AIS8: Includes: Improve IS
Financial Management	Acquiring capital for the commercialization project	FM1: Identify Sources of Capital, Financing Rates	FM2: Define Capital Configuration	FM3: Prepare Capital Plan	FM4: Estimate Capital Costs & Risks	FM5:Acquire Capital	FM6: Revise Estimates & Capital Plan	FM7: Manage Capital Resources	FM8: Improve Capital Plan
Legal Management	Satisfying legal & regulatory requirements	LM1: Identify Liabilities & Regulatory Requirements, Tariffs, Partners	LM2: Design Liability Protections, Warranties, Patents & Product Regulatory Standards	LM3: Design Contracts & Procedures	LM4: Review Protections & Standards by External Certifiers	LM5: Monitor & Control Production Run	LM6: Revise Contracts & Standards	LM7: Monitor & Control Claims	LM8: Adapt Contracts & Standards to Changing Environment

Figure 8: McCoy, Thabet, and Badinelli, 2008's Model for the Residential Industry

Source: McCoy, Thabet, and Badinelli, 2008)

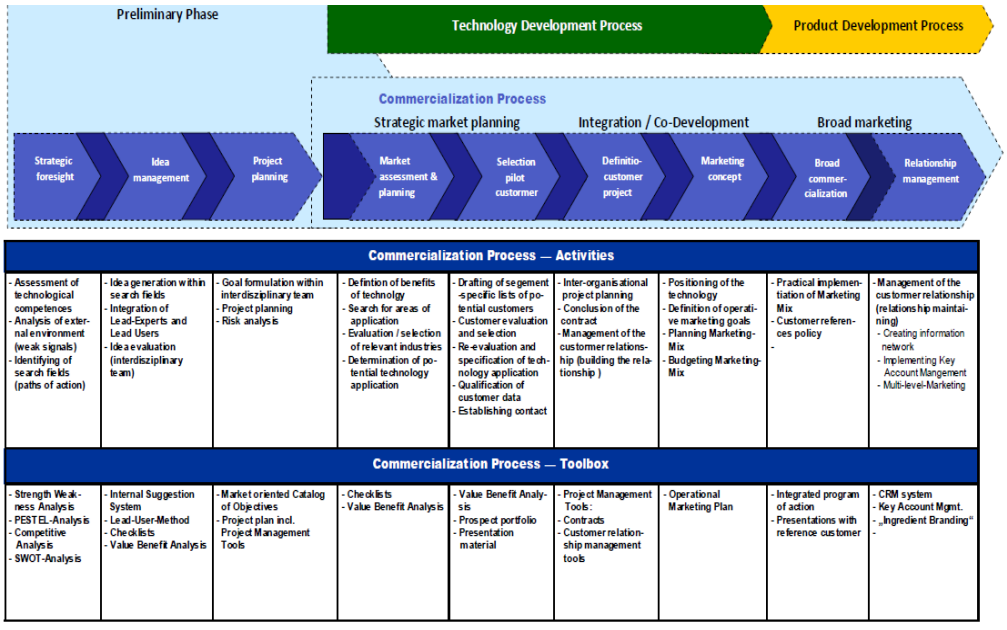

Figure 7: Gaubinger, 2012's Model

(Source: Gaubinger, Schweitzer, and Zweimuller, 2012)

2.2.7 Summary of Existing Models

A comprehensive review of studies provides a greater understanding and offers many valuable insights into key aspects of commercialization for developing our preliminary commercialization model for the petrochemical industry. As a foundation for our preliminary model to be built upon, firstly commercialization is defined in this research as the process of moving a product or process from the initial idea stage to a position in the marketplace where it can generate revenue for the organization. The design of this preliminary model is therefore limited to use up until a product or process successfully enters the marketplace in a revenue-generating position.

Once the basis for the preliminary model is established, important factors relating to successful commercialization will be incorporated into the model. These factors include:

1. Great importance should be placed on the early stages of commercialization.
2. For organizations to review the commercialization process, feedback of information is necessary through a reiterative loop.
3. For simplicity and transparency throughout the organization, the commercialization process should be broken down into smaller distinct stages.
4. Due to many projects failing to commercialize from intellectual right problems, the legal aspect is an important factor.

2.3 Gaps in the Commercialization Models from Literature

Although the previously mentioned commercialization models were chosen because of their suitable for integration into our preliminary model for the petroleum industry, there are several gaps in the models. These gaps can be eliminated, thus improving our commercialization model. A summary of the literature review of existing models, both generic and industry-based, is show in *Table 3*.

From this summary, firstly it can be observed that a gap in literature is that there are currently no existing commercialization model for the petroleum industry. Additionally, none of reviewed models were based on operating environments in Asia. Another gap in the reviewed commercialization models is the lack of a network diagram to illustrate the sequence of activities in the commercialization process. This is because the models were broadly designed for use at the industry-level.

Many of the reviewed commercialization models isolate the activities for protection of IP and legal aspects as separate processes. These contrasts with the matter that many innovative projects fails to commercialize in the petroleum industry due to issues in IP and laws & regulations. A more appropriate approach would be to incorporate relevant activities relating to IP protection and legal aspects for *each* stage of the commercialization process. By doing this, users are reminded of legal actions which must be considered throughout the process.

Chapter 3: Research Methodology

3.1 Development of the Commercialization Model

From literature, there have been several studies of commercialization models, both generic and industry-based. However, there is currently no model which addresses the specific needs and environmental context of commercializing inventions in the petroleum industry. The process of commercializing inventions in the petroleum industry is complex. The objective of this study is to develop a model which allows The Company to effectively commercialize inventions in the petroleum industry.

This study will rely on a combination of qualitative and quantitative research methods for the following reasons. Firstly, the petroleum industry currently has no existing commercialization model in literature to build upon. Therefore, qualitative data collected from relevant knowledge from literature of existing models in other industries as well as interviewing industry experts in Thailand's petroleum industry is required as a foundation for development of the model. Secondly, a quantitative evaluation survey of the developed model can be used so that the findings can be analysed using tables and graphs for trends and relationships. Additionally, following the results of the quantitative survey, another qualitative survey can be used to support the trends and relationships through identifying the rationale behind the evaluation.

3.2 Research Design

For the research design, the development of the commercialization model will be separated into three stages to achieve the research objective:

1. Development of a Preliminary Model
2. Refinement of the Model
3. Company Case Study

Table 4 illustrates the stages and their outputs.

Table 3: Stages of Methodology and their Outputs

Stage in Methodology	Output	Model Level
Development of a Preliminary Model	Preliminary Commercialization Model	Industry-level
Refinement of the Model	1. Refined Commercialization Model 2. Industry Commercialization Model	Industry-level
Company Case Study	Company Commercialization Model	Company-level

It should be noted that the objective and intended use of each model is different. For example, the preliminary model is designed to incorporate data on an industry-level. With respect to the research objective, the models are scoped down throughout each stage until a suitable company-level commercialization model is developed.

3.3 Stage 1: Development of a Preliminary Model

Without an industry-specific model to serve as a basis, the first stage requires a preliminary model to firstly be developed and built upon. The objective of the preliminary model is to provide a rough sketch to a fundamental model which illustrates commonly used stages, work functions, and activities in commercializing inventions as a summary of data collected from literature review and interviewing industry experts in Thailand's petroleum industry. Additionally, the preliminary model will serve as a foundation for further collected data. The following subsections will describe the data collection process of theoretical data and practical data.

3.3.1 Theoretical Data Collection

As a foundation for the preliminary model, the process of theoretical data collection is necessary due to the lack of an existing commercialization model in literature for the petroleum industry. This process includes assembling information in terms of general and industry-specific innovation and commercialization theories, as well as identifying suitable existing commercialization models from literature to integrate together and form the preliminary model. The information which is required

for developing the preliminary model includes, but is not limited to, characteristics of innovation in the petroleum industry, innovation and commercialization strategies relevant to the petroleum industry, the stages in the commercialization process, model structure concepts, roles & responsibilities of individual work functions, and existing commercialization models.

However, not all existing commercialization models from literature may be suitable to apply in the preliminary model. For example, models which were developed in the past may have different characteristics as opposed to those recently published due to the changing competitive environment in the industry. Therefore, the criteria for selecting suitable models from literature are described below.

3.3.1.1 Criteria for Selecting Existing Models from Literature

Defining criteria for selecting existing commercialization models from literature is important as these models will serve as a basis for developing the preliminary model. Thus, the following criteria in Table 5 were defined. It was assumed that if an existing model met all five of these criteria, it was suitable to be applied. However, Criteria No. 5 was arguable. If a model fit all of the other criteria but not Criteria No.5, the model was evaluated of its importance to the study. Nonetheless, if an exception is made, the model would still have to be adapted to suit the current operating environment.

Table 4: Criteria of Industry Experts

No.	Criteria	Importance
1	The model is designed for an industry with similar innovation characteristics as the petroleum industry.	Different industries have different innovation characteristics, and therefore innovation strategies and commercialization processes. Hence, industries with similar innovation characteristics would best reflect the needs of commercialization in the studied industry.
2	The model is reliable and has been successfully tested in the field.	As this study's model will be applied using a real company case study, literature of successfully implemented commercialization models in case studies is desirable.
3	The model integrates theoretical knowledge with practical knowledge.	Similarly to the previous criteria, the selected models from literature should have some degree of practical knowledge and

		implication to reflect this study's objectives.
4	The model has distinct characteristics or elements which correlate with this study's objectives, scope of study, and problem statement.	Literatures of models which do not reflect or help answer this study's objectives are irrelevant to the study.
5	The model is developed recently within seven years of this study.	Industries are rapidly changing and therefore literature of models beyond seven years of this study (year 2010) may be irrelevant to the current industry competitive and innovative environment.

3.3.2 Practical Data Collection

In addition to theoretical data, practical data is required as this will further extend the model to be relevant and applicable to Thailand's petroleum industry. The objective of this step is to collect data on knowledge, experiences, and opinions of

industry experts. Furthermore, information on the interviewed company's commercialization projects, processes, and activities is desired.

In the past, companies in Thailand's petroleum industry have been able to successfully commercialize inventions despite lacking literature on commercialization model. This suggests that the companies have some form of internal commercialization procedures and processes which are specific to the company and petroleum industry. Therefore, further knowledge and experiences on commercialization can be obtained by interviewing industry experts of Thailand's petroleum industry. To ensure that the information obtained from interviews is accurate, the criteria for industry experts are defined below. This is followed by a description of the interview design step.

3.3.2.1 Criteria for Industry Experts

In this study, the criteria used to define suitable interviewees called industry experts, are separated into two sections. The rationale behind defining two sets of criteria for industry experts is that this study's model is intended to provide an overview of activities of work functions for each stage of the commercialization process. Since specific activities in individual work functions are best understood by the employees performing them, it would be more accurate to collect information of these activities directly. However, the author had a limited amount of contactable industry experts which therefore led to the separation of selection criteria.

An interesting point to note was that initially, the criteria for industry experts was defined as employees who had at least five years of experience in the petroleum industry and were in managerial positions. However, it was discovered from the pilot test that several employees with five years of experience in the industry still had not experienced commercializing projects yet. Furthermore, the information provided by managers of the activities performed by individual work functions was rather limited. Therefore, to ensure consistency of data collected from industry experts, the criteria were separated into two sections. The description of these criteria is listed in Table 6.

Table 5: Criteria of Industry Experts

No.	Criteria	Requirement
1	Employees whom are personally or departmentally involved in commercialization projects directly or have experience with at least two commercialization projects.	At least 4+ years of experience in the petroleum industry.
2	Employees who have indirect involvement in commercialization.	At least 8+ years of experience in the petroleum industry.

3.3.2.2 Interview Design

Referring to the objective of the practical data collection step of integrating knowledge, experience, and opinions of industry experts into the preliminary model,

a suitable method to collect this data is through a semi-structured, face-to-face interview guided through open-ended questions (Refer to Appendix A). Using an in-depth interview, the questions involved will be open-ended and therefore provide an assortment of unique interview answers for analysis. Moreover, a wide range of answers has higher probability of covering major areas of interest to this study. The in-depth interview questions were developed through consulting two industry experts.

3.3.2.2.1 Pilot Test

For validation of the designed interview questions, the interview was firstly pilot-tested on eight industry experts from different work functions in Company A over a course of nine days from April 24th - May 2nd, 2017. The interviews lasted between two to three hours and were recorded for analysis. At the end of each interview, the interviewee was asked to recommend areas of improvement to the interview questions. The interview questions were then changed accordingly and repeated at four other companies, namely Company B, Company C, Company D, and Company E. At each company, eight industry experts from different work functions were interviewed over a period of five days with similar conditions to the pilot test. It was discovered that the findings at Company B, Company C, Company D, and Company E were consistent with the pilot test at Company A. Therefore, due to the limitation of contactable industry experts, the information from the pilot test at Company A was included in the study.

The results from these interviews will be analysed for commonalities, and discussed as separate key findings. These findings will then be used to integrate with the theoretical data from literature of existing commercialization models to develop a preliminary commercialization model for Thailand's petroleum industry. However, it should be noted that the author has little experience with innovation in the petroleum industry. Hence, the preliminary model is only a reflection of the author's analysis obtained from qualitative data and literature, and therefore requires further testing and refinement from commercialization experts.

3.4 Stage 2: Refinement of the Model

The second stage of developing a commercialization model for The Company is refinement of the preliminary model. For this stage, the preliminary model was evaluated two times using a combination of a qualitative research method and quantitative research method, namely:

1. In-depth Interview
2. Likert Scale Survey

In this stage, the objective of is to assess the suitability of the integrated theoretical and practical data in the preliminary model. In particular, evaluation of aspects such as the structure of the model, stages in the commercialization process, relevant work functions involved, the activities of each work function, and the sequence of each activity were of interest. From the results of the first evaluation, commonalities and

key findings will be summarized. Then, the preliminary model will be improved using the findings and recommendations from these experts to develop a 'refined model'.

To evaluate the refined model, the second evaluation uses a Likert scale survey to test on a group of industry expert samples. The results from the Likert scale survey will be statistically analysed for determining relationships and to justify the elements in the model. Additionally, the findings from the Likert scale survey will suggest a general consensus from industry experts of how suitable the model is for commercialization in the petroleum industry.

3.4.1 Criteria for Commercialization Experts

In evaluating the preliminary model, a new set of criteria for suitable interviewees was defined, namely 'commercialization experts', due to two major reasons. Firstly, the new set of criteria for commercialization experts was defined to ensure that the interviewee had sufficient knowledge and experience of commercialization projects in the petroleum industry to evaluate the preliminary model. Secondly, the author had access to a limited amount of contactable commercialization experts. This was realized as a result of the findings from the pilot test.

Initially in the pilot test for evaluating the preliminary model, industry experts from Company A were used for interview. However, it was discovered that employees with a low level of experience in commercializing projects provided inconsistent and mostly contrasting evaluations as opposed to employees with high experience in commercialization. For confirmation of these findings, the preliminary model was

piloted again on industry experts in Company B. The results found were consistent with the pilot-test at Company A, and therefore supported the argument for a new set of criteria for commercialization experts. The criteria for commercialization experts are described in Table 7.

Table 6: Criteria for Commercialization Experts

Criteria	Requirement
Employees who have been actively involved in commercialization projects.	At least 5+ years of experience in the petroleum industry with involvement in at least 3+ commercialization projects.
Employees who have been inactively or indirectly involved in commercialization projects.	At least 10+ years of experience in the petroleum industry with experience in at least 5+ commercialization projects.

3.4.2 First Evaluation: In-depth Interview

In the first evaluation, a total of eight commercialization experts were interviewed face-to-face using a semi-structured approach with open-ended questions. The interviews lasted two to three hours on average, and were conducted over a period of five days from May 15th - May 19th, 2017. The commercialization experts were asked of their personal opinions, recommendations for the model, and also to compare

aspects of the preliminary model with those currently practiced at their company. These aspects included relevant work functions, the activities performed by work functions, and stages in the commercialization process. The interview questions were designed with consultancy from two commercialization experts. The findings from these interviews will be summarized and used to improve the preliminary model to a refined model.

3.4.3 Second Evaluation: Likert Scale Survey

In the second evaluation, a five-point scale Likert scale survey of twelve key items was designed to evaluate the elements of the refined model (Refer to Appendix B). The degree of the scale was coded as 1 = strongly disagreeing with the item statement, and 5 = strongly agreeing with the item statement. The survey was designed with consultancy from two commercialization experts and sent by email to 19 contactable commercialization experts in Thailand's petroleum industry. The total population size was limited to 19 commercialization experts due contactable experts. Of these 19 commercialization experts, 15 experts replied with their survey completed which resulted in a sample size of 80% of the total population size. A sample size capturing at least 75% of the total population is sufficient to represent the group. The results from the Likert scale survey will be statistically analysed to find commonalities, and relationships between elements in the model. At completion of this step, the output model is called an 'Industry Commercialization Model'.

3.5 Company Case Study

The final stage of developing the commercialization model is evaluating the industry commercialization model using The Company as a case study. The objective of this stage is to modify the industry commercialization model such that it is specific for use in The Company as a roadmap of only key activities and work functions at each stage of the commercialization process. This objective will be achieved through conducting an open-ended interview with The Company's innovation manager, hereafter referred to as Manager 1, who is responsible for planning and managing the commercialization process.

The data which will be collected from the interview includes The Company's innovation and commercialization strategy, the current commercialization process, and the involved work functions and their responsibilities. Through this collected data, the industry commercialization model will be adapted to conform to The Company's operations, now called the company commercialization model.

Additionally, data on The Company's current organizational structure will be collected and analysed. To support the company commercialization model, a new corporate model will be recommended.

At the end of this last stage, a total of three models will be developed which are:

1. A Company Commercialization Model
2. An Industry Commercialization Model
3. A Corporate Model

The role of the company commercialization model is to serve as a roadmap of important key activities to be completed by work functions during each stage of the commercialization process. The purpose of the industry commercialization model is to support the company model by providing employees with an overview of the entire commercialization process, the activities involved at each stage, and also the relationship between individual work functions. Additionally, the corporate model is designed to also support the company model such that The Company's organizational structure is best fitted to accommodate the model to its operations.

3.6 Data Analysis

In this study, data analysis will occur throughout each of the three stages of the methodology. In stage 1, quantitative analysis methods will be used to analyse the collected data. For theoretical data, the theories and existing models from studies will be analysed through the literature review. Areas of particular interested include stages in the commercialization process, structure of model, and responsibilities of work functions. Then, the data from interviewing industry experts will be transcribed, analysed, and summarized into key findings.

In stage 2, a quantitative analysis of the data collected from interviewing commercialization experts will be used. The areas of interest for evaluation include the stages in the commercialization, the activities of work functions and their sequence, and the structure of the model. The data from the interviews will be transcribed and summarized into key findings. Following this, a qualitative analysis of

the data collected from the Likert scale survey will be used. This will be done by developing tables and graphs of the data to identify relationships, and also justify elements in the model through visualizing a general consensus of the commercialization experts.

In stage 3, a quantitative data analysis will be used to evaluate the data collected from interviewing The Company's innovation manager. Similarly, the data will be recorded, transcribed, and then reviewed to analyse for areas of improvement and adaptions required to fit application in The Company.

Chapter 4: Results & Discussion

4.1 Preliminary Commercialization Model

The objective of the preliminary model is to provide a structural overview of commonly used stages, relevant work functions, and activities in commercializing inventions. Thus, the development of the preliminary commercialization model will be broken down into three key considerations for data collection which are:

1. Structure of the Model
2. Stages in the Commercialization Process
3. Work Functions & Activities

4.1.2 Practical Data

In the practical data collection step, the objective is to collect data of industry expert's experiences, opinions, and knowledge specific to commercializing projects in Thailand's petroleum industry. A total of 40 industry experts were interviewed face-to-face, with eight experts from each company. In the study, individual industry experts will be referred to as 'Industry Expert #', where # indicates the number and company. For example, Industry Expert 1 to Industry Expert 8 are from Company A, and Industry Expert 9 to Industry Expert 16 are from Company B. A list of the interviewed industry experts with their work function and company is listed in Table 8.

Table 7: List of Interviewed Industry Experts and their Work Functions

Work Function	Company A	Company B	Company C	Company D	Company E	Total
Business Development	1	1	1	1		4
R&D	1	1	2	1	2	7
Process Planning	1	1	1	1	1	5
Marketing	2		1	1	1	5
SCM	1	2	1	1		5
Finance	1		1	1	2	5
Information Systems		2		1	1	4
Human Resources			1	1	1	3
Legal	1	1				2

From Table 8, it can be seen that only two industry experts from the legal work function were interviewed. Moreover, the information provided by these industry experts was rather limited as the industry experts from legal were reluctant to share their company's processes due to confidentiality problems. In contrast, seven industry experts from R&D were interviewed and provided a substantial amount of information on their company's processes. Another interesting observation was that industry experts at some companies were more enthusiastic to share information than others. For example, Company C, Company D, and Company E openly shared company information whereas Company A and Company B were more reluctant. From these findings it can be suggested that the volume of information collected and the validity of information provided varied according to the work function, and also company. Therefore from the discrepancy of collectable data, there may be varying accuracy of information and also a bias towards certain work functions with higher information volume. For work functions with insufficient or inconsistent data, theoretical data from literature review was incorporated for support.

4.1.2.1 Structure of the Model

From the results of the interviews, there was insufficient data on a suitable structure for the commercialization model. This was because although every company had a commercialization process, they lacked a documented model, roadmap, or

procedure and the process was informal to semi-formal. Moreover, Company C and Company D which reportedly used a semi-formal commercialization processes with documented information was limited to unable to share their processes due to confidentiality issues. For example, Industry Expert 21 expressed that their company's current process of planning the commercialization of inventions is based on personal experience rather than standard procedures. Thus, the project's success is heavily reliant on the team's experience. Extending this, Industry Expert 22 stated that relying on experience in an industry which is rapidly changing adds substantial risks and uncertainties to the project. For example, changes in demand from new threats such as alternative energy sources have yet to be overcome.

Nonetheless, 32 of out 40 industry experts indicated that they supported the idea of a formalized commercialization model to serve as a roadmap of possible activities to be taken. Industry Expert 40 stated that a formalized commercialization model would help inexperienced employees better visualize the activities involved in the commercialization process. Adding to this, Industry Expert 15 expressed that a structured model would help team leaders plan and manage their project's resources and timeline more effectively. The rationale behind this argument was that project leaders could visually compare their project's current situation to the planned objectives, such as resource allocation and possible deficiencies, as well as if they are meeting key milestones.

From the findings of structure of the model, it can be concluded from the interview of industry experts that although currently companies have been able to commercialize projects based on their personal experience, it would still be favourable to have a formal commercialization model. This is because the model has potential to plan and manage the commercialization process more effectively thus reducing the project's risks when facing unexpected issues. Also, the model can be used as an initial roadmap for helping inexperienced employees visualize the process

4.1.2.2 Stages in the Commercialization Process

From the interviews of 40 industry experts, it was discovered that all interviewed companies had around five to seven stages in commercializing inventions. Additionally, the stages and their descriptions were consistent throughout each company. This suggests that although information on internal processes is not propagated, the commercialization environment of the petroleum industry has led companies to develop similar commercialization processes. Thus, it can be argued that these findings of stages in the commercialization process have been optimized by the interviewed companies for application in Thailand's petroleum industry. A summary of the stages and their description are listed in the following subsection. Furthermore, a comparison of the stages from the interviews is listed in Table 9. Since the findings of the stages from each individual company were similar, they were grouped at a company level.

Table 8: Summary of Stages in the Commercialization Process of Interviewed Companies

Company A	Company B	Company C	Company D	Company E
Project Feasibility	Feasibility Study	Feasibility Study	Project Evaluation	Invention Assessment
Planning and Development	Business Proposal	Business Plan	Business Plan	Business Plan
Marketing	Review of proposal	Marketing Plan	Review Plan	Review of Plan
Manufacturing	Development & Testing	Testing	Marketing Plan	Testing & Modification
Market Release	Improvement	Modification	Testing & Modification	Development
	Market Release	Market Release	Standardization	Market Release

			Market Release	

4.1.4 Summary of the Stages

4.1.4.1 Early Stages

In the early stages of the commercialization process, the focus was on strategizing, project feasibility, and business planning. Although the stage name used at each company varied, their descriptions were relatively consistent.

4.1.4.1.1 Strategizing

In the first stage, objectives for commercializing the invention are determined. Based on this, the activities throughout the project are reflections of how the company plans to achieve these objectives. The objectives of the commercialization project are separated into two categories.

Firstly, the objectives are identified based on the invention's financial returns which are called financial objectives. Consequently, these financial objectives determine a project's allocation of budget and resources. Secondly, objectives are identified based on an invention's business opportunities and prospects which are called prospect objectives.

According to Industry Expert 25, a project usually comprises of a combination between financial objectives and prospect objectives. However, Industry Expert 9 stated that the prospect objectives are usually inversely proportionate to financial objectives. For example, inventions which have high prospect potential will still be

commercialized despite having low financial returns. Nonetheless, a project must still have a feasible level of financial returns as noted by Industry Expert 17.

4.1.4.1.2 Project Feasibility

For the project feasibility stage, this involved assessing or evaluating the invention for its commercial potential and application. The main evaluations of the invention are in terms of its technical, financial, and business aspects. Furthermore, the project is evaluated on its potential to deliver value to the business, and alignment to the corporate strategy. According to Industry Expert 7, the project feasibility stage serves as a filter of commercially incompetent inventions. It was mentioned that only about 1 in 10 inventions are feasible. If an invention possesses commercial potential and is feasible, it passes through to the next stage which is business planning.

4.1.4.1.3 Planning

In this stage of the commercialization process, a business plan is developed to elucidate the required resources, estimate demand and financial returns, develop a marketing plan, and most importantly, decide a suitable commercialization strategy. According to Industry Expert 17, the selected commercialization strategy must align with the innovation strategy as well as the corporate strategy. For example, strategic partnerships are more suitable than the licensing strategy for projects which have business prospects and are aimed to provide business development rather than high returns. Furthermore, the commercialization strategy drives the design of activities to be taken and the outcome.

4.1.4.2 Later Stages

In the later stages of the commercialization process, the focus is on field-testing the invention, modifying it, and then finally market release.

4.1.4.2.1 Testing & Modification

The testing stage allows the invention to be tested in the field during operations. According to Industry Expert 18 and Industry Expert 26, the testing stage is usually separated into three major test groups, namely the initial test, secondary test, and the final test. For the initial tests, the objective is to identify technical issues to resolve before commercializing. For the secondary tests, the objective is to improve financial returns through identifying areas which can reduce costs. And lastly, for the final tests the objective is to approve of any modifications made. Therefore, some companies group the testing and modification stages together. According to Industry Expert 2, if the strategic partnership strategy is chosen for commercialization, the invention is usually tested on the partners company also. By doing this, it helps identify further issues which may occur when the invention is commercially applied at other companies.

4.1.4.2.2 Market Release

The final stage of the commercialization process is market release. In this stage, the invention turns into an innovation and is officially released into the market for commercial use. As stated by Industry Expert 36, “the success of the market release stage was already determined in the early planning stages”. However, this is not always

the case as explained by Industry Expert 28. Sometimes, although the planning stage may be completed perfectly, the invention may still not be successfully commercialized. This is due to the reality of operating in an industry with commodity products, and with high uncertainty and rapidly changing factors. For example, Industry Expert 37 mentioned unpredictable external factors such as financial crisis in 2008 which caused a sudden plummet in demand and immediately rendered any near-completed or on-going commercialization projects pointless.

4.1.4.3 Work Functions & Activities

From the interviews, industry experts from a total of nine work functions were interviewed (refer to Table 9). A summary of the findings are presented in the following subsection. The findings will be grouped according to the work functions. Note that these work functions were selected as they were the most common, yet important, work functions at every company.

4.1.4.3.1 Business Development

The business development function is on a corporate-level and is responsible for identifying and pursuing new strategic business opportunities, as well as creating long-term value for company. These opportunities should be linked to the company's mission and corporate objectives. For example, Industry Expert 9 mentioned that if increasing the company's innovation is a corporate objective, the responsibility of the business development function would be to identify new market opportunities from

drivers of innovation, such as laws & regulations. Additionally, business development handles identifying potential partnerships and other commercial relationships.

4.1.4.3.2 R&D

The R&D function focuses on the technical areas of operations. This work function is mostly comprised of engineers who are continuously looking for ways to improve machinery, equipment, and processes through higher efficiency or cost reductions. Additionally, in most of the interviewed companies, the R&D function consists of a sub-function which is called the Innovation function. In terms of innovation, the R&D function is given high importance since the petroleum industry competes in terms of process improvement and gaining more efficiency. In this sense, the R&D function was referred to as “the powerhouse of innovation” by Industry Expert 33.

In the commercialization process, the R&D function is responsible for the technical aspects of the invention and operations. This includes activities such as formulating a technical design and definition of the invention, field testing, and adaptions made to the invention.

4.1.4.3.3 Process Planning

For the process planning function, their main responsibility is to keep the oil refineries operating at their optimal point through monitoring, planning, and improving the company’s internal operating processes.

In the commercialization process, this work function’s responsibility is to maintain steady operations despite the changes being made. According to Industry Expert 3, the

process planning function also designs the internal processes to support the other functions activities.

4.1.4.3.4 Marketing

In the petroleum industry, the marketing function's responsibility is to observe, understand, and forecast future market trends. Additionally, according to Industry Expert 5, the marketing function analyses the trend of alternatives to petroleum such as solar energy, and benchmarking the company's operations against competitors.

In the commercialization process, the marketing strategy and plan is devised by this function. This includes activities such as assessing the commercial potential of an invention when compared to market trends and consumer demands. Additionally, the marketing function is responsible for identifying potential partners and new market opportunities.

4.1.4.3.5 Supply Chain Management (SCM)

The SCM function handles the company's external processes and with stakeholders along the supply chain including suppliers, outsourcing options, and customers. Additionally, SCM must handle the demand forecasts on a company-level and acquire the required resources. Similarly to the marketing function, the SCM is also responsible for identifying potential partners if a strategic partnership strategy is employed.

According to Industry Expert 12 and Industry Expert 22, in commercializing an invention, the SCM is responsible for evaluating and adjusting certain aspects of the

company's current supply chain such that it accommodates the commercialization project and the new invention.

4.1.4.3.6 Finance

The role of the finance function is to handle all financial aspects such as capital management, acquiring necessary financial resources, and estimating the company's financial returns. In the commercialization process, the finance function is responsible for evaluating the inventions financial feasibility in terms of the costs vs. returns. Additionally, they estimate and plan the total financial resources required for commercializing an invention.

4.1.4.3.7 Information Systems

In the current digital age, the information systems function is the backbone of the company by providing technology infrastructure for communication systems and management of data. According to Industry Expert 31, communication systems are becoming increasingly important due to the advancements in Internet of Things (IoT) and big data. Additionally, Industry Expert 14 and Industry Expert 15 stated that IoT and big data will become core technologies in gaining competitive advantages in the petroleum industry.

In the commercialization process, the information systems function is responsible for designing or revising, and implementing communication systems. The communication system should be capable of disseminating information to relevant

work functions throughout the company. Additionally, this function handles the system for management of data.

4.1.4.3.8 Human Resources (HR)

HR supports the company by employing personnel and workforce, training, and developing teams. Furthermore, HR enforces the company culture and regulates the company's management system and organizational structure. In the commercialization process, HR is responsible for developing a team with suitable employees and skills.

4.1.4.3.9 Legal

The responsibility of this work function is to handle the legal aspects such as IP management, contracts, and agreements with partners. Additionally, the legal function must constantly monitor laws and regulations which may affect the demand for petroleum products. According to Industry Expert 16, changes in laws and regulations can also be viewed as opportunities and drivers of innovation. For example, changing laws on greenhouse gases (GHGs) will require new technology or processes to reduce gas emissions. Hence, it was stated by Industry Expert 8 that companies that are able to identify opportunities in legal are able to react faster which leads to more inventions with commercial potential since every company in the petroleum industry is affected by changing laws.

For the legal function, limited information was obtained from the interviews due to the limitation of contactable industry experts in legal, and also confidentiality issues.

4.1.4.4 Discussion of Findings from the Interviews

In Table 9, it can be seen that all companies firstly start with a strategy stage to determine objectives for commercialization an invention. Then, this is followed by an evaluation or feasibility study of the invention followed by a planning stage. From the interview of industry experts, a commonality found was that 35 out of 40 experts emphasized the importance and necessity of these early stages. The phrase "if these early stages are completed properly, the project will be successful" was frequently repeated. Furthermore, throughout the entire interview, industry experts would regularly mention and revisit these early stages for details and justification of actions, for example "Action A was taken rather than Action B because the objectives of the project were this". Hence, this asserts the importance of the early stages of the commercialization process to the project's success and effectiveness which corresponds to Casto, 1994's study.

Another key finding from four out of five interviewed companies was that there were two review stages. The first review stage was for the business plan and the second review stage occurred before market release. When interviewed, industry experts at Company B, Company C, Company D, and Company E repeatedly mentioned the review stages as a secondary filter, and how implementing these stages reduced obstacles in commercializing inventions. For example, Industry Expert 25 from Company D stated that introducing the "Review Plan" stage has removed errors in the business plan which would have caused problems in the later stages of the

commercialization process and probably led to more resources required. Furthermore, several industry experts mentioned that the modification or improvement stage before market release is also important. The rationale was that “an invention which works here may not work there”. This means that inventions are sometimes initially designed for internal use and thus are devised in a company-specific context. Therefore, modifications to the invention are required to adapt it for commercial application in other companies. These data emphasizing the importance of the review stage is consistent with Isabelle, 2004’s research.

4.2 Development of the Preliminary Model

In developing the preliminary model, the findings from theoretical data from literature and practical data in terms of the structure of the model, stages in the commercialization process, and work functions and their activities will be integrated. A description of the preliminary model and its elements are described in the subsections below.

4.2.2 Structure of Model

Referring to the problem statement of employees not being able to visualize the overall commercialization process, the structure of the model should be capable of incorporating a company’s major work functions and activities in commercialization an invention. For the commercialization model’s structure, a concurrent commercialization process was incorporated (McCoy, Thabet, and Badinelli, 2008) due to three major reasons. Firstly, the petroleum industry competes mainly in terms of

process efficiency which can improve current operational processes in all its work functions. Secondly, a structure of concurrent commercialization process will allow project leaders to manage resources and activities more effectively through being able to visually plan the project. Finally, a concurrent process reflects the reality of commercializing inventions in the petroleum industry as most activities occur in parallel.

Hence, a concurrent commercialization structure is integrated into the preliminary model because innovations can be originated in *any* work function, activities can be viewed visually for better planning and management, and a concurrent process reflects the practical context of commercialization inventions in the petroleum industry.

By integrating a concurrent commercialization model structure, an overview of important work functions for the petroleum industry can be visualized. For example, along the x-axis of the model are the stages of commercialization, the work functions are labelled on the y-axis, and the activities of work functions at each stage of the commercialization process can be labelled in-between. Although this commercialization model focuses on commercializing existing inventions, incorporating concurrent commercialization into the model provides sustainability in terms of commercializing future products and processes.

4.2.3 Stages in the Commercialization Process

According to the theoretical and practical data of stages of commercialization, the following stages and their descriptions were chosen, and are detailed below.

Furthermore, **Figure 9** is an outline of the stages and their sequence in the preliminary model.

4.2.3.1 Project Evaluation

The aim of the project evaluation stage is to decrease the risk of failed commercialization projects which would lead to wasted resources. The nature of inventions and innovation in the petroleum industry is typically high-tech and large scale, and therefore involves high risks and uncertainty. Hence, if a project fails to commercialize, this would result in the company wasting a vast amount of resources. Additionally, failed commercialization projects may cause demoralization amongst employees and also senior management for future projects.

In this stage, the project (existing invention) is assessed to consider its feasibility in terms of technical feasibility, legal feasibility, financial feasibility, and operational feasibility for commercialization. Moreover, another consideration is if the project is actually *worth* commercializing. For example, the company may evaluate the risk of sharing know-how through patenting an invention, and conclude that it is not worth commercializing and better to keep the knowledge as a trade secret. Also, the company may assess the cost required vs. the value to be delivered.

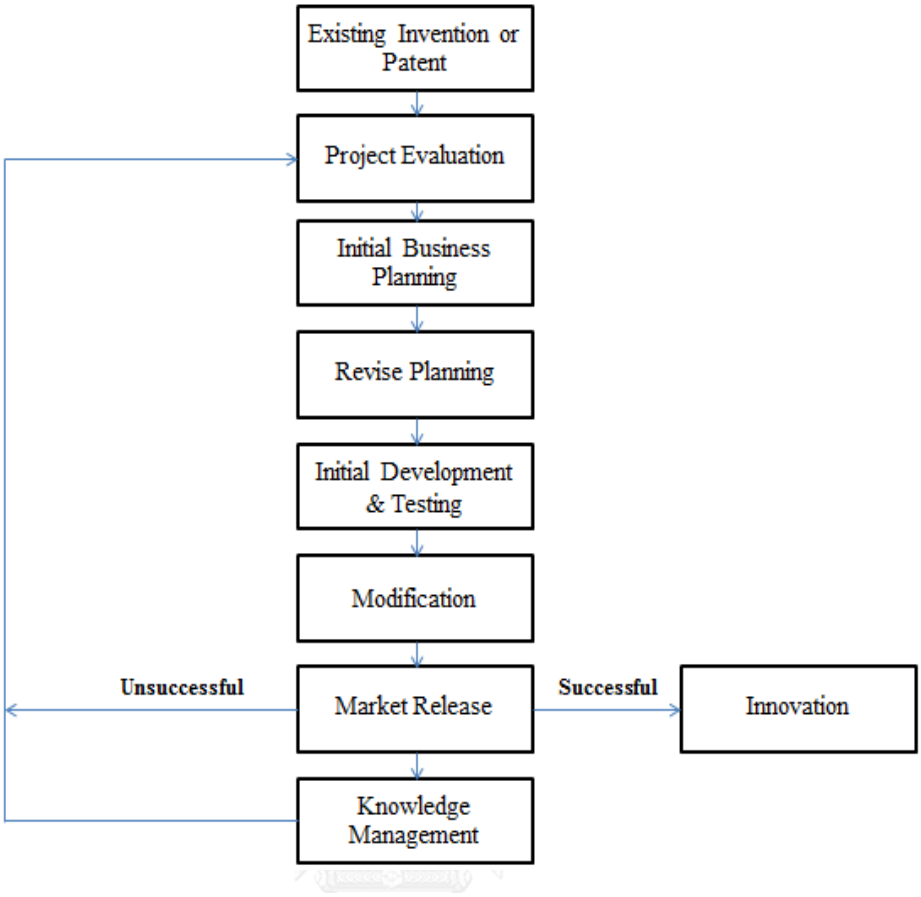

Figure 9: Outline of Stages in the Preliminary Model

4.2.3.2 Initial Business Planning

After evaluating the project, the next phase is designing an initial business plan for commercialization. This includes assessing the company's current resources in terms of infrastructure, structure, and employees. The initial business plan also considers required resources throughout the process of commercializing a project. Furthermore, different strategies are considered such as innovation strategy, commercialization strategy, and IP management.

The aim of the initial business planning stage is to compare the company's current resources with the required resources for commercializing the project, and also to

establish a strategy. Using different strategies, for example commercialization strategies such as licensing or partnerships, will lead to different approaches and end-results, and therefore companies must choose the most appropriate one to achieve their objectives. By strategizing before beginning, this allows the company to plan and allocate resources as well as take actions to acquire any required resources. Furthermore, any unanticipated events

4.2.3.3 Revise Planning

The aim of this stage is to review the initial business plan for improvements. This is the first review stage in the model and is designed to prevent any errors or vulnerabilities in the business plan before implementation. For example, crucial factors such as demand forecasts and financial analyses can be re-evaluated for any external changes which may have occurred between the times of planning to the time of implementation. Furthermore, this stage allows the company to consider alternatives if required, such as outsourcing options for activities which are not core capabilities.

4.2.3.4 Initial Development & Testing

The initial development & testing stage is for assessing the development processes of the project and also the business plan. The aim of this stage is to review and test the project to identify any problems or adjustments. By testing the invention in the field, for example at other company sites or partner's sites, the technology or process can be reviewed for modifications. Additionally, any shortcomings of the invention can

be resolved at an early stage. This reduces the amount of wasted resources when compared to inventions failing at later stages of the commercialization process.

4.2.3.5 Modification

From the results of the previous stage, improvements are made to the business plan and processes. Once these improvements have been made, the processes involved are standardized.

The aim of this stage is to act as a final review stage of all the previous stages. This will lower the risk of failed commercialization through reviewing the process and business plan for final improvements. It should be noted that a major reason found for employees not wanting to commercialize inventions is that they lack confidence due to failing previous commercialization projects. Also, most failed commercialization projects are only reviewed *after* they have failed for problems. By having multiple review stages (i.e. Stage 3 & 5) this significantly lowers the risk of failing.

4.2.3.6 Market Release

In this stage, the technology or process is officially released into the market using the selected commercialization strategy (e.g. licensing, partnerships, etc.). Additionally, the technology or process is continuously reviewed for improvements.

4.2.3.7 Knowledge Management

The aim of the knowledge management stage is to loop the commercialization process such that the knowledge gained or opportunities realized from commercializing the current project may lead to future innovations. For example,

problems with the company's current operations, systems, or infrastructure may be unintentionally identified throughout the commercialization process. If the knowledge is not properly managed, the company cannot capitalize on it. Although the knowledge management stage is located as the last stage of the commercialization process, it is actually an on-going stage throughout the model. This is because new knowledge and opportunities can originate at *any* stage in the commercialization process, and therefore management of this new knowledge is important for sustainable innovation in a company.

4.2.4 Work Functions and their Activities

From the findings of the practical data, this study incorporates the work functions and their activities into the preliminary commercialization mode. For work functions that had insufficient practical data, such as the legal function, theoretical data was added for justification. Note that the preliminary model is intended for use in the industry-level and therefore the work functions were specifically chosen to represent common important work functions throughout the petroleum industry. Additionally, the nine selected work functions are separated into three groups which are business, technical, and marketing according to (Goldsmith, 2016). A summary of the preliminary commercialization model is displayed in **Figure 10**.

Business Functions	Technical Functions	Marketing Functions
Business Development	R&D	Marketing
Supply Chain Management (SCM)	Process Planning	
Finance		
Information Systems (IS)		
Human Resources (HR)		
Legal		

		STAGES OF COMMERCIALIZATION						
		Project Evaluation	**Initial Business Planning**	**Revise Planning**	**Initial Development & Testing**	**Modification**	**Market Release**	**Knowledge Management**
WORK FUNCTIONS	**Business Development**	Assess the invention's strategic business opportunities, potential prospects & partners	Develop objectives for the project and plan to achieve them	Review of project's objectives and consider alternatives to achieve them	Design measurement systems and KPIs across time horizon	Compare results with planned objectives, and adjust plan accordingly	Identify new market opportunities	From the knowledge gained, identify new opportunities for future innovations
	SCM	Evaluate current supply chain and determine required sourcing options	Design or adjustment for new supply chain	Model the designed supply chain	Design measurement systems (Time, cost, quality)	Modify supply chain, and standardize sourcing options	Improve SCM by identifying new opportunities	
	Finance	Economic feasibility - estimate capital costs and risks involved (cost/benefits analysis)	Financial plan and modeling of project	Review of Financial Plan	Acquire required capital	Manage financial resources (areas of cost reduction)	Review and improve financial plan	
	Information Systems	Assess current information systems and identify other required systems	Design IS plan, and its implementation strategy	Install IS and test to identify any mistakes or further requirements	Test IS	Improve IS from test results and standardize	Continuous improvement of IS	
	Human Resources	Identify required personnel and skills	Create teams, assign leaders and responsiblities	Assessment of teams, review of labour costs and reassign or etc., consider outsourcing expertise	Training	Assessment of teams, review of labour costs and reassign or etc., consider outsourcing expertise	Review of human resources and improvement plan	
	Legal	Legal feasibility - Research of existing IP, laws & regulations, and assess 'imitation' risks	Design IP and plan for protection of invention	Review protections and IP management	Monitor legal external environment for future trends	Deal with claims, imitations, and agreements	Manage and adapt contracts and standards to external environment	
	R&D	Technical feasibility evaluation	Detailed design and definition of invention	Prototyping & consider sourcing options	Development of invention	Field testing and invention adaptions	Identify areas of further improvement to invention	
	Process Planning	Evaluation of current processes, facilities, and equipment	Design of processes, and requirements of raw materials/equipment	Test and review process plan	Design measurement systems and KPIs	Improve processes, redesign and standardization of processes	Process improvement plan	
	Marketing	Market potential assessment	Design marketing strategy and plan	Review of marketing plan, monitor trends and potential partners	Market trial and testing	Manage and improve marketing plan	Improve current market plan and identify new market opportunities	

Figure 10: Preliminary Commercialization Model

4.3 Refinement of the Model

In the second stage of developing a commercialization model for The Company, the preliminary model will be evaluated two times using an in-depth interview with commercialization experts followed by a Likert scale survey. The objective of these evaluations is to assess the suitability of the integrated theoretical and practical data in the preliminary model. In particular, evaluation of aspects such as the structure of the model, stages in the commercialization process, relevant work functions involved, the activities of each work function, and the sequence of each activity were of interest.

1.3.1 First Evaluation: In-depth Interview

In the first evaluation, eight commercialization experts were interviewed face-to-face. The commercialization experts were asked of their personal opinions, recommendations for the model, and also to compare aspects of the preliminary model with those currently practiced at their company.

1.3.1.1 Summary of Findings

1.3.1.1.1 Structure of Model

For the evaluation of the model's structure, the commercialization experts gave positive feedback. According to Commercialization Expert 1, the model's structure provides a good overview of the entire commercialization process including the stages and activities involved. Similarly, Commercialization Expert 4 mentioned that the structure is appropriate as it allows users to see the relationships between activities. However, a commonality discovered at the beginning of most interviews was a

misunderstanding that the model was linear. Nonetheless, when explained of the models details, this clarified the misinterpretation. From the interview, a minor recommendation was suggested from Commercialization Expert 5 to change the structure such that it was “circular and non-linear”. However, upon changing and re-evaluating the circular structure, this made the model more complex and confusing which defeated the purpose of a model to provide employees with an overview of the commercialization process. Hence, the current matrix structure was used.

1.3.1.1.2 Stages in the Commercialization Process

For the stages in the commercialization process, some commercialization experts were confused of the names despite explaining the details. According to Commercialization Expert 1, in their commercialization process, the review stages (Revise Planning, and Modification) were combined into stages prior to them. Similarly, this was also mentioned by Commercialization Expert 2. However in contrast, Commercialization Expert 3, Commercialization Expert 5, Commercialization Expert 7 and Commercialization Expert 8 reported that they separated the review stages in their commercialization process to emphasize the importance of review. This argument was consistent with the findings from the industry experts and also Casto, 1994, Isabelle 2004, and McCoy, Thabet, and Badinelli, 2008’s studies. Despite the confusion, only minor changes in the stage names were suggested.

1.3.1.1.3 Work Functions

For the work functions, the commercialization experts stated that they were appropriate to use for in the preliminary model and industry-level model. However, modifications to other relevant work functions in the commercialization process were suggested if the model were to be applied at their company. Examples of these additionally suggested work functions included manufacturing, and production. Although the preliminary model was designed for use at the industry-level, the recommendation from commercialization experts will be considered for the company commercialization model in the last stage of this study.

1.3.1.1.4 Activities and their Sequence

For the evaluation of the activities and their respective sequence in the commercialization process, there were several minor recommendations made to adjust the details of each activity. For example, the descriptions of some activities were too long and needed to be more concise. Furthermore, some descriptions were too short and did not properly describe the activity. Thus, minor changes to the details of activities in the commercialization process were made to more effectively deliver an overview of the process.

For the sequence of the activities, the commercialization experts thought they were appropriate and did not suggest any recommendations.

1.3.2 Second Evaluation: Likert Scale Survey

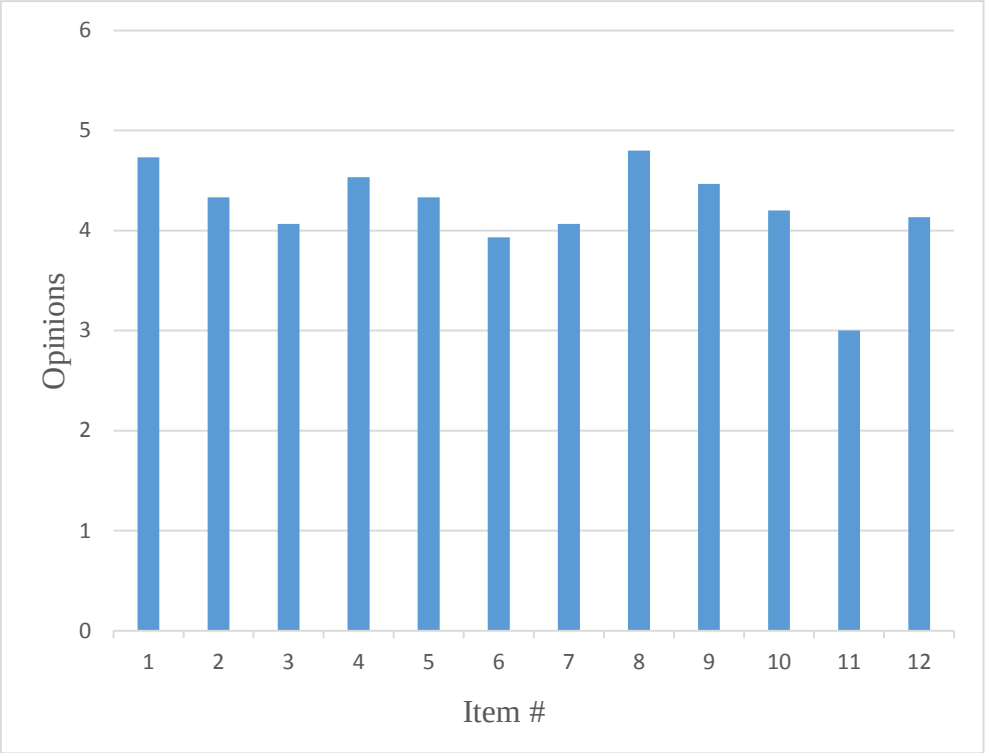

Figure 11: Average Scores from Likert Scale Survey

In the second evaluation, 19 commercialization experts were sent a five-point Likert scale survey with twelve items. Of the 19 commercialization experts, 15 experts replied with a completed survey. The results of these surveys are displayed in **Figure 11.**

From **Figure 11**, an overview of the trend or general consensus of commercialization expert's evaluation of the refined commercialization model can be observed. The items which received the highest average scores were:

- Item 1:

  "The stages in model fully cover the commercialization process of inventions."

- Item 4:

"The model provides an overview of the relationship between work functions."

- Item 8:

  "The model's structure helps provide an overview of the commercialization."

From these evaluations of the refined model from commercialization experts, the model addresses the study's problem statement through developing a model which fully covers the commercialization process of inventions in the petroleum industry, and provides an overview of the relevant work functions and their activities throughout each stage of the process.

However, from the results, these show that all items, except item 11, received high average scores between 4 (Agreeing) and 5 (Strong Agreeing). For item 11 – "The model has practical application", the commercialization experts mostly gave a neutral answer. When interviewed, most of the experts replied that they were unsure of its application in the field because they had never utilized a formal commercialization model. Additionally, another reason for the low average score was because the industry-level commercialization model provided no clear sequence of activities to be taken.

Additionally, although some items received an average score of around 4 (Agreeing), they were still considered to be lacking compared to other items. These other lacking aspects of the model were:

- Item 3:

  “The chosen work functions cover major roles.”

- Item 6:

  “The activity descriptions are accurate and concise.”

- Item 7:

  “The activities in each row are sequential and related.”

When interviewed of the reasoning behind the scores for Item 3, the commercialization experts stated that refined commercialization model only provided examples of the most common and generalized work functions in every industry. However, certain industry-specific work functions such as production and manufacturing were excluded.

For Item 6 and Item 7, the commercialization experts gave relatively lower scores because the commercialization process is different throughout every company. Thus, the activities, their descriptions, and their sequences are also varying in each company.

Table 9: Portion of Results from Likert Scale Survey

Item #	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
1	0%	0%	0%	27%	73%	100%
2	0%	0%	0%	67%	33%	100%
3	0%	0%	7%	80%	13%	100%
4	0%	0%	0%	13%	87%	100%
5	0%	0%	0%	67%	33%	100%
6	0%	0%	7%	93%	0%	100%
7	0%	0%	7%	80%	13%	100%
8	0%	0%	0%	20%	80%	100%
9	0%	0%	0%	53%	47%	100%
10	0%	0%	0%	80%	20%	100%
11	0%	13%	73%	13%	0%	100%
12	0%	13%	60%	27%	0%	100%

In analysing these results using statistical analysis to determine a relationship, a limitation is that the sample size is too small. Nonetheless, the purpose of this model is to serve as a roadmap of activities to be completed and intended for management of the commercialization process. Hence, unlike market research surveys which are

used to predict sales volume, numerical accuracy is not as important as the percentage of agreeing experts.

From the two evaluations of the preliminary model, improvements were made according to the recommendations of the commercialization experts. These improvements were minor and included correcting the description of activities and stages of the commercialization process. The industry commercialization model is shown in **Figure 12.**

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		STAGES OF COMMERCIALIZATION						
		Project Evaluation	**Business Planning**	**Revise Planning**	**Development & Testing**	**Modification**	**Market Release**	**Knowledge Management**
WORK FUNCTIONS	**Business Development**	Assessment of invention's strategic business opportunities & prospects	Develop objectives plan to achieve them	Review of project's objectives and consider alternatives to achieve them	Design measurement systems and KPIs	Compare results with objectives, and adjust plan accordingly	Identify new market opportunities	From the knowledge gained, identify new opportunities for future innovations
	SCM	Evaluate current supply chain and determine required sourcing options	Design or adjustment for new supply chain	Model the designed supply chain	Design measurement systems (Time, cost, quality)	Modify supply chain, and standardize sourcing options	Improve SCM by identifying new opportunities	
	Finance	Economic feasibility	Financial plan and modeling of project	Review of Financial Plan	Acquire required capital	Manage financial resources (areas of cost reduction)	Review and improve financial plan	
	Information Systems	Assess current information systems and identify other required systems	Design IS plan, and its implementation strategy	Install IS and test to identify any mistakes or further requirements	Test IS	Improve IS from test results and standardize	Continuous improvement of IS	
	Human Resources	Identify required personnel and skills	Create teams, assign leaders and responsiblities	Assessment of teams, review of labour costs and reassign or etc., consider outsourcing expertise	Training	Assessment of teams, review of labour costs and reassign or etc., consider outsourcing expertise	Review of human resources and improvement plan	
	Legal	Legal feasibility - Research of existing IP, laws & regulations, and assess 'imitation' risks	Design IP and plan for protection of invention	Review protections and IP management	Monitor legal external environment for future trends	Deal with claims, imitations, and agreements	Manage and adapt contracts and standards to external environment	
	R&D	Technical feasibility evaluation	Detailed design and definition of invention	Prototyping & consider sourcing options	Development of invention	Field testing and invention adaptions	Identify areas of further improvement to invention	
	Process Planning	Evaluation of current processes, facilities, and equipment	Design of processes, and requirements of raw materials/equipment	Test and review process plan	Design measurement systems and KPIs	Improve processes, redesign and standardization of processes	Process improvement plan	
	Marketing	Market potential assessment	Design marketing strategy and plan	Review of marketing plan & monitor trends and potential partners	Market trial and testing	Manage and improve marketing plan	Improve current market plan and identify new market opportunities	

Figure 12: Industry Commercialization Model

1.4 Company Case Study

The objective of this stage is to modify and adapt the industry commercialization model such that it is specific for use in The Company as a roadmap of only key activities and work functions at each stage of the commercialization process. In this stage, The Company's innovation manager, Manager 1, was interviewed of the industry commercialization model using the same interview designs as for the previous stage. Then, from the results of the interview, a company commercialization model was developed.

From the results of interviewing Manager 1, the industry commercialization model received positive feedback in terms of evaluating the model's structure, the stages in commercialization, and the work functions and their activities. Additionally, similar recommendations to the model and scoring were given as the commercialization experts. Manager 1's survey is presented in **Appendix C**.

From the results and consistency with other commercialization experts, this suggests that the developed commercialization model is deemed comprehensive and suitable for the petroleum industry. However, a similar finding which was mentioned by Manager 1 was the uncertainty of the model's practical application to the petroleum industry.

To adapt the industry commercialization model specifically for The Company, Manager 1 was interviewed for the firm's current commercialization process. Due to time limitations of the study and difficulties contacting Manager 1, throughout the

interview, the author and Manager 1 discussed face-to-face where each aspect of The Company's current commercialization process would fit into the developed industry model. These stages are described below.

1. End Game Identification

In the first stage, the End Game is identified and clearly defined in terms of the objectives of the project. The objective of the End Game is to serve as the foundation for all activities in the commercialization process, and each plan and action taken must reflect the End Game.

2. Feasibility Study

In the feasibility study stage, the invention is assessed in terms of the resources and capabilities required, financial returns, and possible business opportunities. The feasibility study involves the financial, technical, and marketing departments.

3. Planning

Following the feasibility study, a plan of activities is created to achieve the End Game. This includes planning in terms of the financial resources, development resources for R&D, marketing resources, and a legal plan is formed to address any issues with IP. Furthermore, supporting roles in this stage include SCM for forecasting demand and planning such resources.

4. Development & Testing

In the development & testing stage, the invention is initially developed using internal processes or outsourced if other capabilities are required. Similarly, the invention is then tested on company sites or partner sites. The key functions involved in this stage are business development, R&D, and marketing.

5. Modification & Improvement

From the previous stage, the invention is improved and adapted to suit the context of the customer or partner's operations. For the internal processes, the financial plan and marketing plan are reviewed against the End Game and objectives.

6. Market Release

Finally in the last stage, the invention is officially released into the market. The major activities occurring thereafter involve identification of new possible opportunities and markets.

As a result of this interview with Manager 1, modifications were made to the industry model such that it was reduced to only key commercialization activities and relevant work functions. Furthermore, the sequence of activities was determined. At this stage, the developed commercialization model is called a company commercialization model, and is shown in **Figure 13**.

Sequence of Activities

Project Evaluation			Initial Business Planning		Revise Planning		Initial Development & Testing		Modification		Market Release	Knowledge Management
Business Development	**Finance**	**Process Planning**	**Business Development**	**Finance**	**Business Development**	**Finance**	**Business Development**		**Business Development**	**Finance**	**Business Development**	
Assess the invention's strategic business opportunities, potential prospects & partners	Economic feasibility - estimate capital costs and risks involved (cost/benefits analysis)	Evaluation of current processes, facilities, and equipment	Develop objectives for the project and plan to achieve them	Financial plan and modeling of project	Review of project's objectives and consider alternatives to achieve them	Review of Financial Plan	Design measurement systems and KPIs across time horizon		Compare results with planned objectives, and adjust plan accordingly	Manage financial resources (areas of cost reduction)	Identify new market opportunities	
	R&D			**R&D**			**R&D**			**R&D**	**R&D**	
	Technical feasibility evaluation			Detailed design and definition of invention			Development of invention			Field testing and invention adaptions	Identify areas of further improvement to invention	From the knowledge gained, identify new opportunities for future innovations
	Marketing			**Marketing**		**Marketing**		**Marketing**		**Marketing**		
	Market potential assessment			Design marketing strategy and plan		Review of marketing plan, monitor trends and potential partners		Market trial and testing		Manage and improve marketing plan		
				Legal								
				Design IP and plan for protection of invention								

Figure 13: Company Commercialization Model

Chapter 5: Conclusion & Recommendations

4.1 Conclusion

In the current period, petroleum is an essential material required by every country in the world due to its vast applications such as for transportation, and producing plastics. As a supplier of these products, the petroleum industry plays an important in driving the global economy. In Thailand, the petroleum industry is one of the major contributors to economy, and is ranked as the ninth largest industry in Thailand as of 2016. However, due to its geographical location, many multinational oil & gas companies have established in Thailand. To remain competitive in the industry, Thai petroleum firms should advance their commercialize processes and utilize innovative technologies to improve their processes and gain competitive advantages.

The studied company, referred to as The Company, is a firm competing in Thailand's petroleum industry and operates one of Thailand's largest oil refineries. The main products which are sold are separated into light products, middle distillates, and heavy distillates. As a strategy to improve its processes, The Company has future plans to expand its oil refinery, increase their operational efficiency, and address the imminent threats to the petroleum industry. As a strategy to explore new products and processes for these issues, The Company should strategize successful commercialization and innovation.

Successful commercialization can bring a company many advantages including financial returns, and create new opportunities such as partnerships. However, the

commercialization of an invention to innovation is a complex process. Furthermore, developing inventions and successfully commercializing them is becoming increasingly difficult due to changes in the market, consumer demands, and the way of operating.

The current problem with The Company is that it has no formalized or documented commercialization process. Therefore, each new innovation project requires developing a new set of plans. In a highly volatile industry, such as the petroleum industry, the nature of competition constantly changes and therefore involves high uncertainty. Hence, developing a new commercialization plan for every project is both difficult, efficient, and involves high risks. Furthermore, senior management and employees don't understand the benefits of commercialization, and are unable to visualize the process. This causes them to not support commercializing projects.

To address these problems, a commercialization model can be used to serve as a roadmap and provide a list of activities to be completed throughout the commercialization process. By using a formalized commercialization model, this will provide an overview of the entire commercialization process, and also allow firms to plan their technical, marketing, and business activities as well as resource allocation.

The objective of this research is to develop a model to effectively commercialize product and process inventions in The Company.

The proposed methodology consists of three major stages in developing the commercialization model. These stages are 1) developing a preliminary commercialization model, 2) refinement of the model, and 3) The Company case

study. For the first stage, a combination of theoretical data from literature review and practical data from interviewing industry experts is used to develop a preliminary commercialization model. Then, this preliminary model is refined through two qualitative evaluations in the second stage, through interviewing commercialization experts face-to-face, and using a Likert scale survey. Finally, the refined model will be evaluated using The Company as a case study. The outcome from this study is two models which are 1) Industry commercialization model, and 2) Company commercialization model.

Against the hypotheses of this study which is "The Company can effectively plan and manage its commercialization process of a product or process invention in the petroleum industry through developing a formalized and documented commercialization model." the qualitative data collected from interviewing industry experts, commercialization experts, and Manager 1 suggested that these hypothesis was true.

4.2 Research Limitations

Using firms in Thailand's petroleum industry, two commercialization models were developed which are 1) industry commercialization model, and 2) company commercialization model. For the industry commercialization model, this was developed based on representation from five petroleum firms in Thailand. However in reality, this does not cover the majority of total population of petroleum firms in Thailand. Most of the information on the specifics of company's commercialization

process was confidential. Thus, the context of the commercialization model was limited to the possible data provided. Furthermore, due to the limited amount of contactable experts, the sample size for qualitative data is rather small. Therefore, statistical analysis of the data did not provide any interesting results or evidence of relationships between aspects in the model.

4.3 Research Contributions:

Many companies operating in Thailand's petroleum industry currently do not have a formalized commercialization process or model. Additionally, there is currently no literature on commercialization models for the petroleum industry or Asia region. From the gap analysis, existing literature on commercialization models focus on a narrow set of individualized concepts, therefore leaving gaps such as an absence of sequential activities and completeness of the model. In this study, the development of two commercialization models, at the industry level and company level, in Thailand's petroleum industry addressed the gaps identified in both industry and literature context.

4.4 Further Research:

1. The commercialization model was based on qualitative information in Thailand's petroleum industry in 2017. Any future trends may lead to changes in the model's activities and stages.

2. The sample size of this study was relatively small for a qualitative study. Hence, to further validate the results, the study should be repeated to evaluate a larger sample size.

3. The commercialization model has only been evaluated based on qualitative surveys from interviews, and thus lacks practical evaluation.

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APPENDIX

Appendix A: In-depth Interview Questions

	Sections	Description
	Section 1: Personal Information	
1.1	Job & Position	
1.2	Responsibilities	
1.3	Years of Experience in the Petroleum Industry	
1.4a	How many commercialized projects have you been *actively* involved in?	
1.4b	What was your role and responsibilities in the commercialization process?	
1.4c	Which departments/teams did you have to communicate with?	
	Section 2: Industry Information	
2.1a	Why is commercialization and innovation important for the oil and gas industry?	
2.1b	Why is commercialization and innovation important your company?	
2.2a	How has innovation in the petroleum changed over the years?	
2.2b	Why has it changed this way?	
2.2c	What impacts have these changes caused?	
2.2d	How has your company adapted to these changes?	
2.3	What is the current trend and future trend for innovation in the petroleum industry?	
	Section 3: Company Information	
3.1	Overview of Company	
3.2	What is your company's innovation strategy?	
3.3	What is the innovation culture?	
3.4	What is your company's commercializaton stratetgy?	

Appendix B: Likert Scale Survey

Question	#	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
The stages in the model fully cover the commercialization process of inventions	1	☐	☐	☐	☐	☐
The name of stages of commercialization are suitable	2	☐	☐	☐	☐	☐
The chosen work functions cover major roles	3	☐	☐	☐	☐	☐
The model provides an overview of the relationship between work functions	4	☐	☐	☐	☐	☐
The activities fully reflect commercialization of inventions in the petroleum industry	5	☐	☐	☐	☐	☐
The activity descriptions are accurate and concise	6	☐	☐	☐	☐	☐
The activites in each row are sequential and related	7	☐	☐	☐	☐	☐
The model's structure helps provide an overview of the commercialization process	8	☐	☐	☐	☐	☐
The model supports effective management of commercialization activities	9	☐	☐	☐	☐	☐
The model is easy to understand and navigate	10	☐	☐	☐	☐	☐
The model has practical application	11	☐	☐	☐	☐	☐
The model is applicable to the company	12	☐	☐	☐	☐	☐

VITA

Soranart Ngamcachonkulkid was born on the 14th of December, 1994 in Bangkok, Thailand. He graduated secondary school from British International School Phuket, Thailand in 2011. Then, he pursued his Bachelor's Degree in Chemical Engineering from Sirindhorn International Institute of Technology (SIIT), Thammasat University. After graduating in 2015, he went on to study a Dual Master's Degree Program in Master of Engineering in Engineering Management from Chulalongkorn University, and a Master of Science in Engineering Business Management from Warwick Manufacturing Group (WMG), the University of Warwick. Currently in 2017, he is working for Thai Samsung Electronics Co., Ltd. as a Management Trainee in Product Marketing.

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