Evaluation model for research and development commercialization capability

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The purpose of this research is to study the research and development (R&D) commercial utilization situation, evaluation process situation, and identify criteria for commercialization capability in Thai Government research institutes. The data was collected by in-depth interviews and purposive sampling was deployed. A series of interviews were conducted with 14 Thai experts from all the eight Thai Government research institutes which stipulated R&D commercialization as their mission. The research results reveal that most of the Thai R&D institutes focus on basic research; hence, the developed technology does not fit to industry demand. This paper therefore suggests that the research institutes should set the research agenda based on market conditions together with technology drivers. To assess the commercialization capability, six criteria for R&D project commercialization capability are identified. These are: technology, marketing, finance, intellectual property, resource, and their beneficial impact, which should be considered but at different levels relating to the R&D development process. This paper is based on innovation theory to decrease the ambiguous subjectivity of Fuzzy expert systems. Moreover, the proposed model explains major criteria to be used at each R&D development process step to ensure commercialization capability exists.

Keywords: commercialization capability; research and development; R&D evaluation process and criteria

1. Introduction

For the last century, Thailand has encountered several crucial problems such as repeated crisis, economy, politics, and natural disasters. The failure of the country’s development made the ability of competition decrease and stick in the middle-income trap; hence, it cannot be competitive both in terms of value and quantity (TSI, 2013a). Therefore, to sustainably develop Thai industries one should consider the marketing base maintenance by emphasizing an image-building campaign on quality superiority and differentiation, and product quality consistency. The competitive advantages of Thai entrepreneurs could be enhanced by producing quality products which have specific and varying characteristics in order to be competitive in the world market. Moreover, it should utilize a differentiation strategy to build development by great leaps forward, emphasizing the R&D commercialization and developing the domestic research to be competitive in terms of innovation.

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R&D investment of Thailand is at a low level in the last decade (GERD/GDP = .024%). Moreover, 60% of the research production is the responsibility of governmental section (TSI, 2013b). Therefore, R&D commercialization must rely on technology transfer as the crucial mechanism which is in its formal process through legal instruments such as patent, ownership transfer, agreement, and in its informal process such as research distribution, consultancy, and conversation. Therefore, the process of research transfer and development is a complicated interaction between research institutes and innovation seekers. Currently, the interaction between the technology owners and technology transferees is absent, and only the transfer level which focuses on machines and equipment more than knowledge transfer (Miller, McAdam, Moffett, & Brennan, 2011) is present. The crucial problem supported by the government includes the low level of commercialization furtherance caused by the allocation of limit resources to respond to the various goals from a number of sides; policy-makers, academia, and general public. Moreover, to bring research contributions to commercial success is still risky, especially with technology not ready to launch through the market. The result is that the industrial sectors do not interact with the government sectors; hence, R&D is not furthered but is separated between the fund providers and industrial sectors (Aoshima, Matsushima, & Eto, 2011). The problem of entrepreneurs to move research to commercialization furtherance is the lack of R&D visions and mindset. New products and service development processes are therefore judged by an administrative concept which leads to cost reduction, manufacturing procedures, and lead times which ultimately affect the budget negatively. Hence, the organizational development by sustainable innovation has to build a vision of R&D at the beginning of a project (Holtzman, 2011). The study of processes and evaluation of commercialization potentials of R&D will be beneficial for project management, strategy adjustment, and prevent resources flow to the incapable projects. Previous studies about commercialization furtherance of R&D were carried out in terms of inbound innovation by using IP Business plan but lacked empirical studies to explain the usage of outbound innovation (Huizingh, 2011).

In the past, the evaluation of R&D commercialization capability focused on one side from the usage perspective. The researchers focus on the potential of developing new technology rather than emphasizing industry or market demand. On the other hand, the industrialists only look at short-term benefits such as financial returns and customer satisfaction which may tarnish the level of innovativeness and they therefore rarely develop a competitive capability in the long run. Thus, the development of evaluation about commercialization capability of R&D project is vital to assist R&D manager and entrepreneur in selecting potential projects with high commercial value. This research aims to establish a comprehensive assessment process and criteria for evaluating R&D project commercialization capability. The framework will act as a modified stage-gate at each R&D development process.

The conceptual framework for R&D commercialization capability was synthesized to answer the research questions as follows: First, how is the situation of R&D commercialization process in Thailand? Second, what are the R&D commercialization capability indicators and criteria?

2. R&D commercialization

R&D and innovation support a sustainable increase in the effectiveness, growth, and competitive advantages. The policy to support R&D activities is usually done through the governmental research institutes (Hewitt-Dundas & Roper, 2011) to build the
linkage between universities and industrial sectors in the form of research agreements, licensing, laboratory facilities, knowledge transfer, research papers, and start-ups (Raesfeld, Geurts, Jansen, Boshuizen, & Luttege, 2012). University–industry technology transfer can be divided into three categories as follows: (1) the research funded by the government and its contributions are considered as academic papers, (2) spin-off and licensing; this research is funded by the private sectors and it is an agreement between the researcher and the fund providers. The productivity is new product and intellectual properties, and (3) co-research; this is funded by both government and private sectors and is regarded as the most efficient in innovative distribution (Rossi, 2010).

2.1. Commercialization process

The R&D commercialization process according to the literature review consists of four stages (Allen, 2003; Chesbrough, 2006; Logar, Ponzurick, Spears, & France, 2001; Miller et al., 2011; Tidd & Bessant, 2009) as follows:

Stage 1: Search; the research institute recruits or searches the existing researches by considering the potential signals, understanding the related environments, and strategies from the innovative resources;

Stage 2: Select; the selection of potential R&D commercialization capability to create the business matching and draft of legal agreement, technology transfer plan, and recruit multidisciplinary team members;

Stage 3: Development; the development of R&D to become a new product.

Stage 4: Commercialization; when innovation was launched to the market, all agreements and documents are collected to negotiate the compensation. The profit dividend from the research institute is used for developing the R&D of future generations. Whereas the entrepreneurs have to learn from the development, create the knowledge base, and improve by using knowledge management to build the competitive advantage (Table 1).

2.2. Commercialization criteria

Numerous R&D transfers have not been successful because the nature of innovation itself is uncertain, difficult to predict, and, especially so, for radical innovation (Herath & Bremer, 2005); therefore, to deal with innovation one has to rely on professional, risk-based decisions, and error acceptance (Tidd & Bessant, 2009). To select research and development (R&D) projects, one has to consider six attributes together because every side is related to the others.

2.2.1. Technology

The key factors for consideration include technological trajectories, technology capacity, comparative advantage (e.g. newness and complexity), customer benefit, technology lifetime, development period, time to market, technology compatibility, technology applicability, and technology cycle (Chiesa, Frattini, Lazzarotti, & Manzini, 2009).
| Author               | Search                          | Selection/criteria     | Development/transfer                     | Commercialization       |
|---------------------|---------------------------------|------------------------|-----------------------------------------|-------------------------|
| Logar et al. (2001) | Proposals, Project selection    | Technical, IP, Market  | Industry match making                   | Sale                    |
| Allen (2003)        | Invention (connection, discovery)| Product development, Opportunity recognition (Business concept) | Business development    | Business plan           |
| Chesbrough (2006)   | Internal and external research project | Venturing, investing | In-licensing/technology acquisition, Implement | Business model          |
| Tidd and Bessant (2009) | Search                        | Select                 | Capture (spin-off, licence, sell)        | Business building and growth |
| Miller et al. (2011) | Invention, Technology appraisal | Patent, Market research | Funding ( Licence, JV)                  |                         |
2.2.2. Marketing

Marketing attributes should be studied to determine the possibility five years in advance, to calculate the success, opportunity, and risk, strategy determination and business plan by market analysis. To address this area requires finding the necessary information.

2.2.3. Financial

Several researchers measure the level of success of a R&D project by applying financial information (e.g. Margin, sales) and forecast the returns such as economic trends, competitive data, etc. (Frederick & Kuratko, 2010), as well as considering the innovative product’s values, such as uniqueness, consumer behavior changing, imitation, and value chain (e.g. Net present value: NPV, Rate of return: ROI, Internal rate of return: IRR). There is an effort to increase the risks and uncertainty in the long run together with the increasing income from the products, and share value (Callen, Gavious, & Segal, 2010) or include risk management in these calculations (Herath & Bremser, 2005); therefore, to deal with innovation one has to rely on professional, risk-bas; Kwak & Dixon, 2008; Yongjian, Xinping, & Shouqing, 2008).

2.2.4. Intellectual property

R&D evaluation should be conducted together with the IP search, IP portfolio, and patent mapping to detect patentability including novelty and freedom to operate: FTO (Apperson et al., 2005). IP valuation is the key driver of innovation transfer. The valuation methods are (1) Cost Approach; this is calculated by the cost of R&D as the value determinants, (2) Income Approach; this is calculated by the potential incomes, (3) Market Approach; this is the value determination if a similar product has been sold in the market as the reference. At any rate, the factors affecting the value of intellectual properties have to be considered. These include: IP law, IP exploitation, and enforcement such as R&D development process, substitute technology, and difficulty–ease in the development and approval, etc. (Jungwook, Yunbæ, Byungchul, Bodum, & Chanmin, 2009).

2.2.5. Resource

Resource - Based View theory focuses on the strategy of internal resource control to create the ability of sustainable competition. At the first stage of study in the 1980s, this focused on the tangible resources (Wernerfelt, 1984) while today the concepts have been a change to the importance of intangible resources, such as know-how connection, and intellectual capital (e.g. patent, organization capability, and Business model) (Teece, 2010). The necessary resources for the R&D commercialization in the Thai Business Incubation Center include human resources; potential managers, internal expert, field expert, and coaching as well as the organizational resources; trust and giving honor and clear goals (Somsuk, Punnakitikashem, & Laosirihongthong, 2010).

2.2.6. Impact from R&D project

R&D do not only deliver tangible benefits such as data resource, universal network, and being the mechanism of knowledge transfer; therefore, a comprehensive evaluation of
potentials should use financial performance with non-financial performance (NFP) (Kulatunga, Amaratunga, & Haigh, 2007). The evaluation of potentials for using NFP should evaluate continuous growth and learning processes (Tidd & Bessant, 2009), customers satisfaction (Cardinaels & Veen-Dirks, 2010), management capability, and high technology (Liao, Tseng, Lin, & Ho, 2007). Moreover, R&D evaluation can be used to follow the conduction of R&D projects as Project management (Kim & Oh, 2002; Kulatunga et al., 2011; Pillai, Joshi, & Rao, 2002; Stanley et al., 2010).

The R&D commercialization process according to the conceptual framework consists of four stages and six criteria as show in Figure 1.

3. Research methodology
Following typical qualitative research methods, in-depth interview was employed to examine the indicator, criteria, and process of R&D commercialization capability evaluation. Purposing sampling with suggestions during the interview or snowball sampling is deployed to reach the fourteen participations of R&D project evaluation experts in eight Thai government research institutes or incubators which stipulated R&D commercialization as their mission as follow:

(1) Agricultural Research Development Agency (ARDA): ARDA gives the funds for agricultural research from basic to commercial research. There are more than 100 project proposals but, on average, 20 researches are approved per year. The commercialization proportion is set at 60% as the goal according to the budget proportion.

(2) National Innovation Agency (NIA): NIA is a market-driven grant agency to support the entrepreneurs for developing and commercializing R&D and linking the entrepreneurs as well as the researcher. There are around 200 R&D projects per year, but the commercialized rate was around 40%.

(3) National Science and Technology Development Agency (NSTDA): NSTDA is the largest incubator and science park in Thailand which produces basic research and applied research for technology transfer to the industrial sectors. During the last five years, NSTDA had on average 1700 research projects, but it makes the commercial rate around 10% of the applied researches.

Figure 1. Conceptual framework for R&D commercialization process and evaluation criteria.
(4) Thailand Institute of Scientific and Technological Research (TISTR): TISTR produces in-house R&D and gives consultancy to the industrial sector. There are around 200 research projects per year and around 20% are commercialized. The researches funded by the TISTR include preliminary study, lab scale, prototype development, and scale up.

(5) National Research Council of Thailand (NRCT): NRCT is the largest Thai research-funding agency whose role is to propose the National research policy and give the research funds. NRCT has approved on average 1700 projects but has no commercialization report.

(6) Thailand Research Fund (TRF) TRF has more than 1000 research projects per year. TRF has performed Innovation Business Plan Grant Program: IBPG to develop the TRF researches business plan and Business Feasibility Study.

(7) National food institute (NFI): The NFI has been conducting innovation projects since year 2009 until now, to give the research funding and academic help to entrepreneurs for doing 70–95 research projects per year.

(8) Thailand Textile Institute (THTI): The Ministry of Industry has given funding to support the Functional and Technical Textiles project from the budget year of 2005–2011 and there were 38 research projects finished. The contributions which could be furthered in terms of commercialization were 22 projects (57.89%).

The participants are divided into six experts and eight project managers/decision-makers, as shown in Table 2.

The data were collected during the time period, December 2012–March 2013. The semi-structured form was employed and interviews were approximately one to three hours. The respondents were asked to describe their current method, process, criteria, and indicators for R&D commercialization. In addition, problems during the assessment process were revealed. The interviews were recorded and summarized in the interview conclusion form afterwards for subsequent coding and analysis.

Table 2. The classification of participants according to different categories.

| Institute                                                                 | Participant category |
|--------------------------------------------------------------------------|----------------------|
| Agricultural Research Development Agency (ARDA)                          | Expert 2 Project manager 2 Total 2 |
| National Innovation Agency (NIA)                                         | 1 1 2 |
| National Science and Technology Development Agency (NSTDA)               | 1 1 |
| Thailand Institute of Scientific and Technological Research (TISTR)     | 1 1 2 |
| National Research Council of Thailand (NRCT)                             | 2 1 2 |
| Thailand Research Fund (TRF)                                             | 1 1 2 |
| National food institute (NFI)                                            | 1 1 |
| Thailand Textile Institute (THTI)                                        | 1 1 |
| Total                                                                    | 6 8 14 |
The data was analyzed by contents from sound record and interview record to build conclusions on the R&D model according to the purposes. The researchers investigate the trustworthiness of data analysis which included: (1) Triangulation, which was deployed to check credibility. (2) Transferability; to make sure that the study results could indicate the characteristics of the group studied by determining the qualifications of main informants at the first stage to get the sample group. (3) Confirmability; to check the audit trail (e.g. contact letters, interview recording, conclusion forms).

4. Research result

4.1. The R&D commercial utilization situation

4.1.1. Research field and innovation level

ARDA, NFI, and THTI are specialized research Institutions that publish research continuously. These organizations support the research for several fields which include NIA and TISTR. Most of The multi-field research institutes, including NSTDA, NRCT, and TRF have the main objective of creating knowledge. And with more than 70% basic research and 30% applied research, the goals of this applied research were varied, such as research into policy, public, community, academic, and commercialization. The organizations which emphasized commercial utilities (70% or all research) include NIA, NFI, and THTI. However, there is a difference in the level of innovation supported. NIA supports new research from the country level up, while NFI, and THTI consider innovation levels from the organizational to the country level. NSTDA commercialized R&D intensively by establishing the technology-benefit review (TBL) and the technology-licensing office (TLO) to perform the duty of technology transfer, IP valuation, and negotiating licensing agreements. For contributions from 2005 to 2013, there were 105 commercialized research projects and around 70 IP agreements.

The organization which clearly used the IP benefits was ARDA, through successfully licensed products such as Longanoid cream, CAPSELLA. On the other hand, the organizations which had no IP management included NIA, NFI, and THTI because they didn’t have the expertise or an established budget to supervise the intellectual properties.

4.1.2. Research instruments

NSTDA is one organization which has a R&D evaluation system due to it having the manual, criteria, and conceptual framework to make decisions from its research, whereas TISTR have a post-project evaluation to evaluate the worthiness of its projects; therefore, it has a weakness with the capability of decision-making. Organizations in which there were no criteria and manual to evaluate research include ARDA, NIA, NFI, and THTI. However, it was found that it held conferences among its experts to evaluate the project consistently. Moreover, these are the smaller organizations which hold not more than 200 projects per year; whereas, the large organizations which have a larger degree of variation in project themes and have more than 1000 projects per year included TRF and NRCT which had no R&D commercialization report (Table 3).
4.2. R&D commercialization Process

The R&D that was supported by the government sectors had different time scales according to the industry sector and Product Life Cycle. The short life cycle industry had was around six months – one year to market, but the long life cycle industries, such as the medical industry and, machinery had more than three years to market.

4.2.1. Technology-push model

The government organizations NRCT and TRF developed, by emphasizing their technological ability. Both tried to solve the problems. TRF established Innovation Business Plan Grant Program to encourage potentials of R&D to be written into companies’ business plans and brought the study results to the scale-up phase. In 2012, there was a project on business plans which was successful in commercializing four projects. These projects included the ‘Banana Society.’ The NRCT established the 2 V research project which gave funds to co-research (researchers who match entrepreneurs). According to the last operation of 120 projects, such as Parabolic Solar Cell, Online Fingerprint Identification, and Coconut Shell-Activated Carbon, however, there is no report of whether any have signed an agreement with the private sectors. But, it was found that the NRCT research (Noni Juice Health Drink I-Cap) was commercialized under the control of NIA.

4.2.2. Market-driven model

The organizations devoted to develop research by focusing on market needs are: NIA, NFI, and THTI. These projects are proposed by entrepreneurs to get financial and academic support. The researchers should be found from potential universities and should be connected to the study of business plans and proposal of co-research. The researcher would get compensation for the produced research but the rights belonged to the entrepreneurs.

The organizations which used the commercial utilities effectively in terms of innovation and the completion of a number of successful projects include NFI and NIA. NFI has the provision in the agreement that in two years, if there are no new products to launch, NFI can publish the information. These are the crucial factors which ensure that
almost all of the research can be commercialized. NIA has no in-house R&D but has the potential to do research from outside in the Search stage. Moreover, NIA had clear R&D selection objectives in the selection stage. The research which would be commercialized had to have the novelty to create a competitive advantage and the determination to consider only the prototype model. This allowed them to get the sufficient information from the decision-making stage and reduce the risks of the development stage. There was a flexible work ethic because it was a small organization. This meant that there were flexible administration and clear purpose of commercial utilization at the first stage of project.

4.2.3. Coupling model

The organizations which used the coordination work process between the research development and marketing department included TISTR, NSTDA, and ARDA. TISTR’s research was conducted according to the prototype and the entrepreneur’s requirement, whereas NSTDA and ARDA established the intellectual properties’ management departments to consider the possibility of marketing as a whole and supervise the technology transfer process. They coordinated with the R&D developments who consider the technical possibility. This model is the effective process because there was the proportion of R&D commercialization higher than TISTR and NSTDA. This was because the organization was in a small size; therefore, it helped in terms of coordination to consider the possibility in technical and marketing terms from the basic research to the technology transfer.

Figure 2 depicts the R&D commercialization process. We found that each R&D process step adopted different criteria when determining commercialization capability. The six criteria are Technology, Marketing, Finance, IP, Resource, and Impact (the details are shown in Table 4). Each criterion should be considered at a different level when related to R&D development process. For example, the market-approach idea from the search stage should be considered with two criteria in mind: resources and impact from R&D project. After the R&D project was approved and developed at the lab-scale level,
Table 4. Selection R&D evaluation criteria and indicators (Number of expert interview = 14 cases).

| Criteria                  | Indicators                      | Items                              | The average number of adopted criteria (%) |
|---------------------------|---------------------------------|------------------------------------|-------------------------------------------|
| Technology capability     | Technology                      | Preliminary study                  | 64.29                                     |
|                           | technology                      | Newness                            | 78.57                                     |
|                           |                                 | Comparative advantage              | 71.43                                     |
| Technology competency     | Technology                      | Technology readiness:              | 42.85                                     |
|                           | research                        | research phase                     |                                           |
|                           |                                 | Compatible with existing technology| 28.57                                     |
|                           |                                 | Standard and regulation            | 42.85                                     |
| Intellectual property: IP | IP protection                   | Patentability                      | 71.43                                     |
|                           |                                 | Level of Protection (national or PCT) |                                           |
|                           |                                 | Types of IP                        | 28.57                                     |
|                           |                                 | Up-front                           | 28.57                                     |
|                           |                                 | Royalty fee                        | 28.57                                     |
| Marketing                 | Market potential                | Market trend                       | 85.71                                     |
|                           |                                 | Market share                       | 78.57                                     |
|                           |                                 | Market growth                      | 57.14                                     |
| Market strategy           | Market target                   | Market target                      | 85.71                                     |
|                           |                                 | Competitors analysis               | 64.29                                     |
|                           |                                 | Business plan                      | 28.57                                     |
|                           |                                 | Market strategy                    | 14.28                                     |
|                           |                                 | Process improvement                | 28.57                                     |
| Market analysis           | Market mix                      | Market mix                         | 35.71                                     |
|                           |                                 | 5 Force models                     | 35.71                                     |
|                           |                                 | SWOT                               | 35.71                                     |
| Finance                   | Financial analysis              | Product price                      | 71.43                                     |
|                           |                                 | Budget details                     | 35.71                                     |
|                           |                                 | Cash flow                          | 50.00                                     |
|                           |                                 | Break-even point                   | 50.00                                     |
|                           |                                 | Pay-back period                    | 35.71                                     |
| Financial return          | Net present value: NPV          | Net present value: NPV             | 57.14                                     |
|                           |                                 | Internal rate of return: IRR       | 42.85                                     |
|                           |                                 | Cost benefit ratio                 | 42.85                                     |
| Resource                  | Human resources                 | Researcher knowledge and experience| 57.14                                     |
|                           |                                 | Multidisciplinary team             | 21.43                                     |
|                           |                                 | Business experience                | 28.57                                     |
|                           |                                 | Product development process        | 57.14                                     |
|                           |                                 | understanding                      |                                           |
|                           |                                 | Enthusiasm and Ambition            | 14.28                                     |
|                           |                                 | Good governance                    | 42.85                                     |
|                           |                                 | Risk management                    | 28.57                                     |
| Impact                    | Sustainability                  | Social impact                      | 71.43                                     |
|                           |                                 | Economic impact                    | 21.43                                     |
|                           |                                 | Environment impact                 | 71.43                                     |
|                           |                                 | Innovation capacity                | 28.57                                     |
|                           |                                 | Innovation linkages                | 28.57                                     |
|                           |                                 | The satisfaction of the R&D users  | 35.71                                     |
the technology must be evaluated. On the one hand, when the prototype level is completed, the marketing criteria should be considered before extending the productivity to the scale-up level to collect the data for financial and IP evaluation. On the other hand, the research should be completely developed at all levels without the selection process in between. The final project must be evaluated using all six criteria together at one time. Hence, this might be too late to terminate the failing R&D project.

4.3. R&D commercialization capability indicators and criteria

The R&D evaluation process of Thai research institute and incubators can be divided into three main phases.

Phase 1 basic consideration was conducted by the project coordinators or the project managers to select work irrelevant to the purposes of support. The policies or main mission of the organization affected the consideration but it depended on the determination of research topics to accept the project proposal. The consideration by the project managers would emphasize each criterion differently according to the level of R&D. The consideration of R&D lower than the prototype level was given importance as being technologically possible. Secondly, it was the marketing and business possible. Then the background of the researcher was considered, such as being a researcher who had previous contributions in accordance with the research or having the capabilities in terms of related fields with the research. The projects proposed by the entrepreneurs would be considered the experiences of technology transfer and good governance.

Phase 2 consideration for decision-making was conducted by the experts’ team consisting of the experts related to the main technology in the research; financial experts, marketing experts, and intellectual property experts. The significance of each criterion depended on several factors, such as stage of R&D and value chain. Moreover, it focused on personal resources about knowledge and research experience, and concordance with the organization strategies, such as NIA giving support of innovative research. The TISTR focused on the research in accordance with the competitive advantage of organizations. Today, TISTR is interested in renewable energy. According to the interview, various organizations started to pay attention to the NFP evaluation, with regard to economic, social, and environment effects, enhancement of innovative capability to the entrepreneurs, and satisfaction of the users from the research to be in accordance with the ISO 9002.

Phase 3 post-project evaluation was conducted to respond to the objectives of project conduction. The organization which managed the criteria was TISTR. This was indicated in the manual of worthiness evaluation by evaluating the economy, society, and environment, as well as the satisfaction of research users. The organizations which had the goals to commercialize included NSTDA, NIA, ARDA, NFI, and THTI, which would consider a number of technology transfers or financial returns. The knowledge-intensive organization included NRCT and TRF, who evaluate the research production situation in Thailand with regard to a number of research fields, a number of researches, and research budgets. According to the research study, there were no organizations which had a formal report of evaluation on long run projects to follow the long-term effect of research utilization.

Phase 1 and phase 3 concentrate on project management, but phase 2 concentrates on the R&D project termination which supports the select stage in the R&D commercialization process and the R&D commercialization evaluation criteria. The Thai research institute and incubators should consider the six criteria consisting of nine items
of technology, five items of intellectual properties, eleven items of marketing, eight items of finance, seven items of resources, and six items of impact, as shown in Table 4.

4.4. Problems and obstructions
The in-depth interview revealed that the R&D evaluation problems are as follow:

- Most of the researches in Thailand were not developed for the marketing-oriented research. This should be improved by using the marketing criteria to select the topics of research at the early stage before giving any support, or doing co-research in the industry sector through the research institute.
- A lot of entrepreneurs lacked understanding about the nature of the innovation. The organizations which gave their support to governmental research should make an understanding with the entrepreneurs at the beginning and also increase the marketing consultancy when the products are launched, especially the SMEs.
- The nature of using market-driven research which did not accept the high risks caused by radical innovation prevention. Moreover, most of the Thai entrepreneurs are Original Equipment Manufacturer (OEM), which usually buyout ready-made technology abroad and have no in-house R&D. This affected the innovation capability and the interest of the entrepreneurs was low. The entrepreneurs should set up a research division when the open innovation is applied in the organization to enhance self-innovation capability and create the sustainable competitive advantage.
- Non-multidisciplinary R&D teamwork causes an absence of the holistic consideration, especially marketing and technology aspects. Therefore, some of the research institutes did not have sufficient evaluation criteria. In addition, the problem of interpretation made the precision of evaluation depend on the skills of the fields related to the research of the experts.
- It lacked substance from the intellectual properties protection. This might be because of wrong attitudes that at the revealing of stage, the process or concept might be imitated. Moreover, the process of application in Thailand took a lot of time and wasted opportunities to enter the market which made most of the entrepreneurs choose to keep them as a trade secret. The trademark was used as a marketing strategy to protect the intellectual properties. In case of co-research, the clear proportion of IP ownership right is needed to avoid risky conflict which could cause the negotiations to be canceled.

5. Conclusion and discussion
This study showed that Thai R&D institutes focus on basic research and that they are not concerned with market and commercialization. Therefore, it causes no technology transfer because the developed technology does not fit the industrial demand and the industrialists do not perceive high benefits from the technology which leads to a lack of interaction between entrepreneurs and the research institutes. This should be improved by adding higher commercialization concerns and emphasizing this issue in the form of vision, mission, and policies of resource allocation. In addition, management should improve direction to allocate the human resources as well as creating the criteria of
R&D recruitment clearly, and being able to collect the marketing and business information completely when the project is proposed. The conduction will affect the image of the organizations and this will become the whole resource of the market-driven approach proposal from researchers. Not only the goals of utilities from R&D were found to be a problem, but also the innovative level of commercialized R&D which found that almost all of previous R&D projects or developed technologies were only supporting incremental innovation. Consequently, the R&D project in Thailand currently cannot create the competitive advantage at the global level. The development of science and technology in Thailand should cooperate with an international research fund to generate R&D budget and to enhance the knowledge via a co-research partner.

The crucial factor which causes the effectiveness of the commercialization capabilities is to work coordinately through all processes between the technological and marketing divisions, which may be in the form of co-research between the researcher and entrepreneurs. This would be an advantage to the innovation capability in the long run because the R&D from the private sector would be more sustainable, driven by the goals and focusing on the commercialization and cooperation in the form of Cluster (Hewitt-Dundas & Roper, 2011). For coordination, this may happen in the organization in the form of cross-function, and a multidisciplinary team, such as marketing and research appointment to co-consider about the techniques and marketing possibility from the basic research to the commercialization stage.

At many research institutes, incubators depended on the consideration from the experts and lack of commercialization forecasting instruments. Moreover, the conduction in the hierarchical governmental system separated the duties from one another. In addition, the small organization or specialist research institute supported R&D commercialization more than the large one. In other words, the organizations which did not have in-house R&D could apply the R&D for commercialization effectively if there was high potential at the search stage. However, intellectual properties should be considered to reduce the legal problem and enhance the images of the organizations in the long run.

The IP application in Thailand did not have the commercial potential because of the nature of the industry and the wrong attitudes about intellectual properties. Understanding and knowledge about IP utilization should be given to the researchers and entrepreneurs together with improving the efficiency of the IP application process in accordance with the technology life cycle. In addition, it should increase the consciousness on IP for the consumers and increase the strictness of IP enforcement to create an IP supports atmosphere.

To assess the commercialization capability, the R&D project must be conducted up to prototype or scale-up level according to the comprehensive evaluation model of R&D commercialization capability at each R&D development process. In summary, the six criteria for R&D project commercialization capability are technology, marketing, finance, intellectual property, resource, and beneficial impact.

6. Limitations and implications
The study was confined to the Thai Government incubators and research institutes; nevertheless, similar problems may be found in other regions with the same level of R&D development. Further research should compare this comprehensive evaluation model of R&D commercialization capability with other countries or the industrial sector within Thailand. According to the qualitative method, quantitative research with larger amount of respondents should be studied in further research to confirm this research finding.
Results from this study have implications for R&D managers or entrepreneurs who want to commercialize research, based on the market together with technology. Obtaining the comprehensive evaluation model is necessary to prevent resource meltdown, and R&D policy-maker can use these findings to establish a supportive policy for successful R&D commercialization.

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