

## CHAPTER III

### RESEARCH METHODOLOGY

#### Introduction

This chapter described the research methodology to achieve the answers for the research questions. The data collection and analysis involved (1) the primary study and (2) the model validation. The primary study of this research consisted of two parts. The first part was the analysis of factors affecting the growth of the UIJRPTT in Thailand. The second part was the analysis of factors affecting the effective UIJRPTT and the development of the effective UIJRPTT model. The model validation was the case studies which was representing a small number of cases where the UIJRPTT was implemented. The methodology of this thesis integrated both qualitative and quantitative approaches in data collection and analysis. The mixed approach is normally considered that it can expand the scope and deepen insights from the study in each research topic (Bliss, 2001 in Espin, 2006). The qualitative work illustrates information which helps interpret the meaning of events and guiding actions while the quantitative work supports data summary and estimates the relationships of variables. The qualitative research fitted this study because it allowed for diverse data collection and analysis to answer the research questions deeply and widely of why there was little number in the UIJRPTT in Thailand and what were the factors affecting the effective UIJRPTT, and what model of effective UIJRPTT should be. In this chapter, the component of the qualitative method which was the in-depth interview, and the collection of data from reliable source were discussed. The quantitative method was applied for descriptive statistics analysis and testing the conceptual models and hypotheses related to the factors and variables affecting the growth and the effective UIJRPTT. The description and justification of the data collection methods, questionnaire design and its test results, scales and measurement also were presented. Before the qualitative and quantitative research methodology was discussed, the population and sampling issue was presented in the first section of this chapter. Detail of this thesis's methodology was described in the following sections.

## **Population and Sample**

The primary study of this research, as mentioned above, consisted of two parts. Those included: (1) analysis of factors affecting the growth of the UIJRPTT and (2) analysis of factors affecting the effective UIJRPTT and the development of the effective UIJRPTT model. These parts employed the in-depth interview and the questionnaire survey to collect the data. This section therefore provided the information on population and criteria in selecting the interviewees and questionnaire respondents in the sampling process.

According to Page and Meyer (2000), the definition of the specific population and sample can set the boundaries to which research findings may be generalized outside the collected research data. The population for this research, in principle, included research group and faculty members, researchers and administrative officers in the governmental universities as well as business units who engaged in the photovoltaic technology and U-I technology transfer during June 2003- June 2009. Due to the fact that there was no survey of such population, it was difficult to determine all satisfactory population. To select the sample, it was the research's consideration that it should be individuals who had direct background related to photovoltaic technology research, technology transfer and the UIJR. For the university side, eight universities namely: Chulalongkorn University (CU), Kasetsart University (KU), Khon Kane University (KKU), King Mongkut's University of Technology Ladkrabang (KMITL), King Mongkut's University of Technology Thonburi (KMUTT), Mahidol University (MU), Naresuan University (NU), and Silpakorn University (SU) were found conducting the research related to the photovoltaic technology. The names of the universities' laboratories and research groups are shown in Table 8. Some university names were recommended and confirmed by university researchers in the photovoltaic field. For the industry side, five names of photovoltaic cells and module assembling and manufacturing firms were found from the list in the website of the Ministry of Energy of Thailand. Those firms included: Solartron, Bangkok Solar, Thai Agency Engineering, Ekarat Solar and Sharp Thebnakorn. The company manufacturing locations are shown in Table 9. Therefore, the author decided to purposively and conveniently draw the sample units and set the sampling frame

which is the list of sampling units from the eight universities and five photovoltaic firms.

The university sample unit selectively consisted of faculty members, researchers, and administrative officers and industry members who could provide the informative data. The sampling list procedure incorporated two steps. The first step involved a screening of research background of the faculty members who involved in the laboratory related to renewable energy and photovoltaic technology from the university laboratory/faculty websites, aimed at developing a database of key informants. Faculty members and researchers were requested, where appropriate, to indicate their colleagues knowledgeable in the same research area. From the preliminary search, the number of the university' faculty members and some tenured researchers sample was around 72 persons. For the administrative officers, due to the fact that some of the TTO in big universities comprised of various divisions and a large number of officers, the author therefore viewed that to keep the balance of the number of the TTO administrative officer sample not to be higher than that of the academics which could affect the bias of the results, and considering the fact that not all TTO staffs work related to the U-I collaboration, the number of the TTO administrative officer population of each university were equally limited to 8 persons. For the industry, the screening data from the websites to the administrative board was conducted and the liaison office staffs from the personnel division were asked about the number of head of division and engineers related to the production and R&D. From the preliminary search, the number of the industry sample unit was around 110 persons.

In order to indicate the appropriate sample size derived from the small population of the sample frame, the important thing that should be considered was the criteria for the sample size. The sample size should be large enough to perform advanced statistics analysis conducting in this research for developing the effective UIJRPTT model such as confirmatory factor analysis (CFA) and structural equation model (SEM) analysis. The author adopted the subject-to-variable ratio rule of thumb which indicated that the ratio of sample size to the number of model parameters should be at least 5 cases for each item (Hair, et al, 1998; Kline, 1998) and the sample sizes for SEM should exceed 100 to 150 to ensure accurate parameter estimates (Anderson,

Gerbing, and Hunter, 1987; Lei and Lomax, 2005). The factors and variables in both parts of the primary study contained not more than 20 items and the variables in the conceptual model for effective UIJRPTT were only 19. Therefore, the sample size of more than 150 sample size was sufficient for the CFA and SEM analysis in this research. However, due to the fact that it was expected that the response rate was expected to be around 30-40%, the author therefore decided to increase the number of sample size to 246 which was the number that gained from the preliminary survey.

The questionnaires were distributed mostly through e-mails and partly handed over to 72 targeted faculty members and researchers, 64 administrative officers in the universities. The response rate in the first two months was low at around 20% due to the fact that almost all faculty members and administrative officers ignored to answer the e-mails. Some faculty members and academicians gave the reasons that the questionnaire was too long or they did not have time or never answer any questionnaires. Some of administrative officers declined to answer the questionnaire giving reasons that they were not involved with the photovoltaic technology transfer or could not access the e-mails. The author, therefore, called and went to the sample laboratories and research groups to: (1) ask the faculty members and researchers to complete the questionnaires and (2) meet and ask more non-tenured/tenured researchers, PhD students, and administrative officers in the sample frame totaling 57 persons to complete the questionnaire. As a result, the questionnaire returned from the university respondents totaled 96 with the response rate of 49.74%. To estimate the non response bias, early and late respondents were compared across the construct under study and respondents characteristics. A Levene's test for the equality of variance was conducted to identify potential differences in variances between the groups, followed by an independent samples t-test. No significant differences emerged from the data, neither in terms of parameter values. Based on the lack of significant differences in mean between early and late respondents, it was suggested that a problem of non response bias was unlikely and that the sample was adequate for further analysis.

As for the industry respondents, the author provided 110 questionnaire forms to the liaison offices of five firms considering the response rate could be around 35-40%. The participants included head of departments related to photovoltaic technology

development, production and R&D/QC/QA, engineers, scientists, and senior technicians/staffs. The questionnaire returned from the industry respondents were 54, resulting in the response rate of 49.09%. Details of the questionnaire respondent characteristics were discussed in Chapter IV.

**Table 8 Universities Sampling Units in Preliminary Search**

University	Faculty	Number	Research Office	Number
Chulalongkorn University (CU)	Faculty of Engineering Faculty of Science	16	Division of Research Development and Promotion	Director or Rep: 1 Head of Dept and research admin: 7
Kasetsart University (KU)	Faculty of Science	10	Research and Development Institute	Director or Rep: 1 Head of Dept and research admin: 7
King Mongkut's University of Technology Thonburi (KMUTT)	Faculty of Engineering Clean Energy Systems School of Energy, Environment and Material	9	Institute for Scientific and Technological Research and Service (ISTR), Thai Industry Technology Integrating Center	Director or Rep: 1 Head of Dept and research admin: 7
Naresuan University (NU)	School of Renewable Energy Technology Faculty of Science	17	Institute of Research and Development Administration (IRDA)	Director or Rep: 1 Head of Dept and research admin: 7
Silpakorn University (SU)	Faculty of Science	6	Research and Development Institute Incubation Center	Director or Rep: 1 Head of Dept and research admin: 7
Khon Kane University (KKU)	Faculty of Science	4	Research and Development Institute	Director or Rep: 1 Head of Dept and research admin: 7
Mahidol University (MU)	Faculty of Science	6	Research Management and Development Department	Director or Rep: 1 Head of Dept and research admin: 7
King Mongkut's University of Technology Ladkrabang (KMITL)	Department of Electrical Engineering,	4	Research Administration Division	Director or Rep: 1 Head of Dept and research admin: 7
<b>Total</b>		<b>72</b>		<b>64</b>

**Table 9 Photovoltaic Firms Sampling Units in Preliminary Search**

<b>Company</b>	<b>Sample Units (Rough Survey)</b>
Solartron Public Co.,Ltd. (Assembling Firm with factory in Nakornratchasima)	15
Bangkok Solar Co.,Ltd. (Assembling Firm with factory in chachengsao)	40
Thai Agency Engineering Co.,Ltd. (Assembling Firm with factory in Ayutthaya)	15
Ekarat Solar Public Co.,Ltd. (Assembling and Manufacturing Firm with factory in Chachengsao and Rayong)	35
Sharp Thebnakorn Co.,Ltd (Assembling Firm with factory in Nakornpathom)	5

For the qualitative approach, the in-depth interview was an instrument in collecting the data. An in-depth interview can be defined as a “personal interview”, which uses extensive probing to get a single partner respondents to talk feely and to expressed detailed believes and feeling on a topic” (Kinneer, et al, 1993). In-depth interviews have been found to be valuable when the research objective is to generate ideas about a complex concept (Fern, 1982) and when the expected information is likely to vary considerably (Ticehurst and Veal, 1999). The in-depth interview in this thesis was conducted with: (1) head of department and/or laboratory director or key persons, selected researchers of the university laboratories/faculties and (2) director and/or key administrators of the university TTO. The criteria used to purposively selected the first group of the university interviewee was because they had experience in arranging the U-I joint research with the industry and conducted photovoltaic related research. The interviewees consisted of 2-3 persons from each laboratory/facility depending on the laboratory size and availability of the interviewees. The second university interviewee group was chosen because the director and key administrative staffs were directly responsible for technology transfer and had experience in promoting and managing the U-I joint research and collaborations as well as other incentives program and funding scheme. The interviewees consisted of 1-3 persons from each university TTO depending on the availability and individual permission. For the industry, the in-depth interview was conducted with: CEOs or representative, head of R&D department, head of production department and senior engineers considering that they had experience and involved

with the company's decision making and advice giving related to production and R&D. The interviewees were ranged from 1-5 persons depending on the size of the company and the availability. The interview was continued until a consensus was reached on the relevant factors and variables involved in the research questions. The in-depth interview was conducted with 45 university professionals and 18 industry professionals. In those numbers, 19 interviewed professionals also answered the questionnaire. Details of the interviewee characteristics were discussed in Chapter IV.

The model validation part employed the questionnaire survey to collect the data from case studies. According to Fellows and Liu (1997), case studies encourage in-depth investigation of particular instances within the research subject. The case study stage is to collect data related to each variable indicator of the factor. The questionnaire survey was targeted at the university and industry professionals who had/have been working and involving in the UIJRPTT projects during 2003-2009 as reported by the respondents in the primary study and at some professionals who are working the university and industry that the UIJRPTT were implemented. They were the same sample units as the previous part. The three selected case studies included: (1) joint project (consortia) between SERT and Thai Agency Engineering Co., Ltd. related to research and development for photovoltaic cell and equipment test; (2); joint project (sponsored research) between SERT and Bangkok Solar related to grid connected photovoltaic system and (3) joint project (sponsored research) between SERT and Ekarat Solar related to solar cell for water sprinkler. The project information was described in Chapter IV Part Four. According to the fact finding, the three projects involved with 5 lecturers and 4 researchers from SERT. 16 industry professionals were purposively selected to be the sample for the study considering that (1) they were involving directly with the joint projects; and/or (2) they were working in the field of production or R&D in the company involving in the project. Those included CEO representative, head of division and engineers from Thai Agency Engineering, head of department and engineers from Ekarat Solar, head of department and engineers from Bangkok Solar. Moreover, due to the fact that the questionnaire related to the work of TTO, administrative officer from the Research Administrative Division of NU were selected to be the respondents. In total, 30 professionals from

SERT and three industrial companies were called, e-mailed and all of them replied the questionnaire. It should be noted that the samples obtained from the case studies were not intended to have determination for any complex statistical analysis. The purpose of this part was to validate the developed path model and associated equations with specific indicators. Therefore, a small sample was required in each project. It should be noted that: (1) Project 1 n= 10; Project 2: n= 10 which included university professionals from SERT and the professionals from the two companies; and (2) Project 3 n= 10 which included the administrative officers from the Research Administrative Division who were working in the field of research promotion, due to the fact that SERT had limited number of staffs and this research involved the work of TTO, and the professionals from Ekarat.

### Research Design

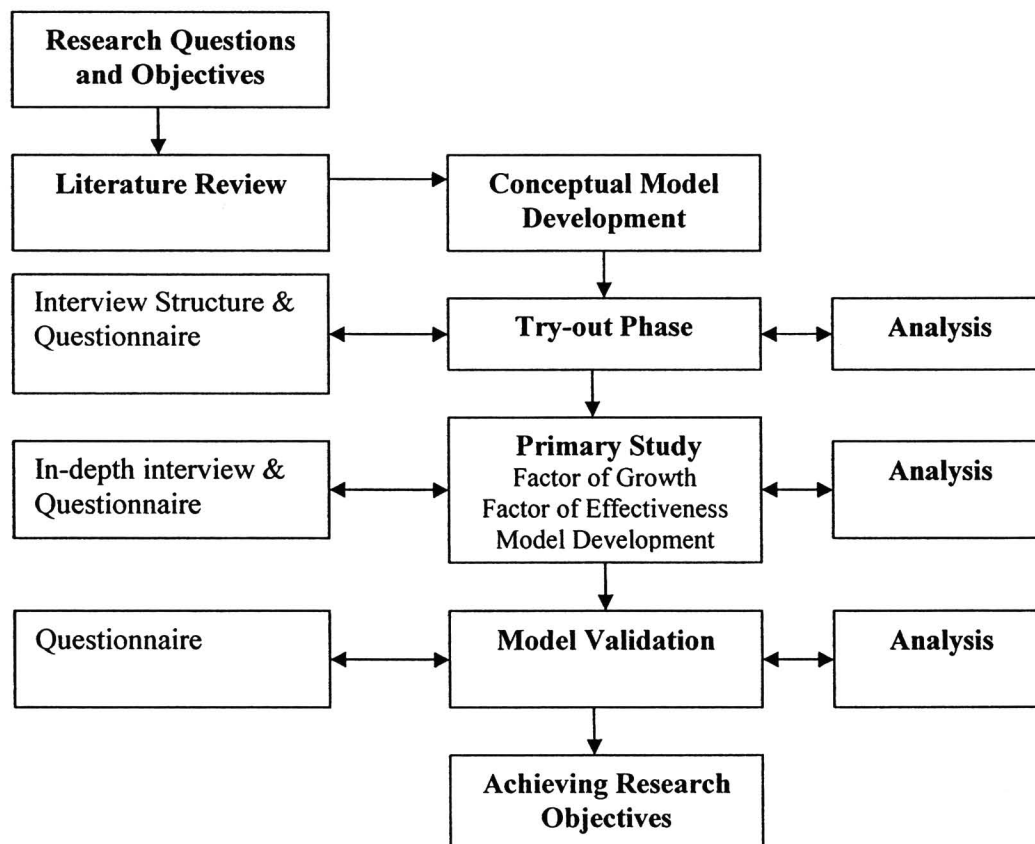


Figure 8 Research Structure

The research work of this thesis was designed in to conduct step-by-step to achieve the research objectives as illustrated in Figure 8. The conceptual model development) was aimed to develop a conceptual model for the UIJRPTT based on the literature review in Chapter II. The try-out phase was aimed to reinforce the validity of the questionnaire survey. The primary study was aimed to (1) answer the question of why there is little number of UIJRPTT and to (2) determine the main factors and variables of the conceptual effective UIJRPTT model and the relationship between them and to finalize the complete model. The model validation was aimed to refine and validate the effective UIJRPTT model with the project-based case studies where the UIJRPTT was implemented.

### **1. Conceptual Model Development**

Starting from the past and exiting literatures, the hypothesized factors and variables affecting the growth and effective UIJRPTT were addressed. The conceptual model for effective UIJRPTT in Thailand was then completed and illustrated in Chapter II. Through the lens of the studies, the factors affecting the formulation and hindering the growth of the JRPTT in Thailand were hypothesized. Those comprised of: (1) *characteristics of university (C1)*: level of technical knowledge and absorptive capacity, lack of motivation, and practical difficulties with negotiating and managing collaboration (loss of academic freedom, lack of structure to find partners, lack of consistency); (2) *characteristics of industry (C2)*: technical knowledge and absorptive capacity, lack of motivation to learn, attitude of industry (viewing that the value of research collaboration is not high enough, viewing that university overvalues of their technology capabilities), and management barriers (low level of corporate support depends on investment cost, time spending); and (3) *transfer context and organizational structure (C3)*: university's lack of technical and information service, lack of communication, cultural differences (profit and non profit organization, bureaucratic and entrepreneur), inadequate infrastructure (inadequate supply of technical human resources, lack of linkage with S&T communities) and inappropriate confidentiality and intellectual property management.

For the development of model of the effective UIJRPTT in Thailand, the factors and variables were hypothesized. Those included: (1) *characteristics and perspectives of university (D1)*: capability in receiving and transfer technology in

terms of technical and fund, adequate specialist, researchers and students, adequate research tools and equipment and willingness and motivation for team work with shared value; (2) *characteristics and perspectives of industry (D2)*: capability in receiving and transferring technology in terms of technical and funds, willingness and motivation to work with university with shared value, and perspectives on worthiness and value of joint research in terms of economic and intellectual value, and understanding cultural differences; and (3) *joint research mechanism (D3)*: communication effectiveness, management of coordination office and joint research program, IP management, and incentive system, and (4) *outcome factor* was expected to include growth and joint research performance (quality and economic performance).

The following steps of the research design were: (1) to reinforce the validity of the interview questions and the questionnaire survey and uncover any gaps in the research through the try out phase and (2) to identify the main factors and variables affecting the growth of the UIJRPTT and to determine the main factors and variables affecting the effective UIJRPTT of the conceptual model and the relationship between them and to finalize the complete model. This task was accomplished in the primary study. However, before the primary study, the try-out phase was conducted to test and ensure the research instruments particularly the questionnaire survey. The try-out phase results were given in the following section.

## **2. The Try-out**

The objective of the phase was to test the validity and reliability of the data and to acquire the necessary feedback to facilitate the refinement of the interview question and questionnaire survey for the primary study. Based on the literature review in Chapter Two, the interview questions and questionnaire were developed to cover the research framework and provided to three experts in U-I collaboration and photovoltaic technology transfer to judge the appropriateness of the interview questions and to test the validity of the questionnaire.

The interview questions were investigated by the experts and viewed that it was relevant to the research questions and objectives. With regard to the questionnaire form, it consisted of five major parts. Those included: (1) Part A: background information, asking the name, organization, position, experiences, research experience, perception on necessity of UIJRPTT and organization experience

in UIJR; (2) Part B: factor affecting UIJRPTT growth, asking the respondents to rate opinion on item statements related to hypothesized factors as barriers to the UIJRPTT growth and their impacts; (3) Part C: factor affecting the effective UIJRPTT, asking the respondents to rate opinion on statements related to hypothesized factors influencing and essential to the effective UIJRPTT and their impacts; (4) Part D: outcome factor of the effective UIJRPTT and (5) Part E: evaluation of the current characteristics and perspectives of university and industry and joint research mechanism. The use of five Likert scale in Part B and C as interval scales implied that respondents treated the differences between the option that they anchored with statements 'strongly disagree = 1' to 'strongly agree = 5' in column A and the impacts from 'strongly negative = 1' to 'strongly negative = 5' in column B. In part D, the outcome variables and current status of the hypothesized factors in part E were measured by five Likert scale 'very low/very poor = 1' to 'very high/very good = 5' and treated as interval scale for further analysis. The interpretation of the mean value according to Srisaad (2002) used in this research were: (1) 4.51-5.00=strongly agree/very high/very good/strongly positive; (2) 3.51-4.50=agree/high/good/positive; (3) 2.51-3.50=neutral/adequate/ satisfactory; (4) 1.51-2.50 = disagree/low/Poor/negative; (5) 1.00-1.50 =strongly disagree/very low/very poor/strongly negative. The drafted questionnaire was sent to the thesis advisors for consideration before forwarding to three experts.

Three experts examined and determined whether the items in the questionnaire adequately representing the relevance of theory and literatures framework. The Index of item objective congruence (IOC) across the experts' ratings of each questionnaire item's relevance was then calculated. The item rate was normally on a three-point scale (from -1 = item not clearly measuring objective 0 = unclear 1 =item clearly measuring objective). The IOC for the total instrument is the proportion of items rated by the experts. An IOC score of at least 0.50 indicated good content validity (Rovinelli and Hambleton, 1977). The experts determined that the questionnaire items were relevant to the literature framework and research objectives with the value higher than 0.50 indicating an acceptable level of content validity. Spellings and wordings in some questions and statements were corrected and translated into Thai before the try out to test the reliability.

The try out was conducted in June-July 2009 by sending the questionnaires to a small of the target population of 32 university and industry professionals via e-mails and by hands. 24 questionnaires were returned, representing a response rate of 75%. Out of all respondents, 7 were university faculty members, 10 were TTO administrative offices and 7 were industrial engineers and staffs who had average working experience of 4.6 years. Some participants commented on wordings and difficulties they faced during the process such as the questionnaire length and time required completing the questionnaire. Changes were made in wording checks while the length remained. Concerning the statistical analysis, the internal consistency to test the questionnaire reliability was conducted using the Cronbach's alpha which is the instrument estimating the proportion of variance in the test scores that can be attributed to true score variance. The acceptable value of the alpha coefficient should be more than 0.80 (Streiner & Norman, 1995) Drawn the data from all parts in the questionnaire except Part A, the Cronbach's alpha coefficient results using SPSS were: (1) part B: was 0.90 (for column A) and 0.80 (for column B); (2) part C, the alpha coefficient was 0.90 (for column A) and 0.92 (for column B); (3) part D, the alpha coefficient was 0.81; (4) part E, the alpha coefficient was 0.82. This meant that the test was reliable. For Part C and D which was the major part of the questionnaire because the results of this part were drawn to develop the model of effective UIJRPTT. The construct validity was conducted through CFA. Part C and D had the favorable construct validity as the CFA results showed that the construct model of their factors had good fit with the data (Chi-Square=95.54, df=92, p-value=0.3795, RMSEA=0.041) and all factor loading greater than 0.30 with the range of 0.30-0.89 which was acceptable in explaining the variance of the factors and ensure validity.

### **3. The Primary Study**

The aim of the primary study was to examine and analyze the factors influencing growth and effective UIJRPTT. It also aimed to develop and validate the model factors and variables to finalize the model of effective UIJRPTT in Thailand. The primary study comprised of the research work described in the following parts.

3.1 Analysis of Factors Affecting Growth of UIJRPTT This part aimed to answer why there was little number of UIJRPTT in Thailand as well as to identify and to analyze the factors affecting the growth of UIJRPTT in Thailand. The research

instruments, data collection and data analysis conducted in this part were presented as followed:

3.1.1 Research Instrument The research instruments designed to acquire the qualitative and quantitative data in this part consisted of reliable document collection, in-depth interviews, and questionnaire surveys. Document collection was conducted by viewing that it was necessary to investigate and analyze the potentials and gaps of the UIJRPTT context. To do so, the author investigated governmental strategy reports, university and industry annual reports and data base from reliable websites, university publications and enquiries on various issues related to the hypothesized factors and variables. The review issues included: the government policies and supports, funding schemes, number of lecturers, funds, incentives and IP management of university and the industry performance related to the UIJRPTT.

The second instrument was the in-depth interview. The interviewees were asked on the issues related to strategy of photovoltaic firms and university on R&D and photovoltaic technology within the context of globalization and competitiveness, why industry and university conducted small number of joint research, to what extent the mentioned cause affecting the decision making of the universities and industry in conducting joint research, and how to increase the U-I joint research for photovoltaic technology transfer, to acquire the relevant qualitative data. The interview question is shown in appendix B. It should be noted that the interview questions were developed on the basis of literature review and were refined by the three experts before being used. As discussed earlier, the in-depth interview was a “personal interview”, by which the interviewee could talk feely; therefore, the structure of the question was somehow adjusted considering the appropriateness and characteristics of the interviewees. For example, if the interviewees were the CEO of the company and head of the department or key faculty members with full of experience and visions, they would prefer to express their ideas and analytical views, therefore, the author would allow them to speak freely and ask them more on strategic perspectives. Whereas the senior engineers and researcher were asked about the research topics and practices, working procedures and their views related variables in more detail.

The third instrument was the questionnaire. In the questionnaire form, the respondents were asked to provide the information and rate their opinions on the following issues:

1) Background of respondents on position, research work experiences, perspective on the necessity of the UIJR, experiences of organization in joint research, funds and technology transferred (detail as shown in appendix A part A);

2) Involving factors (*characteristics of university, characteristics of industry, and transfer context and organizational structure*) and variables. The respondents were requested to indicate five Likert interval scale of the items stated in the questionnaire that they treated the differences between ‘strongly disagree = 1’ and ‘strongly agree = 5’ in column A and their impacts in ‘strongly negative = 1’ to ‘strongly positive = 5’ as barriers to the growth of UIJRPTT in column B (detail as shown in appendix A part B). For example, in Column A, the respondents were requested to rate whether they believed that the item statement “the university was not a reliable knowledge and technological source was the barrier of the UIJRPTT”. The results were used to determine the importance/significance of the items in the form of factor barriers. Column B ascertained the respondents’ perceptions of the potential impact of the variables. The respondents could also specify the others factors and variables that did not exist in the questionnaire questions.

3.1.2 Data Collection As discussed in section 3.1, the author collected data from the university and industry sample by employing the mentioned research instruments. A letter of permission was sent to all universities and the photovoltaic firms prior to the conduct of the research. It explained the purposes of the research study, the reasons for the in-depth interview, questionnaire survey and document and data collection. For the interview, the university respondents were contacted directly through telephone calls and emails to arrange an appropriate time for the interviews whereas some of them were asked for the interviews on the day the author visited the university. The interviews with the industry samples were conducted by making appointment directly with the interviewees or via industrial liaison office and via telephone calls. The interviews were recorded with an MP3 recorder with no objection

from the respondents. For the questionnaires, they were sent to the university samples via e-mails and by-hand and to the industry sample via the liaison office. A few numbers of university and sample were asked to answer the questionnaire via telephone calls as they did not have time and could not access to e-mail.

**3.1.3 Analysis of Data** For the qualitative data, as outlined in Miles and Huberman (1994), the author employed three major stages of qualitative data analysis of in-depth interviews: data reduction, data display, and conclusion drawing/verification. Data reduction involves the selection, simplification, and transformation of raw data into an analyzable form. Furthermore, the secondary data from reliable sources related to hypothesized factors and variables were gathered for further analysis. The qualitative data from the interview transcripts and data collection was summarized and judged to one of three initial categories those were: (1) the viewpoint of respondents on necessity of joint research and their strategies for R&D and UIJRPTT; (2) potential and gap analysis of the UIJRPTT; (3) determinants and driving factors to formulate and impede the growth of the UIJRPTT.

The quantitative approach was applied through the analysis of data from questionnaire surveys using the Statistical Package for Social Sciences (SPSS) version 8.0. The mean, standard deviation and percentage of the data result from the overall respondent, and the comparison of the results obtained from the university and industry respondents were analyzed with an aim to identify the influential factors perceived as barriers to the growth of UIJRPTT and their extents. Further discussion by applying the theoretical aspects, the real Thai context, and the nature of factors were conducted to explain and answer the research questions of why there is little number of the UIJRPTT in Thailand.

### **3.2 Analysis of Factors Affecting the Effective UIJRPTT and Development of Effective UIJRPTT Model**

This part aimed to identify the factors affecting the effective UIJRPTT and its subsequent outcomes as well as to develop the model of effective UIJRPTT in Thailand. The research instruments, data collection and data analysis conducted in this part were presented as followed:

**3.2.1 Research Instrument** The research instruments applied in this part was almost the same as the first part of the primary study discussed earlier. The

questionnaire and in-depth interview were the research instruments used in this part. To acquire the quantitative data, in the questionnaire, the respondents were asked to state their opinions on the following issues:

1) Factors and variables drawn from conceptual model in Chapter Two namely: *characteristics and perspectives of university, characteristics and perspectives of industry, and joint research mechanism*. The respondents were requested to indicate five Likert scale on the factor variables affecting the effective UIJRPTT that they treated the differences between ‘strongly disagree = 1’ and ‘strongly agree = 5’ in column A and their impacts in ‘strongly negative= 1’ to ‘strongly positive = 5’ in column B. The data set obtained from column A was used to indicate the factor that the respondents viewed as important factor for the effective UIJRPTT while that of column B was used to formulate variable constructs and determine causal paths. The detail is as shown in appendix A part C.

2) The degree of the enabling factors affecting the outcome factor that consisted of growth, and quality and economic performance. The respondents were requested to indicate five Likert scale on the outcome factor variables that they viewed least affecting to greatly affecting (detail as shown in appendix A part D).

3) The current situation of factors: *characteristic and perspectives of university and industry* as well as *joint research mechanism*. The respondents were requested to indicate their opinion in five Likert scale from very low/poor to very high/good (detail as shown in appendix A part E).

For the in-depth interview, the interviewees were asked about the issues related to the influential factors they viewed could affect the effective UIJRPTT in Thailand, the possibility and to what extent that variables such as government policy and supports, strategic plans of university and industry in developing R&D, motivation IP management and university incentive system could affect the effective UIJRPTT, and the needs of university and industry for effective UIJRPTT. The questions were shown in appendix B. It was worth noted that the questionnaires and interview issues were developed on the basis of the literature review and refined by several experts and professionals from university and industry before being used.

3.2.2 Data Collection As stated in 3.2.1 (b), in this part, the data was collected from the respondents with the same data collection techniques.

3.2.3 Analysis of Data The quantitative approach was applied through the analysis of data from the questionnaire surveys in four parts. Those included: (1) factors affecting the effective UIJRPTT and their extents; (2) degree of the factors affecting the outcome factors; (3) development of the effective UIJRPTT model and (4) the level of existing factors namely characteristic and perspectives of university and industry and the U-I joint research mechanism. The SPSS was employed to perform the preliminary analysis such as normality and reliability and the Linear Structural Relationship (LISREL) 8.80 student version were undertaken to analyze the data included CFA and SEM path analysis.

The overall mean value and standard deviation for each enabling factors and outcome variables in the model, their impact and level of existing characteristic as well as the U-I joint research mechanism were calculated. The mean value and standard deviation for variables within the respondents groups – the university and industry side – as well as paired sample *t*-test were also calculated and presented to understand the perspectives of the two sides. The mean value for variables in column A that was greater than three (3.0) would indicate that respondents perceived that the variables were important while in column B would indicate that the variable had impact to the effective UIJRPTT. The normal distribution test and correlation analysis by drawing the data from column B was conducted by SPSS. The analysis helped indicate the appropriateness of the data set for further conducting factor analysis. In this research the level of significance (*p*) to test the hypothesis was 0.10.

For the purpose of this study, SEM which is an effective technique for conceptualizing a theoretical model, confirming relationships between variables (Zain, et al., 2005, Waroonkun, 2007), was utilized for the two main tasks. Those were: (1) for the CFA and (2) the determination of significant causal paths between factors. CFA is the statistical technique to verify the factor structure of a set of observed variables. It allows testing the hypothesis by which a relationship between observed variables and their underlying latent constructs exists (Angsuchoti, Wijitwanna, and Pinyopanuwat, 2008). Through data summary, the enabling factors as latent variables:

*characteristics and perspective of university* with four observed variables, *characteristics and perspective of industry* with four observed variables, and *joint research mechanism* with five observed variables as well as the outcome factor with three observed variables were examined. By developing the CFA measurement model, the latent constructs of the factors were identified and indicated the factor loadings and error variances. Factor loading should be higher than 0.30 (Tantiwattankul, 2003). The outcome of the CFA model was the final enabling factors and variables for the model of effective UIJRPTT. The determination of significant causal paths between factors from the CFA model was conducted through the path analysis. The goal of path analysis was to test theoretical relationships of set of variables (Kelloway, 1998). For this study, it served to identify the relationships between the exogenous factors and the outcome factor as endogenous factor in the model.

The Goodness of Fit Statistics (GOF) was used to determine the adequacy of model fit to the data. The GOF indices included the chi-squared ( $X^2$ ) test, the ratio of  $X^2$  to the degrees of freedom ( $X^2/df$ ), Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), and Normal Fit Index (NFI). Moreover, the measurement model were tested the validity, by investigating the factor loadings (estimated and standardized loadings) which should be higher than 0.30 and with significance  $t$ -value ( $>1.96$ ). The reliability of the measurement model were investigated by calculating the square multiple correlation ( $R^2$ ), construct reliability ( $\rho_c$ ) and average variance extracted ( $\rho_v$ ) of Diamantopoulis and Siguaw (2000) (Angsuchoti, Wijitwanna, and Pinyopanuwat, 2008). The adoption of the model was done after the model was measured by consideration of its fit, validation and validity and reliability. In the case that the hypothesized model did not fit the given data, the model was modified and tested again using the same data.

**Table 10 Summary of Goodness-of-fit and Model Evaluation Indices**

Measurement Indices	Recommended Value	Value Range	Notes
Chi-square statistics ( $X^2$ )	Tabled $X^2$ value		The $X^2$ test indicates the amount of difference between the expected and observed covariance matrices. $X^2$ value close to zero indicates little difference between the expected and observed covariance matrices.
Degree of freedom (df)	$>0$		An estimation of measurement models requires degree of freedom above 0 and thus a larger number of observations than free parameters.
Rate of $X^2$ to the degrees of freedom ( $X^2/df$ )	$<2$		$X^2/df$ values should situate below the acceptable value of 2.
Root mean square error of approximation (RMSEA)	$<0.05$ (Ideal) $<0.08$ (Acceptable)		RMSEA measures absolute fit that related to residual in the model. It is the square root of the average amount that the sample variances and covariance differ from their estimates.
Goodness of Fit Index (GFI)	$\geq 0.90$ (Adequate) $\geq 0.95$ (Good)	0 to 1	GFI is a measure of the relative amount of variance and covariance in sample data.
Adjusted Goodness of Fit Index (AGFI)	$\geq 0.90$ (Adequate) $\geq 0.95$ (Good)	0 to 1	Adjusted GFI takes into account the degree of freedom available for testing the model.
Normal Fit Index (NFI)	Close to 1 (Perfect fit) $> 0.9$ (Acceptable)	0 to 1	NFI is the comparative fit indices, most sensitive to violations of normality and to small sample size
Comparative Fit Index (CFI)	Close to 1 (Perfect fit) $> 0.9$ (Acceptable)	0 to 1	CFI is accurate across estimation methods; useful for comparing nested models
Construct Reliability ( $\rho_c$ )	$> 0.60$		$\rho_c$ refers to the absence of random errors in the measurement to ensure consistent, accurate and predictable findings using item loadings and error variances
Average Variance Extracted ( $\rho_v$ )	$> 0.50$		$\rho_v$ refers to convergent validity of all constructs which describes the correlation between different measurements. It is calculated to indicate that the items account for a considerable larger degree of variance than the measurement error.

For the qualitative data analysis, the review of the interview transcripts and the indication of the data into two categories were conducted. The three categorized issues included: (1) factors affecting to the effective UIJRPTT and their extents, and (2) the recommendation and suggestion to improve the effective UIJRPTT. The qualitative data analysis could be used to support by confirmation the variables and factors affecting the effective UIJRPTT as well as refine the model with more detail and concrete recommendations. Further discussion by applying the

theoretical aspects, the real Thai context, and the nature of factors were conducted to explain and answer the research questions and further adopted the model of effective UIJRPTT.

#### **4. Model Validation**

The objective of the phase was to validate the effective UIJRPTT model by evaluating the significant variables, factors and outcome factor and their linking paths. The paths included: (1) characteristics and perspectives of university to the outcome factor, (2) characteristics and perspectives of industry to the outcome factor and (3) joint research mechanism to the outcome factor. Based on the interview results and literature review, the variables indicators were discussed and identified, and, later, used to develop the questionnaire developed. The questionnaire was provided to three experts to judge the appropriateness. Moreover, individual items were worded carefully to minimize measurement error and avoiding ambiguity.

With regard to the questionnaire form for the case studies, it consisted of three major parts. Those included: (1) Part A: background information, asking the name, organization, position, year of experiences, and research experience related to photovoltaic; (2) Part B: evaluating effective UIJRPTT in Thailand, asking the respondents to rate on the expectation in each variables and indicators based on their experience in the UIJRPTT projects, (3) Part C: the outcome factor of the effective UIJRPTT, asking the respondents to rate scale on their expectation on the outcome of the effective UIJRPTT. The use of five Likert scale in Part B and C as interval scales implied that respondents treated the differences between the option that they anchored with statements 'very low = 1' to 'very high = 5'. The interpretation of the mean value according to Srisaad (2002) used in this research were: (1) 4.51-5.00=very high; (2) 3.51-4.50= high; (3) 2.51-3.50=adequate; (4) 1.51-2.50 = low/; (5) 1.00-1.50 =very low.

The comparative analysis prediction for the significant causal paths identified by the effective UIJRPTT model derived from the primary study was conducted to validate the reliability of the path equations and their associated standardized path coefficients and to confirm the model. The analysis process, adopted from the work of Waroonkun and Stewart (2007), began with the comparison of the differences between the mean value of the primary study and the three case studies.

This could be calculated firstly by comparing the raw mean value of the primary and of the case studies. Secondly, the developed path equation of the effective UIJRPTT model was used to calculate the mean score for the each three case studies. Finally, the actual scores for the case studies were compared against predicted Z-scores. To do so, the actual scores obtained from the case studies in each factor were converted to an equivalent Z-score or standard score on the original mean factor score in the primary study. A Z-score is a transformation of a raw score into standard deviation units which allow one to learn how far above or below the mean is any given score and how extreme the score is relative to all other scores (Hoover, 2009). The formula for converting from an original or "raw" score to a Z-score is:  $z = (x - \text{mean}) / \text{S.D.}$  where:  $x$  is a raw score to be standardized derived from the case studies; mean is the mean value of each factor from the primary study; S.D. is the standard deviation of each factor from the primary study. The actual scores were later used to be calculated the predicted score replacing in the structural model equation. The predicted score was then used to determine the predicted mean value of each factor derived from each case study. The actual mean value from the primary and predicted mean value in each factor from the case studies were compared to indicate the differences in percentage. The actual and predicted mean values for outcome factor that are close with low percentage differences appeared that the path equation is highly reliable for the prediction of the effective UIJRPTT.

The overall research design and outcome were demonstrated as shown in the following tables.

**Table 11 Research Design and Outcome**

<b>Stage</b>	<b>Descriptions</b>	<b>Outcome</b>
1. Conceptual Model	<ul style="list-style-type: none"> <li>• Review of Thailand's university-industry collaboration and joint research context</li> <li>• Review of factors of growth and effective of U-I joint research and technology transfer</li> <li>• Critical review and integrate the existing models and studies related to U-I joint research and technology transfer to create conceptual model relevant to the UIJRPTT</li> </ul>	<ul style="list-style-type: none"> <li>• Develop the questionnaires and interview question for the try out</li> <li>• Create the factors affecting growth and effective UIJRPTT</li> <li>• Create a conceptual model of effective UIJRPTT in Thailand</li> </ul>
2. Try out 2.1 Questionnaire Survey 2.2 Interview Question 2.3 Analysis	<ul style="list-style-type: none"> <li>• Develop the questionnaire and interview questions</li> <li>• Statistical analysis for questionnaire validity and reliability test</li> </ul>	<ul style="list-style-type: none"> <li>• Confirmation of questionnaire and interview questions</li> </ul>
3. Primary Research 3.1 Analysis of Factor Affecting Growth  3.2 Analysis of Factor Affecting the Effective UIJRPTT and Development of effective UIJRPTT	<ul style="list-style-type: none"> <li>• Distribution of survey questionnaire and in-depth interview with professionals in university and photovoltaic industry</li> <li>• Data collection from reliable sources related to hypothesized factors</li> <li>• Data, inductive and descriptive statistic analysis</li> <li>• Distribution of survey questionnaire and in-depth interview with professionals in university and photovoltaic industry</li> <li>• Data, inductive and statistic analysis which include descriptive, CFA, path analysis and GOF</li> </ul>	<ul style="list-style-type: none"> <li>• Potential and gap analysis</li> <li>• Confirmation of factors affecting growth of UIJRPTT, barriers and determinants</li> <li>• Confirm factors affecting effective UIJRPTT and outcome factor</li> <li>• Finalize model of effective UIJRPTT</li> <li>• Evaluation of current status of factors</li> <li>• Refine the model with recommendation</li> </ul>
4. Model Validation 4.1 Questionnaire 4.2 Analysis	<ul style="list-style-type: none"> <li>• Development of questionnaire survey through case studies</li> <li>• Actual and predicted comparative analysis</li> </ul>	<ul style="list-style-type: none"> <li>• Validate the effective UIJRPTT model</li> </ul>

**Summary**

This chapter described the research methodology and research design of this thesis study. The mixed qualitative and quantitative methods were used to for two major parts in the primary study. Those included the part of: (1) analysis of factors affecting growth of UIJRPTT; and (2) analysis of factors affecting the effective UIJRPTT and development of effective UIJRPTT model. The case study in four projects involving the UIJRPTT was selected to be the instruments for model validation. The conceptual model and the results of the try out were described in this chapter to lay out the understanding in of the research design of the whole research study and the primary study. Detail of the population and sample, research instruments, data collection and data analysis of the primary study and model validation were described in detail in this chapter.