CHAPTER 4

RESEARCH METHODOLOGY

4.1 Introduction

This chapter presents the process followed in designing the IT Infrastructure Flexibility (ITIF) Maturity Model. The maturity model needs a minimum set of the most significant factors to measure for improvement (Khandelwal & Ferguson, 1999; Tapia, 2007). Thus, the identification of critical success factors (CSF) for ITIF from the construction industry perspective has become the first step in this research methodology, continued with the development of the maturity model. Many researchers that has developed maturity model used these methods, for examples, Tapia (2007), Maier, et al (2009), Alshawi & Arif (2001), Niazi, et al (2003), and Jochem, et al (2011). Thus, it was possible to adopt a maturity model development process as demonstrated by previous researchers.

4.2 Research methodology

In developing a maturity model, there are few methods found in literature. The most common method is a combination of questionnaire and case studies, which was employed by many researchers such as Jochem, et al (2011), Salleh (2007) and Software Engineering Institute (1991). The identification of CSF was done through questionnaire, continued by case studies for maturity model development. Other researchers employed case studies, questionnaire, or focused-group as one single method, for example Arsanjani & Holley (2005), Gartner (2004), and Niessink, et al (2002), however they usually already had predetermined factors to be analyzed in maturity model. This research adopts a combination method of questionnaire and case studies due to insufficient data available about CSF of ITIF in the Malaysian construction industry.

The research comprises a number of tasks as shown in Figure 4.1. ***Task 1*** involves identifying an appropriate ITIF construct and confirms a list of potential ITIF factors from the construction industry perspective, to be included in the survey. The list of ITIF factors was extracted from literature reviews and construction industry's expert opinion. The questionnaire design was developed for determining the level of importance and correlation for each factor to be evaluated in the maturity model. After which, the most important of ITIF success factors were extracted from statistical analyses, an initial maturity model was developed in ***Task 2***. In ***Task 3,*** case studies were carried out to triangulate the predetermined factors. With the results of case studies and information from literature review of literature, the criteria for each maturity level is determined in the Preliminary ITIF Maturity Model. The final model will be ultimately designed specifically for construction organizations.

The reason of bringing two distinct methods in this research was because to answer two different form of research objectives - the first was to find ***what*** are the CSF of ITIF, and the second was to understand ***how*** the determinants of maturity levels for the ITIF for each CSF. Based on these needs, Yin (2009) highly recommends that survey is a justifiable method for conducting an exploratory study, and on the other hand, 'how' question is explanatory and leads to the use of case studies.

The research started with preliminary data gathering to explore about the IT in construction industry. This includes an overview of IT from the construction industry perspective, trends of IT change and its implications, and approaches that has being used by Malaysian construction organizations to face the rapid IT change, as well as about IT infrastructure flexibility (ITIF), maturity model, and its implementation in Malaysia. In supporting the findings from literature, an expert opinion method was conducted. A construction industry survey was administered. In order to establish the questionnaire, a pilot study was conducted to help identifying the factors that are important to be measured. Before the questionnaire was sent out to the respondents, the questionnaire was gone through a content validation process and it was pre-tested to fifty respondents from the targeted population. Findings from the questionnaire are important in identifying the CSF of ITIF in the construction industry, which the identified CSF are measured in the development of an initial ITIF Maturity Model. The maturity of each factors were determined trough literature review in order to form an initial ITIF Maturity Model. Then, case studies method was used to triangulate the ITIF factors for model's practicality in the Malaysian construction industry. The details for each method is are explained in following sections.

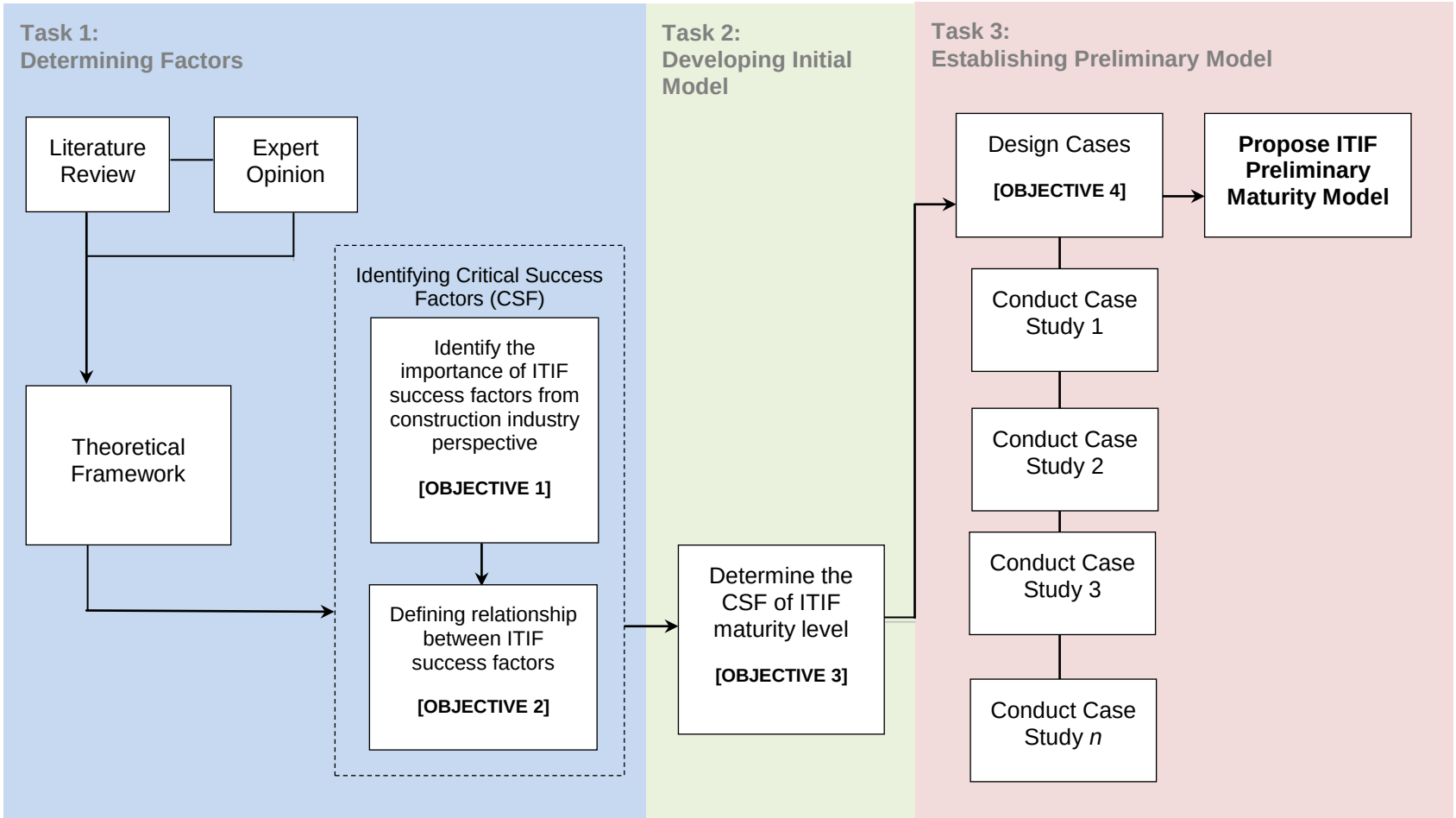

Figure 4.1: The research methodology, modified from Tapia (2007).

4.3 Preliminary Data Gathering

This research started with the exploration of current trends of IT changes in the construction industry, followed by the investigation on approaches or practices used by the construction industry. This step is very important for this research because the subject of discussion is relatively new (Babbie, 2010). ITIF was proposed to assist construction organizations to cope with technological change. The topic exploration was divided into two parts; the first part was to review the published literature, and the second part was to conduct two separate formal discussions with industry experts.

4.3.1 Literature Review

For the purpose of exploring the subject field in detailed, it is recognized that multiple sources of information would need to be examined. Literature review is important to clarify ongoing dialogue in the literature related to the research, hence establishing gaps to extend prior studies (Creswell, 2009). While investigating the potential subjects of ITIF and maturity modeling, the study started with literature review from journals and books published, majority of them were from between the year 2000 to the first part of 2013, which were written only in English. The source materials of the data were obtained from libraries' databases, which cover 225 technology and social science journals (International Science Indexed (ISI), and Scopus database). The computerized databases were chosen because they are the major sources to journal articles and documents (Creswell, 2009). Recent conference papers were also followed to keep this research up-to-date with present results. In addition, Google Scholar, Google Web, and specialized databases and other information sources available on the Internet are also explored.

4.3.2 Experts Opinion

The findings from literature reviews were being into practical perspective through communication with experts in this field. Expert opinion is a technique that is used to assist in problem identification and clarifying the issues relevant to a topic (Cooke, 1991). E-mail correspondence was made with five authors in the field of ITIF (whose studies are commonly being used as a reference in ITIF literature) via electronic mail, with 40% of them responded. Mutual discussions were made about the importance of ITIF and the need of a maturity model.

In addition, formal discussions with IT managers in government departments related to construction industry were conducted; they were from Public Works Department of Malaysia (PWD) and Malaysian Construction Industry Development Board (CIDB). These discussions were important to clarify current situation of IT adaptation and implementation in the Malaysian construction industry, as well as to understand how the construction industry would cope with technological change. The PWD and CIDB are the construction policy maker and implementer, and they were the government's main players in promoting the massive use of IT in the Malaysian construction industry. PWD is a federal government department in Malaysia. The respondent from a Quantity Surveying and Contract Department, which employs 328 members of staff and has responsibility in construction and maintenance of public infrastructure in the country, for examples federal state roads and public government buildings. The department has its own IT Division that runs many IT solutions in order to enhance and integrate the public sector project management and construction procurement procedures such as electronic tendering. Respondents from CIDB were from a subsidiary of the board, where 44% of the subsidiary's staff are IT experts with

IT-related qualifications. This establishment is a key driver for Malaysian national initiatives in integrating IT into the national construction framework. The subsidiary provides information and communication technology (ICT) advice for CIDB and offers IT solutions for the construction industry; where they are responsible for national projects worth an average of USD2.5 million in each project. Among successful IT projects the organization has developed include in-house software for the national construction board, national electronic tendering portal, and construction intelligence portal in Malaysia - many of the projects are also patented. The organization also offers IT training services for construction practitioners.

On top of this, the private sector's perspectives were taken into account, too. A Chief Information Officer and a Senior General Manager (Technical) from two property-construction groups in Malaysia were participated in formal discussions that were conducted in separate sessions. The discussion focused on their strategies to implement IT in current situation of rapid IT change. The first property-construction group was established in 1974; one of the most significant developments is a township that was developed in 800 acre of area, located in Kuala Lumpur. The other group was formed in 1983 with a portfolio covers major projects in Selangor, Perak, Kedah, which includes housing, lifestyle living, commercial development, resort, theme parks, and property investment. Both of the groups have developed their tailored end-to-end integrated IT solutions that are run by certified IT consultants and technical engineers in the group.

4.4 Critical Success Factors of IT Infrastructure Flexibility

The dimensions along which maturity will be measured must be derived from a systemic perspective. Khandenwal and Ferguson (1999) suggested the combination CSF method in a maturity model by gauging the maturity of an organization, industry, or region by the correspondence of the CSF. CSF is often identified after the successful completion of certain activities; hence, the factors provide information that is near to real life experience (Niazi, et.al, 2003). By having CSF in maturity model, it provides better understanding about the types of information and needs that is useful for the model's users (Jochem, et al, 2011).

4.4.1 Pilot Study

The objective of conducting the pilot was to confirm that the factors of ITIF gathered from literature reviews are relevant to be measured from the construction industry perspective. Besides, the pilot study can reveal deficiencies in the design of a proposed questionnaire instrument and these can be addressed before proceeding with the main study (Maxwell, 2005).

Seven construction companies were selected to participate in a pilot study lasting 3 weeks during 2011. Selected companies were from different areas in the construction industry - a policy maker, construction consultancy practice, contractor, materials supplier, IT developer, and an IT consultant company with ten-year experience in developing IT systems for the Malaysian construction industry. All selected companies have an IT department. The participant mixture provided a diverse view and perspective from the various professional involved in the industry. They are

referred to as Organization A, B, C, D, E, F, and G to maintain the anonymity of the companies. In total, interviews were conducted with thirteen participants from senior management positions. The summary of all the respondents is listed in Table 4.1.

Table 4.1: Respondent's organization overview

Organization	A	B	C	D	E	F	G
Establishment Year	1872	1994	2000	1934	1983	1995	2001
Business Sector	Public Authority	Construction board	IT consultant	QS Consultant	Developer	Construction supplier	IT consultant
Total No. of Employees	3,702	App. 1000	50	App. 3000	1,678	20	Not revealed
Type of systems developed	Electronic tendering, cost management database, web portal, data management system.	Electronic tendering, industry portal, e-procurement	Electronic tendering, industry portal, technical software.	Construction management system, and data management using Extranet.	Data management system, internal electronic mail, web portal.	Web portal, data management system.	Open source solution, virtualisation, web development, GIS.
System developer	In-house, vendor	In-house, vendor	In-house, vendor	In-house	In-house	In-house	In-house
Informants' positions	(1) IT Manager (2) IT Consultant	(1) Chief Information Officer (2) IT Manager	(1) Chief Operating Officer (2) IT Manager (3) Software Engineer	(1) Head of IT Department (2) System Engineer	(1) General Manager of Technical	(1) Chief Executive Officer (2) IT Manager	(1) Chief Executive Officer

The semi-structured interview sessions were carried out with each respondent to allow them to give their opinion and view on the relevancy of ITIF success factors to be measured in the construction industry. At the same time, the respondents have the opportunity to propose other factors that can contribute for the success of flexibility in IT infrastructure. Data collected focuses on the success factors of ITIF based on the success and failure experience of each organization. The factors are categorized under three dimensions; technical, people, and management, which was structured based on the literature findings (Byrd & Turner, 2000; Fink, 2009). Thirty-three factors were synthesized from the literature review that fell under the abovementioned dimensions,

as compiled in Table 4.2. The semi-structured interview questions can be found in Appendix A.

Table 4.2: Pilot study results.

Elements	Feedback from the Construction Industry Perspective	Factors	Code
Technical Dimension			
Connectivity	100% of respondent strongly agreed that utilization of open systems network mechanism (TCon6) has security issues, thus is not important to utilize in construction IT projects. 6 out of 7 respondents suggested utilization of Virtual Private Network (VPN) (TCon4) as one of the success factors for being flexible.	▪ IT system utilization ▪ 24-hours connection ▪ Virtual Local Area Network (VLAN) utilization ▪ Virtual Private Network (VPN) utilization ▪ Minimal steps for data access	▪ TCon1 ▪ TCon2 ▪ TCon3 ▪ TCon4 ▪ TCon5
Compatibility	100% of respondent strongly agreed that easy adaptation to various vendors' database and management systems protocols and standards (TCom5) allow insecurity to an IT system and it is not suitable to be measured form the construction perspective.	▪ Common operating system (OS) ▪ File formats standardization ▪ Quick integration ▪ Transparent access	▪ TCom1 ▪ TCom2 ▪ TCom3 ▪ TCom4
Modularity	100% of respondent strongly agreed with the factors.	▪ Design to be reconfigurable ▪ Reusable applications used ▪ Object-oriented programming (OOP) technologies utilization	▪ TMod1 ▪ TMod2 ▪ TMod3
Data Transparency	6 out of 7 respondents agreed that offering wide variety of types of information (TDat5) is not a common practice in the construction industry as the so much information is confidential. *Additional comment*: Many security layers should be implemented but every layer involves simple steps.	▪ Analytical processing utilization ▪ Access control level (ACL) utilization ▪ Central data processing ▪ Real-time information	▪ TDat1 ▪ TDat2 ▪ TDat3 ▪ TDat4

Table 4.2, continued.

Elements	Feedback from the Construction Industry Perspective	Factors	Code
People Dimension			
Technical Skill	5 out of 7 respondents agree. *Additional comment:* 2 respondents believe that deep interest and long experience are more important than the qualifications they hold.	▪ Multiple operating system (OS) skill ▪ Multiple programming languages skill ▪ Network management and maintenance ▪ Data warehousing ▪ Cross-trained	▪ PTech1 ▪ PTech2 ▪ PTech3 ▪ PTech4 ▪ PTech5
IT Management Skill	100% of respondent strongly agreed that willingness to change (PMngt3) of IT personnel is a key element to cope with technological change. 100% of respondent agreed that IT personnel must have an ability to interpret management needs and provide technical solutions.	▪ Commitment to learn ▪ Be updated ▪ Willingness to change ▪ Ability to interpret management and technical needs	▪ PMngt1 ▪ PMngt2 ▪ PMngt3 ▪ PMngt4
Self-Management Knowledge	100% of respondent agree. *Comment*: 4 respondents suggested that this is a must-have-factor in the top-level management, while 4 respondents believe that all IT personnel need to have leadership.	▪ Teamwork in multidisciplinary environment ▪ Self-directed and pro-active	▪ PPer1 ▪ PPer2
Business Knowledge	5 out of 7 respondents agreed that IT personnel do not have to be expert in the construction industry limitations (PCKnow2), but need too aware about it. 100% of respondent strongly agreed that understanding of construction processes and stages is a vital knowledge that IT personnel should have to ease the digitalization process (PCKnow3) *Additional comment*: To have both IT & construction knowledge in one IT personnel is rare, but training and education is important to help them understand the construction business knowledge.	▪ Awareness of critical success factors (CSF) ▪ Familiar with the construction environment constraints ▪ Understand construction processes	▪ PCKnow1 ▪ PCKnow2 ▪ PCKnow3

Table 4.2, continued.

Elements	Feedback from the Construction Industry Perspective	Factors	Code
Management Dimension			
Technical-oriented Services	100% of respondent strongly agreed with the factors.	▪ Communication channel management ▪ IT security management ▪ Connectivity ▪ Data management	▪ MSup1 ▪ MSup2 ▪ MSup3 ▪ MSup4
Management-oriented Services	100% of respondent strongly agreed with the factors.	▪ Standard operating procedures (SOP) ▪ IT project management ▪ Training and education ▪ Research and development	▪ MSup5 ▪ MSup6 ▪ MSup7 ▪ MSup8

Through the pilot study, thirty-eight factors of ITIF have been extracted that the respondents agreed its relevancy to be measured under Malaysian construction industry perspective. All the factors are marked as independent variables because they represent the value being manipulated (Morgan, Leech, Gloeckner, & Barrett, 2011). Figure 4.2 lists thirty-eight success factors drawn from three dimensions of technical, people, and management that contributes to flexible IT infrastructure, with 5 factors were newly discovered. The new factors were (1) utilization of virtual private network (VPN), (2) familiar with the environmental constraints within the construction industry, (3) understand construction processes and stages, (4) willingness to accept changes, and (5) ability to interpret management and technical needs.

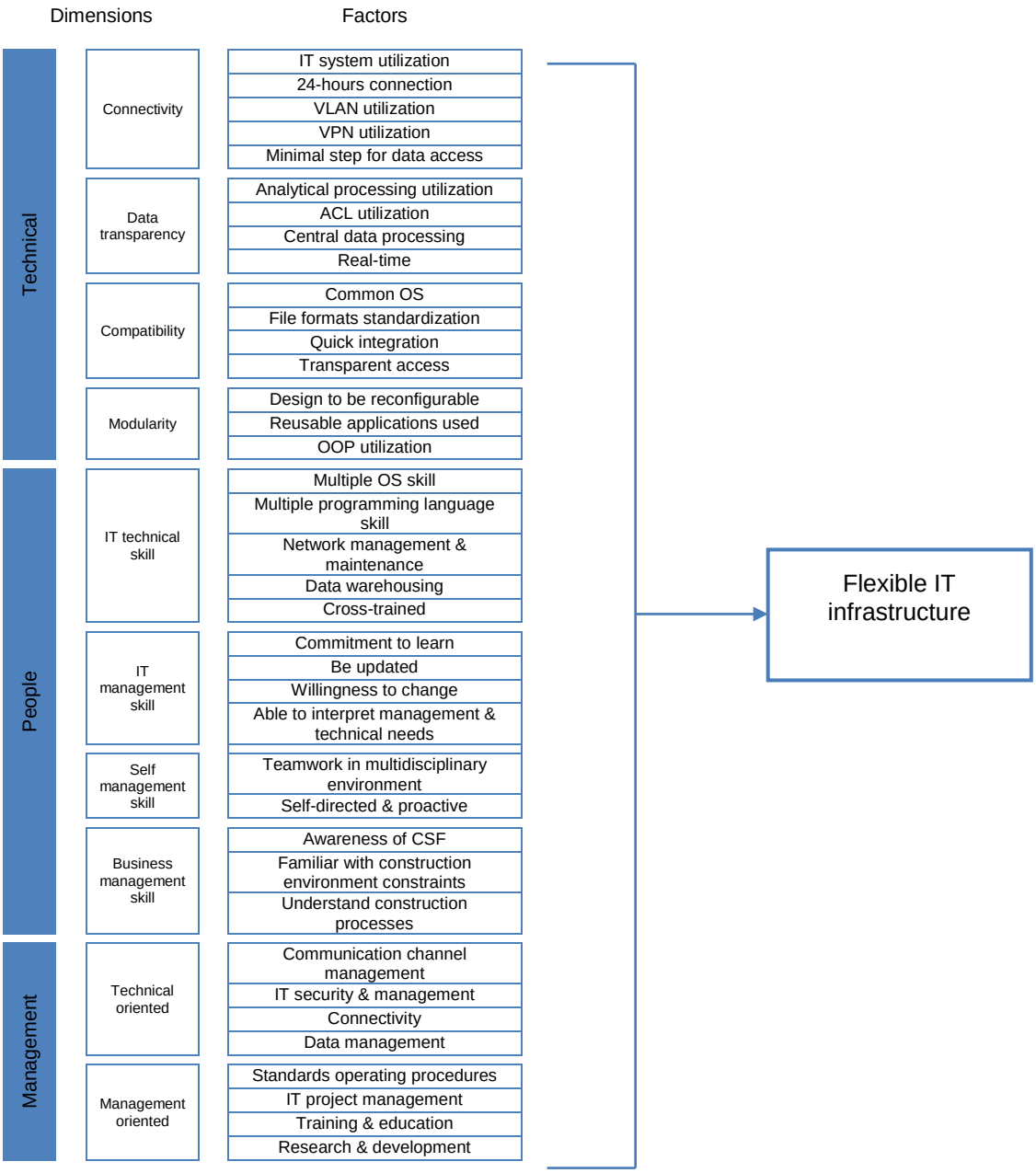

Figure 4.2: List of the success factors of ITIF from the construction industry perspective

4.5 Questionnaire design

The questionnaire for this research was adopted from Byrd & Turner's (2000) and Fink's (2009) work – both put a major efforts to develop a valid and reliable instrument to measure ITIF. Questionnaire is proven as the fastest and the most effective technique for statistical data and opinion collection compared to other methods (Broadbent & Weill, 1997; Burns, 2000). Questionnaires collect information from a large portion of group and can be gathered in a standardized way. In this way, questionnaires are deemed to be the appropriate option, as this research required a large sample size to reflect the whole construction industry perspective. Four sets of technical elements were developed that consist of sixteen items, four sets of people elements that bring fourteen items, and two sets of management dimension that have eight items. The main questionnaire survey consists of two sections; Section A addresses the general information about the respondent's background and experience, and Section B lists the selected ITIF factors. In Section B, the instrument used a five-point Likert scale, as used by Byrd & Turner. The respondents were asked to rate the importance of each factor that contributes to ITIF success using the scale of 1 to 5 as follow:

1 – Not important

2 – Slightly important

3 – Very important

4 – Strongly important

5 – Extremely important

The first draft of the questionnaire was discussed with supervisors and colleagues through several stages. In the early stages, the questionnaire was revised several times to ensure that questions related to the concepts being tested. Issues such as the questions flow, usefulness of instructions and readability of the questionnaire and the layout of the questionnaire were considered. The questions are made easy to understand to ensure high completion rates (Faux, 2010; Zikmund, 2003).

4.5.1 Content Validation

Once the initial questionnaire was completed, it was pre-tested through seven separate interviews with academic and industry experts. The experts were three IT managers and two senior IT technicians for the construction companies, a Director from a public-listed company in main board of Kuala Lumpur Stock Exchange (KLSE) and with an academician with more than seven years experience in construction IT in the United Kingdom. The interviewees were firstly briefed on the purpose of the study, and then asked to evaluate the questionnaire items for their understandability, clarity, relevance, and completeness. They were given a content validation assessment form to evaluate the said elements by rate them using 5-Likert Scale, ranging from "Not Relevant at All" to "Strongly Relevant".

Following the interviews, many questionnaire items were modified, especially the technical terms. This process managed to improve the accuracy of the questionnaire so that the respondents could get clear meaning of the words used in the questionnaire, clear arrangement and sequence of items, and clear response format and instructions for respondents. According to Haynes et al. (1995), content validation minimizes any potential error variance associated with an assessment instrument, and to increase the

probability of obtaining supportive construct validity indices in later studies. They defined content validity as the degree to which elements of an assessment instruments are relevant to representative of the targeted construct.

4.5.2 Questionnaire Pre-Test

The purpose of pre-testing the questionnaire was to analyze the response rate and to preliminary examine the measurement qualities of questionnaire items through descriptive analysis (Faux, 2010). With the Internet, an online survey was launched with the assumption that the targeted respondents were IT literates. Unfortunately, the response rate was very low where it managed to get only two respondents in month's time. Therefore, the Researcher decided to use the traditional way of field survey, which was administration via postal mail.

Through postal mail, the modified questionnaire was pilot-tested with fifty organizations; with thirty-one respondents. Table 4.3 shows the descriptive statistics of each questionnaire. The statistic measures number of valid values, minimum value, maximum value, mean, and standard deviation. The pre-test surveys led to two conclusions. First, the methodology of a postal mail could be employed in this study, as long as the questionnaire was addressed to the right respondents – directly addressed to IT Director, IT Manager, or IT Department. Second, despite the small number of records, questionnaire items demonstrated good measurement qualities – mean were scale-centered and not extreme, standard deviations were around 1.0 for most items, and responses usually covered the whole range of the scale.

Table 4.3: Descriptive statistic of questionnaire pre-test.

	N	Minimum	Maximum	Mean	Std. Deviation
Utilization of IT communication	31	1	5	4.10	1.106
24 hours connection	31	1	5	3.48	1.288
Utilization of VLAN	31	1	5	3.32	1.326
Utilization of VPN	31	1	5	3.39	1.230
Minimal step for data access	31	1	5	3.35	1.199
Utilization of analytical processing	31	1	5	3.23	1.087
Utilization of ACL	31	1	5	3.48	1.262
Central data processing	31	1	5	3.19	1.302
Real-time	31	1	5	3.29	1.039
Common OS	31	1	5	3.84	1.128
Standardization of file formats	31	1	5	3.90	1.106
Quick integration of new system	31	1	5	3.77	.956
Transparent access	31	1	5	3.39	1.145
Design to be reconfigurable	31	1	5	3.48	1.029
Reusable applications used	31	1	5	3.13	1.176
Utilization of OOP	31	1	5	3.26	1.237
Multiple OS skills	31	1	5	3.45	1.179
Multiple programming languages skills	31	1	5	3.10	1.136
Network management & maintenance	31	1	5	3.81	1.078
Data warehousing	31	1	5	3.19	1.138
Cross-trained	31	1	5	3.42	1.148
Commitment to learn	31	1	5	3.90	1.193
Updated	31	3	5	4.06	.727
Wiling to change	31	3	5	4.26	.773
Able to interpret management & technical needs	31	1	5	3.90	1.106
Teamwork in multidisciplinary environment	31	1	5	3.58	1.205
Self-directed and pro-active	31	3	5	4.26	.729
Awareness of CSF	31	1	5	3.74	1.182
Environment constraints	31	1	5	3.55	1.121
Construction processes	31	1	5	3.74	1.032
Communication channel management	31	1	5	3.29	1.160
IT security & management	31	1	5	3.68	1.107
Connectivity	31	2	5	3.97	.795
Data management	31	1	5	3.68	1.107
Standards operating procedures	31	1	5	3.45	.925
IT project management	31	1	5	3.52	1.092
Training & education	31	1	5	3.23	.884
Research & development	31	1	5	3.19	1.108

4.5.3 Population

In the first part of the questionnaire, respondents were asked to provide personal information and the organization al details. This part consisted seven items – duration they have worked for construction companies and their job title, the organization's market segment and specialization, registration's grade, number of employees, and the annual gross revenue.

Given that most of the measures require IT familiarity and understanding, this study sampled the respondents from a population of construction organizations that actively using IT in their business. Based on an approach that a managerial perspective is needed to provide valid evaluations of strategic measures, respondents who have both IT professional and managerial positioning is selected. The respondents include General Manager, IT Directors, IT Managers, IT professionals and construction professionals that hold IT-related management-level positions. Even junior IT managers (e.g. IT team leaders), or project managers, who felt able to evaluate strategic measures and technological aspect, were included in the study.

All respondents were working for construction-related organizations, as listed in the Construction Industry Development Board of Malaysia's website (www.1bina.my). These include contractors, developers, designers (engineer and architect), surveyors, construction material manufacturers, and also public sector authorities. The respondents were selected from various databases as shown in Table 4.4, as following, in order to ensure the diversity of views about ITIF success factors in the construction industry. The selection was based on the availability of IT department in the respective organizations through a confirmation via telephone conversations and electronic mails. A summary of the research key aspects were explained to ensure the respondents agree to take part in the research, they are fully aware of the nature of the research, and of their role within it.

Table 4.4: Sampling distribution.

Business sectors	Databases	Total number of firms	Number of samples
Contractor	Construction Industry Development Board Malaysia	9612	417
Developer	The Real Estate and Housing's Developer Associations of Malaysia	976	200
Architect	Malaysian Institute of Architects	1356	100
Surveyor	Royal Institute of Surveyors Malaysia	318	100
Engineer	Board of Engineers Malaysia	1080	80
Manufacturer	Construction Industry Development Board Malaysia	170	95
Public authority	Public Works Department and Construction Industry Development Board of Malaysia.	8	8
	Total number of samples	**13520**	**1000**

4.5.4 Postal Mail Administration

There was three phase of mailing-out the questionnaire to the sampled construction organizations, which each mailing includes a cover letter, the questionnaire, and a postage-paid return envelope. The cover letter invited the recipient to participate in this research study, specified the objective of the research, and the target population. There was also a note reminder attached suggesting the respondents to reply within two weeks from the date of receiving the letter. The main survey was administered over three consecutive days – 200 mails were distributed on the first day, another 500 mails on the second day, and another 282 mails on the third day. At the same time, 18 questionnaires were circulated through electronic mail as requested by the respondents.

4.5.5 Response Rate

Questionnaire returns were accepted for approximately fourteen weeks since the first distribution. The survey was finalized when no questionnaires were returned for more than a week, after several efforts were made in terms of personal contacts and follow-up calls. Altogether, the response rate was 21.1%, representing 211 respondents out of

1000 questionnaires sent out. The response rate was consistent with the norm response rate in the construction industry for postal questionnaires, which is around 20 to 30 percent (Akintoye, 2000; Takim & Adnan, 2008; Yang, et al, 2011). As for examples, Takim & Adnan (2008) and Adnan & Morledge (2003) have received 20.9% and 20% in their surveys. Nevertheless, the targeted respondent from myriad business categories in construction industry completed the questionnaires; it provides confidence that the responses are reliable.

4.6 Questionnaire Data Analyses

The survey collected 21.1% of total respondents after four months of data collection. The first part of the questionnaire was about the respondents' profile and its demographic of respondents' profile will be discussed in the Chapter 5. In the second part, the importance of the ITIF success factors were measured through 5-point Likert scale that has graded responses to an item which ranging from "1 – Not Relevant at All" to "5 – Strongly Relevant", hence the factors marked as ordinal variables (Hennig, Mullensiefen, & Bargmann, 2003). Based on this nature, the relevant non-parametric tests were used; mean, Severity Index, and Kendall's W test are used for data ranking, and supported by the Spearman Rho correlation coefficient. A combination of these tests was widely used by many researchers in a process of identifying CSF (Fan, Rajib, & Alam, 2012; Ganesh & Mehta, 2011; Idrus & Newman, 2002).

The analysis began with a data ranking process. The purpose of the data ranking is to select the CSF of ITIF for the development of maturity model. The severity indices was measured using the formula referenced by Yusuf et al. (2011):

$$\text{Severity Index (SI)} = \left\{\frac{\sum WF}{n}\right\} \text{x } 100\% \quad \text{.....(ii)}$$

The W is the weight for each rating (which W is equal to rating in scale / number of points in scale, in this case 1/5, 2/5, 3/5, 4/5, and 5/5), F is the frequency of response for each scale, and n is the total number of responses (in this case n=211). Severity Index is used to identify CSF by determining relative important index for each variables, which was then used to rank variables according to their degree of importance (Idrus & Newman, 2002; Ogwueleka, 2011; Oyewobi & Ogunsemi, 2010).

To ensure that the ranking of the variables obtained from the Severity Index was as a result of a consensus agreement between differing groups of the respondents. Kendall's W test was applied to compare the ranking of the variables using Kendall mean rank (Ganesh & Mehta, 2011; Idrus & Newman, 2002; Ifinedo & Ifinedo, 2011). The percentage ratings of Kendall's W mean were calculated using SPSS software to produce a ranking of the variables.

The top-ranked variables that met the criteria set for mean, Severity Index, and Kendall's W mean rank results, were shortlisted. The significance correlation of the shortlisted variables then was tested using the Spearman Rho correlation coefficient. The analyses gave a list of the most important ITIF success factors from the construction industry perspective. The correlation coefficient measures the statistical dependency between variables (Chow & Cao, 2008; Fan, et al., 2012). It assessed the relationship between two variables. This test was performed using the following formula through the statistical SPSS software:

$$\text{Rho}, \rho = 1 - \frac{6 \sum {d_i}^2}{n(n^2 - 1)} \quad \text{.....(iii)}$$

Where $\sum d^2$ is the sum of the squared differences between the pairs of ranks, and *n* is the number of pairs. The research hypothesis used for this task, based on the standard criteria of probabilities that is 0.5% significance level (Field, 2009), were as followed:

H_0 ($p \leq .05$) – The ITIF success factors significantly correlated among each other.

H_1 ($p > .05$) – There is no significant correlation among the respondents rating for the ITIF success factors.

Those variables with coefficient values that reached significant correlated ($p < 0.05$) were recognized for being CSF (Fan, et al., 2012). These strong correlation coefficients support the causal relationship among the factors for successful implementation of ITIF. Therefore, the variables that were not significantly correlated with at least or more than 30% of the total variables listed were not recognized as CSF.

4.7 An Initial Maturity Model Establishment

Once the CSF were confirmed through the previous *Task 1* (as shown in Figure 4.1), the initial model (Figure 4.5) was developed – indicates the criteria for successful ITIF at each level of maturity. Each level addresses different criteria requirements relevant to the IT system's maturity implemented in construction organization. The development process of the initial maturity model consists of designing the maturity

model and setting up the criteria for each level. It begins with determining the scope of the model where the usage boundaries of ITIF Maturity Model and the purpose of the model were defined in this stage – designing the model includes model's type, model's structure, the number of maturity levels, and model's domains.

The most important step in designing a maturity model is the identification of the factors to which the levels apply. The significance of each factor against the maturity levels was studied through review of the literature, as suggested by Yin (2009) that the use of literature helps researchers narrowing scope of each factor to a specific focus. The data was gathered in the initial ITIF Maturity Model, which was discussed in detail in Chapter 6. Table 5 shows the basic elements of the initial ITIF Maturity Model that was tested in the next phase of research.

Table 4.5: Basic features of the initial ITIF Maturity Model

Maturity level	Technical		People			Management	
	Compatibility	**Modularity**	**IT leadership skill**	**Business functional skill**	**Interpersonal skill**	**Technical-oriented**	**Management-oriented**
Level 5	▪ File formats ▪ Integration interval	▪ System design	▪ Teamwork ▪ Independence and proactiveness	▪ IT awareness IT learning commitment ▪ Change willingness ▪ Hybrid skill	▪ Awareness of CSF	▪ Connectivity ▪ IT security management ▪ Data management	▪ IT project management
Level 4	▪ File formats ▪ Integration interval	▪ System design	▪ Teamwork ▪ Independence and proactiveness	▪ IT awareness IT learning commitment ▪ Change willingness ▪ Hybrid skill	▪ Awareness of CSF	▪ Connectivity ▪ IT security management ▪ Data management	▪ IT project management
Level 3	▪ File formats ▪ Integration interval	▪ System design	▪ Teamwork ▪ Independence and proactiveness	▪ IT awareness IT learning commitment ▪ Change willingness ▪ Hybrid skill	▪ Awareness of CSF	▪ Connectivity ▪ IT security management ▪ Data management	▪ IT project management
Level 2	▪ File formats ▪ Integration interval	▪ System design	▪ Teamwork ▪ Independence and proactiveness	▪ IT awareness IT learning commitment ▪ Change willingness ▪ Hybrid skill	▪ Awareness of CSF	▪ Connectivity ▪ IT security management ▪ Data management	▪ IT project management
Level 1	▪ File formats ▪ Integration interval	▪ System design	▪ Teamwork ▪ Independence and proactiveness	▪ IT awareness IT learning commitment ▪ Change willingness ▪ Hybrid skill	▪ Awareness of CSF	▪ Connectivity ▪ IT security management ▪ Data management	▪ IT project management

4.8 Evaluating the Preliminary ITIF Maturity Model through Case Studies

Once the initial ITIF Maturity Model is completed, it was then validated in order to ensure that the factors' maturity resulted from the literature analysis correspond to the purpose of the model – which is to assist construction organizations assessing their IT infrastructure performance in coping with the technological change by considering flexibility issue.

Previous researchers generally used qualitative assessment or statements to develop a maturity model, and may be supported by additional descriptive accounts and also by quantitative measures (Beecham, et al., 2005). When a holistic and in-depth investigation is needed, case study is an ideal methodology to be used (Yin, 2009). As opposed, an action research is used to study current practical situations by repetitive undertakings, suggest improvements, implement, and back again to a new study – this does not fit with the objectives, which is to penetrate deeper into the organization's history actions, current attempts, and future planning (Myers, 2008). Case studies is also well suited for many kinds of IT research, as the objects of study as contemporary phenomena, which are hard to study in isolation (Runeson & Host, 2009). As ITIF is an emerging topic, the concept is a relatively novel in Malaysia, therefore, an exploratory research approach is the most appropriate (Johnson, Leach, & Liu, 1999; Yin, 2009).

Case studies were carried out to test the ITIF criteria requirements based on the commonalities, for example in term of context factors, goals, roles, and key performance indicators. The key focus of conducting case study is to recognize the best practices of each of the identified ITIF success factors to define their levels of maturity.

This research used Stuart et al (2002)'s list of critical points of attention in the process of conducting case studies, as embraced by few researchers in conducting case research in the construction industry (Voordijk, Meijboom, & Haan, 2006). The points are (i) the goal of the research, (ii) research protocol, (iii) case selection, (iv) kind of data needed, (v) data analyses, and (vi) findings validation.

The goal of conducting case studies were to test the initial maturity model by making comparisons across the cases and looking for similarities and patterns of the construction organizations' maturity against the ITIF success factors; and the opportunity for the respondents to define their improvement areas. Consensus discussions determine a move for each factor from the lowest maturity level to a higher maturity level.

4.8.1 Case Selection

The selection of the case studies candidates was based on fulfillment of two criterion: The first criteria is type or organizations investigated, and the second one is the type of IT project selected as the sample of discussion. The target organizations, ranging from medium sized companies to very large multi-national construction companies, have existing IT systems and cover a wide range of IT application areas. They are all based in the Malaysia. It is also important to acknowledge that the data was collected from organizations whom were actively tackling IT implementation issues on a daily basis, therefore the accuracy and validity of data are high.

In order to capture a wider range of perspectives, IT leaders and team members from different departments and levels within each main participating organization were also interviewed. The key respondents involved in the interview sessions were:

(i) IT technical personnel (i.e system analysts, programmers, technicians)

(ii) Middle management (i.e the senior managers)

(iii) Top management (i.e Chief Information Officer); and

(iv) Representatives from the workgroups (i.e unit head, the users)

The IT projects selected during the case studies were a full success project or a partial success, by means that the entire project have met of its intended business objectives, or the system has met only few of its intended business objectives. The IT system was implemented in more than one version that represents rigidness in the earlier version and flexible in the latest version.

It is worth to note that it is difficult to determine the exact number of Malaysian construction organizations that have actively implemented IT. This is because there is no data readily available. Thus, this research suggests that the variety in company size, nature of business sector, type of IT application etc can limit sample bias. This is similar with approach that has been used by other researchers (Baddoo & Hall, 2001, 2003; Niazi, Wilson, & Zowghi, 2003).

Based on the above-mentioned criteria of case selection, 10 organizations were contacted for a request of participation, which was conducted via the electronic mail. Among these contacted organizations, only 3 of them responded, with 11 interviews were conducted; that include face-to-face interaction and telephone conversations. The

interview conversations were digitally recorded to ensure the consistency between data collection and data analysis. Each interview took between one to two hours per session, either individually or in a group depending on the availability of the respondents. The number of respondents involved in each case was varied from two to three persons, and the interviews were completed with multiple visits, ranging from two to three visits. The types of informants in the case studies are shown in Table 4.6.

Table 4.6: Case studies informants

Organization	Informant's Position	Informant Category
Organization Bina	IT Manager System Architect Network Engineer Chief Operating Officer Secretary	Middle Management / Technical Technical Technical Senior management The user
Organization Eko	IT Consultant 1 IT Consultant 2 Organization's administrator	Senior Management / Technical Senior Management / Technical The user
Organization Taraz	Head of IT Department System Engineer Quantity Surveyor	Senior Management / Technical Technical The user

4.8.2 Data Collection Protocol

Given the need for in-depth analysis and flexibility of IT system in an organization, semi-structured interviews were the main form of data collection, supplemented by the study of relevant documentation and internal reports. The semi-structured interviews were meant to gain more knowledge and the viewpoints of the informants about the IT project in a context of 'flexible IT infrastructure'. There are fourteen ITIF CSF that have been selected, and the organizations under investigation were assessed against those criteria, which consist of the initial model, as shown in Table 4.5.

(i) Semi-structured interviews

Section A focuses on the organization's profile and the type of IT project that was chosen by the respondents; Section B looks into the evidence for each

factors collected. The respondents were presented the elements and levels identified before, placed in a random list to allow the respondents to rank and order the level's definitions along a maturity path that needs to match with the presented elements. The information was critical to validate the levels.

(ii) Document and internal reports investigation

Documentary evidences were collected, such as Annual Report, minute meetings, system's Research and Development report, and system design documentations.

4.8.3 Data Collection Approaches and Analysis

(i) Phase 1 – Initial

The organization and IT system assessment began with obtaining overall information about the respective organization. The organizations' official websites were browsed to get early information, and then was further assessed through the interview sessions. Useful information about the organization obtained at this stage was as followings:

- The background of the organization, i.e. history of establishment;
- Nature of business, i.e. specialization and annual turnover;
- People working in the organization that includes organization structure, number of staffs, work groups, roles and responsibilities.

The initial assessment was undertaken with the IT Department to explain the concepts of the model and to identify the IT system within the organization

that is appropriate for validating the model. Then, suitable respondents were identified for interviews, which were carried out individually and/or in a group. The discussion sessions followed semi-structured in interviews and documentary evidence collected and reviewed.

(ii) Phase 2 - Identification of IT system

The assessment continued with an investigation on the IT system. It begins with the review of the type of IT system and its intended business objectives of development, number of expected users, and current status of the system. Then, the sequence of events of respective IT system was investigated - this includes the success and failure timeline throughout the development process, and decision that have made.

(iii) Phase 3 – Determination of the maturity level

The current maturity level for the respective IT system was identified based on reference to the initial model. This question was asked to different respondents. Further details focused on the issues within the *current* level of maturity. The next step of assessment focused on the organizational situation *prior to* implementation of current status of the respected IT system. For example, say the current level of maturity of an organization was at Level 3, the discussion will focus on how the organization has progressed at Level 1, 2, and 3. By using the initial model as a guideline, the respondents then identify which level they want to be in the *future*. The findings indicate how the organizations have progressed and what they would achieve. As a result, the initial model was modified.

The validity of case studies research was done by checking the accuracy of the findings (Creswell, 2009). The reliability of this method was indicated by a consistent approach that was done across different informants (Gibbs, 2007). In this context, Yin (2009) suggests that the procedures of the case studies need to be documented, as many steps as possible. Transcripts were checked to make sure that they do not contain obvious mistakes made during transcription.

(iv) Phase 4 – Model refinement

Analysis of information acquired during the case studies (for examples, views, experience, and knowledge) led to the initial model. The Preliminary ITIF Maturity Model is proposed after extraction, adoption, combination, and modification of the initial model in line with the *life* situation and practices in the construction industry. The initial model was modified based on feedback received during the case studies.

(v) Phase 5 – Report delivery

The draft results were delivered to the participated organizations, upon request, in the final step of data collection approach.

4.9 Conclusion

This chapter started with a discussion about methodologies used to develop a maturity model found in literature, which are a combination of quantitative and qualitative, or a as single method of quantitative or qualitative. Based on the data availability, this research adopts two methods – quantitatively and qualitatively that involves

questionnaire in the first part of CSF identification, and case studies in the later part for maturity model development. The chapter explains the details of the overall research process and research design such as questionnaire development, target respondents, the procedure that was used to undertaking this research, and analysis. The next chapter elaborates on the statistical analysis procedures that were employed and the development process of maturity model.

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