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THESIS

KNOWLEDGE TRANSFER FRAMEWORK FOR PROCESS PLANT CONSTRUCTION PROJECT IN TRANSITION PHASE

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A Thesis Submitted in Partial Fulfillment of
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This study has two major purposes: (1) to investigate the relationship between the risk index (RI) of each risk type and the knowledge element (KE) (2) to build the knowledge transfer framework for process plant construction project in order to minimize the risk. These two purposes aim to achieve the best performance of the project, which will lead a company to be able to compete in the market. In studying the relationship of the RI and the KE, the survey was conducted in Thailand in general organization with negative situation which could be incurred in process plant construction project. The survey was conducted in Thailand totally 71 surveys, the result has shown the KE of "people" was affecting to most of the RI both directly and indirectly. The results provide some support for KE weighted for the effort required by KM gurus that 10% of technology, 20% process, 70% people. The results were also validated by literature review for the cause of construction project factors of failures. Not only the element of "people" as the main factors was validated, it also has shown that the element of "people" and "process" are inseparable.

With the result of the first purpose, the framework to transfer the knowledge in process plant construction project from the construction phase to operation phase was built based on the 4 modes knowledge transfer of Nonaka and the activities that acted as a medium to transfer knowledge. The framework was parallel verified by interviewing of the experienced person. Finally, the framework indicates the timeframe and the mode of knowledge transfer to be focused. This information will be useful for management decision making for improvement.

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Pornpunsa Wuttisanwattana
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF ABBREVIATIONS

API	=	American Petroleum Institute
ASTM	=	American Society for Testing and Materials
ASME	=	American Society of Mechanical Engineers
EOP	=	Emergency Operation Plan
EFQM	=	European Foundation for Quality Management
KE	=	Knowledge Element
KM	=	Knowledge Management
RI	=	Risk Index
RM	=	Risk Management
SOP	=	Standard Operation Plan

KNOWLEDGE TRANSFER FRAMEWORK FOR PROCESS PLANT CONSTRUCTION PROJECT IN TRANSITION PHASE

INTRODUCTION

In the world of economic fluctuation, the economy is changing turbulently. A construction firm needs to improve to survive in the market. An organization is facing many types of problem at each project stage, which can be categorized by risk type. Each of them is trying to avoid their risky stage, which it could lead them out of the business. Risk management (RM) was found as a key factor within an organization thanks to its capability to minimize the probability and impact of threats and capture the opportunities that could occur during the project life cycle. Knowledge management (KM) processes as well have turned out to become a strategic resource for the organizations with its great influence on reducing organizational risk. (Alhawari *et al*., 2012).

In engineering design work, it consists of seeking, modifying, and translating of the information. And a discipline engineer sometimes has to work on the information that is not related to his discipline (Lombard & Yesilbas, 2005). Then later, loss of project resources, including information, is incurred when the confusion among "Project Team's work" and "Responsibilities" is not clearly interpreted. KM during the design and construction activities can prevent this problem. (Bektas *et al*., 2008)

The importance of the information is prominent when the crisis happens in the project. The crisis can be the accidence during construction or operation. The evidence showing that the plant was built based on the acceptable engineering design is required. The financial crisis of the project which was arose from the conflict between owner and contractor requires the full information in every aspect, including every detail in construction. Wining the case in the court means the survival of the organization. In the past few years, in Thailand, the severe accidents were occurred with higher frequency. May 2012 in petrochemical industrial estate area, the toluene tank exploded caused 5 deaths and more than 90 injured. The accident was incurred during the shutdown period when there were more than one contractors involved in the area. The information of the operating plant including the information of the every chemicals in the area was not properly transfer to each parties especially who are not on the same safety standard. These contractors were qualified their safety standard, however, working in specific areas and specific process, learning the new experiences is always needed. (Jamorndusit, 2012). In this case it is seen that sharing the information is very importance. After the case was incurred, each contractor including the owner had to show all of the evidences as much as they can provide to defense themselves from guilty which it could lead the company to lose their reliability and at last the market.

As an organization needs to be competitive by becoming more innovative and introducing new ideas, managing their experiences is needed. (Alhawari et al., 2012). The company is simply defined as a successful firm for high profit or good product. It is known that profit and product are important and both need to compete in the market. To get this success, the company needs to be learning continuously to adapt to competitive environment. (Owen, 1991). In January 2014, ThyssenKrupp, a famous worldwide process plant construction company, said in January 2014, *"For us, innovations and technical progress are key factors in managing global growth and using finite resources in a sustainable way".* It is seen obviously that they are concerned of this matter. (ThyssenKrupp, 2014)

The global connection has forces the organization to be "Global Organization". Global organization has the world as their market place and of course that global organization is a global operation. Global operation will relate to global human resource, global capital, technology, raw material and facilities. (Marquardt M. J., 2002) . Global process plant construction companies have their branch over the world to exploit the market share. Additionally, the nature of this industry is the needs of relation among both customers and vendors. Hence, setting up the local office is the must. Worley Parson — another leading company in process plant construction industry has 157 offices in 46 countries and also the other leading companies have their office in every continent. (WorleyParsons, 2014)

The second significant force is "Technology", internet is the tool to make the global market touchable. It is seen obviously that the today the global company cannot run without computer for 30 seconds. The best computer and software today, it will be old- fashioned one in the few years. Technology with advancement and Innovation is strongly required by the work (Marquardt, 2002). Internet is one of a good example shown that how technology has changed our lives. The internet can build the world business.

With the globalization and technology, employees do not need to be in the office. Most company provides laptop for their employee to work from any places through internet. Employees can also work closely to customers. To improve the company performance the routines work are reorganized, redesigned and/or even reengineered. The company trend to have minimal permanent employee by having temporary in high position and permanent in lower position. Hence the third significant force is to have organization structure transformation.

In service industry, it is seen obviously that customers can complain about the service through web site. Customer's behavior is recorded when they go shopping or get some services. Their requirement is another force for the organizations have to be learning. The customer requirement will force a company to have new performance, standards in quality, variety, customization, innovation time. Additionally, Short product life cycle is also forcing the company to have global partnership and alliances. Knowledge as one the main resource for a company (Johnston, 1991) to get success, is becoming higher important than financial resource as knowledge is the base of company traditions, culture, technology, operation, system, procedure. Hence, knowledge is one of the organization assets. Knowledge patent important is increasing in every company. Process, Management skill, technology, customers and suppliers info or even the old-fashioned experiences, this knowledge can creates the advantage (Marquardt, 2002).

The technology limitation of process plant construction industry depends on the technology of the product also called process technology. However, In a project management points of view, all of company is trying to be expertized in system integration, reliable procurement, and well-known among the suppliers. Therefore, the main contractor company has become keen in studying and investing in new technology, both in process technology and resource technology (Marquardt, 2002).

With globalization, the workers in each level of a company will be required more and as a knowledge work. Today, in manufacturing operation, the workers are expected to be able to trouble shoot when some unexpected cases is incurred, said that our society is moving from industrial era to knowledge era. This will also force an organization to be learning (Marquardt, 2002).

When the organization become global, the workforce needs to be more diverse and mobile a company begins to have human resources from other countries. The gap between labor's supply and demand is forcing the worker to move. (Johnston, 1991) There are forces for worker to mobilize such as relocation, competition, improved productivity, and standardization. For Relocation is seen in the new generation who is young and higher education. Those were born in the in era that the mother homeland is not anymore significant; seeking a better opportunity is their dream. While the labor-short country is seeking the opportunity to improve its own productivity, both skilled and unskilled labor are required. Those young generations who are higher educated and experienced can satisfy this labor's demand. While people living in those countries also need to compete in this labor's demand. They need to improve their own education and experiences in order to compete with foreigners. At the same time, a gap between developed country and developing country is seen as a force of "Global Workforce". The developed country has rapid growth in service industry while some developing country can produce educated people faster than their economy. This will force them to immigrate.

The last force is when everything keeps changing rapidly when certainty is uncertainty. The seven forces mentioned above will have its trend changed very fast. The organization need to be stimulated to have their own KM in order to survive in a few years (Marquardt, 2002).Process plant is also known as a plant that aims to produce a product via the chemical/biological reaction or separation. This type of plant is normally built in the large scale. The process plant industry has a broad range of products including chemical plant, polymer plant, pharmaceutical, some of food and beverage, power plant, oil refinery plant or other refineries, natural gas processing, biochemical plant, water/wastewater treatment. The process plant needs specialized equipment/instrument, units, and technology in the manufacturing process. These plants produce the product that is needed daily. Its product is the fundamental in the both industry and household. Hence, growing of economics affects directly to the process plant construction business (Wikipedia, 2013).

In the view of the construction industry, process plant construction can be executed simply in the case of it is duplicated design from the existing unit, but to differentiate the process plant construction process to the general field of engineering, the following factors are addressed; The unique design, Equipment Variety, Specialist Requirement, Hazardous Operation, Technology Growth, Project Schedule.

The unique design is always there, even the plant has the same technology or duplicated designed, still each plant is inevitably designed to optimize its application based on its circumstances, such as feedstock, water source, capacity, environment impact and etc. Together with the unique design, the variety of the equipment is always there. All equipment in the plant design must be in line with the operational characteristics, its dimension, and also standard requirement such as American Society for Testing and Materials (ASTM), American Society of Mechanical Engineers (ASME), and American Petroleum Institute (API). There can be more than a thousand items in the middle plant size, which each in items has its own specification. Even it was the same equipment; the nature of its feedstock could make its specification different.

Hence, in process plant construction, the specialist with experiences is a must. Specialists or who is generally called a discipline engineer are required to produce coordinated activities in design and also in construction project management. Not only is his qualification of specific knowledge, but also he needs to be with, full with service mind due to the nature of construction project that the work is always in a rush.

Process plant is normally for petrochemicals or chemical production industry, which properly releasing hazardous waste during its operation. The waste can be gases, liquids or chemicals contaminated trash. Therefore, the safe operating practices must be embedded into the operation team member prior to the commissioning process. It is known as “Standard Operation Plan” (SOP) and “Emergency Operation Plan” (EOP). The training will have to be held again and again to have the operators ready for any unexpected case. Even the experienced operators still have to attend every needed training course due to the technology growth. Whatever those operators are experienced for may not enough to run another plant even it is the plant of the same product. With the same product, each plant can be different in a single unit or the whole plant due to the better technology is replaced which it is seen as its uniqueness.

It is easily to expedite the project by providing more resources. Somehow, to have the schedule shorten in the process plant construction, lacking of resources is not always the reasons of the delay. Hence, it cannot be executed by adding more resources. The project sequences are specific. However, the project is possible to be expedited by changing the schedule logic, which can cost or be at risk. Hence changing the logic must be very careful, considered and balanced against the benefits. The project manager will properly be responsible for this. Not only does the time frame that the effect of the project, it also affects its reputation. That is the reason why companies pay the incentive for early completion. Normally, the incentive is mentioned in the contract based on the simply sense that the earlier the plant can run, the faster the money return. Especially, on the maintenance or plant extension project, which some part of the operating plant must be shut down.

The construction project is known as “On Site Execution”. It is a fixed layout, manufacturing. Every related resource must be on site, including some needed support team such as administration, document control. This can be viewed as a new workplace setup. It can be temporary during the construction, but it will be permanent later when the operational phase comes (Watermeyer, 2002).

Generally, process plant construction project progress could be ahead of its schedule in the case of the key person at the beginning phase used to work together. Some investor has just gained the authority to extend the capacity of their plant. In this case, building a plant will be faster and there will be fewer problems. On the other hand, building a new plant which its pioneer team has no experiences of working together, the risks could be raised due to new setting up in each work function. This pointed out that the experience is the key of process plant construction project success.

In the view of KM, it is seen that the experience which is known as the tacit knowledge must be shared among the team. Any miscommunication or lacking of knowledge sharing properly causes a rework. A rework is the main reason of the cost overrun and project delay (BektaŞ *et al*., 2010). The signal of this kind of problem can be misunderstood in the project scope of work, misunderstanding in concept design, miscommunication between concept design and engineering design, shortage of process information etc. For the process plant construction project, the project sequence concept follows the step in figure 1.

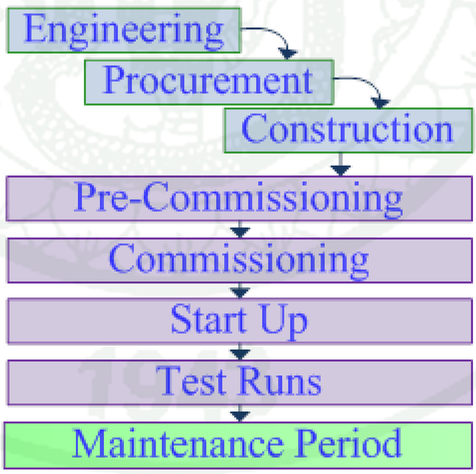

Figure 1 General Practice in Process Plant Construction Project

Source: Marsh and McLennan (2012)

In figure 1, it shows the process plant construction sequences. For the technical information, it starts from the engineering team, the construction team and at last the maintenance team which is in the operation phase. The possibility of information loss during the work transfer between team is captured.

Worldwide process plant construction industry, each organization is trying to overcome each difficulty and forces by keeping the organization itself learning to be the “Learning organization” which is an ideal organization where the organization can sustain their quality and produce the innovation. In this status, the organization will be able to survive in the market. To be the learning organization, the organization need to be learning called “the organizational learning”. This strategy was defined by the Argyris and Schon in 1978 that the organizational learning is the process of detection and correction of errors. During the process, the individual acts as agents to deliver the knowledge. In 2001, Smith defined the organizational learning as the ability of an organization to collect and understanding from experiences through experimentation, observation, analysis, and willingness to examine both successes and failures. This can be concluded that the individual learning ability is the key concept of the organizational learning (Caldwell, 2005).

Problem Statement

Organization management has mostly looked over the policy and strategy because of lacking of understanding of the word of policy and strategy importance. Many companies understand that the policy and strategy is the rule that everyone needs to follow. Their policy and strategy do not stimulate their people to create and share the knowledge but to frame their ideas. The problems are captured after the policy and strategy has been launched or even worse when the management is not able to capture this kind of problems. Management in any organization is not recognized what they need at the beginning of the project start-up thanks to it is not directly profitable

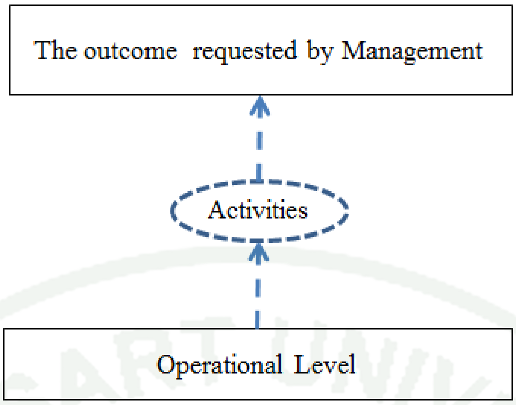

Figure 2 Activities Created Process

In figure 2, generally in owner organization, the organization management has their people done the work to reach their target without guiding whether the management themselves is able to guide or not. The management only knows what they need for the organizational performance. They did not realize the method to have the outcome which created by staffs may lead to worse performance. The management presently is facing a problem that they are not able to identify how the doing activities affect to the organizational performance. The activities are mostly created by their staff freely. Less of management interest in the detail of setting up the activities mostly only focuses on only the results. By then it would be too late to prevent the problem due to they are not realized if there could be any risks while some needed activities is ignored or some activities result negatively.

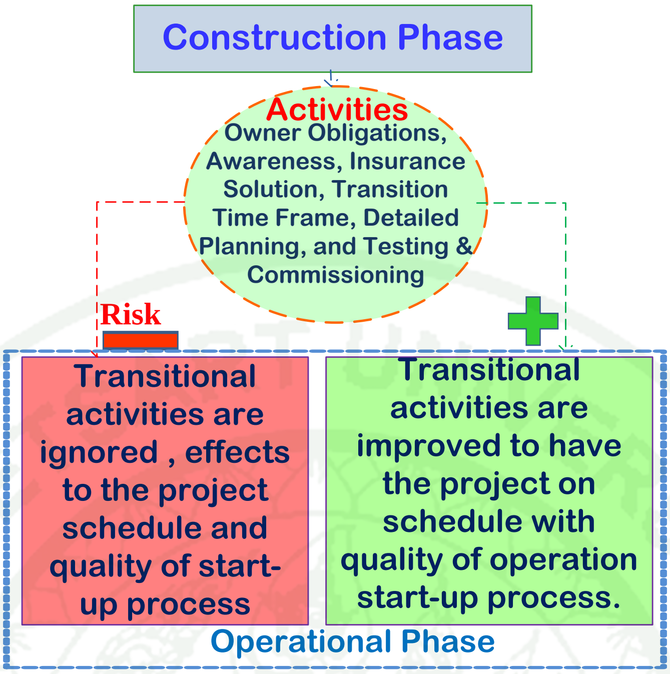

Figure 3 Activities Impact on Organizational Performance

In figure 3, during the process to achieve the outcome, the activities itself acts as the media for knowledge transfer. The knowledge is transferred through the activities during a transition process. The activities created to achieve the operation need possibly enhance the risks in an organization which these risks can obstruct the whole transition process from construction to operation.

And the motivation of individuals is not enhanced; on the other hand it is framed or limited. While, to be able to survive in the market, the organization do need each individuals creativity and transfer and embed into the organization.

OBJECTIVES

The purpose of this paper is to improve the knowl edge transfer performance by building the knowledge management framework for the process plant construction during the transition phase from construction phase to operation phase.

Research Scope

1) The study assesses the root cause of the activities which will lead to have the negative performance in organization from questionnaire. The questionnaire was designed by listing out the activities which can lead to each type of risks in general from many industries randomly, to indicate the relationship of the cause with the knowledge elements. Then the result will be validated by literature review of the failure root cause from both Thailand and the other countries construction industry.

2) To build the knowledge transfer framework, the knowledge transfer related activities from construction to operation are listed and investigated the grounded of each activity in the view of knowledge transfer. This framework will be verified by interviewing of the experts and literature surveys of the factors of knowledge transfer.

LITERATURES REVIEW

Recently in 2011, at the time that Spain was facing the economic crisis. The research of Strategic knowledge management, innovation and performance was studied by Carolina López y Ángel L. Merno Cerdan to find the knowledge management (KM) strategic consequences on firm's innovation and corporate performance. This research applied the codification and personalization on KM strategy which is adopted from Hansen et al.(1999); Alvesson and Kerreman (2001); Hansen and Haas (2001); Flangin (2003); Inuzuka and Nakamori (2004). This research studied based on how the strategic KM i.e. codification and personalization effect on the innovation and organization performance. The research suggested that KM strategy impact on organizational performance should be studied in different dimension of three dimension were chosen 1.) Financial performance 2.) Process performance 3.) Internal performance. The surveys were conducted among 310 Spanish companies to test the model in figure 1. The result shown that both codification and personalization impact on innovation and organization performance. However, KM strategic impacts directly more on innovation, efficient and effective (Nicolás and Cerdán, 2011).

KM was explored based on RM for the information technology projects by Samer Alhawari, Louay Karadsheh, Amine Nehari Talet, and Ebrahim Mansour in the United State. This research studied the relation of RM and knowledge management (KM) to provide a conceptual framework. This framework is called the Knowledge-Based Risk Management subjected to improve its effectiveness and the success probability. This research collected the literature and re-interpret to highlight on RM integration for IT projects. This research merged KM and RM components and the following process was given which are ; Knowledge Essential, Knowledge based Risk Capture, Knowledge based Risk discovery, Knowledge-Based Risk Examination, Knowledge-Based Risk Sharing, Knowledge-Based Risk Evaluation, Knowledge-Based Risk Repository, Knowledge-Based Risk Education. This research provides clearly the understanding of RM and KM process which shows the interrelationship of important factors.

Nonaka as a famous professional in KM field has grouped the knowledge into two main types; First type is "Tacit Knowledge". Tacit knowledge is difficult to be expressed in words it is experienced base knowledge thanks to its specific context. The examples of tacit knowledge are cognitive skills, intuition, images, benefits and metal model, know-how. The second type is called "Explicit knowledge". The explicit knowledge is understandable in words. The examples of explicit knowledge are manual, work instruction, procedure, information database. These two forms of knowledge can be converted into each other; it is called Nonaka's four modes of knowledge conversion. (Nonaka, 1994).

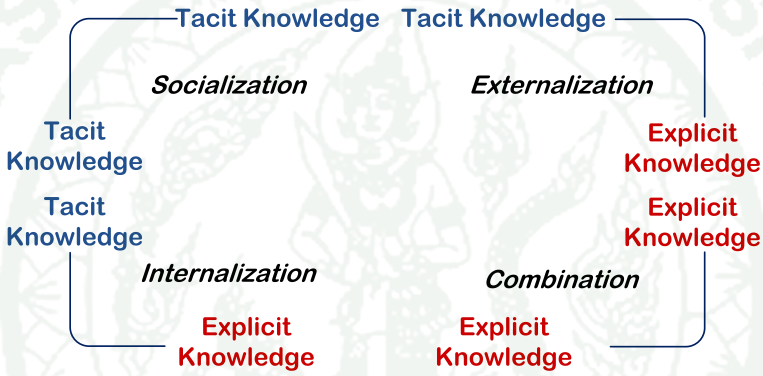

Figure 4 Nonaka's Four Modes of Knowledge Conversion

Source: Nonaka (1994)

In figure 4, there are 4 main conversion processes which is conversion of both tacit and explicit. Socialization is the conversion process between tacit and tacit i.e. transferring the experiences of one person to another person. The conversion is also captured by interaction with customers, suppliers, and plant or site survey. It does not matter to have this conversion incurred in the organization. The main idea of socialization is experience's sharing which is individually taken place.

Externalization is the conversion process that converse the tacit knowledge in to explicit knowledge. Externalization can take place internally and externally. For internal organization, the tacit form can be ideas or images or in other words it is one's own tacit knowledge articulation. For external organization, the tacit knowledge form can be the knowledge from customers, suppliers, or in other words, it is the tacit knowledge of other's translation into an explicit form which is easily understandable.

One's explicit form can be transformed to other explicit form through the process called "combination". The explicit knowledge will be conveyed by document, email or database including meeting, training. In this conversion stage, the information technology is the most helpful. The knowledge can be transformed among group with an organization quickly. The internalization can be seen as an experiment in order to actualize the explicit knowledge or actual doing and simulation. It could be explained that internalization is the transfer process from group to individual. Four mode conversion model of Nonaka is defined as a spiral process. The model is a clockwise spiral that will provide more understanding and deeper knowledge.

In the beginning of 1992, the European Foundation for the Quality Management (EFQM) model was introduced to assess internally for the European Quality Award (Ho, 1995). Then, the EFQM became famous in many organizations as a tool to improve management system. EFQM model is known as a self-assessment framework to identify the strength and also the areas which are needed to improve by focusing on the activities of an organization (Harrington, 1991).

In figure 5, the EFQM model is based on five enablers and four results. The enablers can be defined to be what activities an organization does and the results can be defined to be what an organization achieves. In other words, the enabler is the cause of the results and the feedback of the results is used to improve the enabler. Enabler and results are weighted equally at 50 percent. However, each criterion has different weight (Michalska, 2008).

EFQM model explained that the excellent results depend on performance, society, people, and customers. And these results are achieved by leadership policy and strategy, through four enablers i.e. people, partnership, resource, and process (Dudek-Burlikowska and Szewieczek, 2007). Beginning with one enabler which is internal and not rely on an individual i.e. Policy and Strategy. The policy and strategy is known as a very first important issue to recognize.

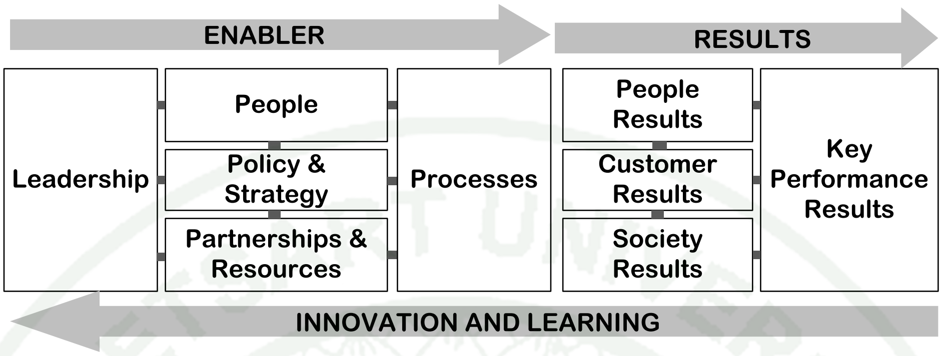

Figure 5 EFQM the Excellence Model

Source: Michalska (2008)

Not so many organizations are able to make it tangible. Policy and strategy is easily defined as the method of mission and vision implementation. Policy and strategy in an organization should be set up to stimulate but not control in order to have an organization encouraged to learn by providing a strategic directive. Policy and strategy needs to ensure also that there are mechanisms of lessons transfer, this will make people to see it clearly that their capability is higher than what they have done and they should not be satisfied with their present result.

Knowledge management concept has three key elements which are people, process, and technology. These three key elements are always come together and are impacted mostly by policy and strategy to some degree. Hence, the policy and strategy provider need to be careful in consideration to any strategy implementation. Most organizations are failed in holistic approach for strategic implementation (Bhatt, 2000).

Figure 6 illustrated the weight of knowledge elements differently on these three elements. In total effort, the technology is 10%, Process is 20%, and people are 70%. The technology is tangible and easiest to implement. However, only when people realize the benefits, the technology and process will be useful (Bhatt, 2000).

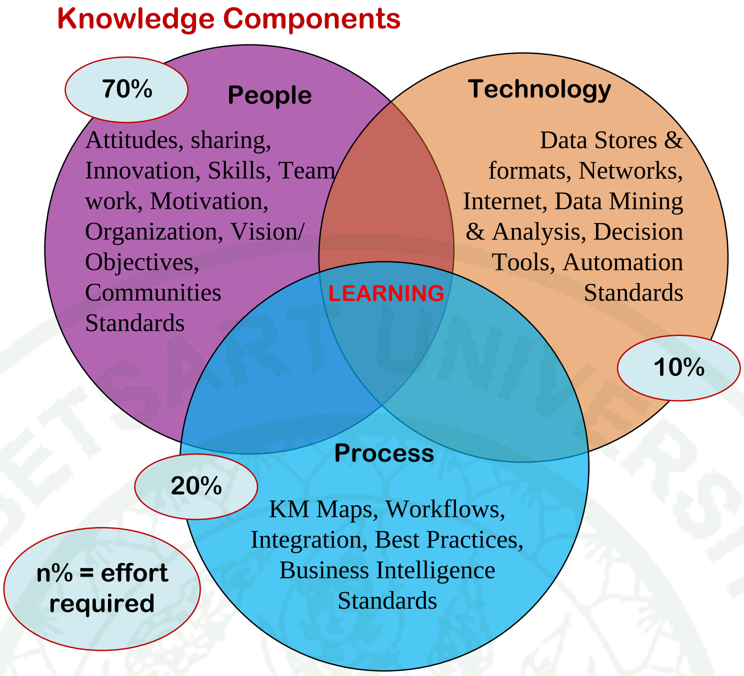

Figure 6 Knowledge management Components and sub-elements

Source: Bhatt (2000)

Research Contributions

This research provides a general overview of the purpose as follows:

1) Identifying the activities of an organization will result in the direction to develop the organization in the term of knowledge components for operational level where the outcome is produced. Strategic management will be able to indicate their activities systematically to gain the ability of knowledge management. The development of knowledge management in an organization will enhance the organization to be competitive.

2) Understanding of the knowledge key element ratio in an organization which may affect to the tacit knowledge transfer process in conversion model of Nonaka, the tacit knowledge in an organization will be collected and installed with the better knowledge management process. And this will enhance the organization to be competitive.

MATERIALS AND METHODS

This chapter provides an overview on the research methodology including the data collection, analysis approaches, and concepts used to test applicability of the models.

Materials

The material used is divided into two main groups:

1. Hardware

    A personal computer, CPU core i5, Ram4GB is used to collect the raw data and process for the statistical result.

2. Software

    The Microsoft excel is used to collect data and create table for this research and questionnaire

    SPSS version 17.0,for windows , is used to analyze the statistical data and to create the model

    Microsoft word is used to create this research document and a part of questionnaire.

Methods

This chapter provides an overview of the research methodology that follows the flow chart in figure 7.

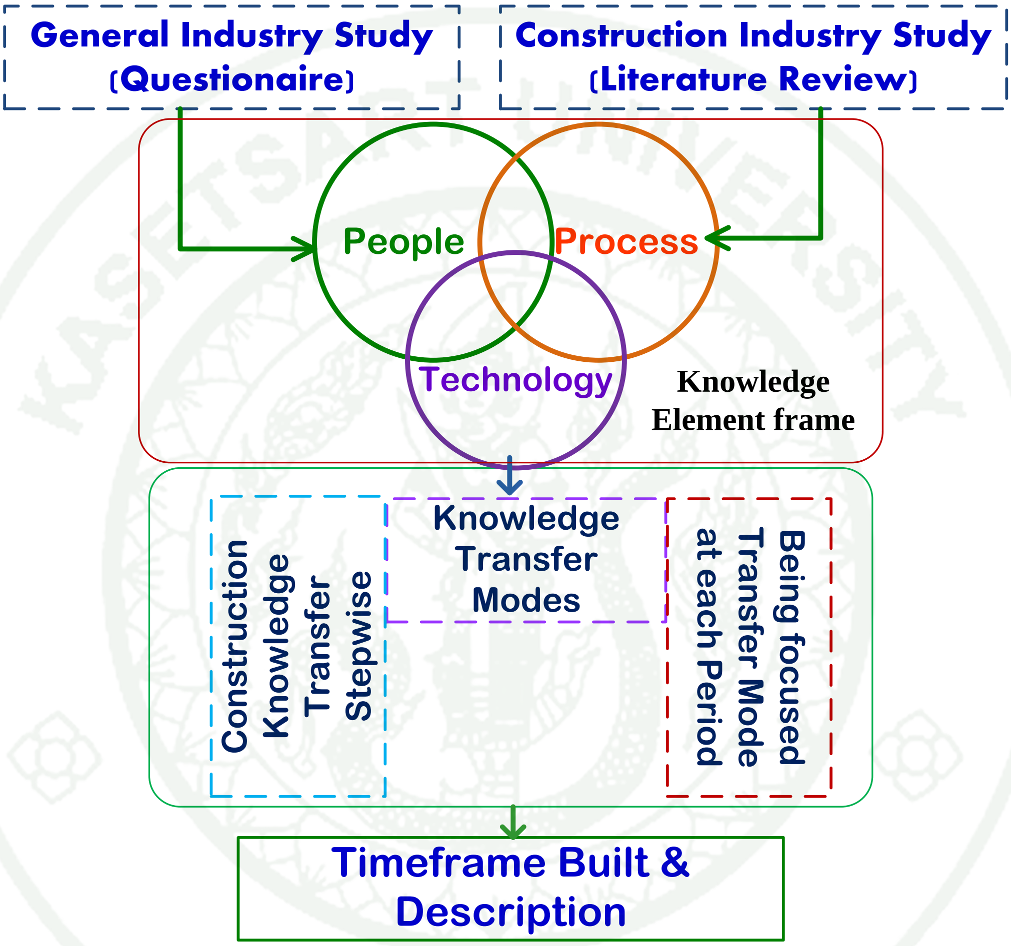

Figure 7 Researches Conceptual Methodology

1. Literature Review and Survey – General Industrial Study

This research began the fact of the knowledge management is ignored during the process plant construction project which there are many knowledge and experiences that need to be managed. And ignoring of knowledge management can also lead to some risky stage of the project. Therefore, the related literatures were reviewed which are risk management and knowledge management to provide the questionnaire. The questions had prepared the circumstances that would lead the organization to the risky state for each risk type and each circumstance is only the circumstances that could be incurred in construction project industrial. From the literature review, it shows that the main effort that is needed for the knowledge transfer is the KE of people. In findings the root cause of the problems the questionnaire was applied. A research from India has shown the major barriers to complete the project and these barriers were grouped based the job function in the project (VYAS, 2013). And another literature is from Egypt were the causes of delay were grouped into the responsibility party (Aziz, 2013). The factors from these two literatures were categorized into the risk types. There are totally 41 circumstances for 8 risk types. The survey intended to address the relation between the risk of each negative situation and the KE which are people, process and technology. The questions of each circumstance were listed to find the severity of the circumstances which the severity was defined as the product of the circumstance frequency and criticality. And the average severity of each risk type is called the "Risk Index" (RI).

$$RI = \frac{\sum_{i=1}^{N}(C \; x \; F)_i}{N} \qquad \ldots(1)$$

Where; C is Criticality

F is Frequency

N is the total number of the answered question

Due to the nature of process plant construction industry that it is temporary organization. Most of people in this field do not get used to organization management. However, they do know which organization they are comfort to work with. Hence, the survey was conducted randomly to many types of businesses. Then analyzing of the relation between RI and the knowledge element was studied by applying chi-square.

2. Chi-Square test of association

Chi-square was a statistic method, used for the test of independence between Risk index of each risk type – independence variables and knowledge element – dependence variables.

Dependent Variables are;

RI_i = Risk Index of Each *i*;

Where *i* is 7 Risk types – Human Capital, Strategy, Reputation, IT, Finance, Market, Natural Hazard

Independent Variables are;

X_j = Type of Knowledge Elements

Where *j* is 3 knowledge elements – People, Process, Technology

The hypotheses were stated below;

H_0 : RI_i is independent from X_j

H_1 : RI_i is dependent to X_j

Where H_0 is the Null Hypothesis and H1 is the alternative hypothesis. Hence, there were totally 21 hypotheses between the RI versus the KE. If H_1 is accepted that is the two variables are related. The level of dependence between the pair of variables can be determined by using standard Chi-Square equation;

$$X^2 = \sum\sum\frac{(O_{ij}-E_{ij})^2}{E_{ij}} \quad \ldots(2)$$

Where *i* and *j* index are the rows and columns of the table. The resulting test statistic from the formula on the left is approximately distributed as X^2 on $(r - 1)(c - 1)$ degrees of freedom. The tests were determined at 95% confidence or at the p-Value less than 0.05.

3. Result Validations

After the each element was identified its effect to the risk, to validate the result for the process plant construction industry, 10 literatures which show the project factors were reviewed. 3 researches were studied for the factor in a construction project in Thailand in 1996, 2004 and 2011. And the rest are mostly from Middle East and south East Asia.

Table 1 List of Literatures for Result Validation

Country	Year of Research	Topic	Number of Factors
Thailand	1996	Construction delays in a fast growing economy: comparing Thailand with others (Ogunlana, Promkuntong, and Jearkjirm, 1996)	26
Thailand	2004	Critical factors influencing construction productivity in Thailand (Makulsawatudom and Emsley, 2004)	23
Saudi Arabia	2005	Causes of delay in large construction projects (Assaf and Al-Hejji, 2006)	73
Malaysia	2006	Causes and effects of delays in Malaysian construction industry (Sambasivan & Soon, 2007)	28
Ghana	2010	Delays in Building Construction Projects in Ghana (Fugar and Agyakwah, 2010)	32
Thailand	2011	Factors Affecting the productivity of the construction Industry in Thailand: the project managers perception (Makulsawatudom, Emsley , and Sinhawanarong, 2001)	23

Table 1 (Continued)

Country	Year of Research	Topic	Number of Factors
Tanzania	2012	Causes and effects of delays and disruptions in construction projects in Tanzania (Kikwasi, 2012)	21
Egypt	2013	Ranking of delay factors in construction projects (Aziz, 2013)	99
India	2013	Causes of Delay in Project Construction in Developing Countries (VYAS, 2013)	85
		Total	453

Once the relationship between each risk types and KE were determined, reviewing of the literatures for construction project industrial was used to validate the results of the relation. The selected literatures are the research that studied in the importance of the construction project failure or success factors. All of the factors were categorized into the KEs. This result can validate the cause of failure in construction project can also be determined based on general study when it was grouped into KEs.

The chosen 10 researches in the table 3 were taken out the factors and grouped each factor into the KEs based on the following table;

Table 2 Category Keyword for Validation

No	Specific Causes in Construction Industry	People	Process	Tech.
1	**Delay by Specific Decision Making**– Inspectors, 3rd Party, Construction Manager, Project Manager, Owner, Approval, Consultant	✓		
2	**Individual** – Ability, Person, Capability, Attitude, Personal Conflict, Culture, nationality, Bureaucracy, Motivation, Rigidity among them, Teamwork, Understanding of individual profile, Incentive, Bonus	✓		

Table 2 (Continued)

No	Specific Causes in Construction Industry	People	Process	Tech.
13	**Poor use of software** – advanced engineering design, documentation, Records, No invest for software, No ability to use software	✓		
4	**Design Drawing/Specification Error or changes** – Inadequate info for construction, mistaken in calculation,	✓	✓	
5	**Improper Project Preparation** – Bidding, Improper Contract Clauses, Project Management Procedure, Legal Disputes among parties , Change orders or Variation order, Insufficient data collection and survey, Vendor/Contractor Evaluation , Poor cash flow, Poor Credit, Unqualified person/team/Contractor, Organization Chart, poor organization culture	✓	✓	
6	**Daily Tasks/ Site Management** – Time Management, Delivery, Site permit/Clearance, Delivery, Mobilization, Poor quality/Damage of Material/ Equipment, Daily discussion, Productivity, resource utilization. Site management, Site Layout, Site Condition, Supervision, Theft, Safety, Financial control on site, Payment Delay, Approval method, purchasing method, Inventory Control, Loss time	✓	✓	
7	**Poor Communication** – Among parties or Workers, poor coordination, poor socialization,	✓	✓	✓
8	**Poor Project Management** – Inappropriate organizational structure, Working hours, Overtime working, Decision Making, Instruction Delay, compensation issues, Contract Management, Procurement Process, Master Schedule, Lack of Resources	✓	✓	✓
9	**Underestimated Cost** – Design, Site Survey, ground Condition, time estimation, Bidding, feasibility study	✓	✓	✓

Each factor was measured in percentage and applied in the KE frame of Dilip Bhatt.

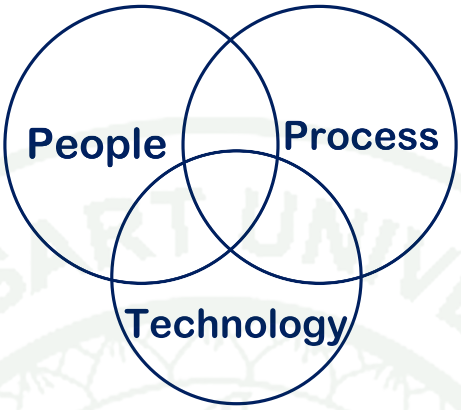

Figure 8 Knowledge Element Frame

Source: Bhatt (2000)

In Figure 8, the factors of project failures will be categorized into knowledge element frame based the keyword in table 2. The validated result was applied to build the framework for the project transition phase which the knowledge are also transformed and transferred during the whole project. The framework built to address the knowledge lost problem in an organization of process plant construction industry.

4. Building the framework and Framework Verification

The information from surveying was used to build the framework for managing the knowledge during the construction project together with verification by interview of experienced person based on grounded theory. Three open questions were used as the topic to discuss;

- How does the transition state between construction and operation look like?
- How does the successful transition process like?
- What could be the factors to fail the transition?

In the first question, the question aimed to have the interviewees interpreted the construction project transition process based on their own experience. In details, the minor questions were also conducted to gain more views such as “how/when does the transition process get started”, “Which are the related process”, “Who is the responsible person to start transition”, “Are there any specific theory/method/practice related in the transition process”, “Do all the process related document need to be complete before the transition occur”. For the second question, it aims to extend the understanding of the transition successful indicator. This question could also provide the detail of when the transition process is complete and how is the activity during the process effect the organization. The third question aims to understand problems which could be incurred during the transition process. The related question that could be conducted are “At which process that the transition has the possibility to fail”, “What could be the tool to prevent the transition failure”

The framework and the interviewing were processing parallel. Adjusting the framework during the interview based on the grounded theory which the experiences can be adopted into a framework. The built framework is final verified by literature review of the knowledge transfer difficulties.

RESULTS AND DISCUSSION

Results

This part presents the research's result that consist of three parts based on the research steps following;

1. Survey of general industrial study

To study the relationship between the KE and the RI that could incur in process plant construction process industry. The results of each risk types are determined in table 3.

Table 3 P-Value of Hypotheses

Risk Type	People	Process	Technology
Human Capital	0.747	0.016	0.23
Strategy	0.014	0.131	0.478
Regulation	0.111	0.083	0.200
Reputation	0.618	0.056	0.242
IT	0.01	0.597	0.501
Market	0.035	0.026	0.091
Finance	0.178	0.625	0.146
Natural Hazard	0.031	0.302	0.64

Table 3 shows the p-Value of each hypotheses. These hypotheses were tested at the 95% confidence level. The relationship is related when the p-value is less than the significant level of 0.05. From the table 3, the p-value shown the RI was influenced by the KE is summarized in the table 4.

In table 4, the result has shown that there were 4 RIs that were influenced by the KE of "people" and there were only 2 RIs that were influenced by "Process", however, one of these is human capital RI. The technology as a KE did not show its effect on the RI. It is viewed the technology itself always needs the human ability to understand and utilize it.

Table 4 Summary of the Relation of Risk Index and Knowledge Element

Risk Type	People	Process	Technology
Human Capital		✓	
Strategy	✓		
Regulation			
Reputation			
IT	✓		
Market	✓	✓	
Finance			
Natural Hazard	✓		

Additionally, the reputation and the finance RI were not influenced by knowledge. The reputation in process plant construction project is very important in the aspect of quality and the service level due to the nature of this business. Additionally, people who are experienced in this business know the reputation as the quality first as the responsibility for the safety and environment, while the financial RI is normally seen, in the process plant construction project, as the unexpected material price fluctuation. This case is incurred when the project is behind the schedule, so the supplier cannot hold the price due to the market force. The regulation is the tasks that need to be studied and prepared prior the project which it is clearly seen at this stage it depends on the ability of the project preparation team. Hence, people as the KE can be concluded that it is the main factor for the process plant construction business.

2. Result Validation

To validate the result of the statistics test for the relation of RI and the KEs, the researches that studied for the factors of project management were reviewed. The selected literatures in table: were reviewed, the result shows in the following figure;

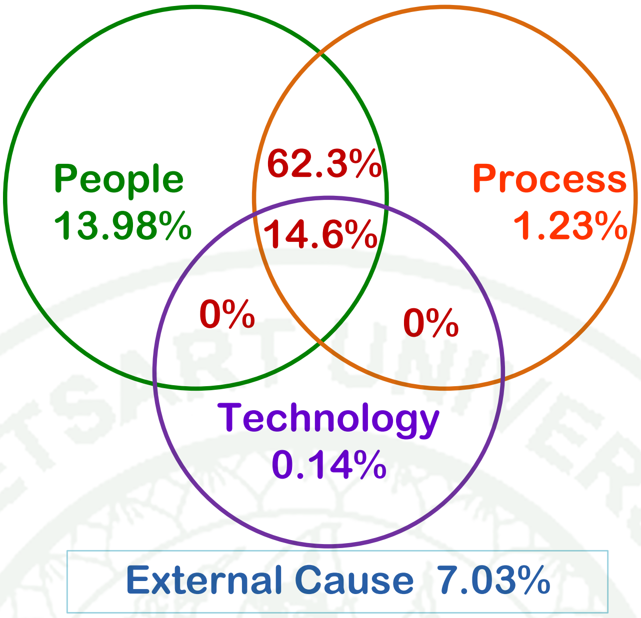

Figure 9 Survey Result Validations

Figure 9 illustrated that the highest percentage of 62.3% is for the combination between people and process. It is obviously seen that to manage and control the project, people must work systematically. It is undivided strategy. The combination of all KEs which are people, process and technology at the percentage of 14.6% and the single factor of people at the percentage of 13.98% could be considered as the second priority. The technology was the element that has no effects on the statistical test; anyhow it was an important part to support the process and to assist people. With this reason, the combination of 3 KEs is the second priority.

3. Building the framework and Framework Verification

The framework for knowledge transfer in process plant construction was built based on the 4 modes knowledge transfer process of Nonaka which are shown in figure 4 and the Knowledge Transfer Step wise in process plant construction project which are listed below;

1. Assign the leader person to provide the transition plan.
2. Start building the operation for the supervisor level

3. Start recruiting operator level and start training
4. Operation team is fully cooperating with construction team for the construction work acceptance systematically
5. The operation team must be full with the ability to run the plant
6. More in practical training after gaining some new knowledge/experience after the project-Close out
7. Be tracking , analyzing the plant performance to address the point to be improved
8. Provide framework to optimize the plant
9. Implement the framework
10. Always keep training.

The example of main tasks incurred in each project stages was indicated based on the knowledge transformation process. The result was shown in figure 10.

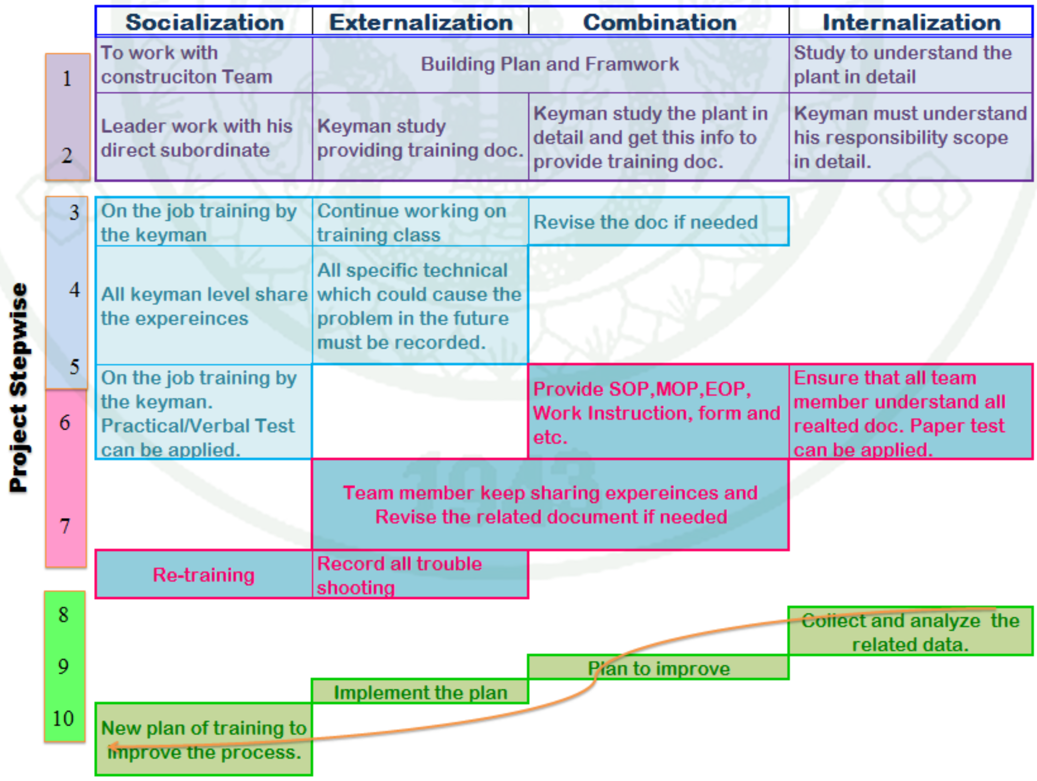

Figure 10 Initial Framework Building

Figure 10 is the initial framework building, after reviewing the knowledge transfer step wise, it was shown that at the beginning of the process step 1-2 called setting up the team leader step, the knowledge was transformed in 4 processes together. This was a guide to address the qualification of the leader and supervisor level. Based on the interviews, this position, in Thailand, is normally responsible by a production manager or COO which mostly failed in providing the knowledge transfer due to his capability. For the production manager or COO, these positions focused on the managing system. While the leader of knowledge management is responsible for receiving all of data and information, then embed it into each individual and organization, including training plan and understanding of competency matrix of each position. This kind of job function is known as “technical training team”. In the developed country, being the outsource team for the technical training team function is normally known such as USA, Japan, China and Singapore. In Thailand, It is hardly found that the company takes this team separated; Most of the team members were hired to the operation team member. For the separated technical training team, this team should be transferred to be “Process Optimization Team” by keeping monitoring the process and provide the optimization plan. However, some stable organization recalls the retired manpower that is full with both explicit and tacit knowledge to fulfill this position.

In step 3-5 called “Getting the team ready”, being ready here is defined as being able to handle the worst case which is expected to incur. The operation team member must be fulfilled in every position or the responsible person of each job function must be available. And each individual must be able to work with the previous team – Construction team which the socialization process is incurred. Each team member need to share his own tacit knowledge and discuss openly, this is where the combination process incurred. To ensure that all members are ready, each individual must pass the entire needed test before the commissioning start; this process is viewed as the internalization. These 3 knowledge transfer process are overlapping process. The leader himself needs to balance these processes. Based on the interview, balancing these processes is also depending on the project complexity.

In step 6-7 called "Collecting Tacit", it is occurring during the commissioning until the work is accepted by the owner. During this period of time every parties work together to start-up the plant. The entire problem is solved here together, and all of the problem should be collected systematically for the further plant operation as the nature of process plant that every plant has its own characteristic. This is including collecting of the data during the construction and is able to highlight which data can be the problem in the future to prevent the risk.

In step 8-10, these steps are processed after the construction team leaves the site. It is where the owner has to develop his own property. These steps are not counted as a transferring knowledge as it is already in operation stage. The 4 modes of knowledge transfer process of Nonaka needs to keep processing.

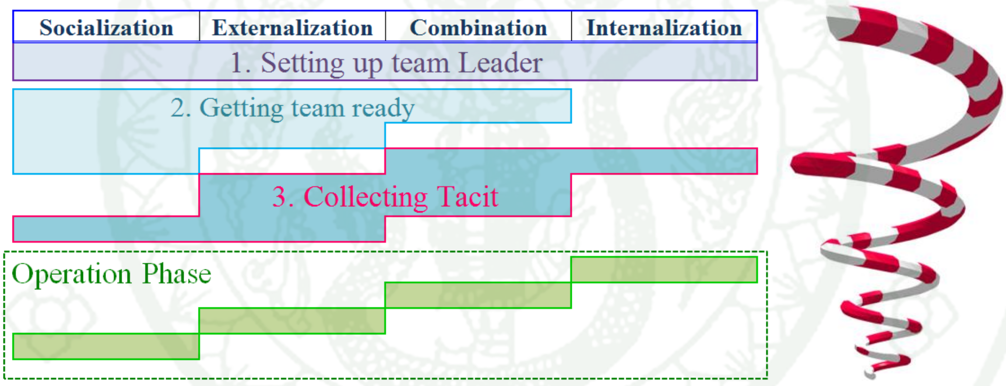

Figure 11 Stage of knowledge Trasnfer in Process Plant Construciton Project

Figure 11 illustrated the summarized stage of knowledge transfer in process plant construction project. However, this is to be reiterated that only when every single is not ignored and being processed with management concern. Every Single step must be concern to ensure the loop of knowledge transfer.

Table 5 showed the details of knowledge transformation modes in each transition stage. The focused mode is the mode that the most worth in term of investment to process.

Table 5 Summarized Framework Descriptions

Transition Stage	Related Person	All Related Modes	Mode to be focused
Setting up Team Leader	Team Leader (1st level) , his direct report staffs (2nd level) and Construction Team	4 modes	-
Getting Team Ready	All Level	Socialization, Externalization, Combination	Socialization & Externalization
ecti ng Taci	Among all operation team members	4 modes	Externalization, & Combination

Table 6 Summarized Timeframe

Transition Stage	Start time	End Time
Setting up Team Leader	Based on Progress (S-Curve), Piping Work, Complexity of a project.	Before the pre commissioning starts
Getting Team Ready	Members of Operations team Member and Complexity of a project.	Before the commissioning, start.
Collecting Tacit	Test Runs Result and Contractor's Demobilization	Before Startup

From the basic framework, it is seen that the framework for knowledge transfer during the transition state of the process plant construction project did not follow the clockwise of Nonaka model. It is only some process occurring in a period of time. To have the framework clear and practical, the knowledge transfer step wise is matched with the construction project step wise as shown in figure 12.

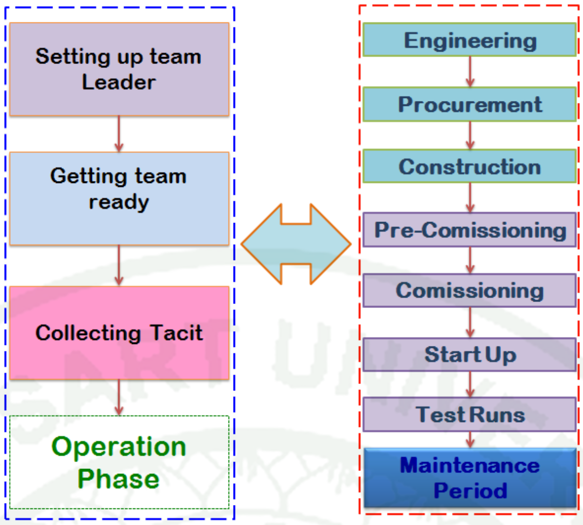

Figure 12 Knowledge Transfer Step wise Vs Project Step wise

Figure 12 illustrated in summarizing that the 3 groups of the activities which are setting up the leader, getting the team ready, and collecting tacit, matching these 3 groups with the actual stage in in process plant construction. And at the same time interviewing of the experienced person both in operation level and management level, their experiences were shared and applied into the framework. Finally, the framework was produced with 3 step end lines.

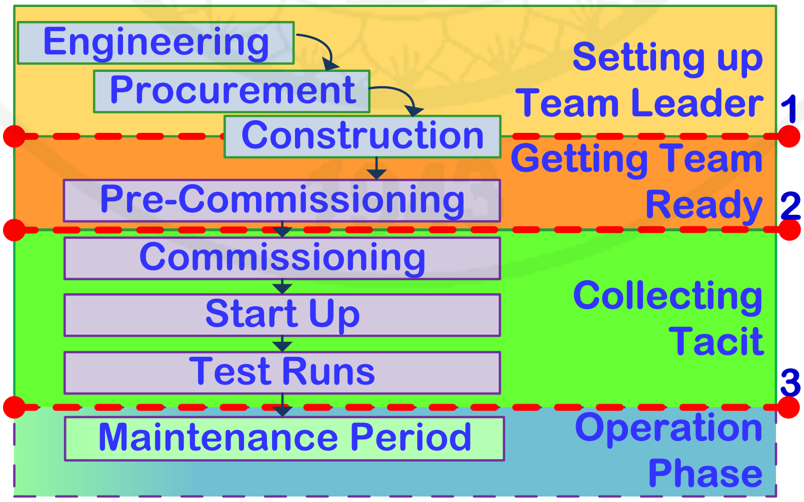

Figure 13 Final Knowledge Transfer Time Frame

Figure 13 illustrated the end time point of each step. Based on the interview, the task in the process plant construction project cannot really be fixed. It was depending on the project complexity. The more complicated of the project is, the earlier that knowledge transfer process need to start or the earlier that the setting up the team leader process has to start. On the opposite, the step end line was easily to define because it acted as a constraint that the task has to be completed to ensure the readiness and not to affect to the next step.

In figure 14 shows the suitable time to start the 1st step – setting up the team leader, were discussed during the interview. This process should start when the overall project progress is about 50 to 75% upon the project complexity. It is also easier to define the starting time line based the project s-curve.

However, it is known basically that to understand the process plant, the operation team needs to understand the piping system. Hence the time to have the team leader should not be later than the piping work start.

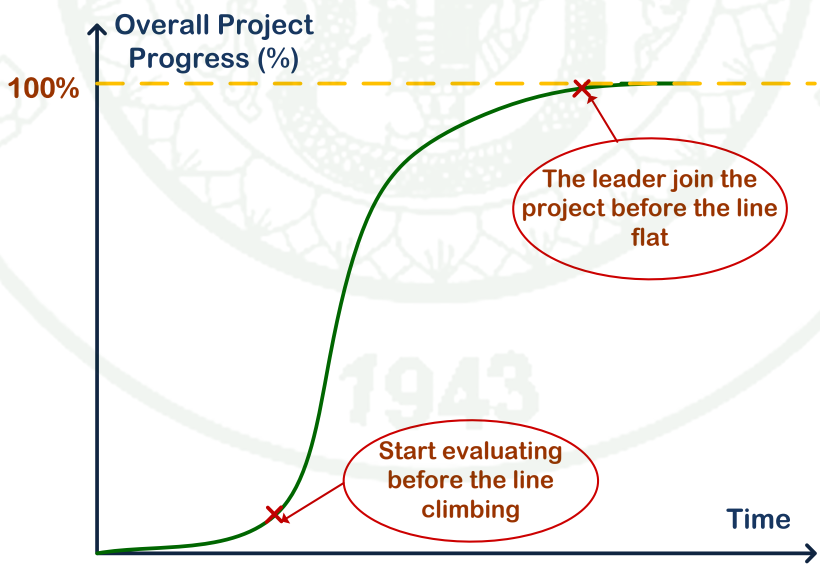

Figure 14 Setting up team Leader Stage in S-Curve

The framework is also in line with former researches. From figure 12, It is seen that, during the knowledge transfer process, the framework has 5 steps on the socialization and externalization and 4 steps on combination. These 3 modes of knowledge transfer are the modes that the individuals bring his own knowledge into another individuals or the organization. To have each individual willing to share his tacit or explicit knowledge, the working environment is needed to support them to be in learning environment. For the temporary organization, the organization culture is the strongly influence factors of knowledge management and is viewed as the compensation of lacking of organizational routine and organizational memory (Lindner and Wald, 2011)

The framework has prevented the knowledge gap between the sender and the receiver by indicate the recruitment method that it must start with the team leader and follow with his direct report staff and the following hierarchy. The knowledge gap is one of the factors that fail the knowledge transfer process (Duan and Nie, 2010).

Discussion

In findings the KEs that effect to the RI of 7 risk types, this aims to prevent the risk by building the knowledge transition framework and indicating the right knowledge transfer process and the KE to be focused.

The research result showed that there were 5 out of 7 RIs not related to KE. Two KEs independent risk indices are reputation and financial RI. In discussion, these 2 elements are the risk that affected by the quality of work and, consequently, the quality of work itself is affected directly by the project management. The project management is one of the thesis project failure causes classification as it is the project's strategy, while the strategy RI is affected by KE.

Four risk indices were related to the KE of "People". Even there are two risk types that may be categorized as the external cause – Market and Natural Hazard, being prepared for the worst case is still processed by people. People are viewed as the key value of the organization. Especially for project organization which has the nature of temporary organization. The qualified people are also seen as the quality of the project. Its importance here is seen in the technical bidding state of the project; the organization chart and the member's resume are normally requested.

The human capital RI is the only RI that is depending on the KE of "Process". The human capital itself is already seen as the KE of "People". It shows that the way of how people get success is related to the people himself inseparable. The working process was meant both organization process, and self-management process. This enhances the importance of people qualification.

With the result, the KE related RI are viewed into people direct effected and people indirect effected. Reviewing the previous process with the same principle is applied to validate the result. The cause of project failures from 10 researches is grouped into KEs. The highest average percentage of 62.3% is from "People & Process" element. It reiterates that People and process are inseparable element. The qualified people will always work for quality.

The framework is started building based on the knowledge transfer step wise and the knowledge transfer model of "Nonaka". Then, the summarized of the knowledge transfer step wise is being indicated its time frame based on the process plant construction project step wise.

The framework shows the whole process starts with the team leader, In the matter of this discussion, selection of the qualified person for this position is the most important initiative process. In the first loop of the knowledge transfer activities, the main activities are started with insertion into the previous team or addition of the work activities to the existing team, hence, getting people understood this, is a part of socialization process where the personality of a person is very important. Traditionally in process plant construction in Thailand, in qualifying process, this person needs to be qualified for both technical skill and managerial skill. In between the technical skill and the managerial skill, there is no evidence that how much it should be weighted in finding the most suitable person.

The framework shows also the ending time of each step which will not affect to the next process. As this framework is a knowledge transfer framework, after the ending time, the work process can still continue. This research points out that the project that keep continue without completion of the knowledge transfer step wise, the project will continue with risks.

Whilst the starting time of each step cannot be indicated it is clearly depending on the project complexity. To estimate the starting time tangibly in the first step “Setting up Team Leader”, the overall progress S-curve and the schedule of piping work are applied together. In the case that the overall s-curve and the schedule of piping work indicate the different starting time, which normally the piping work starts prior the 75% of overall project progress, the project complexity should be considered carefully to provide enough time , however, the 1st step – setting up team leader should start before the piping work hand over.

The second state – “Getting team ready” starting time is clearly depending on the numbers of operation team member. The more complex of the project is, the higher numbers of the team member which is of course required more time. The earliest starting time of this state is immediately when the 1st state is ready.

The last state – “Collecting Tacit” is the shortest period of time as it is expected to be as it is during the commissioning where the cost of raw material and consumables is raised. The plant is hand over when all test runs are accepted. Hence both the owner and the contractor plan to have this period of time to be as short as possible. Collecting tacit is actually embedded into the individual of team member, but in this state the tacit that each individual collected must be recorded systematically. The knowledge will be embedded into the organization and will be re-using later.

The framework has provided the related knowledge transfer process and the knowledge transfer knowledge that need to be focused of each knowledge transfer step in a construction project. The knowledge transfer mode is focused when it happens with more than 2 knowledge transfer activities. This is the guideline to manage the project knowledge with limited resource, the leader should list out the activities of the focused knowledge transfer modes and strictly work on that. However, only 1 or 2 modes of the 4 modes knowledge transfer of Nonaka will always fails. It is shown in figure 10 that in each state of project knowledge transfer, there are always 4 modes together. The focused modes are only guide which process is worth for more investment to support them

CONCLUSION AND RECOMMENDATIONS

Conclusion

The economy has been changed turbulently over decades. A construction firm needs to improve to survive in the market. An organization is facing many types of problem on each project stage which forces a firm into the risky stage. The process plant construction project that has its own characteristics requires many standards combined together that are unique design, variety of equipment and instrument, environment, process technology. Combining each of these requirements is sensitive work which the mistaken can always lead the project into the risky stage and with this result, a firm loss its market place. This research aims to minimize the risky stage by identifying the root cause of each risk and utilizing knowledge management framework which it is low investment activity comparing to other investments. The root causes of the risky stage were detected based on the KEs for 7 risk types. The result of statistical test from 71 surveys shows there are 2 groups of the result which are “People Direct Cause” and “People Indirect Cause”. The results were validated with additional assumption that is – the element of people and process are inseparable to utilize each other. After the root cause was identified, the knowledge transfer framework for process plant construction project was produced based on the 4 modes knowledge transfer model of “Nonaka” and the practical knowledge transfer step wise in process construction project.

Due to the framework was built based on the characteristic of process plant construction project, applying this framework in the other types of construction project may not be suitable such as Buildings, Road, and a pre-engineered building. Focusing mainly of “People” for these types of project may not minimize the risks.

Recommendations

1. This pointed out that “Setting up the team leader” is the initiatives step where the system to create the activities incurred. The qualification of knowledge transfer system of the team leader should be considered. Being able to manage the knowledge transfer system is only one managerial skill. For the future research, to have the most suitable qualified person, a managerial skill should be studied to weight the importance among abilities to handle socialization, externalization, Internalization and combination.

2. This research has provided the knowledge transfer mode to be focused on each knowledge transfer stage. However, the activities to enhance each mode were not recommended. For the future, researching on the activities in process plant construction project of each mode of knowledge transfer could be studied.

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APPENDICES

Appendix A

Questionnaire

Appendix Table A1 Questionnaires

Risk Type		Circumstance	1. Has the circumstance occurred?	2. How critical of the problem?	3. How often of the problem occur?	4. Which area has the action focused? 1-3		
				1-5	1-5	People	Process	Technology
Human capital Risk	1	Has your company ever dealt with employee protests and strike?						
	2	Has a chain of command been often broken or overlooked?						
	3	Have employees and staffs ever had serious disagreement in your company?						
	4	Have employees felt disappointed or lack of belongingness to your company?						
	5	Has your company had a policy of replacing senior or experience staffs with young graduates in order to save the cost but the knowledge had been lost thereafter?						

Appendix Table A1 (Continued)

Risk Type		Circumstance	1. Has the circumstance occurred?	2. How critical of the problem?	3. How often of the problem occur?	4. Which area has the action focused?		
						1-3		
				1-5	1-5	People	Process	Technology
Human capital Risk	6	Has your company lost specific knowledge with retired employees and staffs?						
	7	Has your company been unable to successfully transfer “know-how" from senior to junior staffs?						
	8	In the case of launching new product/service, has your company been consistently unable to provide appropriate training courses to needed staffs?						
	9	Your company's workers don't often have enough skills in to handle new product/service?						
	10	Has your company ever critical failures and mistakes caused by staffs due to the design changes?						

Appendix Table A1 (Continued)

Risk Type		Circumstance	1. Has the circumstance occurred?	2. How critical of the problem?	3. How often of the problem occur?	4. Which area has the action focused? 1-3		
				1-5	1-5	People	Process	Technology
Human capital Risk	11	Has your company ever experienced that none of existing staffs could not work with the newly-designed product/ service except the one who had designed this product/ service?						
	12	Have there any difficulties, if an employee would like to generate new ideas, suggestions, and knowledge?						
	13	Has there any difficulty, if an employee would like to capture and store information, suggestion, experience, specific skill, and knowledge?						
	14	Have there any difficulties, if an employee would like to share information, suggestion, experience, specific skill, and knowledge?						

Appendix Table A1 (Continued)

Risk Type		Circumstance	1. Has the circumstance occurred?	2. How critical of the problem?	3. How often of the problem occur?	4. Which area has the action focused?		
						1-3		
				1-5	1-5	People	Process	Technology
Strategic Risk	15	Was a strategy of new product/ service development ineffective after its launch?						
	16	The back-up plans that could remedy the situation did not exist?						
	17	Your company did not conduct systematic policy and strategic risk assessment prior to a new product/ service's launch?						
	18	Your company did not ensure that a new product/service design would fit with an organization structure?						
	19	Your company did not ensured that a new product/service design would correspond to the market trends?						
Regulatory Risk	20	Has your company been severely affected by unforeseeable law or regulatory changes?						
	21	Has your products/services been subjected to any specific standard relating to consumer safety and environment?						

Appendix Table A1 (Continued)

Risk Type		Circumstance	1. Has the circumstance occurred?	2. How critical of the problem?	3. How often of the problem occur?	4. Which area has the action focused?		
						1-3		
				1-5	1-5	People	Process	Technology
Reputational Risk	22	Has your company ever been in a customer's "black list" as far as you know and can verify?						
	23	Has your product/ service been rejected or cited as non-compliance by a third-party inspector?						
	24	Has your company's shareholders voiced displeasure or concerns about reputation and image in the general public?						
	25	Has your company been sued by other organizations, civic groups, or customer?						
	26	Has your company been mentioned in the news medias for any negative issues?						
	27	Have your company's targeted customers reacted negatively when there is a launch of new product/ service?						

Appendix Table A1 (Continued)

Risk Type		Circumstance	1. Has the circumstance occurred?	2. How critical of the problem?	3. How often of the problem occur?	4. Which area has the action focused? 1-3		
				1-5	1-5	People	Process	Technology
IT Risk	28	Has your company experienced essential data lost or removed from its database?						
	29	Your company did not require user identification and verification for all relevant staffs?						
	30	Has your company encountered with the hackers?						
	31	Has your company ever experienced some instability during data transfers or customer-related transactions?						
	32	Has your company adapted specific IT framework?						
	33	Your company did not continuously invest and upgrade IT To help design your product/service?						
	34	Has your company ever experienced any serious miscommunication between design teams and other functional units that led to delays and overhauls?						

Appendix Table A1 (Continued)

Risk Type		Circumstance	1. Has the circumstance occurred?	2. How critical of the problem?	3. How often of the problem occur?	4. Which area has the action focused? 1-3		
				1-5	1-5	People	Process	Technology
IT Risk	35	Is there an essential data that cannot be accessed for internal use freely?						
	36	Is there a lack of support and linkage between the data base and required data?						
	37	Have you ever worked or made a decision by informal data, and consequently, the situation led you to critical mistake?						
Market Risk	38	Has your product/service market share been severely reduced by current competitors or alternative products?						
	39	Has your company launched new product/ service to the market at the perceived wrong time?						
Financial Risk	40	Has your company ever experienced that raw material prices dramatically changed immediately after a product/Service had been launched?						
Natural Hazard Risk	41	Were there any product/service or operations failure due to natural hazardous conditions and disasters?						

Appendix B

Chi-Square Analysis and Symmetric Measures

Appendix Table B1 Chi-Square analysis for hypothesis of human capital risk

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
1. People						
Pearson Chi-Square	2.189[a]	4	.701	.747		
N of Valid Cases	67					
2. Process						
Pearson Chi-Square	11.850[a]	4	.018	.016		
N of Valid Cases	67					
3. Technology						
Pearson Chi-Square	5.592[a]	4	.232	.230		
N of Valid Cases	67					

Appendix Table B2 Symmetric measures for hypothesis of human capital risk

Symmetric Measures	Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.	Exact Sig.
1. People					
Ordinal by Ordinal Gamma	.202	.230	.892	.372	.372
N of Valid Cases	67				
2. Process					
Ordinal by Ordinal Gamma	.012	.168	.070	.945	.953
N of Valid Cases	67				
3. Technology					
Ordinal by Ordinal Gamma	-.100	.202	-.496	.620	.621
N of Valid Cases	67				

Appendix Table B3 Chi-Square analysis for hypothesis of strategy risk

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
1. People						
Pearson Chi-Square	19.636[a]	8	.012	.014		
N of Valid Cases	67					
2. Process						
Pearson Chi-Square	12.226[a]	8	.141	.131		
N of Valid Cases	67					
3. Technology						
Pearson Chi-Square	7.027[a]	8	.534	.478		
N of Valid Cases	67					

Appendix Table B4 Symmetric measures for hypothesis of strategy risk

Symmetric Measures	Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.	Exact Sig.
1. People					
Ordinal by Ordinal Gamma	.379	.149	2.270	.023	.073
N of Valid Cases	67				
2. Process					
Ordinal by Ordinal Gamma	.321	.184	1.569	.117	.130
N of Valid Cases	67				
3. Technology					
Ordinal by Ordinal Gamma	.051	.261	.193	.847	.856
N of Valid Cases	67				

Appendix Table B5 Chi-Square analysis for hypothesis of Regulatory Risk

	Value	df	Asymp. Sig. (2-sided)
1. People			
Pearson Chi-Square	8.715[a]	8	.367
N of Valid Cases	67		
2. Process			
Pearson Chi-Square	15.793[a]	8	.045
N of Valid Cases	67		
3. Technology			
Pearson Chi-Square	8.261[a]	8	.408
N of Valid Cases	67		

Appendix Table B6 Chi-Square analysis for hypothesis of Reputational Risk

	Value	df	Asymp. Sig. (2-sided)
1. People			
Pearson Chi-Square	13.014[a]	8	.111
N of Valid Cases	67		
2. Process			
Pearson Chi-Square	13.937[a]	8	.083
N of Valid Cases	67		
3. Technology			
Pearson Chi-Square	11.031[a]	8	.200
N of Valid Cases	67		

Appendix Table B7 Chi-Square analysis for hypothesis of Market Risk

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
1. People						
Pearson Chi-Square	14.840[a]	6	.022	.035		
N of Valid Cases	67					
2. Process						
Pearson Chi-Square	15.434[a]	6	.017	.026		
N of Valid Cases	67					
3. Technology						
Pearson Chi-Square	13.828[a]	6	.032	.091		
N of Valid Cases	67					

Appendix Table B8 Symmetric measures for hypothesis of Market Risk

Symmetric Measures	Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.	Exact Sig.
1. People					
Ordinal by Ordinal Gamma	.437	.241	1.347	.178	.170
N of Valid Cases	67				
2. Process					
Ordinal by Ordinal Gamma	.532	.167	2.125	.034	.078
N of Valid Cases	67				
3. Technology					
Ordinal by Ordinal Gamma	.404	.261	1.071	.284	.316
N of Valid Cases	67				

Appendix Table B9 Chi-Square analysis for hypothesis of Financial Risk

	Value	df	Asymp. Sig. (2-sided)
1. People			
Pearson Chi-Square	11.437[a]	8	.178
N of Valid Cases	67		
2. Process			
Pearson Chi-Square	6.200[a]	8	.625
N of Valid Cases	67		
3. Technology			
Pearson Chi-Square	12.109[a]	8	.146
N of Valid Cases	67		

Appendix Table B10 Chi-Square analysis for hypothesis of Natural Hazard Risk

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
1. People						
Pearson Chi-Square	15.992[a]	6	.014	.031		
N of Valid Cases	67					
2. Process						
Pearson Chi-Square	6.137[a]	6	.408	.302		
N of Valid Cases	67					
3. Technology						
Pearson Chi-Square	1.898[a]	6	.929	.640		
N of Valid Cases	67					

Appendix Table B11 Symmetric measures for hypothesis of Natural Hazard Risk

Symmetric Measures	Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.	Exact Sig.
1. People					
Ordinal by Ordinal Gamma	.559	.185	1.883	.060	.084
N of Valid Cases	67				
2. Process					
Ordinal by Ordinal Gamma	.327	.205	1.363	.173	.236
N of Valid Cases	67				
3. Technology					
Ordinal by Ordinal Gamma	.050	.533	.090	.928	.887
N of Valid Cases	67				

Appendix Table B12 Chi-Square analysis for hypothesis of IT Risk

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
1. People						
Pearson Chi-Square	19.546[a]	8	.012	.010		
N of Valid Cases	67					
2. Process						
Pearson Chi-Square	6.683[a]	8	.571	.597		
N of Valid Cases	67					
3. Technology						
Pearson Chi-Square	7.511[a]	8	.483	.501		
N of Valid Cases	67					

Appendix Table B13 Symmetric measures for hypothesis of IT Risk

Symmetric Measures	Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.	Exact Sig.
1. People					
Ordinal by Ordinal Gamma	-.014	.138	-.100	.920	.929
N of Valid Cases	67				
2. Process					
Ordinal by Ordinal Gamma	.211	.142	1.466	.143	.163
N of Valid Cases	67				
3. Technology					
Ordinal by Ordinal Gamma	.181	.163	1.093	.274	.260
N of Valid Cases	67				

Appendix C

Result Validation

Appendix Table C1 Tanzania 2012

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
1	Design changes				1				
2	Delays in payment to contractors,				1				
3	Information delays							1	
4	Funding problems				1				
5	Poor project management,				1				
6	Compensation issues				1				
7	Disagreement on the valuation of work done				1				
8	Conflicts among the involved parties				1				
9	Project schedule changes							1	
10	Supply / procurement problems				1				
11	Bureaucracy	1							
12	Multiple projects by contractors				1				
13	Incompetent contractors				1				
14	Contractual claims				1				
15	Unexpected ground conditions							1	
16	Government interference								1
17	Poor understanding of the project	1							

Appendix Table C1 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
18	Shortage / lack of equipment				1				
19	Shortage of materials							1	
20	Skills shortage / unavailability				1				
21	Acts of God								1
	Total	2	0	0	13	0	0	4	2
	Percentage	9.52%	0.00%	0.00%	61.90%	0.00%	0.00%	19.05%	9.52%

Appendix Table C2 Malaysia (2006)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
1	Improper planning							1	
2	Site management				1				
3	Inadequate contractor experience				1				
4	Finance and payments of completed work				1				
5	Subcontractors				1				
6	Shortage in material							1	
7	Labor supply							1	

Appendix Table C2 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	Externa l
8	Equipment availability and failure				1				
9	Lack of communication between the parties							1	
10	Mistakes during construction stage				1				
11	Labor productivity				1				
12	Quality of material				1				
13	Slow decision making	1							
14	Major disputes and negotiations				1				
15	Construction methods		1						
16	Preparation and approval of drawings				1				
17	Mistakes and discrepancies in contract document				1				
18	Unforeseen site condition							1	
19	Contract management				1				
20	Owner Interference				1				

Appendix Table C2 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	Externa l
21	Change orders				1				
22	Quality assurance/control				1				
23	Waiting time for approval of tests and inspection				1				
24	Unrealistic contract duration and requirements imposed				1				
25	Inappropriate overall organizational structure linking to the project				1				
26	Regulatory changes								1
27	Weather condition								1
28	Problem with neighbors	1							
	Total	2	1	0	18	0	0	5	2
	Percentage	7.14%	3.57%	0.00%	64.29%	0.00%	0.00%	17.86%	7.14%

Appendix Table C3 Saudi Arabia (2005)

No.	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
1	Original contract duration is too short				1				
2	Legal disputes b/w various parts				1				
3	Inadequate definition of substantial completion				1				
4	Ineffective delay penalties				1				
5	Type of construction contract (Turnkey, construction only,.)				1				
6	Type of project bidding and award (negotiation, lowest bidder,.)				1				
7	Delay in progress payments by owner				1				
8	Delay to furnish and deliver the site to the contractor by the owner				1				
9	Change orders by owner during construction				1				
10	Late in revising and approving design documents by owner				1				

Appendix Table C3 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
11	Delay in approving shop drawings and sample materials				1				
12	Poor communication and coordination by owner and other parties							1	
13	Slowness in decision making process by owner	1							
14	Conflicts between joint-ownership of the project				1				
15	Unavailability of incentives for contractor for finishing ahead of schedule	1							
16	Suspension of work by owner				1				
17	Difficulties in financing project by contractor				1				
18	Conflicts in sub-contractors schedule in execution of project							1	
19	Rework due to errors during construction				1				
20	Conflicts b/w contractor and other parties (consultant and owner)				1				

Appendix Table C3 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
21	Poor site management and supervision by contractor				1				
22	Poor communication and coordination by contractor with other parties							1	
23	Ineffective planning and scheduling of project by contractor				1				
24	Improper construction methods implemented by contractor				1				
25	Delays in sub-contractors work				1				
26	Inadequate contractor s work				1				
27	Frequent change of sub-contractors because of their inefficient work				1				
28	Poor qualification of the contractor s technical staff				1				
29	Delay in site mobilization				1				
30	Delay in performing inspection and testing by consultant	1							

Appendix Table C3 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
31	Delay in approving major changes in the scope of work by consultant	1							
32	Inflexibility (rigidity) of consultant	1							
33	Poor communication/coordination between consultant and other parties							1	
34	Late in reviewing and approving design documents by consultant	1							
35	Conflicts between consultant and design engineer	1							
36	Inadequate experience of consultant	1							
37	Mistakes and discrepancies in design documents				1				
38	Delays in producing design documents				1				
39	Unclear and inadequate details in drawings				1				
40	Complexity of project design				1				

Appendix Table C3 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
41	Insufficient data collection and survey before design				1				
42	Misunderstanding of owner s requirements by design engineer				1				
43	Inadequate design-team experience				1				
44	Un-use of advanced engineering design software	1							
45	Shortage of construction materials in market								1
46	Changes in material types and specifications during construction				1				
47	Delay in material delivery				1				
48	Damage of sorted material while they are needed urgently				1				
49	Delay in manufacturing special building materials				1				
50	Late procurement of materials				1				
51	Late in selection of finishing materials due to availability of many types in market				1				

Appendix Table C3 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
52	Equipment breakdowns				1				
53	Shortage of equipment				1				
54	Low level of equipment-operator s skill	1							
55	Low productivity and efficiency of equipment				1				
56	Lack of high-technology mechanical equipment			1					
57	Shortage of labors							1	
58	Unqualified workforce				1				
59	Nationality of labors	1							
60	Low productivity level of labors				1				
61	Personal conflicts among labors	1							
62	Effects of subsurface conditions (e.g., soil, high water table, etc.)							1	
63	Delay in obtaining permits from municipality								1
64	Hot weather effect on construction activities								1

Appendix Table C3 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
65	Rain effect on construction activities								1
66	Unavailability of utilities in site (such as, water, electricity, telephone, etc.)				1				
67	Effect of social and cultural factors	1							
68	Traffic control and restriction at job site				1				
69	Accident during construction				1				
70	Differing site (ground) conditions							1	
71	Changes in government regulations and laws								1
72	Delay in providing services from utilities (such as water, electricity)				1				
73	Delay in performing final inspection and certification by a third party	1							
	Total	14	0	1	46			7	5
	Percentage	19.18%	0.00%	1.37%	63.01%	0.00%	0.00%	9.59%	6.85%

Appendix Table C4 Egypt (2013)

No.	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
1	Delay in progress payments (funding problems)	1	1		1				
2	Different tactics patterns for bribes	1							
3	Shortage of equipment	1	1		1				
4	Ineffective project planning and scheduling	1	1	1				1	
5	Poor site management and supervision	1	1		1				
6	Poor financial control on site	1	1		1				
7	Rework due to errors	1	1		1				
8	Selecting inappropriate contractors	1	1		1				
9	Sudden failures actions	1							
10	Inadequate planning	1	1		1				
11	Incompetent project team	1	1		1				
12	Inadequate contractor experience	1	1		1				
13	Frequent equipment breakdowns	1	1		1				
14	Global financial crisis								1
15	Complexity of project (project type, project scale, etc.)	1	1		1				
16	Legal disputes between project participants	1	1		1				
17	Change orders.	1	1		1				

Appendix Table C4 (Continued)

No.	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
18	Inappropriate construction methods	1	1		1				
19	Unqualified/inadequate experienced labor	1							
20	Conflicts between joint-ownership	1							
21	Slowness in decision making	1							
22	Delay in approving major changes in scope of work by consultant	1							
23	Unreliable subcontractors	1	1		1				
24	Shortage of labor	1	1		1				
25	Suspension of work by owner	1	1		1				
26	Design changes by owner or his agent during construction	1	1		1				
27	Misunderstanding of owner's requirements by design engineer	1	1		1				
28	Mode of financing and payment for completed work	1	1		1				
29	Design errors and omissions made by designers	1	1		1				
30	Shortage of construction materials	1	1		1				
31	Incomplete project design	1	1		1				
32	Low productivity of labor	1	1		1				

Appendix Table C4 (Continued)

No.	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
33	Delay in providing services from utilities (water, electricity, etc.)	1	1		1				
34	Insufficient data collection and survey before design	1	1		1				
35	Equipment allocation problem	1	1		1				
36	Lack of consultant experience in construction projects	1							
37	Defective design made by designers	1	1		1				
38	Lack of design team experience in construction projects	1	1		1				
39	Ineffective delay penalties	1	1	1				1	
40	Late delivery of materials	1	1		1				
41	Mistakes and delays in producing design documents	1	1		1				
42	Improper project feasibility study	1	1		1				
43	Unexpected surface& subsurface conditions (soil, water table, etc.)	1	1	1				1	
44	Price fluctuations								1
45	Frequent change of subcontractors	1	1		1				
46	Delay in obtaining permits from municipality								1

Appendix Table C4 (Continued)

No.	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
48	Poor communication and coordination between owner and contractor	1	1	1				1	
49	Inaccurate site investigation	1	1	1				1	
50	Delay in manufacturing materials	1	1		1				
51	Unreliable suppliers	1	1		1				
52	Delay in approving design documents	1	1		1				
53	Original contract duration is short	1	1	1				1	
54	Damage of sorted materials	1	1		1				
55	Late in reviewing and approving design documents	1	1		1				
56	Inappropriate contractor’s policies	1	1		1				
57	Slow mobilization of equipment	1	1		1				
58	Poor communication and coordination between owner and consultant	1	1	1				1	
59	Poor procurement of construction materials	1	1		1				
60	Inadequate definition of substantial completion	1	1		1				
61	Escalation of material prices								1
62	Delay in site delivery	1	1		1				

Appendix Table C4 (Continued)

No.	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
63	Poor quality of construction materials	1	1		1				
64	Improper equipment	1	1		1				
65	Conflicts between consultant and design engineer	1							
66	Complexity of project design	1	1		1				
67	Inadequate site investigation	1	1		1				
68	Unfavorable contract clauses	1	1		1				
69	Inadequate production of raw material in the country								1
70	Slow mobilization of labor	1	1		1				
71	Unclear and inadequate details in drawings	1	1		1				
72	Changes in material types and specifications during construction	1	1		1				
73	Long period between design and time of bidding/tendering	1	1	1				1	
74	Inadequate project management assistance	1							
75	Poor communication and coordination between consultant and contractor	1	1	1				1	

Appendix Table C4 (Continued)

No.	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
76	Changes in government regulations and laws								1
77	Lack of incentives for contractor to finish ahead of schedule	1							
78	Labor strikes due to revolutions	1							
79	Inappropriate government policies								1
80	Absenteeism	1							
81	Lack of capable representative	1	1		1				
82	Inadequate modern equipment	1	1	1				1	
83	Delay in performing inspection and testing	1							
84	Obsolete technology	1	1		1				
85	Low motivation and morale of labor	1							
86	Additional work	1	1		1				
87	Bureaucracy in bidding/tendering method	1							
88	Inappropriate contractual procedure	1	1		1				
89	Unfavorable weather conditions								1
90	Poor use of advanced engineering design software	1							
91	Delay in performing final inspection and certification by third party	1							

Appendix Table C4 (Continued)

No.	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
92	Problem with neighbors	1							
93	Lack of owner experience in construction projects	1	1		1				
94	Accidents during construction	1	1		1				
95	Loss of time by traffic control and restriction at job site	1	1		1				
96	Personal conflicts among labor	1							
97	Done on site	1	1		1				
98	Slow site clearance	1	1		1				
99	Labor injuries on site	1	1		1				
	Total	19			62			10	8
	Percentage	19.19%	0.00%	0.00%	62.63%	0.00%	0.00%	10.10%	8.08%

Appendix Table C5 Thailand (2004)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
1	Lack of material	1	1		1				
2	Incomplete drawing	1	1		1				
3	Incompetent supervisors	1							
4	Lack of tools and equipment	1	1		1				
5	Absenteeism	1							
6	Poor communication	1	1	1				1	
7	Instruction time	1	1		1				
8	Poor site layout	1	1		1				
9	Inspection delay	1	1		1				
1	Rework	1	1		1				
11	Occasional working overtime	1	1		1				
12	Change orders	1	1		1				
13	Tools/equipment breakdown	1	1		1				
14	Specification and standardisation		1						
15	Interference from other trades or other crew members	1							
16	Workers turnover and changing crewmembers	1							
17	Scheduled working overtime	1	1		1				
18	Safety (accidents)	1	1		1				

Appendix Table C5 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
20	Changing of foremen	1							
21	Overcrowding	1	1		1				
22	Shift work	1	1		1				
23	Weather								1
	Total	5	1		15			1	1
	Percentage	21.74%	4.35%	0%	65.22%	0%	0%	4.35%	4.35%

Appendix Table C6 India (2013)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
1	Accident at site	1	1		1				
2	Bureaucracy	1							
3	Calibration of Equipments	1	1		1				
4	Casual approach in term of safety	1	1		1				
5	Casual approach in term of safety	1	1		1				
6	Casual approach of employees	1	1		1				
7	Certification of Equipments	1	1		1				
8	Change in design	1	1		1				
9	Change in scope of work	1	1		1				

Appendix Table C6 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
10	Changes in Govt. law & regulation								1
11	Complex design	1	1		1				
12	Conflict between owners or partners	1							
13	Conflict between ideas in terms of dail1 target	1	1		1				
14	Confusion	1	1		1				
15	Customer reliability	1	1	1				1	
16	Customers requirement changes	1	1		1				
17	Daily meeting for planning	1	1		1				
18	Daily target & review	1	1		1				
19	Daily working Hours	1	1		1				
20	Decision making power – employee	1	1		1				
21	Delay in design approval	1	1		1				
22	Delay in final inspection – work area	1	1		1				
23	Delay in getting work permit from municipal corp. board	1	1		1				
24	Delay in payment - own employees	1	1		1				

Appendix Table C6 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
25	Delay in payment - vendors	1	1		1				
26	Delay in procurement	1	1		1				
27	Delegation - not in our scope	1							
28	Dependency – Supplier & Customer	1	1		1				
29	Design Fault	1	1		1				
30	Effect on environment	1	1		1				
31	Effect on environment	1	1		1				
32	Equipment size	1	1		1				
33	Estimated project completion was time too short	1	1	1				1	
34	Frequent change of manpower	1							
35	Future planning	1	1		1				
36	Goal not defined	1	1		1				
37	Ineffective management	1	1	1				1	
38	Ineffective supervision	1	1		1				

Appendix Table C6 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
39	Installation problem	1	1		1				
40	Insufficient data while designing	1	1		1				
41	Insufficient tools	1	1		1				
42	Interpersonal relationship	1							
43	Inventories	1	1		1				
44	Lack of awareness about safety	1							
45	Lack of awareness about safety	1	1		1				
46	Lack of discussion	1	1	1				1	
47	Land acquiring problem	1	1		1				
48	Leaving work area - labours	1	1		1				
49	Local development								1
50	Low budget	1	1		1				
51	Lunch time of labours and Management staff is on same time	1	1		1				
52	Market risk								1
53	Material lead time	1	1		1				
54	Motivation	1							
55	Natural causes - flood ,earth quack								1
56	Not following Personal protective equipment	1	1		1				

Appendix Table C6 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
57	Not using WBS - in all field	1	1	1				1	
58	Poor communication system	1	1	1				1	
60	Quality of material	1	1		1				
61	Return of investment ROI	1	1	1				1	
62	Rework	1	1		1				
63	Rigidity of employee & labor	1							
64	Risk while working with electrical equipment & working at height	1	1		1				
65	Risk while working with electrical equipment & working at height	1	1		1				
66	Short receipt	1	1		1				
67	Social problem - School, temple	1							
68	Strategic planning for daily work	1	1		1				
69	Supplied material was defective	1	1		1				

Appendix Table C6 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
70	Team work & co ordination	1							
71	Transit Damage	1	1		1				
72	Unavailability of correct tool for working	1	1		1				
73	Unavailability of water, electricity	1	1		1				
74	Unavailability of work condition	1	1		1				
75	Unavailability of work condition	1	1		1				
76	Unavailability of work permit	1	1		1				
77	Unavailability to test of equipment	1	1		1				
78	Understanding portfolio & interest of employee	1							
79	Unskilled man force - Engineering team	1							
80	Unskilled man force - employees	1							
81	Use of classical technique	1	1		1				
82	Use of classical tools	1	1		1				
83	Weak feedback	1							
84	Wrong estimation	1	1	1				1	
85	Wrong supply	1	1		1				
	Total	14	0	0	59			8	4
	Percentage	16.47%	0.00%	0.00%	69.41%	0.00%	0.00%	9.41%	4.71%

Appendix Table C7 Ghana (2010)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
1	Delay in honouring payment certificates	1	1		1				
2	Underestimation of cost of projects	1	1	1				1	
3	Underestimation of complexity of projects	1	1	1				1	
4	Difficulty in accessing Bank credit	1	1		1				
5	Poor supervision	1	1		1				
6	Underestimation of time for completion by contractors	1	1		1				
7	Shortage of materials	1	1		1				
8	Poor Professional Management	1	1	1				1	
9	Fluctuation of prices								1
10	Poor Site management	1	1		1				
11	Construction methods	1	1		1				
12	Delay in instructions from consultants	1							
13	Late deliveries of materials	1	1		1				
14	Lack of Programme of Works	1	1		1				
15	Delay by sub-contractors	1	1		1				

Appendix Table C7 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
17	Breakdown of equipments	1	1		1				
18	Client initiated variations	1	1		1				
19	Obtaining permit from municipality	1	1		1				
20	Insufficient communication between parties	1	1	1				1	
21	Necessary variations	1	1	1				1	
22	Shortage of skilled labour	1	1		1				
23	Legal disputes	1	1		1				
24	Unfavourable Site conditions	1	1		1				
25	Foundation conditions encountered on site	1	1	1				1	
26	Discrepancy between design specification and building code	1	1		1				
27	Bad weather conditions								1
28	Mistakes with soil investigations	1	1	1				1	
29	Unskilled equipment operators	1	1		1				
30	Accidents during construction	1	1		1				

Appendix Table C7 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
31	Shortage of unskilled labour	1	1		1				
32	Public holidays								1
	Total	1	0	0	21			7	3
	Percentage	3.13%	0.00%	0.00%	65.63%	0.00%	0.00%	21.88%	9.38%

Appendix Table C8 Thailand (1996)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
1	Change orders	1	1		1				
2	Slow decision-making	1							
3	Incomplete drawings	1	1		1				
4	Slow response	1	1		1				
5	Deficiencies in organisation	1							
6	Deficiencies in coordination	1							
7	Uncompromising attitude	1							
8	Delays in work approval	1							
9	Materials management problems	1	1	1				1	
10	Deficiencies in organisation	1	1		1				
11	Coordination deficiencies	1	1		1				

Appendix Table C8 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
12	Planning and scheduling problems	1	1		1				
13	Equipment allocation problems	1	1		1				
14	Financial difficulties	1	1		1				
15	Inadequacy of site inspection	1	1		1				
16	Shortage of construction materials	1	1		1				
17	Late delivery	1	1		1				
18	Price escalation	1	1		1				
19	Low quality of materials	1	1		1				
20	Shortage of site workers	1	1	1				1	
21	Shortage of technical personnel	1	1	1				1	
22	Insufficient numbers of equipment	1	1		1				
23	Frequent equipment breakdown	1	1		1				
24	Confined site	1	1		1				
25	Problems with neighbours	1							
26	Slow permits by Govt. agencies	1	1		1				
	Total	6	0	0	17	0	0	3	0
	Percentage	23.08%	0.00%	0.00%	65.38%	0.00%	0.00%	11.54%	0.00%

Appendix Table C9 Nigeria (2012)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
1	Improper planning	1	1	1				1	
2	Lack of effective communication	1	1	1				1	
3	Design errors	1	1		1				
4	Shortage of supply like steel, concrete	1	1	1				1	
5	Slow decision making	1							
6	Financial issues	1	1		1				
7	Shortage of material	1	1	1				1	
8	Cash-flow problems during construction	1	1	1				1	
9	Increase in quantities								1
10	Mismanagement by the contractor (financial, supplier support, sub-contractor	1	1		1				
11	Executive bureaucracy in the owners' organizations	1							
12	Notification of extra work	1	1		1				
13	Changes in site conditions	1	1		1				
14	Date of notice to proceed	1	1		1				
15	Financing matters	1	1	1				1	
16	Payment for completed works	1	1		1				

Appendix Table C9 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
17	Indicative of experiences	1	1		1				
18	Conflicts in work schedules of subcontractors	1	1	1				1	
19	Contractors regarded contractual relationships	1	1		1				
20	Late confirmation from client and consultant regarding cost,quality and time	1	1		1				
21	Experience of project team	1	1		1				
22	Quality assurance / control	1	1		1				
23	Long period for approval of tests and inspections	1	1		1				
24	Political influence								1
25	Social influence (feedback from resident) EIA								1
26	Failure of RIBA plan of work application	1	1	1				1	
27	Project management issues	1	1	1				1	
28	Site accidents	1	1		1				
29	Negligence	1							
30	Late deliveries of materials and equipments	1	1		1				

Appendix Table C9 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
31	Economic conditions								1
32	Changes of design	1	1		1				
33	User changes	1	1		1				
34	Liquated damage (LAD)	1	1		1				
35	Negotiation during construction	1	1		1				
36	Designers	1	1		1				
37	Mistakes during construction	1	1		1				
38	Possible prejudices	1							
39	Changed orders and mistakes and discrepancie in contract documents	1	1		1				
40	Dispute (variation order)	1	1		1				
41	Religions factors	1							
42	Weather condition (*Force-Marjue*)								1
43	Conflicts of the drawing and specification	1	1		1				
	Total	5			23			9	5
	Percentage	11.63%	0.00%	0.00%	53.49%	0.00%	0.00%	20.93%	11.63%

Appendix Table C10 Thailand (2011)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
1	Lack of material	1	1	1				1	
2	Incomplete drawing	1	1		1				
3	Inspection delay	1							
4	Incompetent supervisors	1	1		1				
5	Instruction time	1	1		1				
6	Lack of tools and equipment	1	1	1				1	
7	Poor communication	1	1	1				1	
8	Poor site conditions	1	1		1				
9	Change orders								
10	Poor site layout	1	1		1				
11	Rework	1	1		1				
12	Absenteeism	1							
13	Occasional working overtime	1	1		1				
14	Tools/equipment breakdown	1	1		1				
15	Interference from other trades or other crew members								1
16	Overcrowding	1	1		1				
17	Workers turnover and changing crewmembers	1	1		1				
18	Specification and standardization		1						

Appendix Table C10 (Continued)

No	Causes	People	Process	Technology	People & Process	People & Technology	Process & Technology	All	External
19	Scheduled working overtime	1	1	1				1	
20	Weather								1
21	Changing of foremen	1	1		1				
22	Safety (accidents)	1	1		1				
23	Shift work	1	1	1				1	
	Total	2	1	0	12	0	0	5	2
	Percentage	8.70%	4.35%	0.00%	52.17%	0.00%	0.00%	21.74%	8.70%

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