กรอบของระบบการได้มาซึ่งความรู้สำหรับหน่วยงานราชการในโครงการก่อสร้างสาธารณะ

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A FRAMEWORK OF KNOWLEDGE ACQUISITION SYSTEMS FOR GOVERNMENTAL AGENCIES IN PUBLIC CONSTRUCTION PROJECTS

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โนฟาเลีย แอนดริยานิ: กรอบของระบบการได้มาซึ่งความรู้สำหรับหน่วยงานราชการในโครงการก่อสร้างสาธารณะ (A FRAMEWORK OF KNOWLEDGE ACQUISITION SYSTEMS FOR GOVERNMENTAL AGENCIES IN PUBLIC CONSTRUCTION PROJECTS) อ.ที่ปรึกษา: ผู้ช่วยศาสตราจารย์ ดร.วีระศักดิ์ ลิขิตเรืองศิลป์ อ.ที่ปรึกษาร่วม: รองศาสตราจารย์ ดร.วิสุทธิ์ ช่อวิเชียร, 151 หน้า. ISBN 974-17-4259-2.

ความรู้ในระหว่างการก่อสร้างมักจะถูกละเลยหรือไม่ได้มีการรวบรวมและจัดเก็บที่เป็นระบบนำไปสู่การเริ่มใหม่ในโครงการในอนาคต โดยมิได้ใช้ความรู้เกี่ยวกับการก่อสร้างจากโครงการก่อนหน้าอย่างมีประสิทธิภาพ ปัญหาดังกล่าวปรากฏในโครงการก่อสร้างทุกประเภทโดยเฉพาะอย่างยิ่งในโครงการก่อสร้างของภาครัฐที่มีการลงทุนมหาศาล วัตถุประสงค์หลักของวิทยานิพนธ์นี้เพื่อพัฒนากรอบของระบบการได้มาซึ่งความรู้ซึ่งหน่วยงานราชการสามารถนำไปใช้ในโครงการก่อสร้างสาธารณะ ผู้วิจัยเริ่มต้นโดยทำการสำรวจโครงการก่อสร้างจริงเพื่อสร้างกรอบเบื้องต้นของระบบ ข้อมูลที่จำเป็นรวบรวมได้จากการสัมภาษณ์บุคคลสำคัญในหน่วยงานราชการวิศวกรของโครงการก่อสร้าง และบุคคลที่ควบคุมระบบข้อมูลและเอกสาร กรอบที่นำเสนอนี้ครอบคลุมแบบแผนซึ่งอธิบายขั้นตอนในการได้มาและจัดเก็บของความรู้ในการก่อสร้าง กรอบเบื้องต้นที่ได้พัฒนาขึ้นจะถูกนำไปประยุกต์ใช้ในโครงการก่อสร้างสะพาน 2 แห่ง ในประเทศอินโดนีเซียซึ่งใช้เป็นกรณีศึกษา ได้แก่ โครงการสะพาน Suramadu และโครงการสะพาน Pasupati ผลการวิจัยแสดงให้เห็นว่ากรอบทั่วไปสามารถถูกดัดแปลงเพื่อสร้างระบบการได้มาซึ่งความรู้สำหรับแต่ละโครงการกรณีศึกษาได้เป็นอย่างดี

ภาควิชา...วิศวกรรมโยธา..... ลายมือชื่อนิสิต.....

สาขาวิชา..วิศวกรรมโยธา..... ลายมือชื่ออาจารย์ที่ปรึกษา .....

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KEY WORD : BRIDGE CONSTRUCTION / KNOWLEDGE ACQUISITION / KNOWLEDGE MANAGEMENT / PUBLIC CONSTRUCTION PROJECTS

NOFALIA ANDRIYANI: THESIS TITLE. A FRAMEWORK OF KNOWLEDGE ACQUISITION SYSTEMS FOR GOVERNMENTAL AGENCIES IN PUBLIC CONSTRUCTION PROJECTS. THESIS ADVISOR. ASSISTANT PROF. VEERASAK LIKHITRUANGSILP, Ph.D. THESIS CO-ADVISOR. ASSOCIATE PROF. VISUTH CHOVICHIEN, Ph.D., 151 pp. ISBN 974-17-4259-2

Knowledge during construction is usually ignored or non-systematically captured and stored leading to a fresh start of knowledge acquisition processes in future projects rather than using construction knowledge learned from previous projects efficiently. This problem exists in all types of construction projects, particularly public construction projects entailing large amount of financial investment. The main objective of this research is to develop a framework of knowledge acquisition systems that can be used by governmental agencies in public construction projects. We began with site investigations to construct a preliminary framework of the systems. Necessary data were collected from interviewing key persons of governmental agencies, engineering representatives at construction sites, and personnel controlling information and documentation systems. The proposed framework includes a scheme that explains the stages of capturing and storing construction knowledge. Once the preliminary framework has been developed, it was applied to two bridge projects in Indonesia used as case studies, namely, Suramadu Bridge Project and Pasupati Bridge Project. The result shows that the generalized framework can be modified to establish the project-specific knowledge acquisition systems for both projects.

Department.....Civil Engineering.....Student's signature.....
Field of Study.....Civil Engineering.....Advisor's signature.....
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Finally, to all readers, due to my intention to present this research pervasively, please accept my sincere apologies for my English usage in this research and any misunderstanding, which may arise from English language.

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CHAPTER I
INTRODUCTION

1.1 General

Knowledge management involves acquisition, organization, sharing, use, and creation of knowledge. Sharing and reusing knowledge depend on acquiring and preserving both tacit knowledge and explicit knowledge as the property of a corporation. Effectively using information and web technologies during the construction phase of a project enables knowledge to be captured and managed to benefit future projects.

The construction organization is unique, fast moving, dynamic, and complex in its operations. In that way, construction is superficially viewed in general dimensions and viewed as a learning organization where people continually expand their capacity to create the results and where people are learning how to work in teams.

Knowledge management in the construction phase deals primarily with the process of creating value from knowledge about construction operations and organizations. Valuable knowledge is available in various forms and media, including in the minds of experts, operating procedures, documents, databases, intranets and other entities. Knowledge can be reused and shared among engineers and experts who participate in projects in order to improve construction processes and reduce the time and cost of solving problems.

Unfortunately, most procedural knowledge and experiences exist only in the mind of an individual participant during the construction phase of construction projects. Even though knowledge has been generated, it is not certain that at anytime knowledge can be captured. Knowledge management in the construction phase aims to collect and share effectively and systematically experiences.

The success of construction organizations depends on the best practices of all project participants. Project participants are a driven key to the success of each other.

Individuals and working groups work together on many capacities: from formal to informal, managerial to technical, on site to off site. A success factor refers to an actual dynamic process by which individuals learn to do their jobs through task performance and interaction during the course of construction. Knowledge has been generated in all those capacities, but capturing, addressing, and storing knowledge have not been accomplished effectively.

1.2 Problem Statement

Knowledge exists in every activity unit, including both explicit and tacit knowledge. Explicit knowledge can be found in the documents of organizations, including reports, articles, manuals, patents, pictures, images, video, audio, software and other forms. It can also be found in an organization's documents such as organizational charts, specifications, contracts, reports, drawings, change orders, data process maps, and mission statements. Explicit knowledge is easier to collect and manage during the construction phase of a project because information and knowledge are available in the form of document.

In contrast, tacit knowledge or implicit knowledge may include process records, problems faced, problems solved, experts' suggestions, procedural knowledge, innovations, and notes on experience. Implicit knowledge is not normally documented or stored in a system database. Capturing implicit knowledge and making it available as explicit knowledge are important to knowledge management during the construction phase. It is also important for reusing knowledge in other projects, and preserving such knowledge as a corporate property. Experience, problem solving, procedural knowledge, and innovation are created and performed in the construction phase of any projects. Implementing knowledge management allows tacit knowledge to be reused in other projects and work improvement in the construction phase to be accelerated. However, knowledge acquisition processes have problems in losing experience, procedural knowledge, problem solutions, and innovation in a project because they are not well captured.

Knowledge acquisition processes entail locating and storing knowledge. Knowledge should be stored in a place that is easy to be accessed, therefore that knowledge is easy to be reviewed in order to be reused in other projects. Moreover, knowledge management should allow document listing so that the storage location of

particular knowledge can be determined accurately. The indexing may be based on needs, part of projects or works, or users.

1.3 Research Objective

The objective of this research is to develop a framework of knowledge acquisition systems that can be used by governmental agencies. This research explores the methods of capturing and storing knowledge in the bank of knowledge by choosing two bridge projects sponsored by the Department of Public Work in Indonesia as case studies.

1.4 Research Scopes

The scopes of this research are as follows.

- This research will be limited to knowledge acquisition processes during the construction phase of construction projects.
- The knowledge acquisition processes emphasize on capturing and storing construction knowledge encompassing construction method, as well as equipment, material and technology.

1.5 Research Contribution

The expected result of this research is a framework of knowledge acquisition systems that can be used by governmental agencies in public construction projects. The research can be used for mitigating knowledge and experience lost during the construction phase due to ineffective capturing and incorrect storing. Governmental agencies can then identify and capture construction knowledge during the construction phase and can store knowledge in a bank of knowledge properly. Governmental agencies can also use the framework of knowledge acquisition as a tool to evaluate the existing knowledge acquisition system.

1.6 Research Methodology

Figure 1-1 illustrates the research methodology used as a guideline to conduct this research. Firstly, existing knowledge acquisition frameworks were explored from previous research. Limitations of previous frameworks were also investigated. The

conditions of case studies were then explored in the preliminary site investigation. The preliminary framework was then developed by integrating existing frameworks with the data obtained from the preliminary site investigation. This preliminary framework can address limitations found in the existing frameworks.

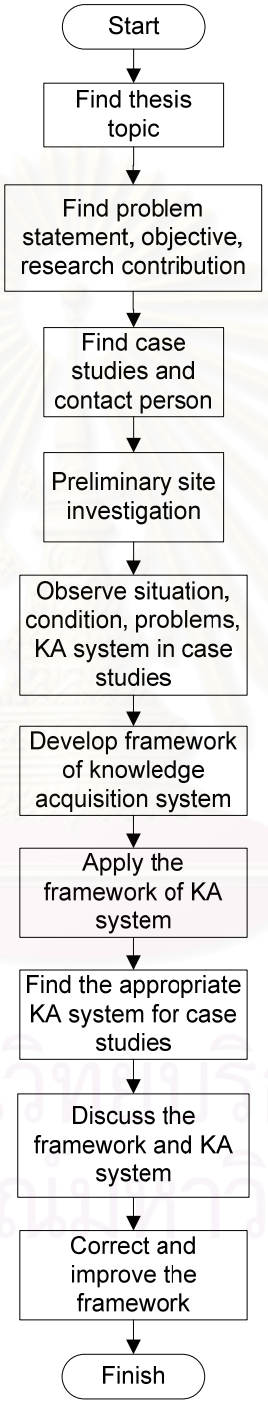


Figure 1-1 Research methodology

Data collection was then performed to obtain more input to the framework and to adjust the framework to fit real practices in the case studies. Data collection was

conducted by interviewing key persons involved in the knowledge acquisition system of the project. The key persons in Suramadu Bridge Project were the senior project manager, team leader of engineer, design checker team, engineer of information management system, and general superintendent of the contractor. The key persons in Pasupati Bridge Project were project manager, technical assistants, chief of supervisors, and contractor. Table 1-1 shows questions asked in the interview sessions, modified from Neve (2003).

The results of the interview sessions were concluded and used for developing a knowledge acquisition framework. The newly developed knowledge acquisition framework was discussed with the expert. The expert in this research was a lecturer of a college participating in the projects. This expert performed the feasibility study of Pasupati Bridge Project and was a supervisor in the project.

Table 1-1 Questions for interview session

No	Question
1	Is it necessary to capture and store knowledge during construction?
2	Is there any capturing and storing knowledge system in the project?
3	What is the important knowledge needed to be captured and stored during construction?
4	What are the activities of each construction process?
5	What is the problem faced during construction processes that happened repeatedly and ever happened before from previous project?
6	What are the methods to solve problem faced during construction?
7	What is the monitoring system for project progress during construction?
8	What is important knowledge during construction in terms of construction method, equipment, material, and technology used in project?
9	What is the vision and mission of project?
10	What are the tools of capturing and storing knowledge used in project?
11	Who will manage knowledge storage, control process of capturing knowledge, and update it?

CHAPTER II
LITERATURE REVIEW

2.1 General

Knowledge is one of the important resources for an organization towards sustaining its competitive advantage. Knowledge in a particular organization is considered unique in nature, and therefore it is difficult for competitors to imitate.

Undoubtedly, a construction organization considers multiple unique realms of knowledge due to the unique characteristics of its work processes. Construction work has specific characteristics in its nature such as its fast pace, dynamic processes, ad-hoc situated decisions, and high rate of turnover. Obviously, in every step of processes, knowledge is created. Unfortunately, this process often occurs without understanding of what the knowledge is.

Although the literature on knowledge management is plentiful as evidenced by its wide availability on the internet and in journals, the issues involved in strategic knowledge management in public construction have been addressed only minimally.

2.2 Knowledge

2.2.1 Defining knowledge

Knowledge originates in the head of an individual and builds on information that is transformed and enriched by personal experience, beliefs and values. Information is interpreted by the individual and applied to his or her purpose. Knowledge formed by an individual differs from that of another person despite receiving the same information. Knowledge is the mental state of ideas, facts, concepts, data, and techniques, recorded in an individual's memory. On the other hand, knowledge, data, and information have different meaning as shown in Figure 2-1.

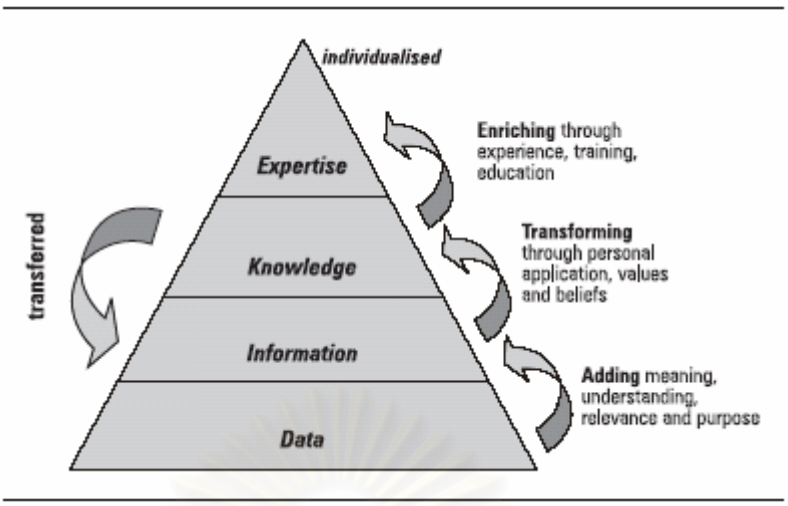


Figure 2-1 Difference between data, information, and knowledge (De Long and Fahey, 2000)

Data incorporate meaning, understanding, and purpose into information. When a receiver enriches the information with his own personal values and beliefs, information becomes knowledge.

An expert specializes in a certain field will build his or her individual knowledge by his or her personal application, whereas ordinary people can only transfer data or information. Unlike information, expertise cannot be transferred to other individuals. Thus, individual transforms information into knowledge by incorporating personal experience, values, and beliefs.

There are two general classifications of knowledge: explicit knowledge and tacit knowledge. Explicit knowledge is knowledge that can be easily expressed, written down, or passed verbally to others. Because of its ease in expression, explicit knowledge is more easily transferred and imitated. On the other hand, tacit knowledge is knowledge that is difficult to be articulated and expressed to others. The management of this type of knowledge is a difficult process. The knowledge may be expressed in terms of a restricted code, which is obvious to organizational members, yet may not be at all obvious to non-members. Indeed, members may not be consciously aware of the existence of the knowledge, and hence it may be difficult to communicate this type of knowledge to non-members.

2.2.2 Knowledge in construction

Knowledge in the construction domain can be classified into three categories (Wetherill et al, 2002):

Domain knowledge

This knowledge forms the overall information context. It includes administrative information (e.g., zoning regulations, planning permission, standards, technical rules, and product databases). This information is, in principle, available to all companies and partly stored in electronic databases.

Organizational knowledge

This is company-specific and the intellectual capital of a firm. It resides both formally in company records and informally in the skilled processes of the firm. It also comprises knowledge about personal skills, project experiences of the employees and cross-organizational knowledge. The latter covers knowledge involved in business relationships with other partners, including clients, architects, engineering companies, and contractors.

Project knowledge

This knowledge includes knowledge in each company and knowledge created by the interaction between companies. It is not held in the form that promotes reuse (e.g., solutions to technical problems or in avoiding repeated mistakes), thus partnerships are generally unable to capitalize this potential for creating long-term knowledge. It includes project records, memory of processes, as well as problems and solutions.

2.3 Knowledge Management (KM)

2.3.1 Knowledge management definition

There are many definitions of Knowledge Management (KM), depending on the organization using it. One of the definitions of KM is the process of capturing knowledge, adding value and understanding of corporate information using IT systems (e.g., intranet, extranet, data and text mining, and groupware software), in order to maintain, reuse, and redeploy that knowledge (Srinivas, 2004)

The concept of knowledge management is related to databases, intranets, document management systems, corporate accounting, learning, business strategy, and management of product development processes. Knowledge management involves not only the movement of data or the transfer of information, but also integration, sharing, accessing, and accumulation of knowledge, as well as

development of expertise in the organization. Knowledge management will support an organization's strategic objectives, particularly for accessing and sharing knowledge in partnering, strategic alliances, and long-term relationships.

Organizations such as government agencies' providers clearly need to capture, organize, and share knowledge to perform good work. They also need to generate new forms of knowledge if they want to survive in long term. In successful organizations, the knowledge is very closely integrated into their strategies and their ability to manage knowledge. Therefore, capturing and storing knowledge are regarded as the core capabilities (Choo and Bontis, 2002).

2.3.2 Knowledge management processes

Knowledge management (KM) processes can be broken down into five phases: knowledge creation, validation, acquisition, distribution, and application (Tserng, 2004). These five phases in KM allow an organization to learn, reflect, and relearn. They are usually considered essential for building, maintaining, and replenishing of core-competencies.

Knowledge creation

Knowledge creation refers to the ability of an organization to develop new and useful ideas or solutions. By reconfiguring and recombining foreground and background knowledge through different sets of interactions, an organization can create new realities and meanings. Knowledge creation consists of all activities intended to produce new knowledge at both the individual and the collective levels. The main processes for individual knowledge creation rely on creativity and problem solving. Creativity may be called the disorderly component and the capability of problem solving may be called the systematic component of the knowledge development process. Collective knowledge creation involves the learning dynamics of teams.

Knowledge validation

Knowledge validation refers to the extent to which a firm can reflect on knowledge and evaluate its effectiveness for the existing organizational environment. This stage has a process of continually monitoring, testing, and refining the knowledge base to suit the existing or potential realities. For example, when an organization employs new sets of tools and technologies, as well as processes and procedures, it may need

to update or refine the skills of its employees so that they can swiftly adapt to new competitive realities.

Knowledge acquisition

Knowledge acquisition processes include identification, capturing of knowledge needs, and collection of knowledge assets. The first step for this process is to identify the expert who has knowledge that is important to be captured and stored.

Knowledge distribution

Knowledge needs to be distributed and shared throughout the organization before it can be exploited at the organizational level. The interactions between organizational technologies, techniques, and people can have direct bearing on knowledge distribution. For example, the organizational structure based on traditional command and control minimizes the interactions between technologies, techniques, and people, and thus reduces the opportunities in knowledge distribution. Similarly, knowledge distribution through supervision and a predetermined channel will minimize the interactions and consequently reduce the opportunity to question the validity of the transferred knowledge. The application of electronic mail, intranet, bulletin board, and newsgroup can support the distribution of knowledge throughout the organization and allow organizational members to debate, discuss, and interpret information through multiple perspectives.

Knowledge application

Knowledge application means making knowledge more active and relevant for the firm in creating values. The criteria of evaluating the usefulness of knowledge are not often readily apparent. However, if a company believes in the usefulness of knowledge in supporting its practical and day-to-day common activities, management should provide sufficient latitude to the communities of practice for experimentation to asses the potential of the knowledge. Certainly, a number of factors, including time period of the completion of the project, project cost, and uncertainty of benefits, need a thorough evaluation. However, a manager often understands that knowledge is potential to make a dramatic effect on the outcome of the project.

Figure 2-2 explains the knowledge management process and shows the positions of knowledge acquisition, capture, and storage.

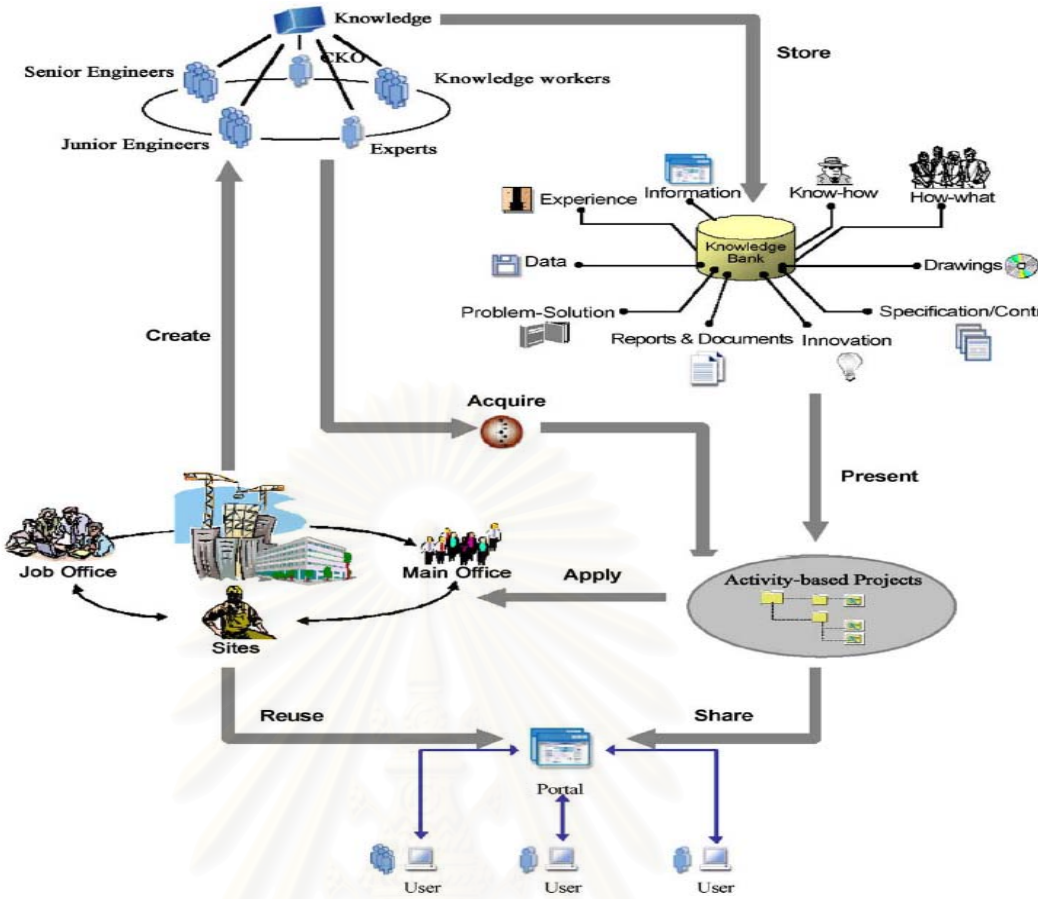


Figure 2-2 KM cycle in organization and construction project (Tserng, 2004)

2.3.3 Generic knowledge management framework in the public sector

The public sector is different from the private sector because of its unique features. The public sector is stakeholder dependent while the private sector is shareholder dependent. The stakeholder approach involves multiple parties in the process and it is much more complex to deal with. In the public sector, the stakeholder can be citizens, state and local governments, private firms, users, and lobby groups, and myriad others. When governments have to make policy decisions and deliver services, care and considerations of the interest of the stakeholders must be taken. In the private sector, however, firms are mainly responsible for their shareholders' interests. Firms must provide shareholders' returns on their investment. Secondly, the private sector is competition based, while the public sector is dependent more on such factors as service delivery, information provision, and knowledge identification, sharing and, utilization. Due to the survival issue, private firms are constantly vigilant of discontinuous environmental changes in order to gain

competitive advantages by adopting new management tools, techniques and philosophies such as KM. There is, however, no such threat in the public sector. In the core public service, organizational changes have not traditionally been motivated by product competitiveness. However, traditional public service monopolies, to some extent, are increasingly challenged with the globalization of information and increased people and capital. Therefore, the public sector should focus more on identification, sharing and, utilization of knowledge (Cong and Pandya, 2003).

People, processes, and technology are the three key elements of the environment. KM focuses on people and organizational culture to stimulate and nurture the sharing and use of knowledge; on processes or methods to locate, create, capture and share knowledge; as well as on technology to store and make knowledge accessible to allow people to work together without being together. People are the most important component because managing knowledge depends upon people's willingness to share and reuse knowledge (Milner, 2000).

2.4 Knowledge Acquisition (KA)

2.4.1 Knowledge acquisition definition

Knowledge acquisition is the process of extracting, structuring, and organizing knowledge from several sources, especially human experts so that their skill in problem solving can be captured and transformed into a computer readable form (Liou, 1990).

Another definition of knowledge acquisition is the process of eliciting, analyzing, and interpreting the knowledge that a human expert uses when solving problems (Kidd, 1987 cited in Wagner, 1990). This whole process of eliciting and encoding expert knowledge for machine use is also commonly referred to as knowledge engineering.

2.4.2 Involvement of human resources in knowledge acquisition

Identifying appropriate domain experts and involving people in the knowledge acquisition process are critical to the success of knowledge acquisition. This is attributes that should be considered when selecting appropriate experts (Liou, 1990).

Expert's domain of expertise, his experience and reputation

The experts chosen should have experience in the specific aspect of the domain. These experts can be distinguished by looking at their outstanding experience compared to other experts active in the domain. Leading experts are recognized by their colleagues and clients.

Availability

The most common problem in knowledge acquisition is caused by time demand on an already busy expert. Management's commitment of an expert's time to a project should be secured. If problems with access are anticipated, an individual should not be selected as the primary expert, regardless of his or her experience and characteristics.

The connections between knowledge engineers, users, and managers influence the knowledge acquisition process. The knowledge engineer is responsible for structuring and constructing the expert system. The responsibilities of knowledge engineers include leading and managing the project, defining the problem domain, selecting hardware and software, acquiring and representing knowledge, implementing the expert system, interaction with users and managers, preparing technical documentation, verifying and validating the system, training users, operating and maintaining the system, and providing advice for further updates.

Users and managers should be involved in the knowledge acquisition tasks, especially in the planning stage where decisions of problem scope are made and in the verification stage where the prototype system is evaluated. The problem scope should be jointly determined by domain experts, users, managers, and knowledge engineers. Domain experts provide a subjective perspective of what the system can do for users, while users provide a broader perspective of how the system may be able to help them. Managers provide strategic guidelines about what should and should not be included in the system. Systems that involve users in the development process tend to be more acceptable to the users when they are delivered.

2.4.3 Knowledge acquisition techniques

The approach used to acquire knowledge determines both the quality of the expert knowledge and the amount of effort required for its acquisition. Various

techniques of knowledge acquisition have been developed, as described by Liou (1990).

Interview

Interviewing is the most commonly used method for getting comments and opinions from others. It is also widely used in eliciting knowledge from domain experts. Structured interviewing is goal oriented. It forces organization upon the participant. The structure provided by the clearly stated goals reduces the interpretation problems inherent in free-form interviewing and allows the knowledge engineer to prevent the distortion caused by expert's subjectivity. When this technique is used, experts either fill out a set of carefully designed questionnaire cards or answer questions raised by the knowledge engineer using an established domain model of the business decision-making activity. Questionnaires can be particularly useful in uncovering relationships and discovering objects of the domain.

Observation

Observation involves observing how an expert solves a real problem. The expert works in his or her accustomed environment without being interrupted by the knowledge engineer. A decision must be made as to how the expert's performance will be recorded. The knowledge engineer may observe and take notes. Alternatively, the problem-solving process may be videotaped. A limitation to this latter technique is that the underlying reasoning in the expert's mind is usually not revealed by his actions.

Post project reviews

Post-project reviews are debriefing sessions used to highlight lessons learnt during a project. These reviews are important to capture knowledge about causes of failures, as well as how they were addressed and the best practices identified in a project. This increases the effectiveness of learning as knowledge can be transferred to subsequent projects. However, if this technique is to be effectively utilized, adequate time should be allocated for those involved in a project to participate.

Recruitment

Recruitment is an easy way to get new knowledge. This technique can help acquire external tacit knowledge, especially from experts. This approach adds new knowledge and expands the organizational knowledge base. Another benefit is that other

members within the organization can learn from the recruited member formally and informally so that some knowledge will be transferred and retained if the individual leaves the organization. Some organizations also try to codify the recruited person's knowledge that is of importance for their business.

Apprenticeship

Apprenticeship is a form of training in a particular trade carried out mainly by practical experience or learned by doing. Apprentices often work with their masters and learn workmanship through observation, imitation, and practice. They focus on improving the skills of the individuals so that they can later perform tasks on their own. This process of skill building requires continuous practice by the apprentices until they reach the required level.

Mentoring

Mentoring is a process where a trainee or a junior staff is attached or assigned to a senior member of an organization for advice related to career development. The mentor provides a coaching role to facilitate the development of the trainee by identifying training needs and other development aspirations. This type of training usually consists of career objectives given to the trainee where the mentor checks if the objectives are achieved and provides feedback.

Training

Training improves staff's skill and therefore increases their knowledge. Its implementation depends on plans and strategies developed by the organization to ensure that employees' knowledge is continuously updated. Training usually takes a formal format and can be internal, where seniors train juniors within the organization, or external, where employees attend courses managed by professional organizations.

Protocol analysis

Protocol analysis is a form of data analysis that has its origin in clinical psychology. To employ this technique, a knowledge engineer describes a problem scenario and asks the expert to talk about his or her thinking process while solving the problem. Experts find it is much easier to talk about specific examples of problem rather than talking in abstract terms. The thinking aloud process may be videotaped and transcribed for analysis. Protocols must be analyzed based on a systematic breakdown

of the information to produce a structured model. The goal is to identify the kinds of objects the expert sees, the attributes of those objects, the relationships among them, and the inferences drawn from these relationships.

Group support systems

Group support systems (GSS) are computer and communication systems that facilitate a group's communication, coordination, and decision making process. Benefits derived from GSS for the knowledge acquisition process include: 1) the electronic documentation of knowledge, 2) the ability to extract knowledge from multiple experts in parallel, 3) conflicts that can be addressed during the knowledge extraction sessions, and 4) interactions among experts that can result in an enlarged and enriched domain of expertise.

Taxonomy

Taxonomy is a collection of terms and their relationships that is commonly used in an organization. Examples of relationship are hierarchical (where one term is more general hence subsumes another term), functional (where terms are indexed based on their functional capabilities), and networked (where there are multiple links between the terms defined in the taxonomy).

Ontology

Ontology supports deep representation (for both descriptive and procedural knowledge) of each term as well as defines domain theories that govern the permissible operations with the concepts in the ontology. Ontology serves multiple purposes in an organization. It can be used as a corporate glossary holding detailed descriptions of every key term used in the organization. They can also be used to constrain the search space of search engines and prune search results, act as a knowledge map to improve the compilation and real time navigation of web pages.

2.4.4 Knowledge acquisition technologies

Information Technology (IT) tools used for capturing and storing knowledge include word processors, knowledge bases and case-based reasoning tools. In most construction companies, information is captured and documented using software applications such as MS Word and Excel. Word processors are the most common IT tools used for capturing and storing knowledge. Such information is generally made

available to all company employees over the intranet. However, most construction companies recognize the need for company intranets to hold more project specific information documents describing the overall project, including its performance and recommendations made at the end of the project. This has significant value, especially for future projects. Some knowledge acquisition technologies for capturing and storing knowledge are as follows (Tsui, 2002).

Groupware

Groupware is a software product that helps groups of people communicate and share information, especially for group decision-making. Groupware supports distributed and virtual project teams where team members are from multiple organizations and in geographically dispersed locations. Groupware tools usually contain email communications, instant messaging, discussion areas, file area or document repository, information management tools (e.g., calendar, contact lists, meeting minutes, and meeting agendas) and search facilities.

Intranet

Intranet is inter-organizational network that is guarded against outside access by special security tools called firewalls.

Extranet

Extranet is an intranet with limited access to outsiders, making it possible for them to collect and deliver certain knowledge. This technology is very useful for making organizational knowledge available to geographically dispersed staff members and is therefore used by many organizations.

Knowledge base

Knowledge bases are repositories that store knowledge about each topic in a concise and organized manner. They present facts that can be found in a book, a collection of books, websites or even human knowledge. This is different from the knowledge bases of expert systems, which incorporate rules as part of the inference engine that searches the knowledge base to make decisions.

2.4.5 Knowledge acquisition methodology

A knowledge acquisition methodology is a guide to knowledge engineers in developing such a plan. A methodology established to perform the knowledge

acquisition task comprises four phases: planning, extraction, analysis, and verification, the details of which are shown in Table 2-1.

Planning knowledge acquisition

The goals of planning, the most important phase of the acquisition tasks, are to identify proper human resources, analyze various knowledge acquisition techniques, and design proper procedures to acquire knowledge.

Knowledge extraction

The primary activity of the knowledge extraction phase is to acquire knowledge from experts through a series of knowledge acquisition sessions, each of which has a particular objective and uses specific techniques and tools. During each session, knowledge engineers must explain session objectives, an approach to acquiring knowledge, and expected results. The outputs from this phase include heuristics, concepts, or classification structures. These can be captured in an electronic format and will require further analysis in order to be represented in a particular knowledge representation scheme.

Knowledge analysis

The primary task of this phase is to analyze the output of the sessions. Heuristics or classification structures are analyzed and formalized into representations, which may be in the form of rules, frames, objects, relationships, or semantic networks.

Knowledge verification

The verification phase involves testing the validity of the acquired heuristics, concepts, and classification structures. Formalized representations are presented to experts. A demonstration of the prototype system for users and experts is also useful. Refinements of represented knowledge can be done by iterating the knowledge analysis phase, but reformulation of heuristics, concepts, or classification structures requires going back to the knowledge extraction phase.

Table 2-1 Knowledge acquisition methodology (Liou, 1990)

No.	Phase	Steps
1	Planning	- Understand the domain - Identify domain experts and users - Define the problem scope - Identify the type of application

		- Develop process models - Plan acquisition sessions
2	Extraction	- Explain the acquisition approach - Discuss objectives of the acquisition session - Conduct the acquisition session - Interview the expert
3	Analysis	- Analyze the acquisition session output - Transfer knowledge into representations
4	Verification	- Develop test scenarios - Verify knowledge with experts

If knowledge captured in the prototype system does not provide the solutions needed for problems, redesign of the knowledge acquisition session will be necessary. This is done by rethinking the knowledge acquisition approaches and procedures. By verifying the knowledge as part of the ongoing knowledge acquisition and review process, expert system developers can minimize the time and money wasted and, thus prevents the development of inappropriate or useless systems.

2.4.6 Knowledge acquisition frameworks

Most of the currents works in knowledge acquisition is application oriented with theoretical basis. Figure 2-3 shows a framework of knowledge acquisition by Kim and Courtney (1988, cited in Wagner, 1990). The framework aims to structure and organize the whole process of knowledge acquisition in general sense by surveying the knowledge acquisition strategies.

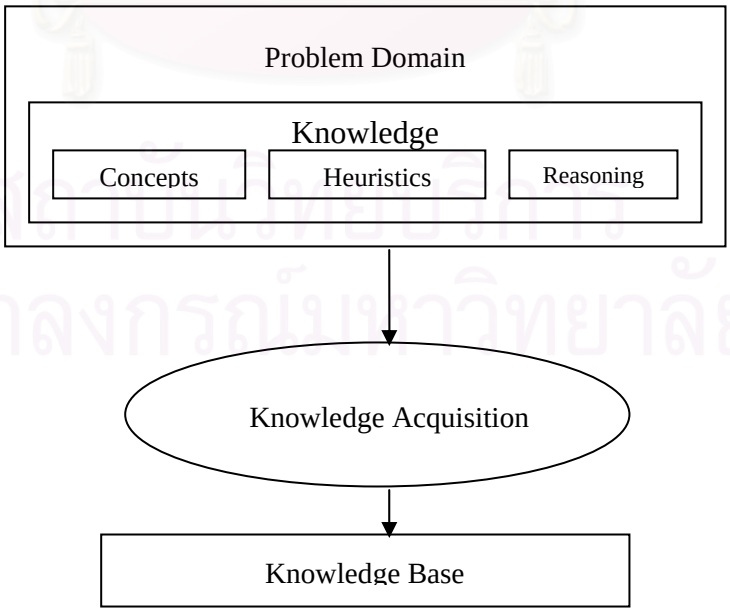


Figure 2-3 A framework for knowledge acquisition
(Kim and Courtney, 1988 cited in Wagner, 1990)

They set up their knowledge acquisition framework based on three types of knowledge contained within the problem domain which are mapped to a knowledge base by means of a knowledge acquisition method. Problems can be classified by their size, complexity, and degree of structure. Knowledge is viewed in terms of three interrelated components: concepts, heuristics, and reasoning. Concepts are defined as facts, first principles, general laws, and causal relationships in a domain. Heuristics are empirical knowledge in the form of pattern action rules which have been acquired through long experience by experts. Reasoning knowledge is the meta-rules or strategies of inference which provide a general approach to problem solving in some domain.

Figure 2.4 illustrates another example of a knowledge acquisition framework proposed by Selbig (1986, cited in Wagner, 1990). A formal language of knowledge acquisition is needed for describing all possible mappings and combinations of knowledge sources, knowledge acquisition mechanisms, and problem domains before a unified conceptual framework can be conceived.

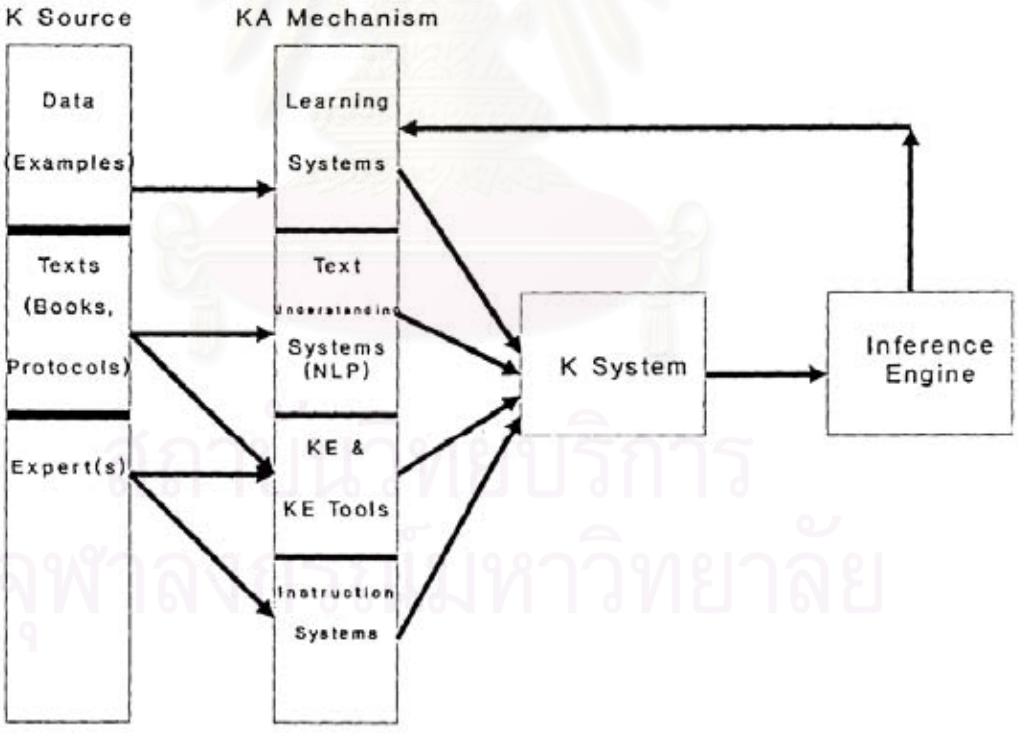


Figure 2-4 Descriptive knowledge acquisition framework
(Selbig, 1986 cited in Wagner, 1990)

These knowledge sources can be mapped into the knowledge system of an expert system via learning systems, text understanding systems, the classic knowledge

and engineering, or even instructional systems. Each of these mechanisms represents a whole area of research that can be rightfully placed within the KA framework as a whole. For example, learning systems are used to derive rule sets from large sets of empirical data. Information is supplied to the learning component from the environment in the form of data, examples, instructions, and even unsupervised observations and discoveries. The learning component then uses this information to modify the knowledge base, from which the inference engine uses to perform a task. Text understanding systems is used for extracting knowledge from books and protocols to use in a knowledge system. Generally, the natural language of the text is transformed into a formal or semantic representation language. These semantic representations are then interpreted in order to summarize the text, answer the questions, or extract information from it. The mechanism of using a knowledge engineer (KE) and a set of tools encompassing what are classically viewed as the true knowledge acquisition problem. Knowledge elicitation tools must also be included and these might include structured interviewing techniques, protocol analysis, and interviewing techniques.

2.5 Conclusions

Five processes comprise knowledge management: knowledge creation, knowledge validation, knowledge acquisition, knowledge distribution, and knowledge application. Knowledge acquisition is a sub process of knowledge management. Knowledge acquisition can be divided into three main stages: identifying knowledge, capturing knowledge, and storing knowledge. Based on the definition of knowledge acquisition, these three stages can be used as the basis for developing the framework of knowledge acquisition system.

The objective of this research is to develop a framework of knowledge acquisition systems that can be used by governmental agencies. By reviewing the literature, two previous frameworks were found. One framework was developed by Kim and Courtney and another one was developed by Selbig. Both of these frameworks are not detail, not communicative, and do not give complete information about tools and sources to capture and store the knowledge. Therefore, a framework of knowledge acquisition will be developed in this thesis to address weak points in these previous frameworks. Moreover, application of the developed knowledge

acquisition framework is based on knowledge acquisition methodology: planning of knowledge acquisition, knowledge extraction, knowledge analysis, and knowledge verification.

CHAPTER III
FRAMEWORK OF KNOWLEDGE ACQUISITION SYSTEMS

This chapter presents the development of the proposed knowledge acquisition framework. The framework was developed by modifying the existing frameworks by incorporating site investigation data. The developed framework is expected to be general and can be applied to any type of public construction projects.

3.1 Methodology for Developing a Knowledge Acquisition Framework

Figure 3-1 outlines the methodology to develop the proposed knowledge acquisition framework. Firstly, the knowledge acquisition processes have to be defined. In this research, the knowledge acquisition processes include identifying knowledge, capturing knowledge, and storing knowledge.

Existing knowledge acquisition frameworks need to be explored to understand their model, type, and limitations (Patel, 2000). This stage aims to know the part of frameworks that needs to be improved. The limitations of the existing knowledge acquisition framework are analyzed in order to improve and develop a new knowledge acquisition framework. The limitations may include unclear stages, tools, methods, and sources of each knowledge acquisition framework process.

Site investigations are conducted in order to know the actual conditions of the existing knowledge acquisition system, the regulation of project and the component that support the system of the existing system such as tools for knowledge acquisition, methods for knowledge acquisition, type of knowledge, experts, and understanding of knowledge acquisition processes.

The framework of knowledge acquisition in this research has been developed based on existing knowledge acquisition frameworks and the results from interview sessions.

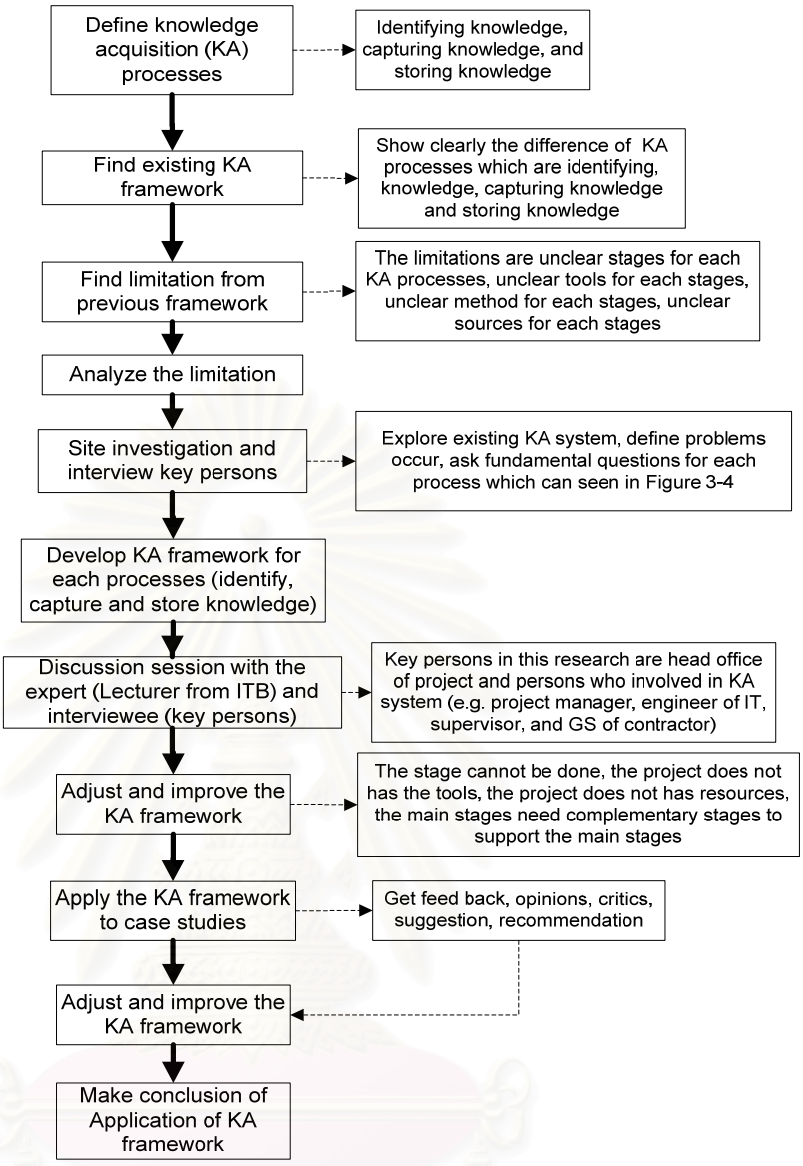


Figure 3-1 Methodology for developing KA framework

3.2 Site Investigation

Site investigation was performed to understand project characteristics, including work environment of each project, progress of work, organization chart of project, and the existing knowledge acquisition system. This was conducted by interviewing key persons in projects and reviewing related reports. Two sites were observed in the preliminary site investigation, namely, Suramadu Bridge Project and Pasupati Bridge Project. Interviews were conducted to assess level of understanding of interviewees about knowledge acquisition in the projects and to obtain their opinions about selecting important knowledge to be captured. The interviewees were

also asked about the current level of knowledge acquisition in the respective project. Interview results became the input to develop the framework.

3.2.1 Suramadu Bridge Project

Table 3-1 shows the list of interview questions of Suramadu Bridge Project. In Suramadu Bridge Project, the interviewees include senior project manager (SPM) (Mr. Chandra B.), team leader/senior project manager representative (TL) (Mr. Bagyo), design checker (DC) (Mr. Eko Prasetyo), engineer of management and information system (EMIS) (Mr. Ashari), and general superintendent of contractor (GSC) (Mr. Guntoro). The results from the interviews can be concluded as follows.

- Important knowledge was determined by breaking down main works into smaller activities, evaluating common problems and obstacles during construction, and studying new technologies used for accelerating the project. These preliminary ideas were then discussed in a meeting attended by the owner, project manager in project site, team design, supervisor, and contractor.
- Goals, vision and mission of project should be clearly defined in advance to give definitive assignment in monitoring the progress of the goals.
- The basic methods of capturing and storing knowledge in a particular project shall be known before so that developing knowledge acquisition system can optimally utilize the existing method.
- Knowledge was tracked down by using reports, employees, and minutes of meeting.
- Important knowledge to be captured was tracked down by examining job descriptions and flow of work in the organization.
- The application of processes and results of framework of knowledge acquisition were subject to engineer of management and information system’s concern.

Table 3-1 Questions for interview session in Suramadu Bridge Project

No	Questions	Interviewee				
		SPM	TL	DC	EMIS	GSC
1	Is it necessary to capture and store knowledge during construction?	X	X	X	X	X
2	Is there any capturing and storing knowledge system in the project?	X		X	X	
3	What is the important knowledge needs to be captured and stored during construction?		X			X
4	What is the list activity of each construction process?	X		X	X	
5	What is the problem faced during construction processes that happened repeatedly and ever happened before in previous projects?		X	X	X	X
6	What are the methods to solve problem that occur during construction?	X	X			X
7	What is the monitoring system of project progress during construction?	X			X	
8	What is important knowledge during construction in terms of construction method, equipment, material, and technology used in project?	X		X	X	X
9	What are the vision and mission of project?	X	X			
10	What are the tools of capturing and storing knowledge used in the project?	X			X	
11	Who will manage knowledge storage, control process of capturing knowledge, and update it?				X	

Note: - SPM : Senior Project Manager
- TL : Team Leader
- DC : Design Checker
- EMIS : Engineer of Management and Information System
- GSC : General Superintendent of Contractor

3.2.2 Pasupati Bridge Project

In Pasupati Bridge Project, the interviewees include project manager (PM) (Mr. Arief), technical assistants (TA) (Mr. Haeral Yandhi and Mr. Hardy), chief supervisor of casting yard (CY) (Mr. Iwan), chief supervisor of cable stay (CS) (Mr. Leo) and general superintendent of contractor (GSC). Table 3-2 shows the list interview questions of Pasupati Bridge Project. These questions are used to explore

the current conditions of knowledge acquisition in the project, employees understanding of knowledge acquisition as well as its tools and methods.

Table 3-2 Questions for interview session in Pasupati Bridge Project

No	Questions	Interviewee			
		SPM	TA	CY	CS
1	Is it necessary to capture and store knowledge during construction?	X	X	X	X
2	Is there any capturing and storing knowledge system in the project?	X	X		
3	What is the important knowledge needs to be captured and stored during construction?			X	X
4	What is the list activity of each construction process?		X	X	
5	What is the problem faced during construction processes that happened repeatedly and ever happened before in previous projects?		X	X	
6	What are the methods to solve problem that occur during construction?		X	X	
7	What is the monitoring system of project progress during construction?	X	X	X	
8	What is important knowledge during construction in terms of construction method, equipment, material, and technology used in project?		X	X	
9	What are the vision and mission of project?		X	X	
10	What are the tools of capturing and storing knowledge used in the project?		X	X	
11	Who will manage knowledge storage, control process of capturing knowledge, and update it?		X	X	

Note: - SPM : Senior Project Manager
- TA : Technical Assistance
- CY : Chief Supervisor of Casting Yard
- CS : Chief Supervisor of Cable Stay

The results of interviews are as follows.

- The framework should be universal and applicable to any work of project.
- The existing knowledge acquisition system should be used as basis to develop the new system. Thus, project's conditions shall be the major input such as existing tools for capturing knowledge and storing

knowledge, procedures of communication system, project monitoring, and job descriptions.

- The progress of project can be evaluated from reports sent to the owner. These reports can also be used as tools for communication, as well as capturing and storing knowledge.
- Knowledge can be captured in the design and planning stage during which alternatives are being evaluated. Comments and suggestions from project's key persons and government on particular alternatives may be captured and considered as important knowledge leading to the method should be used to capture this knowledge during construction.

3.3 Develop Preliminary Framework of Knowledge Acquisition System

The preliminary framework explains the main processes of a knowledge acquisition system. It breaks down the main processes which are to identify knowledge, to capture and to store knowledge into detailed processes, and to analyze the detailed processes step by step. A framework can be conceived as a flowchart, table, work procedure, and schema. In this thesis, the framework is presented in the form of a flowchart and schema (Newman, 1999).

3.3.1 Knowledge acquisition framework from previous research

The preliminary framework in this research was developed by modifying existing frameworks of knowledge acquisition. Figure 3-2 and Figure 3-3 show two existing frameworks of knowledge acquisition system. These existing frameworks consist of three main processes of knowledge acquisition: (1) identifying knowledge, (2) capturing knowledge, and (3) storing knowledge. In Figure 3-2, knowledge is identified after classifying problems. Capturing knowledge is presented as one of knowledge acquisition processes while storing knowledge is presented as a knowledge base.

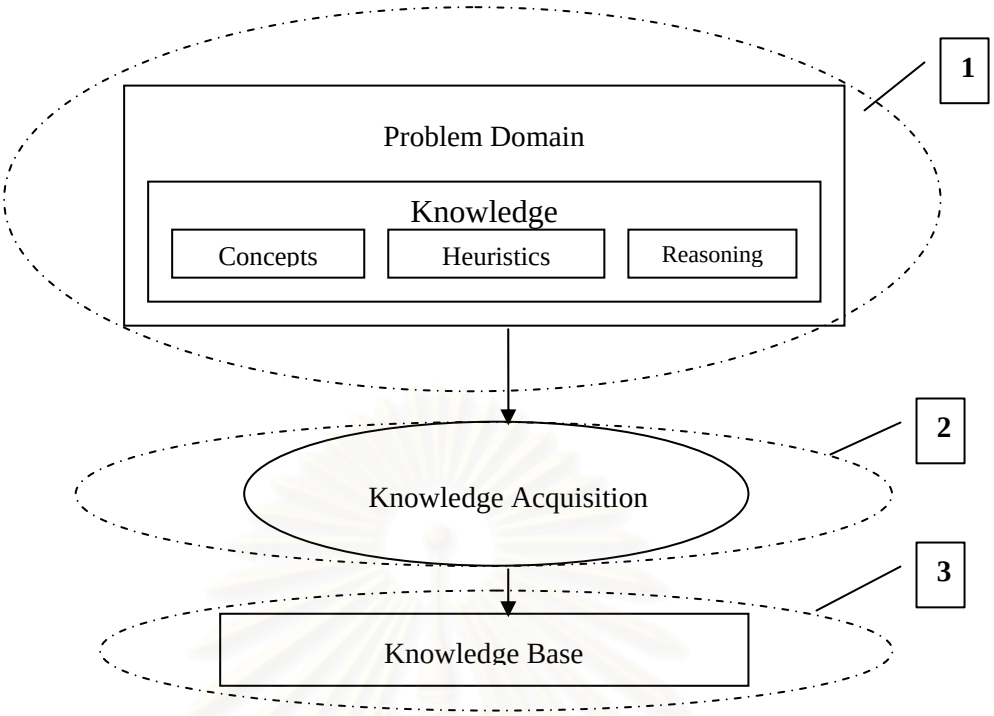


Figure 3-2 A framework for knowledge acquisition
(Kim and Courtney, 1988 cited in Wagner, 1990)

Figure 3-3 presents another existing framework described by Selbig (1986, cited in Wagner, 1990). This framework describes knowledge acquisition process with three phases: knowledge identification, capture, and store. Knowledge identification in this framework is described by defining source of knowledge that may be in the form of data, documents, or opinions from experts. Knowledge capture is described by knowledge acquisition mechanism which shows different methods of capturing different types of knowledge. Knowledge store is described as a knowledge system, including an inference engine, which decides whether the stored knowledge is sufficient or need to be re-captured.

Both frameworks above can be modified to yield a more comprehensive knowledge acquisition system by considering the following aspects:

- identification of knowledge sources,
- knowledge acquisition mechanism, and
- store of knowledge

By adding the aforementioned functions, the preliminary framework of knowledge acquisition in this thesis can be established.

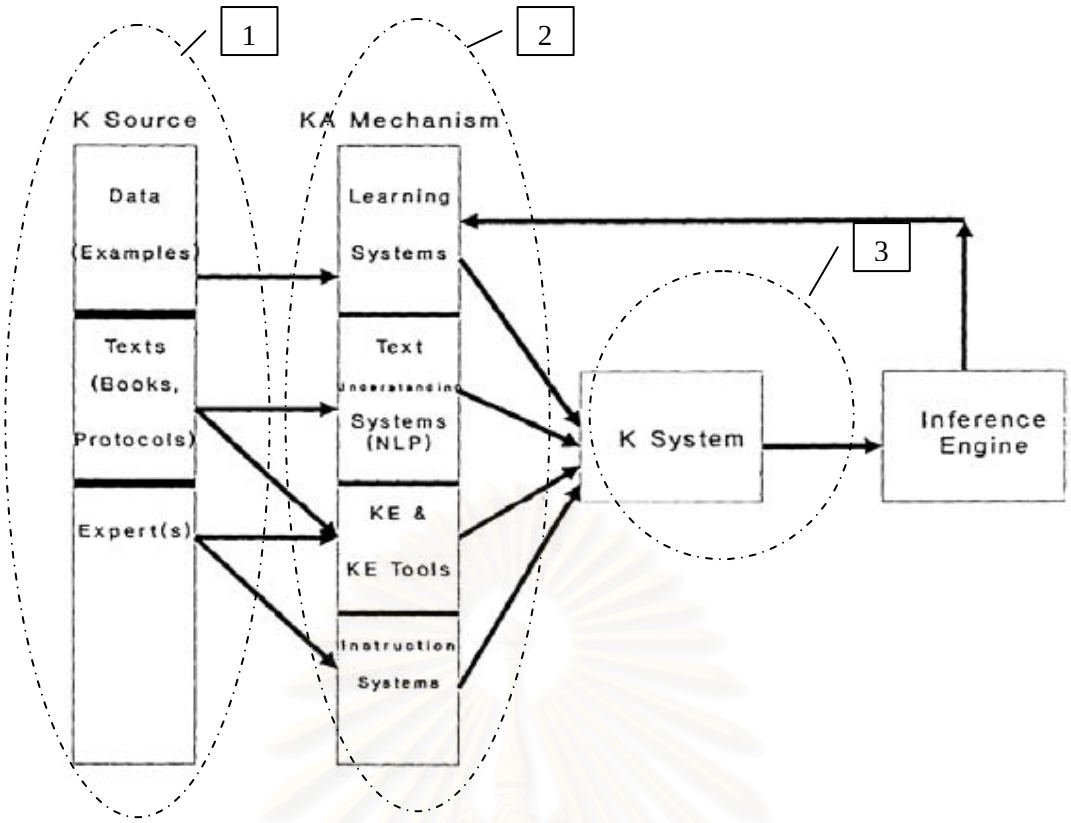


Figure 3-3 Knowledge acquisition framework
(Selbig, 1986 cited in Wagner, 1990)

3.3.2 Knowledge acquisition framework in this research

Figure 3-4 shows a schema of knowledge acquisition processes, consisting of identifying knowledge, capturing knowledge, and storing knowledge. Important knowledge is first identified. After being captured, the knowledge is stored in bank of knowledge. Users can utilize the knowledge by searching bank of knowledge.

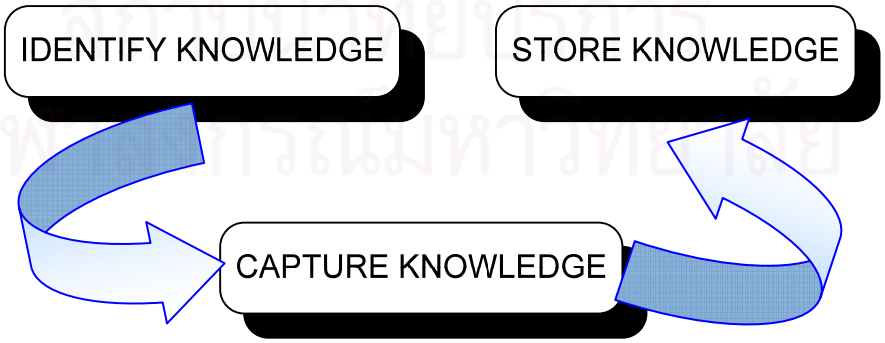


Figure 3-4 Knowledge acquisition processes

The questions shown in Figure 3-5 are used as basis to develop the framework. For example, what the knowledge to be captured and what method to be used are the questions to develop the knowledge capturing stage. The developed framework for knowledge acquisition system is shown by Figure 3-6.

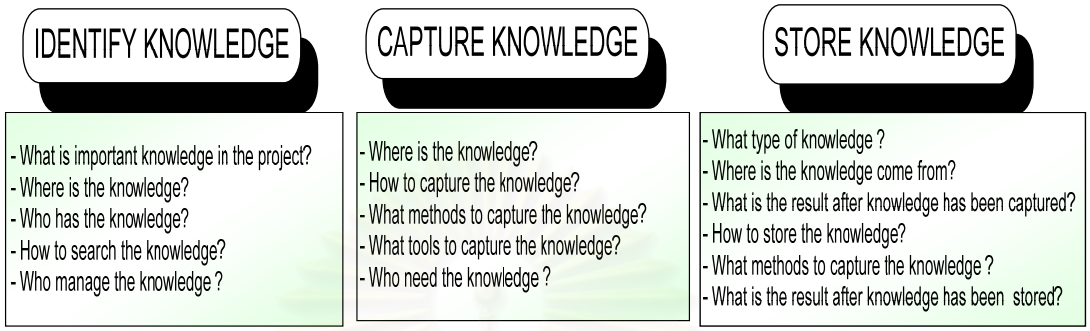


Figure 3-5 Questions for developing knowledge acquisitions system

(1) Create WBS of project

Work Breakdown Structure (WBS) is created to identify the works containing potential knowledge to be captured. WBS divides construction works into major work items. The major work items can also be divided into smaller work items. Breaking down the works is important to determine the strategies to capture the knowledge and at which level the knowledge should be captured. By narrowing down the level of work being observed, knowledge capturing is expected to be more efficient than if it is conducted in the broader level of work. WBS should provide information about time, location, and detailed activities of work items so that knowledge capturing can be performed accurately at the time and location of the specific activity.

(2) Find innovation of project

A project can be unique if it has one or more innovations. The innovations may be found in terms of construction method, material, equipment, and technologies used in the project. An innovation is a new knowledge that should be recorded and may be useful to the subsequent projects. Before being applied to other projects, an innovation should be examined in order to observe obstacles and difficulties may be experienced in its application. Technical reviews of an innovation, information of site condition where it was applied, rationale in selecting this innovation, as well as any measurement and evaluation concerning this innovation can support its application for future projects. Providing such information needs big effort and consumes cost, time,

and human sources. However, after sufficient information has been obtained, the government may save budgets of subsequent projects using this innovation. Normally, information about innovations used in a project can be found in specific reports or by exploring the project characteristics.

(3) Find sources of knowledge

Sources of knowledge should be determined in advance in order to know locations of the knowledge, its flow, and persons related to it. As the locations of knowledge have been determined, knowledge capturing can be conducted to specific location containing the important knowledge.

Knowledge can be obtained from documents, people, or meetings. The documents used as sources of knowledge can be found in the form of periodic reports (e.g., daily reports, weekly reports, and monthly reports), laboratory test reports, contract documents, and specifications. In terms of people, sources of knowledge can be obtained from interview and suggestion from engineers. Minutes of meeting and report of site visit are examples of sources of knowledge in terms of meeting.

(4) Create checklist form

A checklist form is a standard form to check the construction work stage by stage. Normally, a checklist form shows detailed activities of a work according to execution time and helps check the completeness of work performed easily.

A checklist form also supports monitoring construction method which has been agreed between the owner and the contractor. Detailed information such as time, location, and responsible persons of a work, information of the checker and his superintendent should be contained in the checklist form. In addition, this form should provide blank space for the checker to give a note or important information regarding execution of the work. Furthermore, additional information contained in the checklist is set according to project needs and site conditions.

(5) Assign a team to manage flow of knowledge

A team is assigned to monitor new or important knowledge and to manage the process of capturing and storing knowledge. This team is commonly called team of knowledge engineers. The members of this team are site engineers who are capable of

communication and information system, documentation system, as well as tools and method of capturing and storing knowledge, and know the processes of the works.

The project manager or an engineer can be leader of this team as long as he knows well about knowledge flow and knowledge mapping inside the project, and thus he knows exactly time and location to capture the knowledge as well as the persons involved in the process of knowledge capturing and knowledge storing. The team leader should be able to establish clear strategies and plans to capture and store knowledge so that the team can accomplish its job effectively.

(6) Define tools to capture

Tools to capture knowledge can be found in terms of electronic devices such as video camera to record video footage of construction work, tape recorder to record voice of periodic meeting and discussion of problem solving, as well as communication devices to transfer the information about new knowledge to other parties or team members.

(7) Define method to capture

The method to capture knowledge depends on the existing communication system, tools, and culture of the project. Communication systems affect the method to transfer knowledge from one party to other parties. An effective communication system is required if the project is divided into sections and each section is separated from other sections. Transfer information and transfer knowledge are critical in this kind of project. The availability of tools and infrastructure of knowledge capturing governs how the knowledge should be captured. The capturing tools should be available not only on the site but also at the owner's office where all the knowledge should be stored. Therefore, this office should be provided with such communication tools as fax machine, radio telecommunication, internet connection, and telephone line. The culture of the project is another important factor determining the method of knowledge capturing. The method to capture knowledge in a project using paperwork for its works is certainly different from the method used in a project using IT technology.

Based on the tools used in capturing processes, knowledge capturing can be divided into two methods: paper-based method and computer-based method. In paper-

based method, all knowledge capturing processes are performed manually by examining report and other documents. In computer-based method, the process of knowledge capturing elaborates computer as the media. The computer technology can be enhanced with other electronic devices to capture knowledge.

Based on the location of knowledge, method of knowledge capturing can be categorized into: (1) capturing knowledge directly from the site, (2) capturing knowledge from documents and reports, (3) capturing knowledge from meeting or communication between project parties, and (4) capturing tacit knowledge from experts and engineers. Each location of knowledge requires different method to capture the knowledge.

Knowledge capturing is performed by the team of knowledge engineers based on knowledge acquisition planning and according to tools and method that have been defined before. Capturing explicit knowledge can be done more easily than capturing tacit knowledge. As previously mentioned, explicit knowledge can be easily found in reports, video footage of construction work, and other media, but tacit knowledge can be explored and extracted from the sources of knowledge. The sources of knowledge must be analyzed to capture tacit knowledge, thus it requires more time as compared to capturing explicit knowledge.

After knowledge is captured, it is necessary to add properties of the knowledge such as type of knowledge, time and location of capturing process, sources of knowledge, and persons involved in the capturing process. This information is important to support classification of knowledge in the storing processes, and thus helps store knowledge in the right and systematic folder. These properties are also useful for searching or checking the knowledge because the searching engine can use this information as its keywords.

(8) Define tools to store knowledge

Tools to store knowledge depend on the form of captured knowledge. If the captured knowledge is in the form of computer files, storing tools should be in the form of computer systems. If the captured knowledge is in the form of report or document, the knowledge should be stored in the cabinet or book shelves. Other forms of knowledge are digital media such as video cassette or voice record. This

kind of knowledge should be stored and arranged well in the cassettes or compact discs storage box.

(9) Define method to store knowledge

The method to store knowledge depends on the tools to store the knowledge. If the process of storing knowledge uses computer as the tools, the method to store knowledge should be computerized. However, if the knowledge is stored using paperwork, the storing method should accommodate the needs of space and management. A systematic storing method should be introduced to help search and track back the knowledge for modifying or updating purposes. For the computer-based system, the knowledge should be stored in specific folders representing classification of knowledge. The classification can be based on the type of knowledge, type of work containing the knowledge, time chronological order, or indexing system of the knowledge. Similarly, paper-based systems should employ a systematic method to store reports of knowledge on the bookshelf or library. Because many reports will be stored, it will be better if the storing system uses a catalogue system as used in libraries. The indexing can be based on the names of knowledge or time of capturing the knowledge. Moreover, the report should be arranged into an alphabetical order or time order to help track back the knowledge.

(10) Check update

Stored knowledge should be checked frequently so that the knowledge is always up-to-date and suitable with work conditions at that time. Knowledge is updated performed by the team of knowledge engineers. The knowledge is updated by comparing the knowledge stored in the database to similar knowledge that is newly found. Then, similarities and differences between the stored knowledge and the new knowledge are observed to decide whether the stored knowledge is out of date and needs to be renewed.

3.4 Conclusion of Knowledge Acquisition Framework

Figure 3-6 shows the summary of the proposed framework of knowledge acquisition processes. This framework addresses discontinuity of knowledge acquisition processes in the knowledge acquisition framework of Dept. of Public

Work. As comparison, knowledge acquisition framework of Dept. of Public Work is shown in Figure 3-7.

The framework of knowledge acquisition process is a general framework and not specifically used for bridge project. Thus, it can be applied to most types of construction projects. These frameworks will be applied to case studies as will be discussed in Chapter 4.

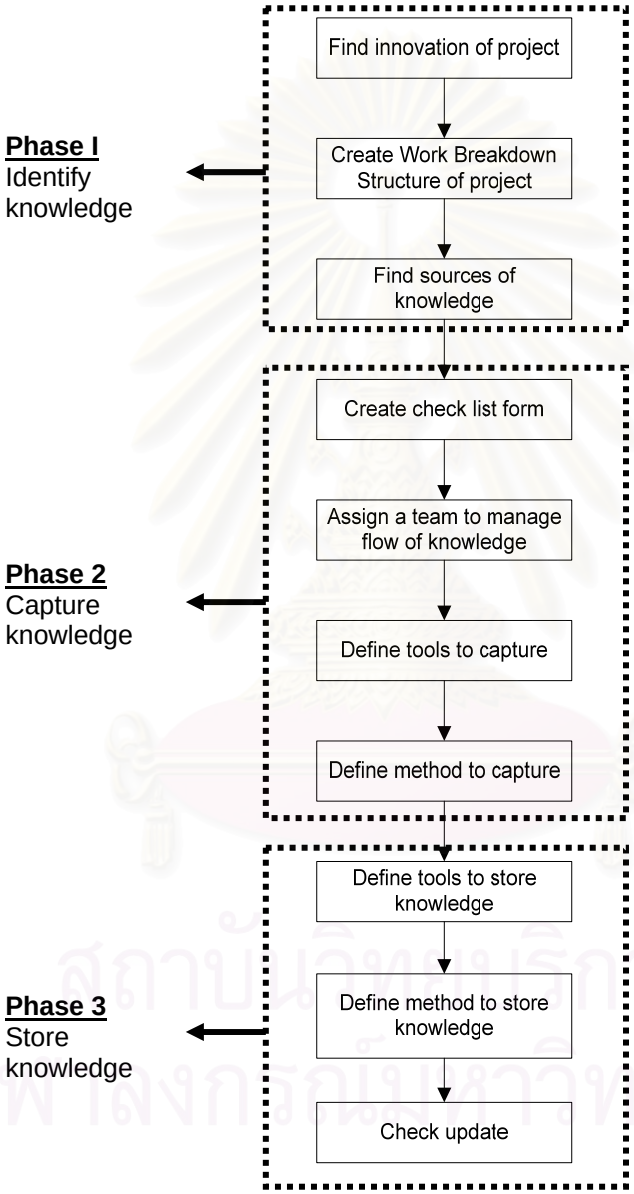


Figure 3-6 Summary of knowledge acquisition framework

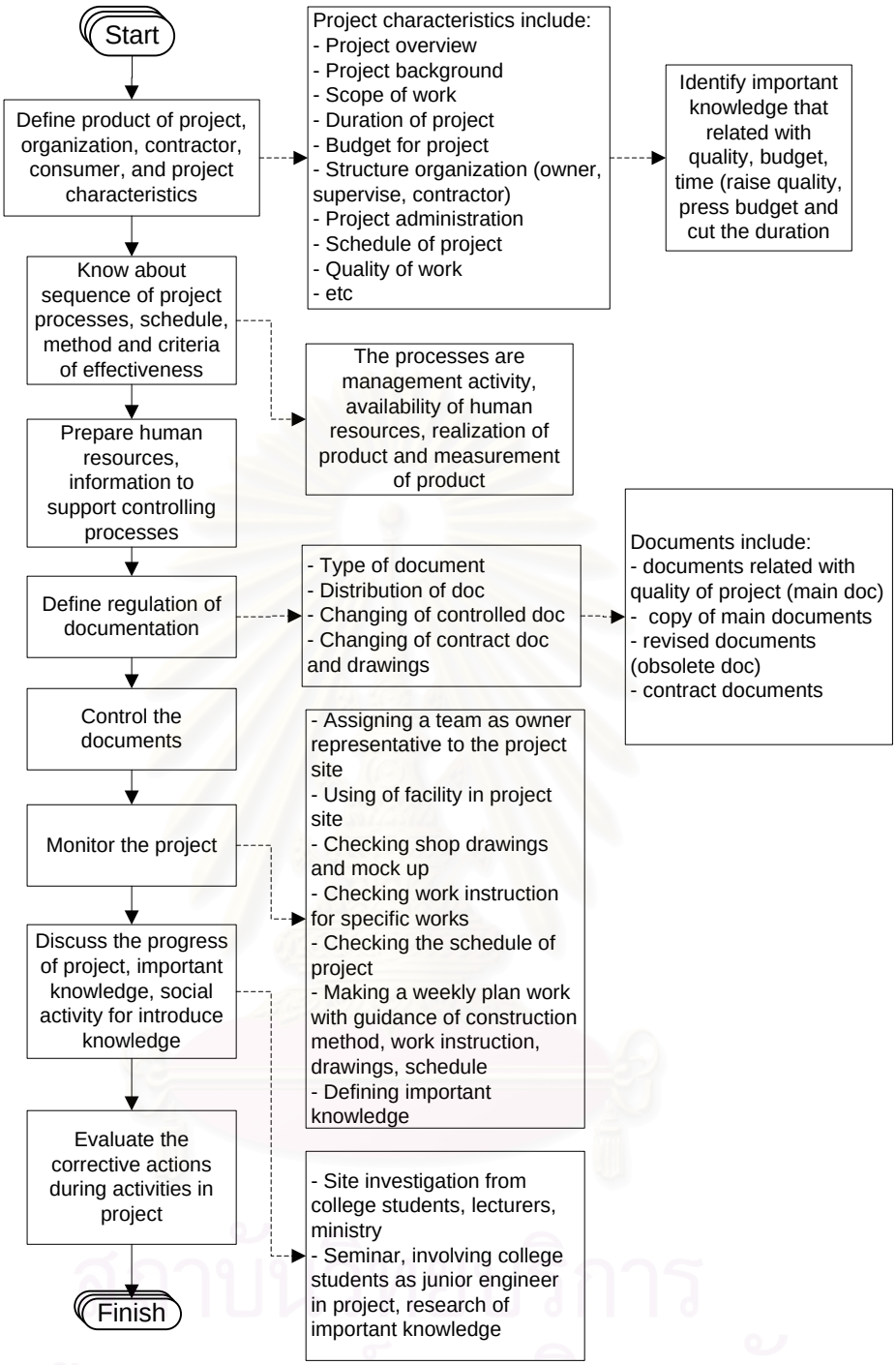


Figure 3-7 Knowledge acquisition framework in Dept. of Public Work

CHAPTER IV

CASE STUDIES

Indonesia is an archipelago with 18,860 islands where the largest population is in Java Island. For the sake of economic development, the connectivity among islands, especially in remote areas, is very important. One of infrastructures used to connect the islands is bridge. This research took two bridge construction projects, Suramadu Bridge Project and Pasupati Bridge Project, as case studies to illustrate the application of the proposed framework of knowledge acquisition method. Both bridges are cable-stayed type and considered a new technology in Indonesia. Figure 4.1 shows a map of Indonesia and the locations of both case studies.

The investigation will focus on construction processes, communication systems, as well as capturing and storing systems of important knowledge from the government agencies' point of view. This chapter presents both case studies, application of the framework, results, and discussion.

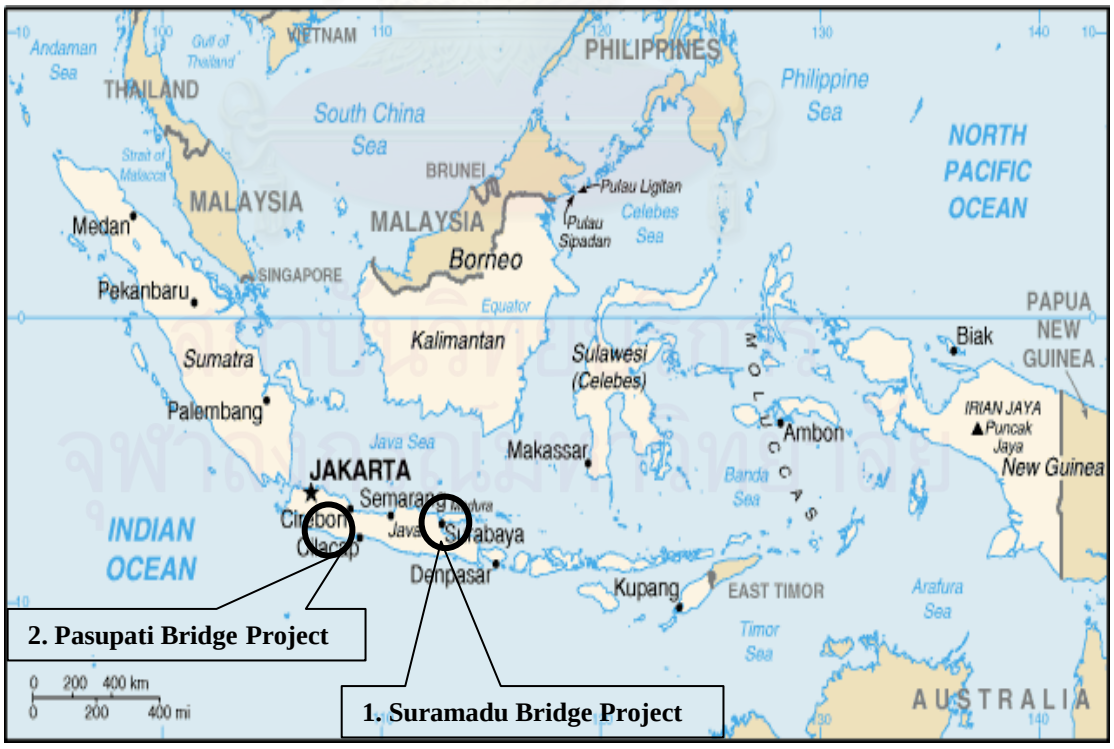


Figure 4-1 Map of location of case studies (modified from www.wikipedia.com)

4.1 Suramadu Bridge Project

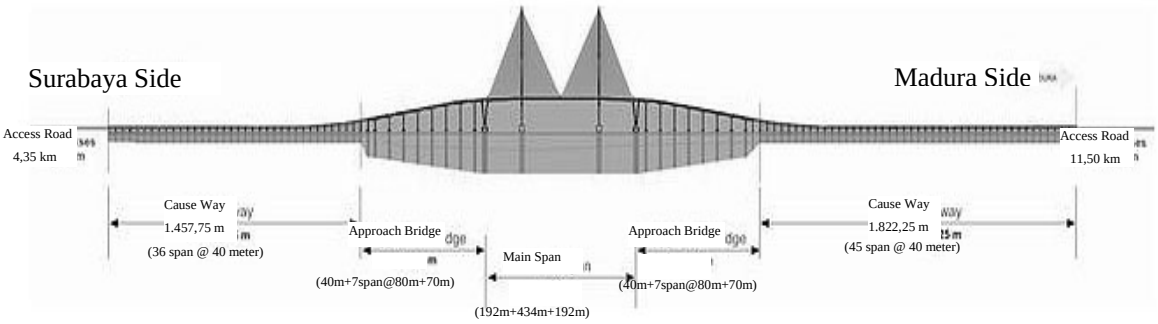
4.1.1 Project overview

Figure 4-2 shows the location of Suramadu Bridge Project which connects Java Island and Madura Island by crossing Madura Straits with span of 5.4 km. The construction of Suramadu Bridge is part of the strategies of area development and in accordance with the master plan of East Java Province, the master plan of Gerbangkertasusila (Gresik, Bangkalan, Kertosono, Surabaya, and Lamongan), and the master plan of Pamekasan, Sampang and Sumenep Regency.

Figure 4-3 shows the longitudinal section of Suramadu Bridge which consists of 1457.75 m long causeway and 672 m long approaching bridge in Surabaya side, 1822.25 m long causeway and 672 m long approaching bridge in Madura side, and main bridge with 818 m long cross over Madura Strait. The bridge has 103 piers and two abutments. The bridge is 30 m wide and is divided into one motorbike lane (3.2 m), one emergency lane (2.3 m) and carriage ways (2 x 3.5 m) on each direction along with the medium.

Figure 4-2 Location of Suramadu Bridge Project

(modified from www.goasia.about.com)



Build Access Road	**2002-2005**
Build Causeway	**2003-2006**
Build Approach Bridge & Main Span	**2004-2007**

Figure 4-3 Longitudinal section of Suramadu Bridge
(booklet of Suramadu Bridge Project, 2005)

The approaching bridge is continuous cast-in-place beams with prestressed concrete box girders. The approaching bridge was constructed by the balance cantilever method. The cantilever on each side is divided into 10 segments, 3.5 m long at each segment. The pier shafts are box sections with various heights from 6 to 28.5 m. The difference of pier height between adjacent piers is about 3.2 m.

The main bridge is a three-span, twin-pylon, double-plane cable stayed structure. The diamond-shape pylon is 136 m high which is divided into the upper part (57 m), the middle part (54 m), and the lower part (30 m). There are three portal beams in the pylon. All of them are box sections except the pylon column, which is a solid structure.

4.1.2 Project background

Suramadu Bridge Project is under responsibility of the Directorate General of Highways, Ministry of Public Works. The project started in 2002 and is now still in progress. The project is expected to finish in 2007. The government has several goals for constructing Suramadu Project including:

- to enhance economic development of East Java Province, especially for Madura;
- to develop Madura Island as a buffer zone of Surabaya;
- to increase the mobility of passenger and goods between Surabaya and Madura Island;

- to stimulate the opportunities for employment, and
- to introduce construction technology development and training ground for Indonesian experts in long-span bridges.

4.1.3 Structure of project organization

Suramadu Bridge Project is a collaboration of Department of Public Work as the Owner; a joint venture of PT. Adi Karya, PT. Waskita Karya (WASKITA), PT. Hutama Karya, PT. Wijaya Karya, and PT. AGRA as the Contractor; and Perentjana Djaja Co. Ltd. cooperating with BIEC Int. Inc and Gatra Cipta Tama Co. Ltd. as the Consultant Supervisor. Figure 4-4 and Figure 4-5 show the organization structure of project management and construction management in Suramadu Bridge Project.

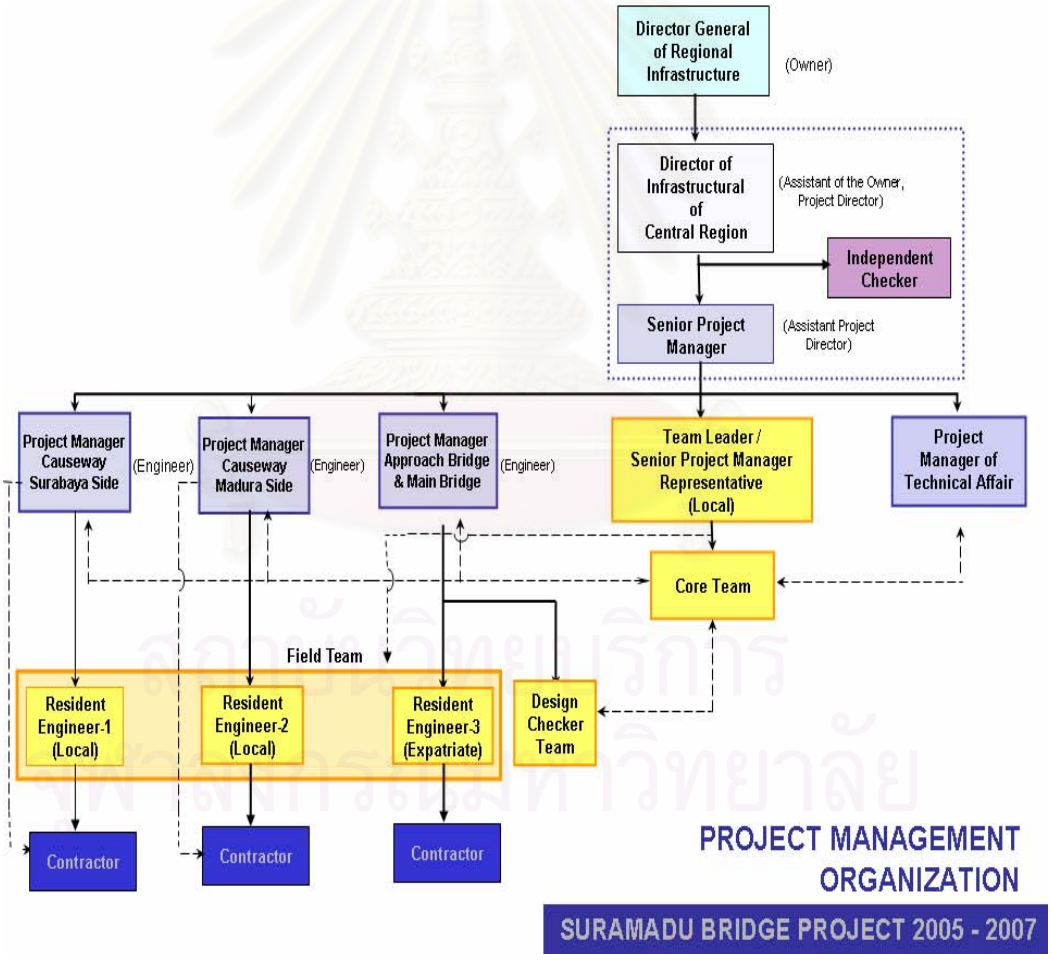


Figure 4-4 Project management organization of Suramadu Bridge Project (monthly report of Suramadu Bridge Project, 2005)

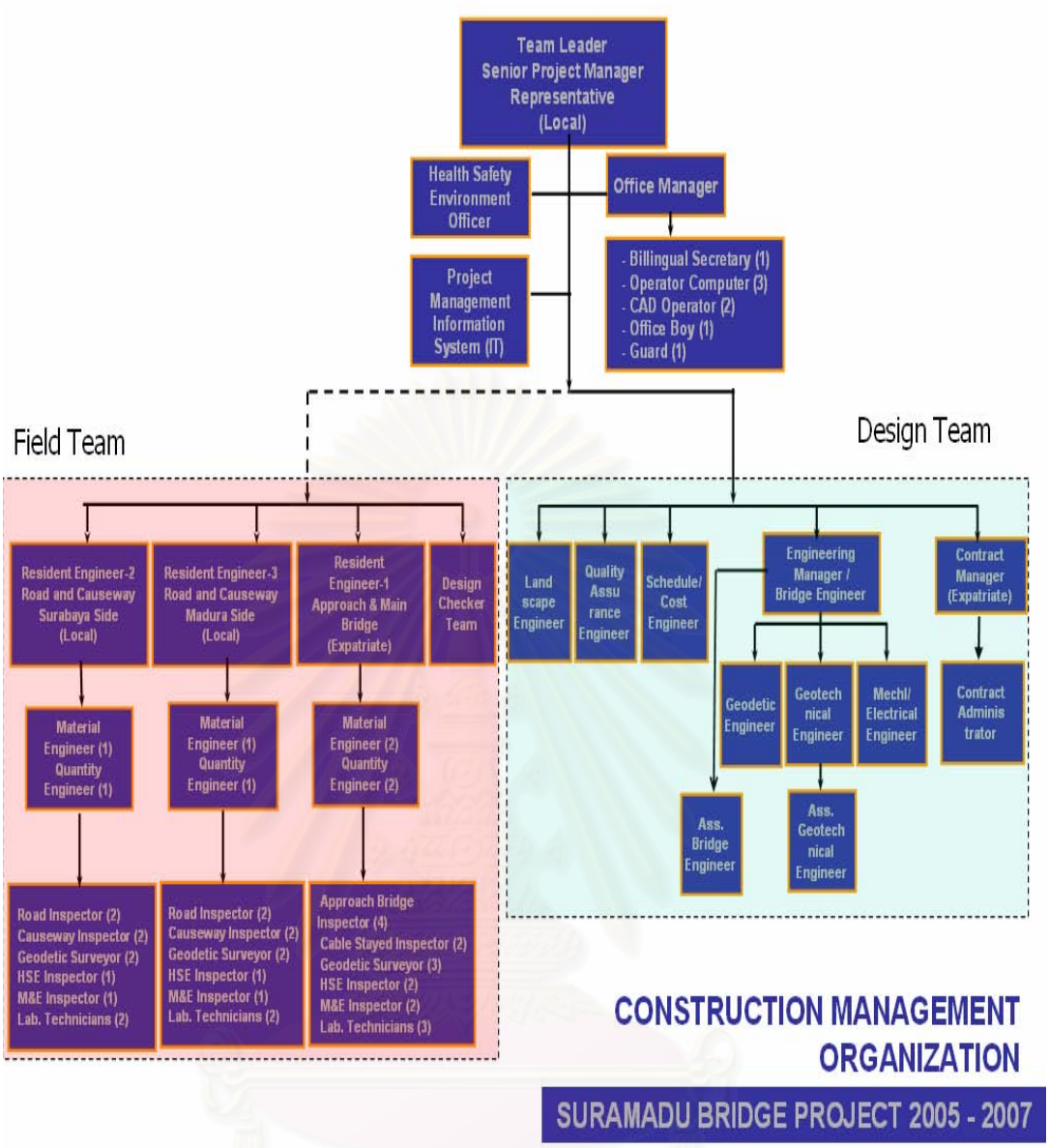


Figure 4-5 Construction management organization of Suramadu Bridge Project (monthly report of Pasupati Bridge Project, 2005)

4.1.4 Existing knowledge acquisition systems

Suramadu Bridge Project is using electronic systems in capturing and storing construction knowledge. Capturing knowledge requires coordination of the contractor, the consultant, and the engineer representative of the owner by using information technology. The system for storing knowledge in the project is using “docu-share” where all files and scanned document are kept in shared computers based on the scope of works in the project. This system enhances the security of data with the implementation of username and password. This system can be used for searching

information and construction knowledge by using keywords. In order to implement the system, the project manager has asked the IT engineer to train all staffs in the project, especially the staff of the owner. The following rules are being applied in using the docu-share system.

- Suramadu Bridge Project each staff can access the “docu-share” by logging into the system by his specific username and password. Users are not allowed to make their own user names. Instead, usernames are provided and created only by the administrator.
- The lowest-level user cannot access all information and data in the “docu-share” (i.e., only general information is shown).
- Each engineer team under the team leader of project manager representative has one special folder. All report, quality test results, and laboratory test results of a team are kept in the respective folder. The folders and contents of “docu-share” are shown in Figure 4-6.

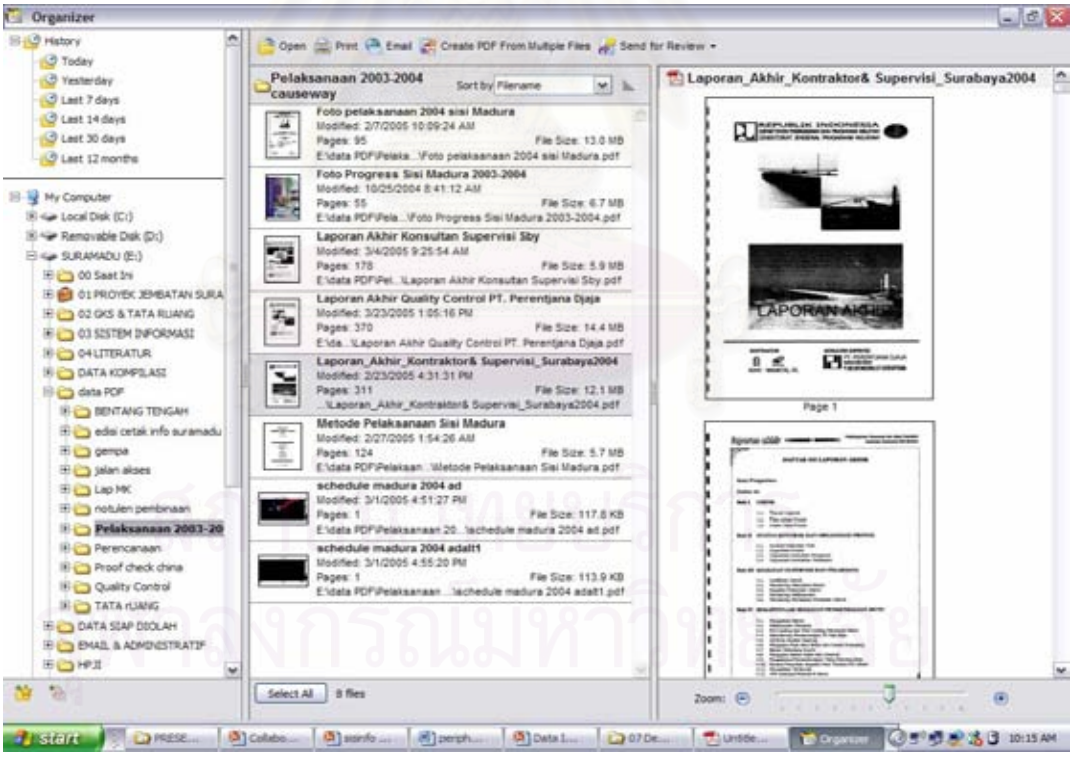


Figure 4-6 “Docu-share” system in Suramadu Bridge Project (modified from Suramadu Bridge Project docu-share system)

Some knowledge is stored in a website and updated weekly. The project web support server on the Suramadu Bridge website provides a collaborative workspace

for teams working on the project. The system allows the users to correspond to each other more securely than public email, to create library of files and notes, to schedule meetings, to perform project management, and to manage contact to all members of team.

A web-based technology is used to create a local website dedicated to an individual construction project. The intranet websites in Suramadu Bridge Project is now being used to access a wide range of construction documents, including drawings, specifications, and requests for information, budgets and meeting minutes. Figure 4-7 illustrates the network system in Suramadu Bridge Project. The communication system using this network system provides a link between Suramadu Project, project site in the middle of sea, project site in Madura Island, and the design checker in Surabaya and Jakarta. The network system is being controlled by one server that manages the website and the communication system. The person who controls server also is automatically managing the "docu-share" as bank of knowledge.

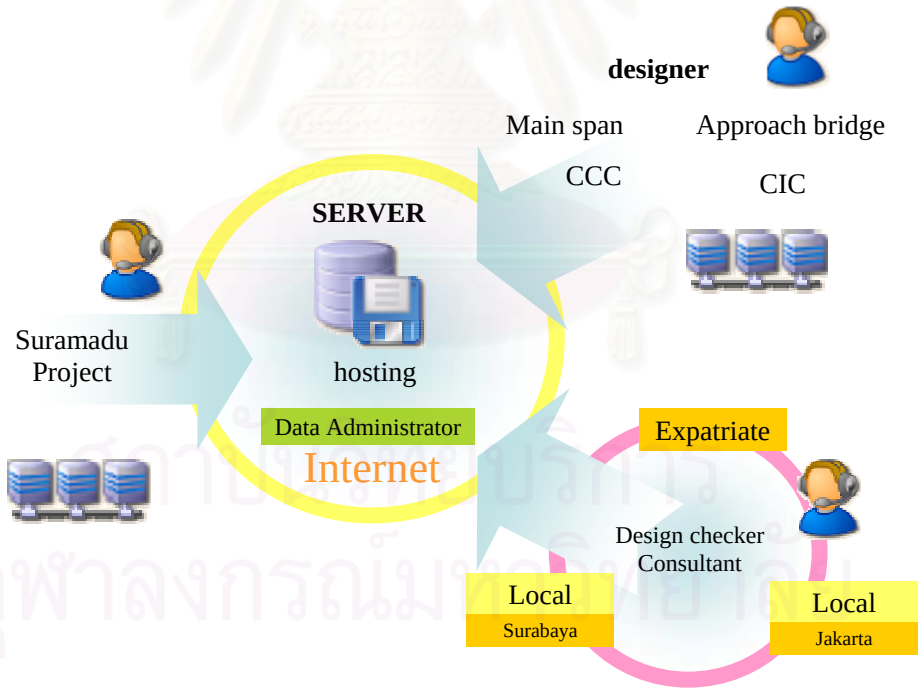


Figure 4-7 Network system used website intranet

Suramadu Bridge Project uses the digital method in storing some construction documents, including CAD, text, picture, and table formats. Digitalization is changing the way in generating, storing, transmitting, and coordinating information. Figure 4-8 and Figure 4-9 show the digitalization scheme of this project.

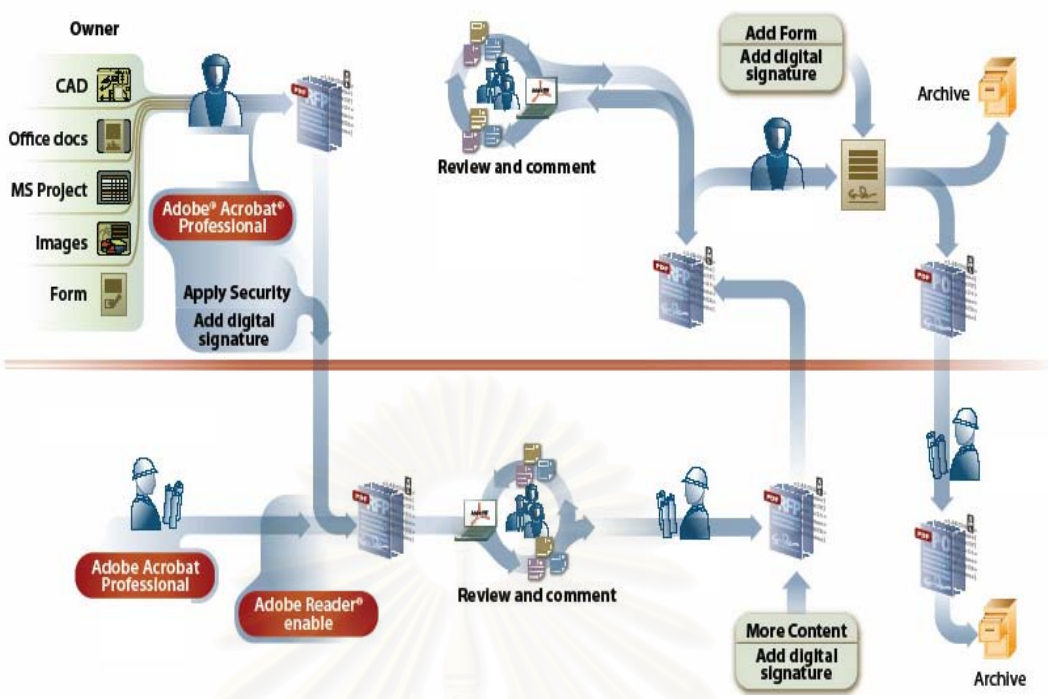


Figure 4-8 Schema of digitalization system in Suramadu Bridge Project (I)

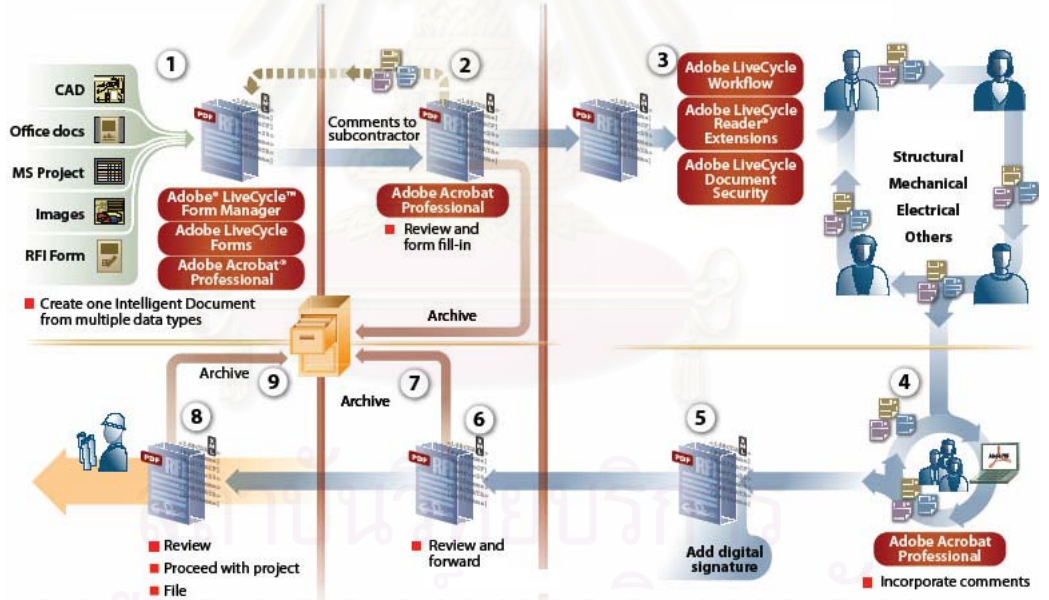


Figure 4-9 Schema of digitalization system in Suramadu Bridge Project (II)

4.1.5 Application of knowledge acquisition framework

This part discusses the application of the propose knowledge acquisition framework to the case studies. The installation of cable stay is selected as the example application of framework in Suramadu Bridge Project. This part also presents the obstacles and difficulties of applying the framework as well as suggestion for improving the knowledge acquisition system in Suramadu Bridge Project. Moreover,

the application of framework is explained according to the stage of a knowledge acquisition framework.

(1) Create WBS

The work in Suramadu Bridge Project can be divided into seven work items: pile foundation, pile cap, pier, box girder, pylon, cable stay, and floor system. Each work item consists of several major works. The major works can be divided into minor works. Table 4-1 presents the work breakdown structure of Suramadu Bridge Project. This work breakdown structure is resulted from an investigation to the works that have important knowledge. Information of project characteristics must also be considered while breaking down the work. Project schedule is also good sources to help break down the work in Suramadu Bridge project.

Table 4-1 Work breakdown structure of Suramadu Bridge Project

No.	Work Item	Major Work	Minor Work
I	Pile Foundation	Working platform	• platform structure • structure • steel pipe pile and steel casing • construction platform
		Boring machine	-
		Slurry preparation	-
		Boring	-
		Hole cleaning	-
		Fabrication and placement of reinforcement cage	-
		Underwater concrete instillation	-
		Pile testing	-
II	Pile Cap	Fabricating of reinforcement for pile cap	-
		Installation of the cooling circulating system	-
		Mass concrete casting	• requirement for the raw materials • mixing and casting • placing and vibrating of concrete • treatment of construction joint
		Dismantling steel box	-

Table 4-1 (cont.) Work breakdown structure of Suramadu Bridge Project

No.	Work Item	Major Work	Minor Work
III	Pier	Formwork	• formwork manufacturing (inner formwork and side formwork) • installation of formwork
		Reinforcement	-
		Casting concrete	• concrete mixing and casting • placing and vibrating of concrete • treatment of the construction joint • curing concrete • dismantling side formwork
IV	Box girder	Construction of cast-in-situ pier segment	• scaffold the segment • formwork • reinforcement and prestressing duct • casting concrete • tension of prestressing tendon • grouting
		Balanced cantilever construction of box girder	• installation of form travelers • pre-compression of form traveler • construction of standard segment
		Prestressing work	• preparation of tensing device • prestressing material • tension of prestressing tendon
V	Pylon	Main facilities for construction pylon	• lifting equipment • floating batching plant ship or mixing station • climbing formwork
		Footing and column construction of pylon	-
		Construction of portal beam	-
		Control measurement	-
VI	Cable stay	Setting of the cable system	-
		Winding off cables	-
		Cable hanging	-
		Cable tensing	-

Table 4-1 (cont.) Work breakdown structure of Suramadu Bridge Project

No.	Work Item	Major Work	Minor Work
VII	Floor system	Construction of waterproof coating on bridge deck	-
		Construction of asphalt concrete pavement	• preparation prior to pavement work • construction method of asphalt concrete pavement
		Construction of expansion joint	-
		Construction of guardrail	-

(2) Find innovation of project

The innovation in a project is an important knowledge that is necessary to be captured. Examples of innovations in Suramadu Bridge Project are found in the installation of cable stay because such work is considered new in Indonesia. Table 4-2 to Table 4-4 present the important knowledge in the installation of cable stay including construction method, material, and equipment used in the installation of cable stay. The tables also show description of the knowledge that are considered important to be captured and expected to be useful for the next project. Other works in Suramadu Bridge Project having important knowledge are presented in Appendix A.

In addition to innovation, important knowledge can also be captured from unpredicted problems faced on site and their solutions. Normally, after a problem has been found, a technical analysis is conducted, including analysis on construction method, material, equipment, site condition, as well as workmanship involved in the problem.

In Suramadu Bridge Project, recording of problems occurred in the field is not managed well. The problems are only reported during the meeting and sometimes are not recorded in the minutes of meeting. The application of the knowledge acquisition framework reveals that the problems in the field should also be reported with the innovation as the solution of the problem. The owner should then set a meeting attended by the contractor, supervisor, engineer representative, and designer to discuss how to solve the problems. As the solution is usually only a corrective action, the meeting should also discuss the possibility of finding a preventive action so that the same problem can be predicted and prevented before it occurs. This new solution is considered as important knowledge and should be captured and stored.

Table 4-2 Construction method of installation of cable stay

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Installation of cable stay	Setting of the cable system	• A lifting platform is set along the bridge direction on the tower top. One end of the polyspast is hauled by the winch. Another end is fixed with sling and hanger to lift cable. The maximum theoretical lifting capacity of the lifting device is about 200 t.	monthly report, daily report, specification, meeting minutes	team leader of design checker	monthly meeting	web site
2	Installation of cable stay	Winding off cables	• Cold cast anchors plus cables are made in the factory and transported to the site by truck or ship. For short cables, the ship is berthed under the bridge. • The cable reels are placed on the off cable drum on the off cable ship and the cold cast anchor of the cable reel is opened. • Let the traction wire down through pulley at the girder end, then connect the traction wire with the cold cast anchor head on the ship through the anchor plug, and drag the cable up to the bridge surface using the winch on the girder surface. • Cable pulleys are placed in the interval of 20-30 m on the girder surface, the winch on the girder winds off cable. • When the anchor head at another end comes out of the reel and reaches the girder top, the anchor with the lifting system on pylon should be connected.	monthly report, daily report, specification, meeting minutes	team leader of design checker	monthly meeting	result of comparative study
3	Installation of cable stay	Cable hanging	• For short cable, a tension rod is connected to the anchor head and lifted to the open of the cable sleeve in pylon top by using the tower crane or dropping the lifting rope from the pylon top. The rope out of the cable sleeve is then connected to the tension rod at the end of the cable, and dragged out of the rear end of the jack using a winch in the pylon. • For hanging of medium long and long cables, the cable is dragged or lifted to the bridge surface using crane. After that, the winding off cable is completed and the tension connection rod is connected. Then, the cable starts to be hung.	monthly report, daily report, specification, meeting minutes	team leader of design checker	monthly meeting	-

Table 4-3 Material used in installation of cable stay

No.	Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Anchor of cable stay	Location	• Anchor in the counterweight concrete block at bridge end, at the lower end of other cables, steel anchor boxes, composite of anchor plates, cushions, bracing ribs, and stiffeners, all cables in the main girders.	monthly report	engineer of material	monthly meeting	-

Table 4-4 Equipment used in installation of cable stay

No.	Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Vibration absorber	Function	• To control the vibration of cable, vibration absorber is placed in the cable sleeve, and the surface of outer HDPE sheath is set as bifilar helix.	monthly report	-	monthly meeting	-
2	HCA damper	Position	• Located between cable stay and bridge deck	monthly report, daily report, specification, meeting minutes	-	monthly meeting	-

(3) Find sources of knowledge

After important knowledge has been identified, the sources of the knowledge are then located. The last four columns in Table 4-2 to Table 4-4 show the sources of the knowledge that can be found from documents (e.g., monthly report, weekly report, daily report, and specifications), people (e.g., field engineer, team leader, designer), meetings (e.g., monthly meeting and meeting minutes), other source (e.g., web site), or combination of them.

In Suramadu Bridge Project, some reports do not mention sources and locations of events having important knowledge. Thus, tracking back the knowledge is more difficult because the information is not complete. For example, when the box girder collapsed, only post conditions and corrective actions were reported without showing the sources of information. The report showed information as follows.

- level of loss and damage where the adjacent box girders were dislocated and some box girders fell down to the sea
- fatal incidents caused the death of a worker
- comment from project manager
- comment from the contractor
- evacuation of collapsed box girders to project warehouse
- condition of fallen box girders and the suggested remedies to them
- laboratory test result of the fallen box girders, including core drill test, hammer test, and ultrasonic test

To solve this problem, the engineers who wrote the reports should be interviewed to add the missing information. Furthermore, after obtaining complete information, the report should be revised by writing addenda containing all information. In the case above, the report should also show information as follows.

- Who did evacuation of the fallen box girders?
- Who did estimate the level of destruction of the collapsed box girders, and what were the criteria to asses the level of destruction?
- What should be the references to see the test results?
- What are the documents supporting contractor’s arguments?

In addition, the report should also present the preventive action and innovative method to avoid the same problem in the future. This preventive action and innovative

method can be developed from technical review to the site condition and quality of work causing the problem. The additional information should include:

- cause of the incident
- chronological report of the work before the incident occurred
- stability analysis on the piers in bearing lateral and vertical load
- analysis on deformation and dislocation of box girders.

(4) Create checklist form

Quality control in the project is supported with quality assurance along the execution of the work. Therefore, before executing the works, the contractor should propose method of the work, including material and equipment used to perform the work. All items mentioned in the proposal should be incorporated in the checklist form so that monitoring of the work matches with the action on the site. Thus, the process of capturing knowledge can be performed more easily and accurately.

The checklist form in Suramadu Bridge Project should be created after the method statement proposed by the contractor is approved by the owner, engineer representative, and supervisor. The contents of the checklist form should be in accordance with the method statement form the contractor and the suggestions from the engineers. The suggestions can be in terms of innovation or modification of construction method, adjustment of standard operation and procedure, as well as consideration in using material and equipment that should be adopted by the contractor. The knowledge engineers can then create the checklist form and ask for an approval from the project manager. The checklist should contain:

- construction method and the sequences,
- responsible person in the site,
- responsible person in the laboratory,
- referred drawing and shop drawing,
- measures and their allowable tolerances,
- discrepancies between method statement with actual work, and
- innovation of favorable modification of work.

Table 4-5 to Table 4-8 show some examples of the checklist form that can be used in Suramadu Bridge Project.

Table 4-5 Checklist of reinforcement steel work

	Work Inspection for Reinforcement Steel Work																No: Location :
	Checklist Description															Tolerance	Inspection measure
Drawing Reference No. Shop drawing No.	1. Design drawing 2. Formwork 3. Quantity and form of rebar 4. Steel wire 5. Installing bitterly of concrete block 6. Rebar cleaning from oil and corrosion 7. Rebar check according to design drawing 8. Accuracy and straightness of rebar 9. Verticality of rebar 10. Tightening with steel wire 11. Installing concrete block 12. Steak and overlapping 13. Visual check 14. Cleaning the area																
	Date	Inspector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Recommendation
Drawing/ Specification																	
Inspection 1																	
Inspection 2																	
Inspection 3																	
Explanation: A=Accepted R=Rejected																	
Document related : - daily report (DR) - weekly report (WR) - monthly report (MR) - etc	Note : Supervisor/Inspector (……)																

Table 4-6 Checklist of concrete work

	Work Inspection for Concrete Work		No: Location :
	Checklist Description	Tolerance	Inspection measure
Drawing Reference No. Shop drawing No.	1. Cleaning the area of work 2. Sturdy or readiness of formwork 3. Vibrator equipment 4. Slump test equipment 5. Installing rebar as design and not corrosion 6. Installing concrete cover 7. Water soaked 8. Preparation of concrete pump 9. Preparation of man power 10. Preparation of equipment for support 11. Mixer truck arrival time record and checking of concrete condition 12. Slump test 13. Supervising during the execution 14. Design of top elevation 15. Finishing 16. Concreting curing 17. Compressive strength test		

	Date	Inspector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Recommendation
Drawing/ Specification			ready	ready	available	available	yes	yes	already	ready	already	available	already	already	already	ready	done	curing system	complete	
Inspection 1																				
Inspection 2																				
Inspection 3																				
Explanation: A=Accepted R=Rejected			A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	
Document related : - daily report (DR) - weekly report (WR) - monthly report (MR)	Note :																			Supervisor/Inspector (……)

Table 4-7 Checklist of formwork

	Work Inspection for Concrete Work														No: Location :
	Checklist Description													Tolerance	Inspection measure
Drawing Reference No. Shop drawing No.	1. Design of formwork panel and scaffolding 2. Measure dimension of construction according of design drawing 3. Measure of ace position or straightness according of design drawing 4. Construction of formwork must be strong to detaining of liquid concrete pressure 5. Extension of formwork must be flatten and unlikeness 6. Forms and measurement of formwork according to design 7. Surface of formwork must be clean, flat, and surfacing with oil 8. Construction of formwork must be practical and natty 9. For column formwork 10. Re-check of formwork dimension and elevator as according to design 11. Visual check (cleanness, smoothness) 12. Supervising during the execution														
	Date	Inspector	1	2	3	4	6	5	7	8	9	10	11	12	Recommendation
Drawing/ Specification															
Inspection 1															
Inspection 2															
Inspection 3															
Explanation: A=Accepted R=Rejected															
Document related : - daily report (DR) - weekly report (WR) - monthly report (MR)	Note : Supervisor/Inspector (……)														

Table 4-8 Checklist of prestressing work

	Work Inspection of Stressing										No: Location :
	Checklist Description									Tolerance	Inspection measure
Drawing Reference No. Shop drawing No.	1. Concrete test result have reached characteristic concrete strength after 28 days 2. Existence of corrosion or oil on stressing wire 3. Anchoring detain 4. Grouting with mix of cement, sand and water for workability injection < 0.45 5. Check the strength 6. Tension control and extension cable, recording and comparing with theoretical calculation 7. Conducting grouting with mix of cement, sand and water 8. Cover anchor with mix cement and sand										
	Date	Inspector	1	2	3	4	6	5	7	8	Recommendation
Drawing/ Specification											
Inspection 1											
Inspection 2											
Inspection 3											
Explanation: A=Accepted R=Rejected											
Document related : - daily report (DR) - weekly report (WR) - monthly report (MR)	Note :										Supervisor/Inspector (……)

(5) Assign a team of knowledge engineer

The knowledge engineers in Suramadu Bridge Project are commonly called as the management and information system (MIS) engineers. The MIS engineers are responsible for documenting and reporting all activities in the project. The MIS engineers are also responsible for preserving all information, publishing relevant information to the public, as well as giving response to public opinions, comments and constructive suggestion about Suramadu Bridge Project.

Only one knowledge engineer is assigned to manage knowledge acquisition at this 5.4 km bridge. Furthermore, the construction is performed from both sides, Surabaya side and Madura side, separately. This method brings another problem in managing knowledge acquisition processes for the whole project due to a long distance between checkpoints. Therefore, the processes of knowledge acquisition should be supported by a team of knowledge engineers that at least consists of:

- one team leader who is responsible for controlling the whole knowledge acquisition processes, finishing the process of storing knowledge, and solving problems faced on the site regarding knowledge acquisition processes.
- two engineers who are responsible for capturing knowledge on the site as well as at the site office. One engineer is assigned to manage knowledge capturing at Surabaya side and another one is assigned to manage knowledge at Madura side. These engineers are also responsible for monitoring the application of checklist and to collect the filled checklist form from the field supervisor. These engineers should collect knowledge from other documents such as minutes of meeting, project booklet, site visit report, pictures, videos, as well as reports on innovation and its technical review. This knowledge is then combined into one report containing captured knowledge as well as its sources and supporting documents.
- one engineer who is responsible for gathering knowledge from two engineers above and for matching the similar knowledge from Surabaya side and from Madura side. He is responsible for writing a report combining captured knowledge from both sides and discussing the

contents with the engineer representatives of sides, project manager, and chief before sending the report to his colleague responsible for storing the knowledge.

- one engineer who is responsible for storing the reports about the knowledge. He is also responsible for classifying the knowledge and storing similar knowledge into the same folder.

(6) Define tools to capture knowledge

Suramadu Bridge Project is using several tools in capturing knowledge such as video camera, tape recorder, web camera, scanner, PDA or tablet PC, and fax machine. However, since project site is divided into three sections (i.e., Suramadu side, Madura side, and sea side), there should be good management to optimize the use of these tools.

Because the distances between three checkpoints are quite long and separated by the sea, wireless system is proposed to connect all three sections. For example, wireless transmitters and receivers should be located in each section to ensure real time communication between sections. The transmitter can use point-to-point transmission to the receivers at other sections. To accommodate the needs of knowledge transferring within a section, a wireless network with several access points is sufficient. Therefore, the tools used in the sections should be enhanced with wireless device and connected to the network. For example, waterproof video cameras can be located at some points to monitor the movement of a barge when supplying materials to the sea side or to monitor the floating base in supporting a tower crane when moving material from barge to a storage area on the sea side. Similarly, video cameras can be placed at Surabaya side and Madura side to monitor availability of material and equipment being mobilized to sea side. These video cameras should be wireless connected to the nearest access point and connected to the network.

A central computer then processes the video footage and sends it via the transmitter to the receivers at other sections. In other words, all sections can monitor what is happening at another section. Thus, anytime a problem occurs, all parties in all sections can directly recognize and pursue remedies. Figure 4-10 and Figure 4-11 illustrate the proposed towers and wireless devices positions. The wireless transmitter and receiver are placed on the tower.

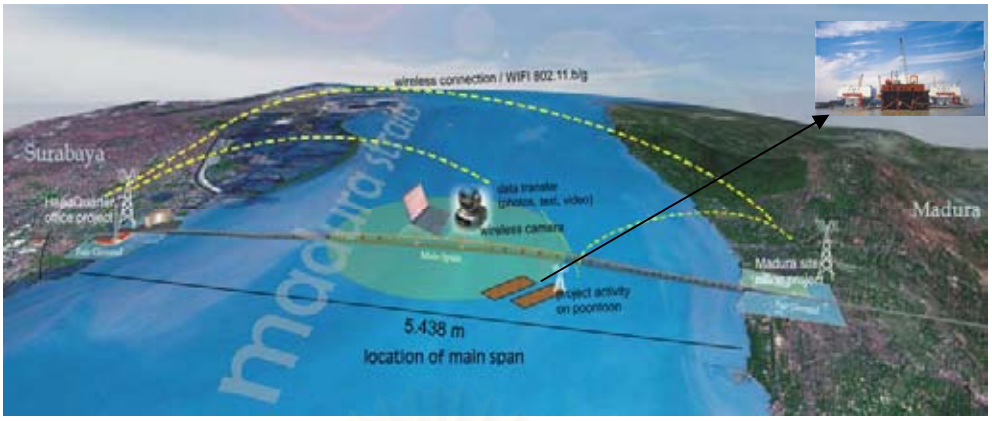


Figure 4-10 Proposed wireless connection for capturing knowledge (modified from www.gogleearth.com)

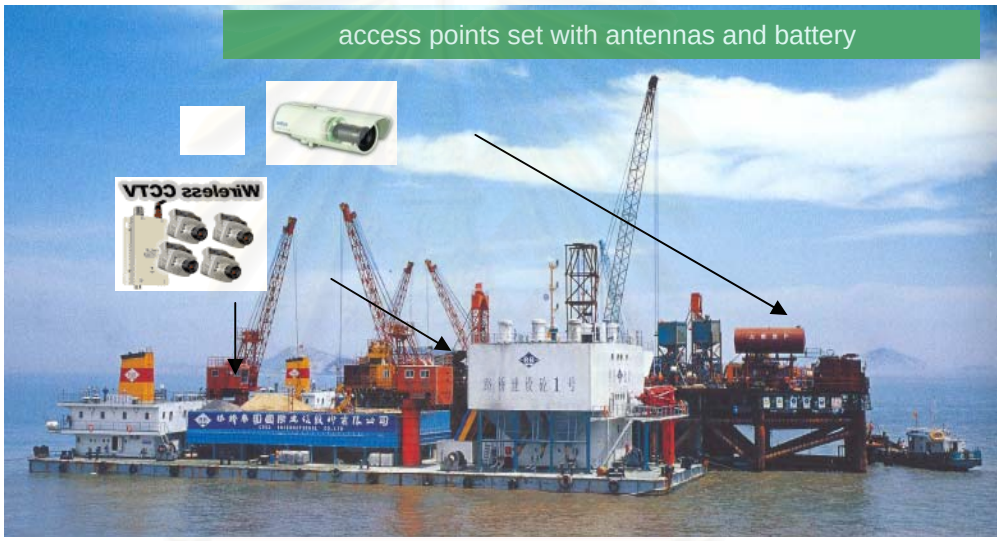


Figure 4-11 Knowledge capturing on the sea section (modified from docu-share system of Suramadu Bridge Project)

Field engineers and knowledge engineers can communicate each other by using radio communication or walky talky, and thus the field engineers can help the knowledge engineers capture the knowledge. Whenever the engineers want to collect an important knowledge, he can directly inform to the knowledge engineer via radio communication. Otherwise, he can make a note about the knowledge in PDA or tablet PC and send it to the knowledge engineer at the end of his work shift.

(7) Define method to capture knowledge

Most of capturing knowledge processes in Suramadu Bridge Project are computer-based and using other electronic devices to help the processes. Wireless video cameras capture the actual activities in the field and can be combined to review

the whole construction processes. The comments about the video, standard operation procedure, related knowledge, and comments from the expert should be added to improve and explain the video more clearly.

Explicit knowledge can be easily captured using a computerized system. However, the knowledge captured in Suramadu Bridge Project was not successfully performed because of the limited electronic devices and employee's familiarity to work with paperwork. There is only one scanner to digitize the documents used by all project parties. The owner does not provide any digital video camera to the knowledge engineers so that the knowledge engineers have to get the record from the contractor which is unedited. As a result, it is difficult to capture the knowledge from such video.

Capturing tacit knowledge is more difficult than capturing explicit knowledge. Knowledge of senior engineers should be captured in the discussion session. When sharing knowledge occurred, there are exchange of experiences and skills between the senior and junior engineer. This knowledge should be recorded and considered as an important tacit knowledge. The process of capturing knowledge should be added with information about time and location of the knowledge being captured.

(8) Define tools to store knowledge

Tools to store knowledge should be able to keep all data, information, and knowledge for a long period and incorporate additional information such as time and location of capturing knowledge. The program in the system should automatically ask the user to completely fill in the essential information mentioned previously before quitting the system so that the user will not forget to complete the information.

There should be a centralized computer system to control and manage all electronic devices used for storing knowledge. This computer is operated by a knowledge engineer and enhanced with a security program and backup facilities. The computer should be able to access those devices and:

- to synchronize the use of devices,
- to organize flow in and flow out of knowledge and its supporting information in the storing system, and

- to help the knowledge engineer classify the knowledge systematically so that tracking back of knowledge in the future can be performed more easily and fast.

(9) Define method to store knowledge

After defining tools to store knowledge, method to store knowledge should be determined according to the available tools. The method to store should also be defined according to the type of knowledge. For example, it is more suitable to store tacit knowledge in a voice record format. Knowledge of construction method is better if it is stored in a video or animation format.

(10) Check update

The stored knowledge will be used to monitor the progress of the project and report to the owner. Docu-share system is being used by Suramadu Bridge Project as the storing system. However, docu-share does not support records of comments and suggestions from the user. Moreover, the process of knowledge transfer and exchange using this system is quite complicated. The user should get an approval from the project manager before requesting user ID and password from the system administrator. Because the system administrator does not frequently check his account and evaluate the request, the request is often delayed. In addition, the user ID and password given to the user will be expired if the user is not active within a quite short period. Therefore, the user is not interested in accessing the docu-share.

There should be a program in the system that can automatically respond to the request according to the level of authorizer of the user. For example, a request authorized by the project manager will be processed faster than a request authorized by a section head. Therefore, the user can request to his superintendent and the superintendent fills in the online request and submits it to system administrator.

The system should also provide a forum where project staffs, engineers, and workers discuss about a particular topic related to the project. In this forum, everyone can post his comments or suggestions regarding new knowledge or innovation. The users can also criticize the stored knowledge and propose its modification in case that the knowledge is out of date or incorrect. The summary of the discussion should be distributed to all users via email so they can update their knowledge about the project.

4.1.6 Results and discussion

The site conditions of Suramadu Bridge Project were conducive to the application of knowledge acquisition framework so that this proposed framework can be successfully applied in the project. Other factors determining successfulness of the application of knowledge acquisition framework include:

- The project visions care about capturing and storing all information and knowledge in the project. Even though the purpose is to build library or museum of technology, but this idea directly supports the application of knowledge acquisition framework.
- Tools and equipment for capturing and storing knowledge in the project have been prepared before, but the utilization of them is not as planned. The human resource to manage the tools to capture and store knowledge is not sufficient. However, the availability of tools can promote the application of the framework.
- The culture of the project where the engineers realize the importance of knowledge acquisition will support the application of framework.
- The transfer of information and knowledge in this project is computer-based. Therefore, it was so helpful for the application of framework because a long distance between sections needs fast information and knowledge transfer. Thus, it is helpful to the knowledge acquisition process in this project.

The interviews with the project manager, chief designer, and engineer of MIS show that the framework is sufficient to support the knowledge acquisition system in the project. Some comments gathered from the interviewees are as follows.

- “Knowledge capturing using wireless video camera will be useful to help engineer of MIS monitor the work and report the progress of the project to the chief designer. The information captured from the video can also be useful to the future projects, especially bridge.” (Ashari, 2005)
- “Team of knowledge engineers is very helpful to the document distribution, collecting of comments and suggestions, and knowledge capturing and storing in the project that has huge area and scattered project sections.” (Prasetyo, 2005)

4.2 Pasupati Bridge Project

4.2.1 Project background

Pasupati Bridge Project was under responsibility of the Directorate General of Regional Infrastructure, the Ministry of Settlement and Regional Infrastructure, the Department of Public Work, all of which are government agencies. The government has the following goals for Pasupati Bridge Project, as follows.

- To increase capacity of the west-to-east lane in Bandung and to accommodate increasing traffic volume on that road,
- To reduce traffic jam in the downtown of Bandung,
- To expand the road network in Bandung,
- To support regional economy by reducing travel time on the west-to-east lane,
- To decrease pollution.

Pasupati Bridge was proposed in an old city plan included in Carsten document plan and became the obsession of Bandung citizen since 1931. This bridge connects the cities of Pasteur and Dago by crossing Cikapundung hill.

The government of Bandung proposed realization of Pasupati Bridge Project to Ministry of Infrastructure in October 1988. Department of Public Work assigned a financial study to LAPI-ITB in 1992-1993. The action was continued by proposing the budget to BAPPENAS (National Development Planning Board). The project was funded by Kuwait Fund for Arab Economic Development (KFAED).

4.2.2 Project overview

Pasupati Bridge project is located in the city of Bandung, the capital of West Java Province, situated approximately 180 kilometers south east of Jakarta. The objective of the project is to improve traffic flows in the east-west direction by providing a direct connection between Pasteur road in the west and Surapati road in the east. The bridge commences at Junjunan road and continues along Pasteur road on an elevated approach structure to a cable stayed bridge spanning the Cikapundung valley. The cable stayed bridge is connected to Surapati road by an elevated approach structure which passes over Tamansari road and Juanda road. An access ramp is provided at Pasirkaliki, and access ramps are provided at Cihampelas and Tamansari.

Figure 4-12 shows a longitudinal section of Pasupati Bridge Project consisting of a bridge section (303 m) a cable-stayed section (161 m), viaduct sections (2,147 m), and improved road segments (2,500 m) The east and west approach viaducts were constructed using precast pre-stressed concrete segments erected using the balanced cantilever principle. The cable stayed bridge was originally designed to be use precast prestressed concrete units; however, an alternative construction method, a cast-in-situ prestressed concrete superstructure, was chosen instead.

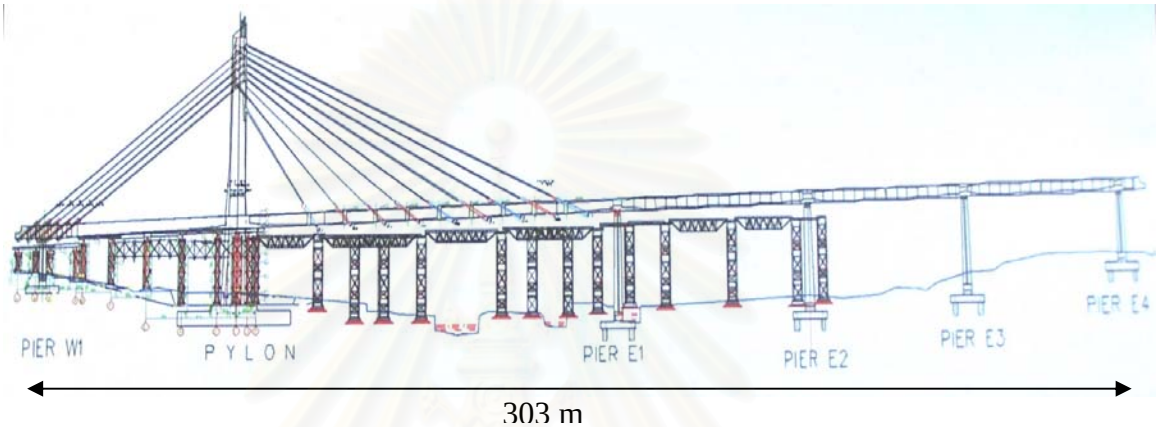


Figure 4-12 Long section of Pasupati bridge
(Booklet of Pasupati Bridge Project, 2005)

4.2.3 Structure of project organization

Pasupati Bridge Project was a collaboration of Ministry of Settlement and Regional Infrastructure as the Owner; a join venture of WIKA-Waskita-CGC as the Contractor, and Sir William Halcrow with INDEC, LAPI-ITB as the Consultant Supervisor.

There was no specific person in this project assigned to control all the data from the contractor, consultant supervisor, and engineer representative. The process for storing and capturing knowledge was still conventional. The interviewees in this project were the project manager, technical assistants, chief of general affair, and chief field supervisor of casting yard and cable stayed. Figure 4-13 shows the project organization structure of Pasupati Bridge Project. It also shows the relation among owner, owner representative in the project site, contractor, and supervisor. Figure 4-14 shows the organization structure of contractor. Figure 4-15 shows the organization structure of owner representative in project site.

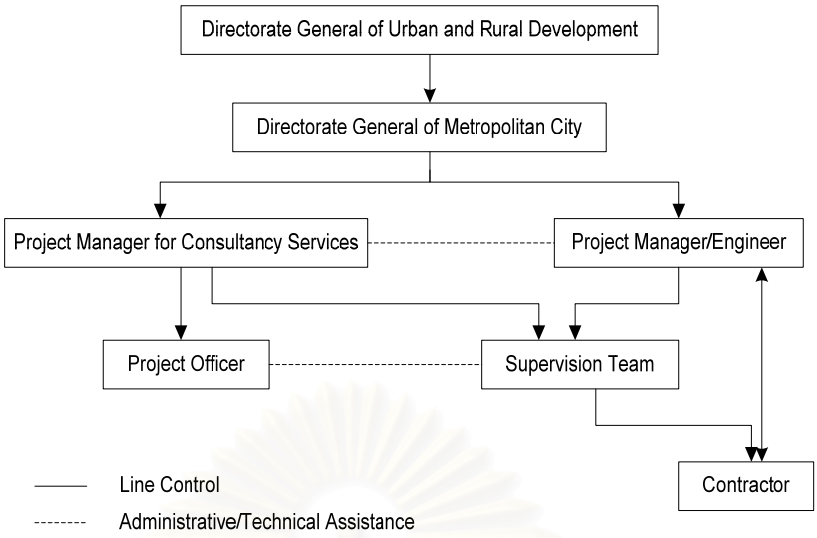


Figure 4-13 Project organization chart of Pasupati Bridge Project

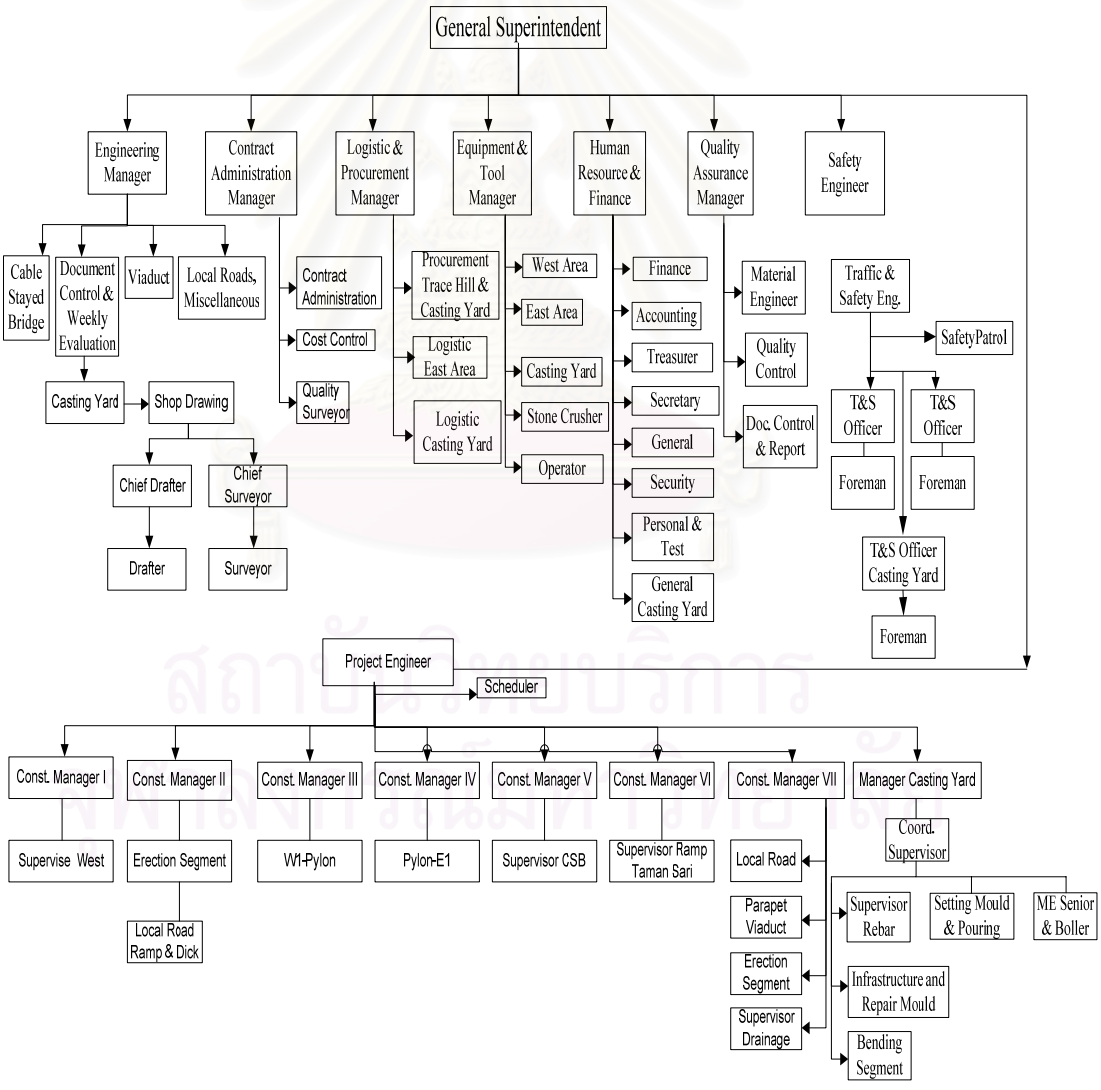


Figure 4-14 Contractor organization chart of Pasupati Bridge Project

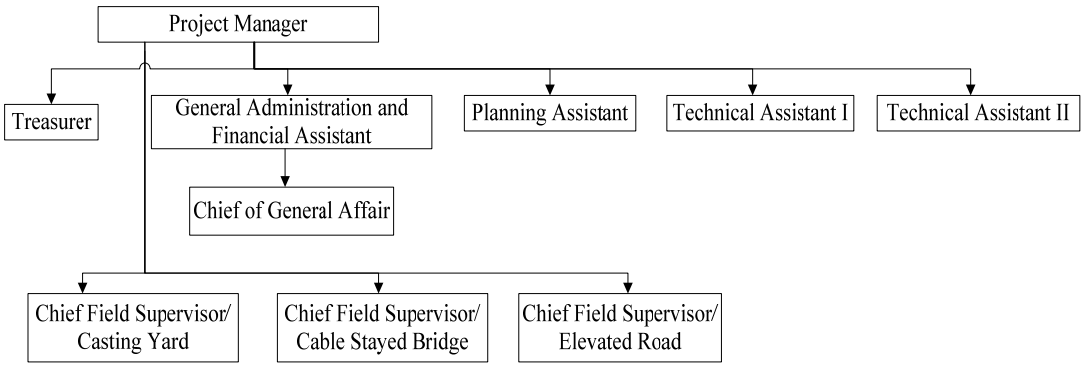


Figure 4-15 Project management organization chart of Pasupati Bridge Project

4.2.4 Existing conditions of knowledge acquisition system

Pasupati bridge project used the conventional methods, paper-based method, for capturing and storing important knowledge. Only a small part of work used information technology. For example, the installation of cable and quality checking were recorded and stored in the electronic format.

Figure 4-16 shows the existing condition of knowledge acquisition processes in Pasupati Bridge Project. First, the Department of Public Work assigned the project manager and the team to monitor and control the project site. This team had project office in the Department of Highway. The work started only when a pre-construction meeting between team representative and contractor had been held. At the same time, standard operation and procedure, construction method, equipment, material, equipment, and technology used in the work were decided.

During construction, the team monitored the process of works. Innovation and special technology were also captured and reported in the monthly report. However, not all reports were saved in computer. The reports were separated monthly. These reports were then submitted to the Department of Public Work in Jakarta. This delivery was often delayed so that the report reached center office late. Moreover, the delivery needed extra cost.

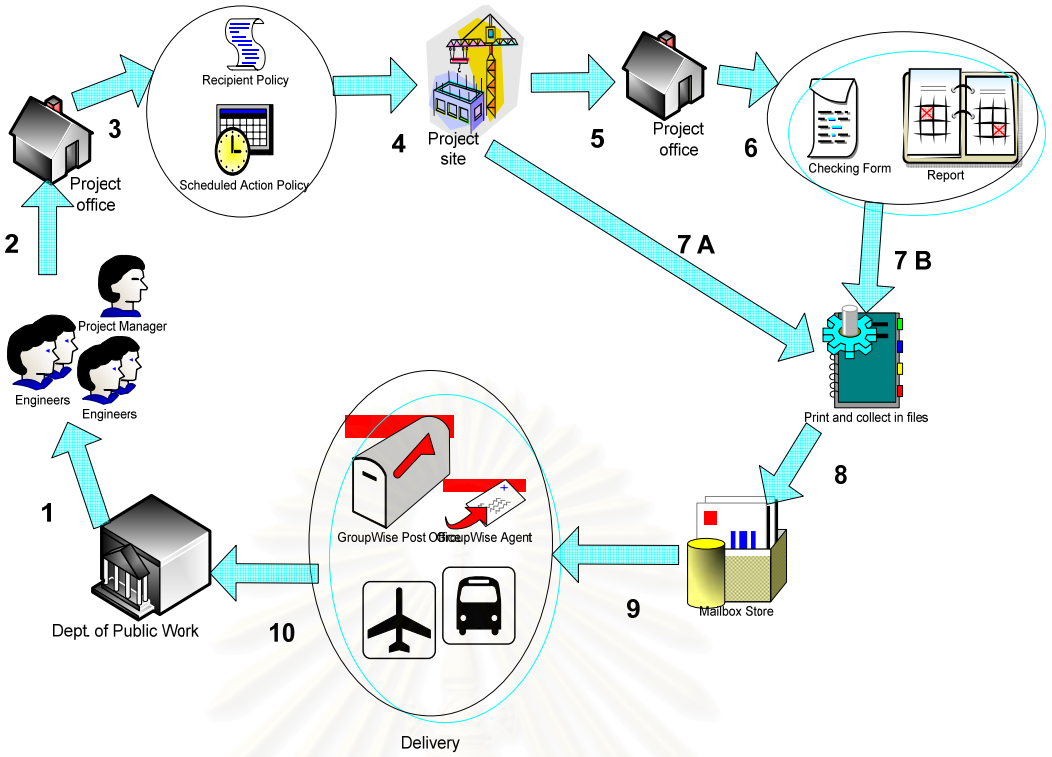


Figure 4-16 Existing condition of knowledge acquisition in Pasupati Bridge Project

4.2.5 Application of knowledge acquisition framework

(1) Create WBS

Table 4-9 shows an example of work breakdown structure (WBS) in Pasupati Bridge Project. The WBS should incorporate information gathered from other documents such as s-curve, method statement, and specifications. To ensure that the WBS covers all work items, the knowledge engineers should discuss with the project supervisor, contractor, and bridge experts.

Table 4-9 Work breakdown structure of Pasupati Bridge Project

No.	Work Item	Major Work	Minor Work
I	Bore pile	Setting out	-
		Drilling	-
		Inserting skeet cage	-
		Installing tremie pipe	-
		Pouring concrete	-
		Digging for pile cap	-
		Cutting of pile head	-
II	Pile cap	Bore pile	-
		Excavating the pile cap	-
		Leaning concrete	-
		Installing formwork and placing reinforcement bar	-
		Pouring concrete	-
		Curing concrete	-
III	Pier	Installing formwork and pacing reinforcement bar	-
		Pouring concrete	-
		Curing concrete	-
IV	Retaining wall	Bore pile	-
		Pile cap	-
		Wall	• Installing formwork and placing reinforcement bar • Pouring concrete • Curing concrete
V	Precast concrete segment work	Cutting and bending rebar	• Cutting and bending rebar in fabrication area • Grouping rebar and storing in temporary storage
		Installing reinforcement on Jig	• Fabricating rebar on Jig become rebar cage • Covering concrete • Overlapping • Installing accessories (drain holes, electrical holes, lifting holes) • Preparing block out of LUD and bearing
		Setting mould	• Setting bulk head • Setting of suffit table with match cast • Setting of wing form • Setting mid core • Setting small core

Table 4-9 (cont.) Work breakdown structure of Pasupati Bridge Project

No.	Work Item	Major Work	Minor Work
V	Precast concrete segment work	Lifting reinforcement into mould Concreting precast segment	• Pouring concrete from mixer truck into bucket at gantry • Testing of concrete • Moving gantry into its position • Pouring bottom slab
		Finishing concrete	
		Curing concrete	
		Stripping mould	• Stripping mid core • Stripping small core • Stripping small core • Stripping wing form
VI	Pylon	Installing and grouting bottom pot bearing	• Preparation • Application of grouting pot bearing
		Installing and grouting anchor lud	-
		Installing and grouting upper pot bearing	-
		Erecting segment	• Preparation of work • Erecting segment • Preparing segment joint • Application of epoxy • Prestressing work
VII	Installation of cable stay	Preparation work	
		Installing pylon anchorage	• Sliding the trolley with the anchorage • Installing chain block and connect with tower crane • Lifting the anchorage with the handling accessories • Feeding the anchorage into guide pipe • Fixing the anchor head on to the bearing plate
		Delivering deck anchorage	• Delivering anchorage from prefabrication • Preparing trolley on deck with handling accessories • Lifting the anchorage using crane on to trolley at the end of span • Feeding the anchorage on handling accessories • Storing trolley on to anchor position
		Installing the cable stay	• Installing HDPE pipe • Installing the strand

(2) Find innovation of project

Innovation can be found from the WBS made by knowledge engineers. As mentioned before, the WBS should then be discussed with the project supervisor and contractor to get additional information regarding actual site conditions. Innovation or work having important knowledge can be found when a new construction method is proposed to address obstacles due to site conditions. Knowledge engineers should make note about the discussion and conclude from which work items the important knowledge can be captured. Normally, the important knowledge should be considered from four aspects of work: construction method, material, equipment, and technologies used in the project.

Pasupati Bridge Project used special equipment and materials considered new technologies in Indonesia. Most of these equipment and materials were imported or designed from other countries. The special equipment and materials used in Pasupati Bridge Project are discussed below.

- Casting mould

  Used for cement production at casting yard, Baros Cimahi. Blueprint was bought from Canada and the mould was fabricated in Jakarta. The contractor prepared fourth set casting mould to cast 658 segments, but because of the project acceleration four other sets of casting mould was required. Totally, there were eight sets of casting mould.

- Launching gantry

  Used for lifting, launching, and installing concrete segment in the position planned. This launching gantry was imported from Italy. This equipment looked like a steel-frame bridge that can lift segment with maximum load of 158 ton. In the beginning, the project needed one unit of launching gantry, but because of the project acceleration, another unit of launching gantry was needed. Totally, two units of launching gantry were required to finish the project on time.

- Low-bed trailer

  Used for transporting concrete segment from casting yard in Baros Cimahi to the location of project. This trailer is very specific with the ability

of its wheels to turn following the direction of the head of trailer, so that carriage of segment can pass through all of narrow road near by the project site. The project operated two units of low bed trailer to comply carriage about 658 segments.

- Shock Transmission Unit

  This equipment reduces lateral load from pier to the box girders. This equipment was imported from France and installed in bridge construction in Indonesia for the first time. This equipment became popular since the earthquake in Kobe, Japan. Pasupati Bridge Project installed 76 shock transmission units located on box girders.

- Pot bearings

  This tool is related to structure displacement. Pasupati Bridge used 202 pot bearings, 84 units on the ramps, 102 units in the viaducts, and 16 units on the cable stays, all of which were imported from South Korea. Three types of pot bearing were used: fixed, sliding, and guide bearing. Guide bearings with capacity 250-540 ton were used on the ramps, those with capacity 600-2,400 ton were used on the viaducts, and those with capacity 900-4,500 ton were used on the cable stays.

- Heavy shoring

  Used as a temporary support deck of cable stayed bridge while casting the concrete until post-tensioning of deck and installation of cable stays finished. Because of project acceleration, volume of heavy shoring increased from 70,000 m^3 to 143,000 m^3. This heavy shoring was imported from Taiwan.

- Cable stay

  Pasupati Bridge used a parallel strand system, the second generation of cable stayed technology. This system used seven 15.7 mm galvanized wire strands. Each cable stay consists of 19 strands (1 unit), 75 strands (10 unit), and 91 strands (8 unit), which are combined using stressing method. The material of cable stays was imported from France and South Korea.

- Flowable Concrete

  A chemical additive was needed to make the concrete flowable and can spread over on the segment and pier head more. The slump value of flowable concrete is 19 cm.

(3) Find sources of knowledge

Capturing method in Pasupati Bridge Project used paper-based method. Therefore, recording the sources of knowledge in the reports is very important because it will help track back the knowledge from the knowledge storage. The sources of knowledge should be defined in the planning stage of knowledge capturing processes, especially after determining works that are potential of having important knowledge. For example, Table 4-10 to Table 4-13 show the important knowledge in pylon work as well as the sources of knowledge.

(4) Create checklist form

Pasupati Bridge Project did not use any checklist form to capture knowledge from the site. This project only had the standard operation and procedures and pre-construction meetings as guidelines to control and monitor the work. Therefore, the checklist form should be developed to help monitor and control the work. The checklist form should cover all activities in the project so that lost knowledge is minimized. The checklist form should provide a space for the inspector or supervisor to add notes regarding important knowledge or innovation found on the site. Finally, the contents of checklist form should be discussed with the contractor, supervisor and designer before applying the checklist form to the works. The discussion aims to get comments, suggestion, or additional information about actual site condition so that the checklist form can represent the real activities performed on the site.

Table 4-10 Construction method of pylon

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Install and grouting bottom pot bearing	Preparation installing and grouting pot bearing	• Surface of concrete shall be grouted, so that surface clean of cement water, clean from grease, mud and lose material, surface of concrete is saturated. • Elevation/level top bearing have been prepared from leveling and marking. • Pot bearing shall be installed as in drawing	monthly report	field engineer	meeting minutes	field engineer
2	Application of grouting pot bearing	Execution of grouting	• Continue using pressure pump from one side until all of area full.	monthly report	-	-	-
3	Application of grouting pot bearing	Curing	• Closed by wet gunny least 8 hours.	monthly report	-	-	-
4	Erection of segment	Preparation of erection segment	• Access road below launching gantry must compacted and no settlement. • There should be enough room for maneuver of low bed trailer. • Traffic flow around erection location has to be arranged safely. • Position of winch for erection is in the save distance from pier column. • Low bed trailer position for erection must be in correct position. • Recheck all duct holes for permanent pre-stressing. • Recheck all inlet and outlet for top bearing grouting. • Install of steel bracket for top temporary pre-stressing and all bolts are installed well. • Set up tilting jack for alignment of viaduct and check the cross fall and gradient.	monthly report	field engineer	meeting minutes	field engineer

Table 4-10 (cont.) Construction method of pylon

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
5	Pre-stressing work	How to do it	• Moving and joint segment, still moved by gantry. • Stressing jack equipment. • PC strand and stress bar. • Stressing temporary pre-stressing top and bottom slab. • Surface of joint segment. Clean all epoxy laitance. • Install PC strand for permanent pre-stressing in correct location and number. • Permanent pre-stressing after one pair of segment is combined and then recording the stressing result including elongation.	monthly report	-	-	-

Table 4-11 Equipment used in pylon work

No.	Name of Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Equipment for grouting pot bearing	Type of equipment	• Pressure pump	daily report	field engineer	meeting minutes	-
2	Erection of segment	Type of equipment	• Launching gantry machine in function and safe. Function of this equipment is to lift and move the segment in proposed position	daily report	field engineer	meeting minutes	-

Table 4-12 Material used in pylon work

No.	Name of Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Material of grouting	What kind of material use for grouting	• Mixing 1 bag (25kg) conbextra HF and 4.5 dm 3 water using hand mixer	daily report	field engineer	meeting minutes	-
2	Epoxy material	What kind of material use for epoxy	• Nitobond EC product, ready for sufficient volume	daily report	field engineer	meeting minutes	-

Table 4-13 Technology used in pylon work

No.	Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Pylon construction method	The stages of construction	• Manual concrete segment with manual formwork • Erection tower crane • Erection climbing formwork outer and inner form with tower crane • Setting reinforcement bar • Setting formwork after reinforcements bar completely installed • Pouring second segment should be layer per layer with concrete bucket • Removing formwork • Lifting up climbing form work • Inner panel must be change permanent bottom pre-cast, before pouring • The pylon anchorage with the guide tubes will be pre-installed at the steel prefabrication yard	monthly report	-	-	-

(5) Assign a team of knowledge engineer

The team of knowledge engineers should consist of engineer representatives and other engineers because the number of engineer representatives is limited. The engineer representatives should concentrate on their main duty that is to supervise the project on behalf of the owner. If they concentrate more on knowledge acquisition processes, the monitoring of project will not be adequate. Much information was missing in the reports due to time restriction of the engineer representatives in preparing the reports. By having members specially dedicated to the knowledge acquisition processes, the knowledge acquisition processes can be monitored more closely. However, the chief of this team should be the chief of supervisor who knows work flow and the actual condition in the field.

The team of knowledge engineers is very important to Pasupati Bridge project because paper-based system used in this project consumes a significant amount of resources because of its quantity. The knowledge engineers must prepare several reports about the knowledge, make few copies to be distributed, classify the reports, put the reports in the right places, and modify the reports if it is out of date. All these activities are conducted manually and deal with a large amount of paper. Therefore, this job should be switched to other employees outside the knowledge engineer.

There should be at least six members in the team of knowledge engineer of Pasupati Bridge Project, including:

- a team leader who is also the chief of supervisor. The team leader is responsible in controlling the whole process of knowledge acquisition.
- two knowledge engineers who are assigned to supervise and capture knowledge in the Pasupati Bridge Project. One engineer is responsible for the bridge section and another one is responsible for the road section. These engineers have to make monthly reports of capturing knowledge and send them to the office of knowledge engineer to be combined with other reports.
- a knowledge engineer who is responsible for combining reports from the two previous engineers. This engineer is also responsible in matching the reports with documents from engineer representatives.

- a knowledge engineer who is responsible for storing knowledge. His duties are to receive the reports, give indexes to the reports, put them in the correct places, and prepare them for revision.
- a knowledge engineer who is responsible for updating the knowledge. He is also responsible for controlling reports distribution.

(6) Define tools to capture knowledge

There was no specific tool to capture knowledge in Pasupati Bridge Project. The engineer representative only used radio communication to communicate each other, but number of radio communication is not sufficient. Therefore, capturing knowledge should be done by making notes on log book about the knowledge before typing and saving the report in the computer.

(7) Define method to capture knowledge

Knowledge should be capture by using the combination of paper-based and computer-based methods. The paper-based method should be used to capture knowledge from documents, while computer-based method should be used to capture knowledge directly from the field. When the engineer in the field finds new knowledge, he can write down the knowledge in the paper, PDA, or tablet PC before sending it to the knowledge engineer to store it in the storing place. In the office, the knowledge engineer should then type the knowledge and store it in the computer as computer file. If it is necessary, the knowledge engineer can print the stored knowledge as a report.

Computers, folder cabinets, and bookshelves are suitable to store knowledge in Pasupati Bridge Project because most of the captured knowledge is in the form of documents and reports. The cabinets and bookshelf should be allocated well so that it will be easy in placing knowledge at the correct place and also easy to be searched in the future.

(8) Define method to store knowledge

The knowledge storing method in Pasupati Bridge Project was not appropriate, and thus it took a long period of time to search a particular document. The storing method

should be systematic as well as fast and easy to find the document. After being captured, knowledge should be stored in a temporary storage and classified according to the division of the final storage. After that, the knowledge can then be stored to the real storing places.

(9) Check update of storage knowledge

Updating knowledge in Pasupati Bridge Project took a long period of time because of its paper-based method. After the knowledge being revised, there should be a mark whether the document has been revised and number of revisions. The obsolete reports should be kept so that they are easy to be found if there is need to track back the revisions.

4.2.6 Results and discussion

Pasupati Bridge Project should use the paper-based method for capturing and storing knowledge because the project site is not far from the owner's office, and thus the knowledge acquisition processes can be performed more effectively using this method. Capturing and storing knowledge can be done by using a checklist form, reports, minutes of meeting, and other documents. The framework of knowledge acquisition system can be applied successfully to this project; however, the following factors must be considered.

- the willingness of engineer representatives to participate in the application of framework of capturing and storing knowledge
- the engineers' understanding about the importance of knowledge acquisition and how to perform the knowledge acquisition
- training about the existing system of capturing and storing knowledge to new members of the knowledge engineers
- approval and suggestions from team leader of knowledge engineers who knows the actual flow of work in the field

Hardy (2005) claimed that if the knowledge is stored in the appropriate places, tracking back the knowledge will be fast and easy. Yandhi (2005) supported this argument by giving this comment.

"Storing knowledge using a catalogue system will help track information back if the owner suddenly requests for a particular knowledge."

4.3 Highway Project

The knowledge acquisition framework can also be applied to other construction project such as a highway project. The application of framework is discussed as follows.

(1) Create WBS

A work breakdown structure is created in order to track down the location of important knowledge. In this hypothetical highway project, the work can be broken down into:

1. Roadway and access way
2. Untreated subbase and bases
    a. Spreading and compacting
    b. Watering
    c. Prime coating
3. Cement treatment
    a. Cement treating for base and subgrade
    b. Cement mixing in plant and on site
    c. Spreading and compacting
4. Road mixed surface
5. Asphalt concrete
6. Seal coat
7. Portland cement concrete pavement
8. Drainage structure
9. Bank protection
10. Erosion control

The Table 4-14 to Table 4-17 shows the WBS in the highway project.

Table 4-14 Portland cement concrete construction method

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Final finishing	Procedure	• The 16 foot steel cut float is used as the finishing tool. At joints of bridge segments, bridge and culvert connections, and sections with poor finishing, this float should be used to remove surface roughness. • The use of this float should be delayed until the surface is hard enough to avoid leaving a steel trowel. The finished surface should always be of a roughened texture, and the use of the final float should be delayed until such texture can be obtained.	monthly report	-	-	-

Table 4-15 Portland cement concrete equipment

No.	Name of Equipments	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Spreading machine	Function	• This machine can distribute the concrete within side forms. It can also reduce segregation of the concrete.	daily report	field engineer	meeting minutes	-
2	Trailing vibrator	Function	• To reduce the rock pockets during spread the concrete, the vibrators should have sufficient length and weight so that they can penetrate the concrete sufficiently effective.	daily report	field engineer	meeting minutes	-

Table 4-16 Portland cement concrete material

No.	Name of Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Calcium chloride	Function	• Calcium chloride has been found to be an effective strength accelerator. It should be added up to 2% by weight of the cement.	daily report	field engineer	meeting minutes	-

Table 4-17 Portland cement concrete technology

No.	Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Protection pavement	Curing compound	• The membrane should be protected from unnecessary abrasion, and if large areas of membrane have been broken, the curing compound should be reapplied.	monthly report	-	-	-
2	A layer of straw	Protection of pavement	• The concrete should be covered with impervious black paper or canvas stretched over frames at a sufficient height to allow lanterns to be placed under the blanket. Concrete should be placed over compact subgrade.	daily report	field engineer	meeting minutes	-

(2) Find innovation of project

Important knowledge should be defined first and then classified into four main items: construction method, material, equipment, and technology. Knowledge can be clarified from video record of the work process, voice record of the meeting, interview and conversation between experts and key persons of the project, and documents such as specifications and contract documents.

(3) Find sources of knowledge

Knowledge can be gathered from documents (e.g., specification, contractor daily report, monthly report, weekly report, and contract document), people (e.g., engineer's daily report, questionnaire, and interview), meeting (e.g., meeting minutes and voice records of the meeting). Sources of knowledge should be added during storing of knowledge and the result of knowledge capturing should be collected in a report.

(4) Create checklist form

Supervisor and knowledge engineers should be involved in checking the sequence of work as mentioned in the checklist form. The criteria have standard measure and their tolerance value to decide whether an item is approved or rejected. Table 4-18 shows the checklist form of portland cement concrete pavement work.

If a criterion in the work is beyond the acceptable range written in the checklist form, the knowledge engineer should make a note about the discrepancies. For example, in construction of joint, specifications provide that weakened plane joints should be constructed by either the formed joint or sawed joint method. Occasionally, a combination of the two methods can be used. The knowledge engineers should make a note of this new knowledge to capture the knowledge and incorporate it in the report.

(5) Assign a team of knowledge engineer

The team of knowledge engineer should be assigned to perform all knowledge acquisition processes. This team is responsible for identifying the knowledge, capturing, and storing the knowledge. This team is also responsible for checking whether the stored knowledge needs to be updated.

Table 4-18 Checklist form of portland cement concrete

<table>
<tr><td></td><td colspan="2">Portland cement concrete pavement</td><td>No:
Location :</td></tr>
<tr><td rowspan="2"></td><td>Checklist Description</td><td>Tolerance</td><td>Inspection Measurement</td></tr>
<tr><td>1. Batch yardage. A running total of a number of batches that the contractor has proportioned should be kept. Counters should be placed at both the plant and mixer. With two counters it is possible to obtain a more accurate count of the actual number of batches
2. Pavement yardage. A comparison of the pavement yardage with the batch yardage will indicate any necessary adjustments in size of batch
3. Cement record. Though not a pay quantity a complete record should always be kept of cement received, used and wasted. The tabulation will indicate the cement factor being obtained and also help detect errors in weighing.
4. Sieve analysis and proportion
5. Beam breaks
6. Tie assembly
7. Reinforcing steel
8. Rate of application sealing composed</td><td></td><td></td></tr>
<tr><td>Drawing Reference No.

Shop drawing No.
</td><td colspan="3"></td></tr>
<tr><td>Document related :
- daily report (DR)
- weekly report (WR)
- monthly report (MR)
- etc</td><td colspan="3">Note :

Supervisor/Inspector

(……)</td></tr>
</table>

(6) Define tools to capture knowledge

Tools for capturing and storing knowledge used in the project can be checklist forms, tape recorder, field testing, and engineer's daily report.

(7) Define method to capture knowledge and capture knowledge

Some reports used for capturing and storing knowledge are:

- Reports required upon start of work
  - notice of materials to be used
  - compensation insurance rates
  - checklist form of work
- Report required during construction
  - contract change orders
  - load slips
  - extra work
  - daily record of platform scale weights
  - weekly statements of working days
  - daily water report
  - weekly plant and street report of bituminous mixes
  - weekly report of PC concrete structures and pavements
  - weekly report on cement treated and treated bases
- General records during construction
  - Record of contract quantities and payment
  - Engineer's daily report

Time and location of capturing knowledge as well as knowledge engineer who responsible to the respective knowledge capturing should be written down on the checklist form, tape recorder, field testing form and engineer's daily report.

(8) Define tools to store knowledge

PDA, radio communication, and tablet PC are examples of the tools that can be used to store knowledge in the field temporarily. After that, this knowledge should be transformed in the report and saved or stored in the correct folder cabinets.

(9) Define method to store knowledge

The hypothetical highway project should use paper-based method in storing the knowledge because the project is typical for the whole segments. Besides, paper-based method is cheaper than computer-based method. However, the storing method should employ systematic codification and indexing for the reports so that tracking back the knowledge in the future can be performed more easily.

(10) Check update

Knowledge will be classified according to time it is captured. This classification supports updating and searching of knowledge in the folder of computer system.

4.4 Conclusions

There are differences between the knowledge acquisition system of Suramadu Bridge Project and that of Pasupati Bridge Project. Site condition of Suramadu Bridge Project is separated into three sections and the distance between sections is quite significant. This condition requires high level of communication between sections. As the sections are separated by the sea, wireless technology should be able to accommodate this need. Moreover, the capturing and storing systems should be computerized so that the knowledge acquisition system can be connected directly to the wireless communication system. All information and knowledge transferred among sections can be directly recorded and saved in the computer system. It is the knowledge engineer's duty to arrange and manage flow of the knowledge.

A paper-based system should be appropriate for Pasupati Bridge Project because the distance between the project site and the owner's office is not far. Therefore, project monitoring, knowledge capturing processes, and reporting can be done continuously. The limited availability of computer systems can be problematic; however, this problem can be handled by managing the use of computers between the users so that the users can finish their works by the computer simultaneously.

This framework of knowledge acquisition has also been applied to highway construction project. Because of the limited tools and short distance between project site and owner's office, and because the project is typical in all sections, paper-based is preferred as the system of knowledge acquisition of this project.

“The differences of knowledge capturing systems in Suramadu Bridge Project and Pasupati Bridge Project are caused by different levels of technology used in the tools of knowledge capturing. Visions of Suramadu Bridge Project in its knowledge acquisition have been defined clearly so that there is budget allocated for knowledge acquisition processes. On the other hand, even though Pasupati Bridge Project intended to document all knowledge in the project, because of the limited budget the paper-based method is more suitable for this project.” (Soekirno, 2005).

The proposed framework of knowledge acquisition can be applied to other heavy construction projects as well because the structure in this framework is general. As an example, the framework has been applied to highway construction project.

The knowledge acquisition framework can be applied effectively if there is a coordination between project engineers and the supervisor. Moreover, the supervisor can help the process by filling in checklist form as correctly and completely as possible. Therefore, it is important to include the supervisor as the member of the knowledge engineers team. Other factors determining application of the knowledge acquisition framework are

- Tools to capture and store knowledge determine the method of capturing and storing knowledge in the project.
- Experiences and IT skill of the engineers affect the quality of capturing knowledge. Knowledge engineer should have capability in IT and skill in the construction work.
- Distance between project site and owner’s office affect the communication system used.

CHAPTER V
SUMMARY AND CONCLUSIONS

This research has developed a framework of knowledge acquisition system that can be used by governmental agencies in public construction projects. The proposed framework addresses the method for identifying important knowledge, capturing, and storing knowledge, so that it can be used to develop a knowledge acquisition system. This chapter presents important conclusions from this research.

5.1 Summary of Knowledge Acquisition Framework

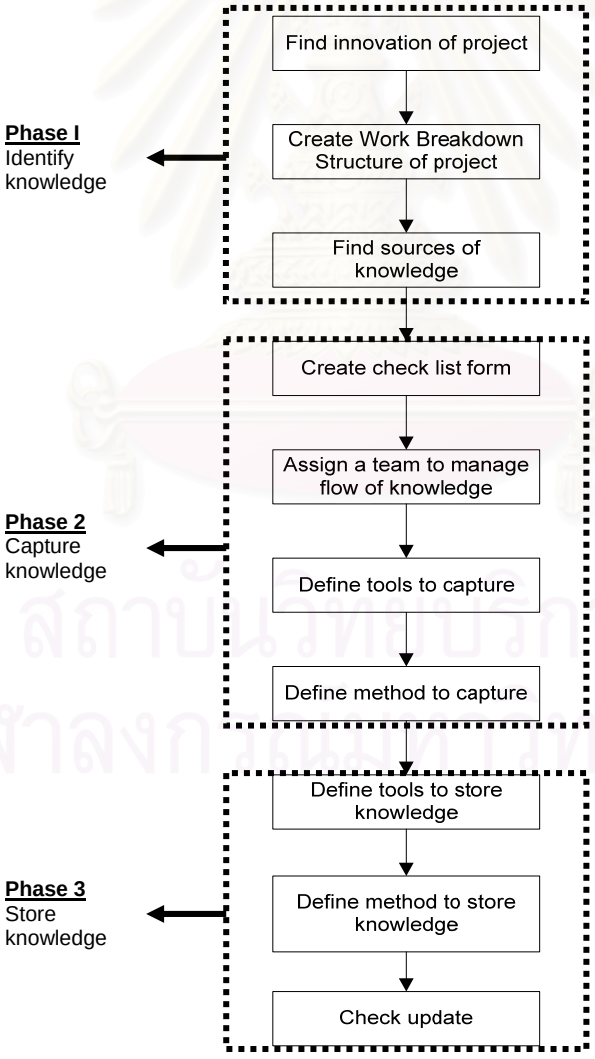


Figure 5-1 Framework of knowledge acquisition

The framework of knowledge acquisition consists of 10 stages, as shown in the Figure 5-1. The first three stages are in the knowledge identification phase. The following four stages are in the knowledge capturing phase. The last three stages are in the knowledge storing phase.

5.2 Applications of Knowledge Acquisition Framework

There are two kinds of capturing and storing knowledge: paper-based and computer-based method. Each method has advantages and disadvantages. The paper-based method needs paperwork, but it is efficient if the project is continuous and typical, for example highway project. The computer-based method is faster, efficient, accurate, and consumes less human resources. However, the computer-based method is more expensive, need higher skill of workers and better coordination.

Tacit knowledge is captured by interviewing the experts, project manager, contractor, supervisor and contractor to discuss solutions of the problems occurred on the site. The results from the discussions are then reported and recorded as the knowledge capturing processes. Capturing explicit knowledge can be achieved by taking video footage or voice record from the field.

5.2.1 Suramadu Bridge Project

Suramadu Bridge Project had introduced electronic tools in capturing and storing most of existing knowledges. Identifying knowledge in this project was tracked down from project characteristics and work breakdown structure (WBS). Involved parties in the WBS were identified and workflows describing their collaboration were created. A checklist form was then created for all work items. The contents of this form had been discussed between engineers, project manager and supervisor. Information contained in the checklist form was also gathered from monthly reports, contract documents, specifications, and method statements proposed by the contractor. Junior engineers were less involved in this stage even though their fresh idea might have added value to the result. Thus, involvement of junior engineers may be increased by assigning them to the preparation team.

Actually, this list should be agreed by the owner representative, supervisor, and contractor before apply to the field. However, there was difficulty to meet an agreement between contractor and owner representative because the application of

checklist was not stated in the contract documents. Therefore, the contractor resisted to apply the checklist form. It is suggested that the agreement to apply checklist form is included in the contract documents. The content of the checklist can be prepared later after contract is signed; however, the contractor should agree that he is willing to use the checklist form in capturing knowledge.

Assigning team to control the flow of knowledge could not be done in this project due to unavailability of human resources mastering in IT and electronic devices. Therefore, Suramadu Bridge Project hired an IT engineer for the project. As this IT engineer did not have experience in the related works, training was necessary to fasten engineer's adjustment to the existing work environment. However, it is suggested that the knowledge engineers shall be a team so that work load can be appropriately distributed among team members.

The knowledge capturing process in this project utilized electronic tools. The knowledge capturing during construction activities was performed by video camera recording and taking pictures. The videos and pictures were then reviewed and discussed whether there is knowledge captured in the videos or pictures. When new important knowledge was obtained, this knowledge was saved in the "docu-share" system, including videos or pictures supporting it. Tacit knowledge is difficult to capture. However, this project tried to capture knowledge from experts using notes of discussion between experts and senior engineer. New and important knowledge can then be reported by the individual engineer. The compilation of all knowledge from member of team can be a knowledge which is complete, accurate and up to date.

There should be effective communication between project parties to avoid mistakes in capturing knowledge. Because this project had two main fields: on the land side and on the sea side. The communication should be supported by sufficient facilities. In fact, facilities in the project were not sufficient to support communication between land side and sea side area.

5.2.2 Pasupati Bridge Project

In Pasupati Bridge Project, knowledge was identified from pre-construction meeting attended by the owner, owner representative, supervisor, and contractor of the project. This meeting discussed work breakdown structure (WBS), level of work

observed, and method statements proposed by contractor. After method statements were agreed, a checklist form then was created.

Project characteristics are explored and main construction works are classified by analyzing contract documents, specifications, and method statements. In this project, the framework was only applied to one sample of work, constructing floor system.

Method to capture knowledge in this project did not focus on utilizing computer system but the completeness of report within a specific period. There were more than nine engineers involved in the capturing process. This number was sufficient to capture knowledge effectively within shorter time. This team is also effective in identifying source of knowledge and defining important knowledge to be captured. Each engineer created a report according to his job description. In reality, all engineers discussed about their works and created a report covering all aspects in project monitoring. This report did not specifically discuss detail of knowledge captured. It is suggested that an engineer shall make report of his own job description so that he can focus more on knowledge he responsible for.

The limited availability of engineers caused more workload for each engineer. This condition made flow of knowledge could not be monitored perfectly. Moreover, there was no special assigned person or team to monitor and compile information of important knowledge to be a comprehensive report about this knowledge. As result, some detail of important knowledge could not be captured or lost. Finally, this project hired experts from academic institution (i.e., lecturers of Bandung Institute of Technology). Daily meetings with the experts were held to discuss and create report about important knowledge, and to verify the validity and completeness of the knowledge.

Pasupati Bridge Project used paperwork for all systems of capturing and storing knowledge. These systems required catalogue systems to make storing of knowledge more systematically and to make searching of knowledge easier.

5.3 Conclusions from the Case Studies

This research develops framework of knowledge acquisition consisting of ten stages and the case studies showed that the framework can be applied successfully.

Government agencies then can select which methods of knowledge capturing and knowledge storing that match with the actual conditions such as vision and mission of project, project budget, continuities of project task, completeness of project, as well as imported technology, material and equipment used in the project.

However, these obstacles faced during the application of knowledge acquisition framework.

- There was difficulty in applying the framework through organization. Cooperation by each person in the project, especially a team for special job, is necessary.
- The willingness for sharing knowledge from senior engineers through junior engineers was very difficult to found. This is also obstacles for the person who manages knowledge to capture and store knowledge on time and smoothly.
- The lack of information and technology tools was obstructing capturing and storing knowledge.
- The limited knowledge about information and technology in this century affected updating the old knowledge.

5.4 Future Work

An interesting future research in terms of knowledge management is to develop systems for mapping and storing the location of knowledge with computer systems. The framework of knowledge acquisition in this research can be used as a guideline to make a system for knowledge mapping which prepares the location, time, position, and type of knowledge. Knowledge mapping is an important practice consisting of survey, audit, and synthesis. It aims to track the lost information and knowledge during the knowledge acquisition. It explores personal and group competencies and proficiencies. It illustrates or "maps" how knowledge flows throughout an organization. Knowledge mapping helps an organization appreciate how the loss of staff influences intellectual capital, assist in the selection of teams, and match technology to knowledge needs and processes.

The knowledge map is a navigation aid to locate explicit as well as tacit knowledge. The knowledge map also shows the dynamic relationships between stored

knowledge. The knowledge map, an outcome of synthesis, portrays the sources, flows, constraints and sinks (losses or stopping points) of knowledge within an organization (Grey, 1999).

The knowledge in an organization should be mapped because of these reasons.

- It encourages reusing knowledge and preventing reinvention, and thus saving search time and acquisition costs
- It highlights important expertise and suggests ways to build connectivity between experts to increase knowledge sharing
- It discovers effective communities of practice where learning is happening
- It provides a baseline for measuring progress with knowledge management projects
- It reduces the burden of experts by helping staff find critical information quickly
- It improves customer response, decision making, and problem solving by providing access to applicable information
- It highlights opportunities for learning and leverage of knowledge
- It provides an inventory and evaluation of intellectual and intangible assets

For knowledge mapping, these key questions will be asked to engineer who has important knowledge and important experts in the organization.

- What type of knowledge is needed to do your work?
- Who provides the knowledge, from where do you get it, and how does it arrive?
- How do you add value to the knowledge and what are the critical issues?
- What happens when you are done with adding the value to the knowledge?
- How can the knowledge flow be improved and what is preventing you doing better and faster improvement?
- What would make your work easier?
- Whom do you go to when there is a problem?

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APPENDICES

Suramadu Bridge Project

A.1. Pile Foundation

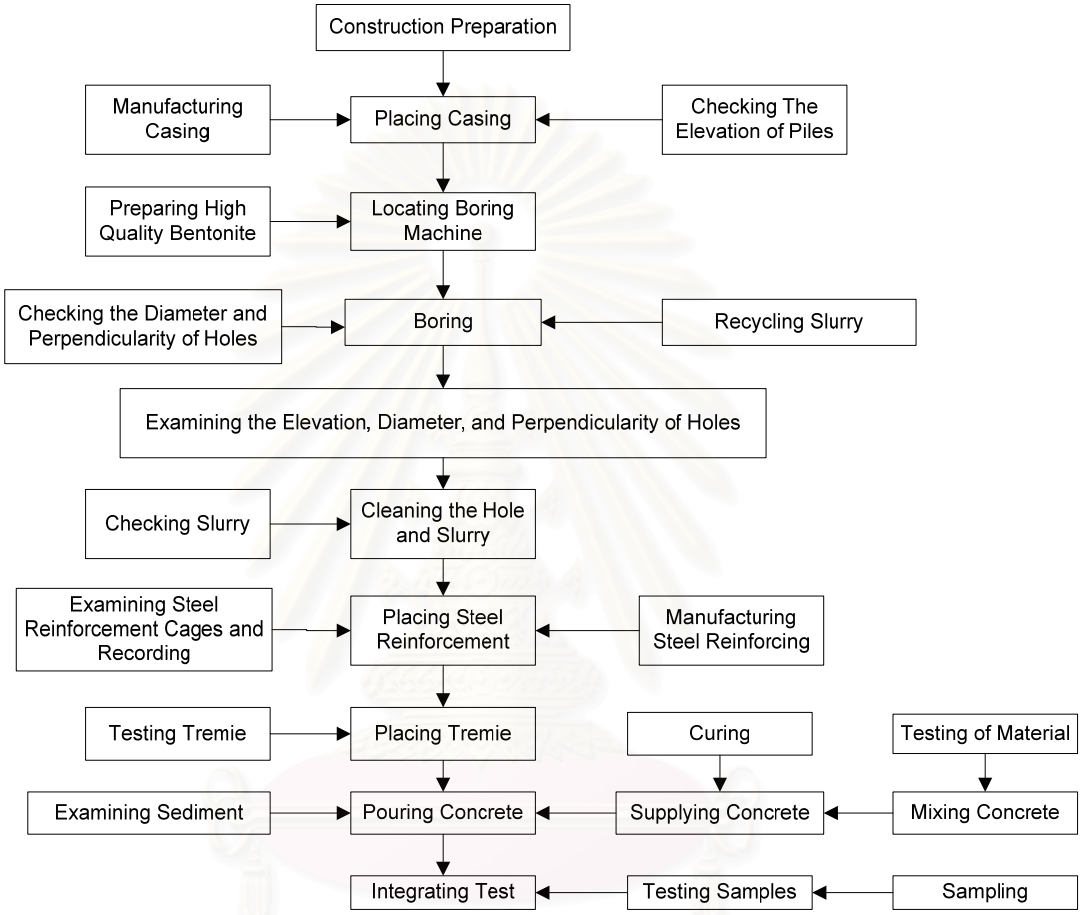

Figure 1 Work flowchart of pile foundation

A.2. Pile Caps

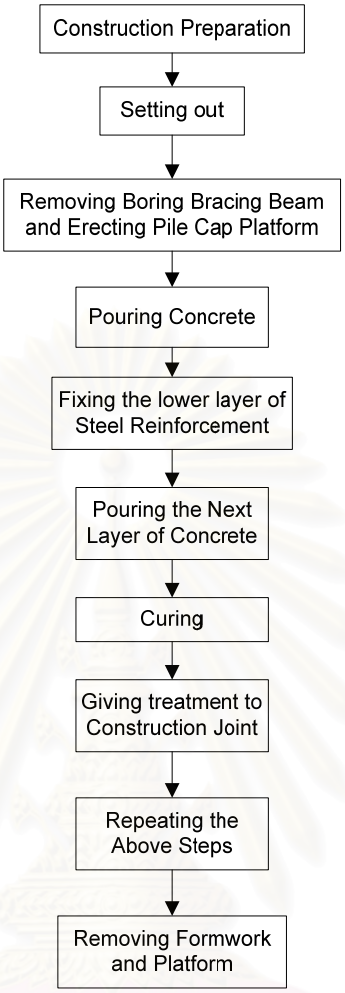

Figure 2 Work flowchart of pile cap

A.3. Pier

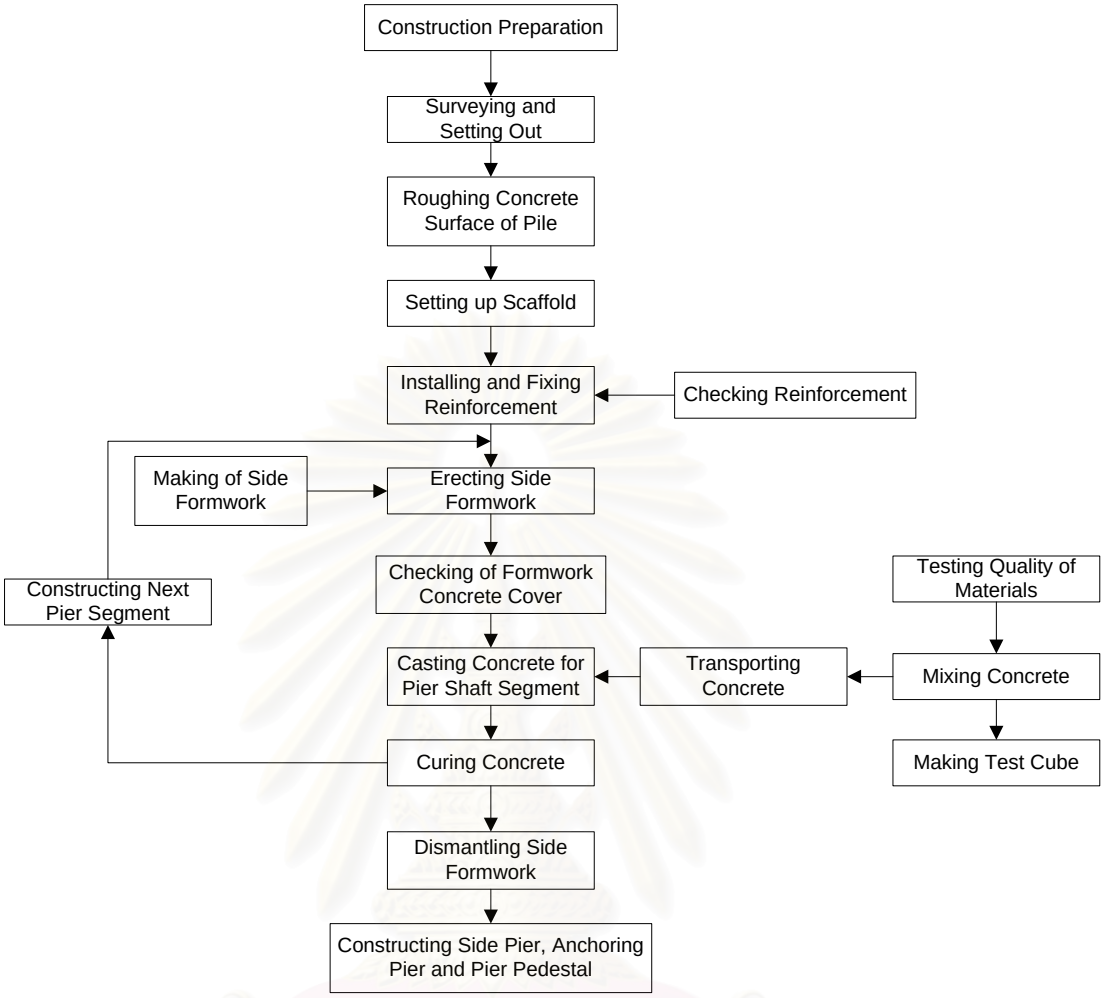

Figure 3 Work flowchart of pier

A.4. Box Girder

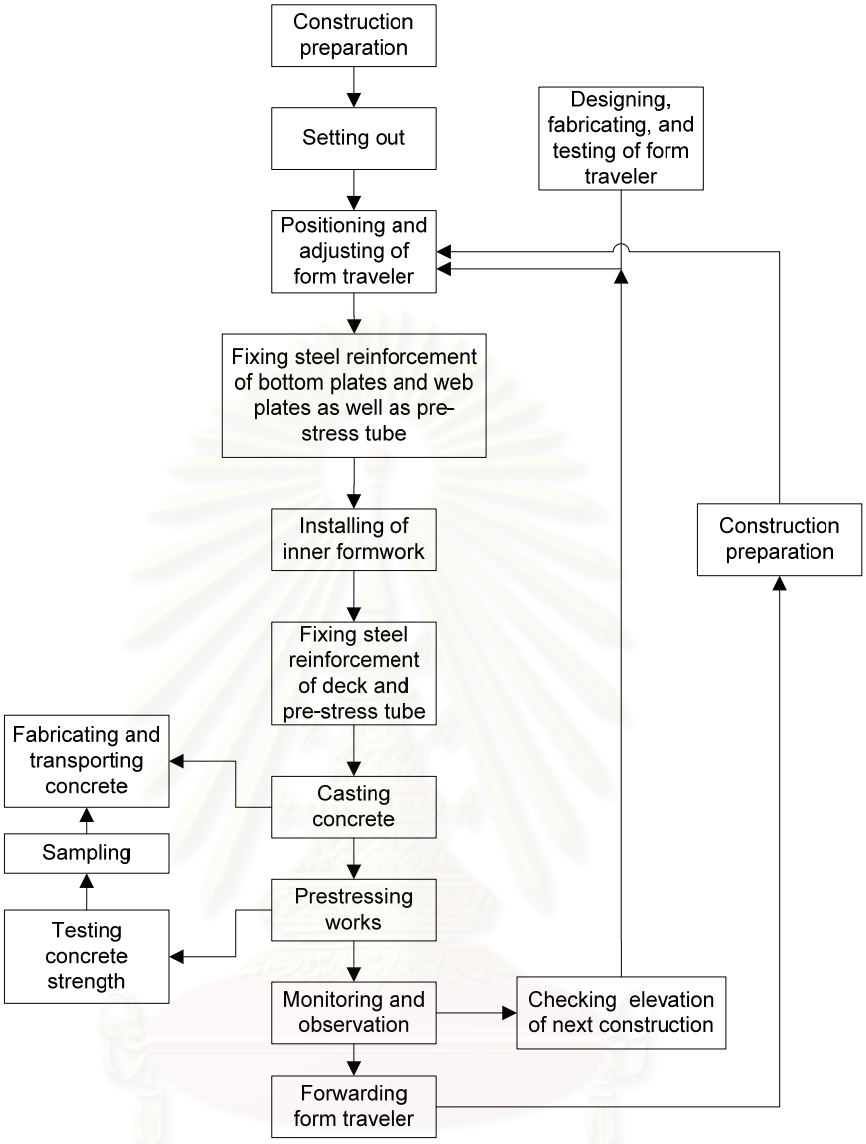

Figure 4 Work flowchart of box girder

A.5. Pylon

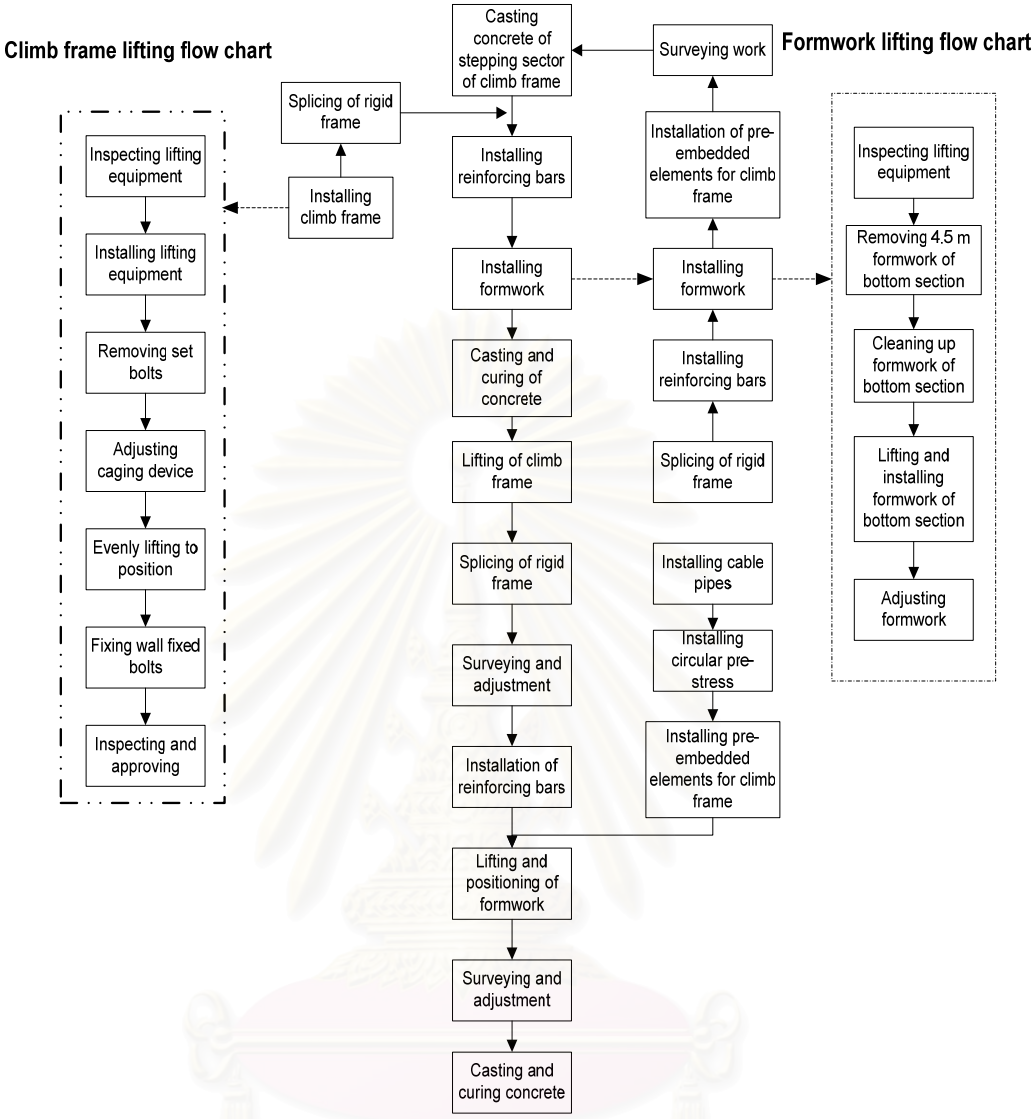

Figure 5 Work flowchart f pylon

A.6. Installation of Cable Stay

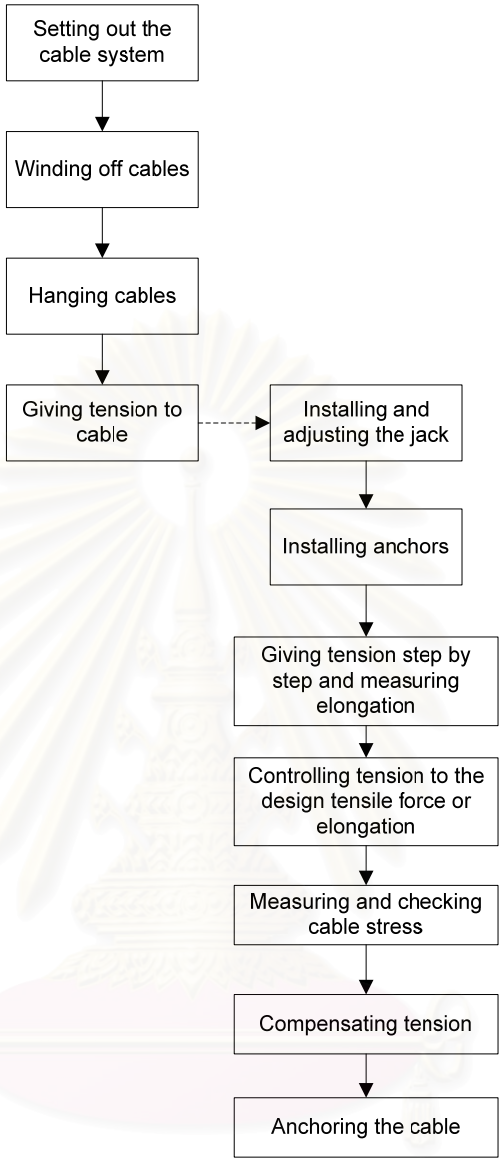

Figure 6 Work flowchart of cable stay installation

A.7. Floor System

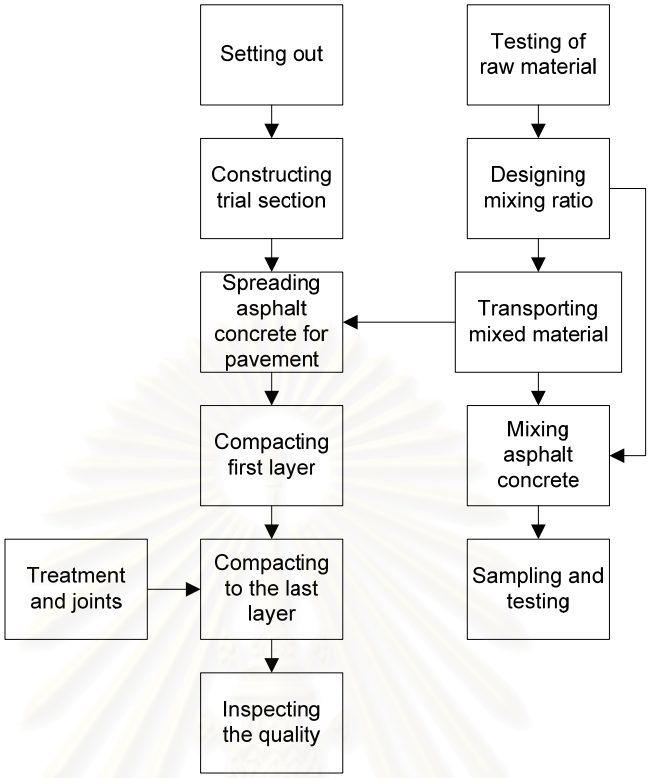

Figure 7 Work flowchart of floor system

Table 1 Construction method of bore pile

No.	Name of construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Constructing platform	building platform for pile foundation in the sea	• surveying and positioning using GPS • carrying out pile driving operation for casing and steel pile by large pile driving ships • driving steel casing and steel pipe pile • connecting the steel piles each other horizontally • fixing the upper structure of platform with floating cranes • fixing support shoulder on the wall of casing to bear the beam	daily report, monthly report, inspection, checking list	field engineer	meeting minutes	guidebook
2	Slurry preparation	protecting the reinforcing steel of the pile from corrosive effect of chloride	• mixing fresh water and bentonite to make slurry. By using slurry circulation, the dregs can be removed and the boring hole can be cleaned	monthly report	inspector and supervisor	-	-
3	Boring	boring in the sea	• preparation • laying sleepers properly on the boring platform, fixing the steel rails, use a floating crane to hoisting and installing the boring machine into place, erecting the boring rig and adjust and installing hoisting system • lifting the drilling head into the casing to prepare for boring • placing boring machine then adjust the pedestal and keep it steady, so as to ensure that it will not sink during boring • using less pressure and choosing the right speed	contract, document, monthly report, inspection, checking list	team leader, checker	-	-
		cleaning hole	• checking the depth, diameter and the verticality of the hole.				

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Table 2 Equipment used in bore pile work

No.	Name of Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Drill equipment	Using for reinforcing bar	• prepared in the pontoon which brought equipment for driving casing and drilling	daily report	field engineer	meeting minutes	-
2	Vibratory hammer	-	• the equipment for driving casing • driving casing work, started with measurement of drilling point position. Driving barge shall be anchored tightly to prevent exceeding movement caused by wave and wind	-	-	-	-
3	Surveying platform	Function	• Surveying instrument should be placed at the position as planned. For one bore pile, three surveying instrument is used appropriately to surveying SOP.	daily report	field engineer	meeting minutes	-
4	Feeder barge	Function	• Feeder barge carries casing pipe from stock yard and moves to driving position.	monthly report	field engineer	meeting minutes	-
5	Crawler crane	Function	• Pipe casing is moved to driving position. Pipe casing is moved from feeder barge to bore pile feeder using crawler crane with 100 ton capacity. • Pipe casing has to be lifted vertically and placed precisely so there is no inclination in driving casing. • To keep the verticality of the casing, a leader stuck on the barge shall be used. Allowed inclination is not exceed 20 mm per meter. Vibratory hammer should be installed on the pipe casing after pipe casing in the position.	-	-	-	-
6	Drill pipe stabilizer	Function	• Torsion and bending should be prevented in the boring process thus it increases the stability of the boring machine.	-	-	-	-

Table 3 Material used in bore pile work

No.	Name of Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Casing pipe	Function	• Casing pipe is directed into its position by direction of surveyor. If the casing is in the position, it will be ready for driving work. Casing pipe shall be shot at the edge of the pipe. After driving casing work has finished in a row, leveling survey was made. Then the casing that is not leveled was be leveled to make the setting of the next points.	daily report	field engineer	meeting minutes	-
2	Slurry for bored pile	Mixing ratio	• 100kg fresh water, 8 kg bentonite, 0.003 kg ammonium polyacrylate, 0.03 kg soda powder	-	-	-	-
3	Bentonite slurry	Disposal mud	• Use bentonite slurry to protect bore hole wall from failure especially for uncovered bore hole. Extracted mud from drilling auger discard to disposal barge and carry it to disposal site. Extracted mud and slurry shall be discharge to the designated location by engineer	-	-	-	-

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Table 4 Technology used in bore pile work

No.	Name of Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	RCD method	Method for drilling work	• The objective is using RCD method is to reduce construction time and to make the work uncomplicated • Drilling machine is put on pipe casing and drilling work shall be done simultaneously with removal of extracted mud • Use two RCD machine and two fleet of crane barge • Find specified depth, 45 m from the bottom of pile cap • Keep straightness of drilling • For drilling hole which is not covered by pipe casing, hole diameter in any direction does not exceed 5% from specified diameter • To prevent the drilling auger hitting the steel casing during drilling, BHA stabilizer should be installed	-	-	-	-

Table 5 Construction method of pile cap

No.	Name of construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Fabricating and installing reinforcing bar	preparation	• Reinforcing bars shall be carried out to worksite using formwork and rebar feeder barge. Reinforcing bars shall be fastening together using tie wire and crossing bars shall not be welded to main tension. • Where lapped splices are approved the lap length shall be 40 bar diameter and the bars shall be provided with hooks. The twisted ends of tie wire shall be directed away from concrete surfaces that will be exposed	daily report	field engineer	meeting minutes	guidebook
		installing reinforcing bars	• Installation of reinforcing bar shall be started following installation of bottom and side formwork.	monthly report	-	-	-
2	Concreting	sealing concrete method	• As bottom formwork is still submerging in the sea water and preventing from sea water, sealing concrete shall be used • The method for this pouring concrete is using pipe • Sealing concrete shall be poured for 0.3 m height • Next pouring concrete for 0.5 m in the height shall be started after sealing concrete has reached required strength. That 0.5 m height of concrete, shall be purpose for supporting of next pouring concrete • Construction joint will not be permitted between a depth of 75 cm under the lowest water level and 75 cm above the highest water level • In construction joint, wash concrete surface with water spray and the contact surface shall be sprayed with mortar cement then concrete pouring of the next segment shall be started. The fall of pouring concrete must be kept from hindered the rebar to avoid segregation.	contract document and monthly report	chief supervisor	-	-

Table 5 (cont.) Construction method of pile cap

No.	Name of construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
3	Curing concrete	The causes of concrete construction crack	• Compressive strength shall become secondary concerning comparing to cold joint and cracking as consequence of heat hydration • Larger cement and larger volume which will poured, more heat hydration will occur • Heat hydration is influenced by concrete volume, outer temperature, initial temperature of concrete, water cement ratio, cement type, and admixture • Temperature difference between inner concrete and surface concrete shall cause compressive force and tensile force in entire concrete. • To prevent concrete from cracking, the temperature difference shall not exceed 250.	daily report	field engineer	-	-
4	Curing concrete	Method to place the component for curing	• Plastic layer shall be installed first. Spread the plastic to entire top surface concrete. When it is completed, styrofoam layer shall be installed. Last layer of insulator system is sand. Sand spread to entire surface of Styrofoam. It will take 7 days for curing concrete.	monthly report	field engineer	meeting minutes	-

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Table 6 Equipment used in pile cap work

No.	Name of Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Crawler crane	Using for reinforcing bar	• *Reinforcing bar shall be lifted by crawler crane from formwork and rebar feeder to pile cap worksite. • After that workman shall direct and install reinforcing bar inside the formwork.	daily report	field engineer	meeting minutes	-
2	Barge for batching plant	Function	• Raw material of concrete are carried to batching plant barge using concrete feeder.	daily report	field engineer	meeting minutes	-
3	Vibrator concrete	Method to use it	• Using for compact the concrete • The vibrator should not be moved more that 1.5 times the radius of its action range each time and keep a distance of 5-10 cm from side formwork and be inserted to the concrete of the previous layer by 5-10 cm. • Casing of concrete should be carried out continuously and if it must be interrupted for some reason, the time of interruption should be shorter than the time of initial setting of concrete of previous layer.	monthly report	field engineer	meeting minutes	-

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Table 7 Material used in pile cap work

No.	Name of Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Raw material of concrete	Size of concrete of the piles	• Raw material of concrete such as sand, aggregate, cement, and additive agents in accordance with two to three times the size of concrete of the piles.	daily report	field engineer	meeting minutes	-
2	Bars	Reinforcing bar	• Where lapped splices are approved the lap length shall be 40 bar diameter and the bars shall provided with hooks. The twisted ends of tie wire shall be directed away from concrete surfaces that will be exposed. • When fixed reinforcement is to be left exposed for a delayed period of time, it shall be thoroughly cleaned and painted with neat cement grout. • Total rebar joint in the same section should not exceed 50% from total installed rebar on that section. • Install concrete block to keep the distance between reinforcing bar and outer side of formwork.	daily report	field engineer	meeting minutes	-
3	Concrete	Concreting	• In sealing concrete, concrete shall not be dropped freely into form from heights greater than 150 cm. • Concrete shall not be deposited directly through water	daily report	field engineer	meeting minutes	Web site
4	Styrofoam	Insulator concept for curing concrete	• Styrofoam insulator is used to keep concrete temperature and the water content.	daily report	field engineer	meeting minutes	Web site
5	Plastic	Part of insulator structure	• Insulator structure consist of plastic, Styrofoam, and sand. • Plastic have good ability to keep heat and water content from concrete hence hydration process • At rainy time, water cannot contact the concrete which will degrade the surface concrete temperature and it will invite cracking	daily report	field engineer	meeting minutes	Web site
6	Sand	Part of insulator structure	• Sand is chosen as insulator system complement. That is to protect Styrofoam from damage and to keep from directing sunlight. It will prepare also for next working segment so it can be started while control temperature is still working.	daily report	field engineer	meeting minutes	Web site

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Table 8 Technology used in pile cap work

No.	Name of Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Concreting	Sealing concrete method	• As bottom formwork is still submerging in the sea water and preventing from sea water, sealing concrete shall be used • The method for this pouring concrete is using pipe • Sealing concrete shall be poured for 0.3 m height • Next pouring concrete for 0.5 m in the height shall be started after sealing concrete has reached required strength. That 0.5 m height of concrete, shall be purpose for supporting of next pouring concrete • Construction joint will not be permitted between a depth of 75 cm under the lowest water level and 75 cm above the highest water level • In construction joint, wash concrete surface with water spray and the contact surface shall be sprayed with mortar cement then concrete pouring of the next segment shall be started. The fall of pouring concrete must be kept from hindered the rebar to avoid segregation.	contract document and monthly report	chief supervisor	-	-
2	Curing concrete	Method to place the component for curing	• Plastic layer shall be installed first. Spread the plastic to entire top surface concrete. When it is completed, styrofoam layer shall be installed. Last layer of insulator system is sand. Sand spread to entire surface of Styrofoam. It will take 7 days for curing concrete.	monthly report	field engineer	meeting minutes	-

Table 9 Construction method of pier

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Installing climbing form	The key point	• Installation of climbing form shall be started from side formwork installation. • Install side formwork in entire fourth side • Adjust adjustment brace and adjustment kicker so formwork in required position. • Make spacer hole as supporting at formwork installation for next segment • Install platform in the bottom of formwork. It used for finishing purpose of last concreting segment	contract document and monthly report	chief supervisor	-	-
2	Segmental casting method	Pouring concrete	• The treatment of the joint between two segments needs to attend according to strength and resistance of concrete. Therefore, construction joint be done correctly. • Shorten the interval between the two concrete casting segments so as to reduce the internal force added on account of the different shrinkages between two segments	monthly report	field engineer	meeting minutes	-
3	Casting concrete	Concrete mixing and casting	• Concrete slump should be controlled within 18 cm. It should be pumped into formwork directly from concrete mixing station.	monthly report	-	meeting minutes	-
4	Installing reinforcing bar	Construction of prestressing	• Have fourth steps, pulling tendons, tensioning, tensing order, and grouting	monthly report	-	meeting minutes	-

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Table 10 Material used in pier work

No.	Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Formwork	Material using for formwork	• Bottom formwork consists of phenol film and 50/70 wood. Bottom formwork used for the first 50 cm pouring concrete of bottom pier.	monthly report	-	-	-
2	Cement with low hydrate heat	Help the construction joint	• In Segmental casting method, cement with low hydrate heat will help the construction joint into good stickiness. Just prior to pour the concrete, use clean water to moisture the roughing surface of the segment before	monthly report	-	-	-
3	Side formwork (steel)	Material using for formwork	• Side formworks for the piers are made of steel to be processed by a specialized formwork factory. • In order to ensure the appearance of the piers surfaces, no connecting bar is used passing through two side formwork. • The face plate is made of steel plates of 5 mm thick and reinforced with I type steel (8 cm high). The annular frame for the side form is made of a welded truss with I type (20 cm high). • The joints of the form segments, the joints between the horizontal, vertical, and annular frames are linked by bolting	monthly report	-	-	-

Table 11 Equipment used in pier work

No.	Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Crawler crane	Installation of climbing form	• Climbing form shall be moved up by crawler crane to next segment	monthly report	-	-	-
2	Piston type grouting pump	Function	• The pump pressure should be controlled at 0.5-0.7 MPa while grouting. The pump pressure can be adjusted higher if the ducts are long. The duct fill full with cement paste and keep certain period of time when the pump pressure reaching highest	monthly report	-	-	-
3	GPS	Function	• Adjust positioning control for formwork of pier	monthly report	-	-	-

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Table 12 Technology used in pier work

No.	Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Installing reinforcing bar	Construction of prestressing	• Have fourth steps, pulling tendons, tensioning, tensing order, and grouting • Pulling the tendon, part of the longitudinal tendons was pulled to position before concrete casting. • Tension of pre-stress tendon is a key working procedure in the pre-stress system. Both tension force and elongation of tendon shall be controlled, and tensing operation shall be done with a proper speed. • Tensing order, tensing was performed as the order in the drawing, and followed the principle to tense symmetrically. • Grouting, Longitudinal prestressing duct was grouting through one end • Before grouting, the pipe should be blown clean with compressed air then wash clean with clean water. Grouting should be carried out slowly.	monthly report	-	-	-
	Method of scaffolding construction	Cast in situ of pier	• The method is using combination of steel pipe and IWF steel. Install concrete box below pier for bearing support construction. It shall be used for keeping the balance of pier, then install horizontal I-WF support and vertical IWF support	monthly report	-	-	-

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Table 13 Construction method of box girder

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Installing travelers form	Lifting system	• Form traveler is composed of main triangular truss system, bottom basket system, suspension system, formwork system, anchoring system, and moving system • The lifting system is composed of a front beam, a middle beam and slings. All the slings shall be processed with steel. The upper and lower front beams shall be linked with slings. The rear crossbeams of bottom basket shall be anchored on the bottom slab of the cast box girder and it will be unloaded after casting of each segment. Every sling will use a hoisting jack as a hoisting system. When the hanging basket moving into position, use a hoisting jack up the slings and bottom basket to the designed position.	monthly report	-	-	-
2	Constructing standard segment		• Casting of standard segment must be symmetrically performed taking the transverse axis of the pier body as a center, and its transverse casting shall be performed symmetrically taking the central line of the bridge, the construction deviation must be controlled within the range of design requirements • The elevation and linearity of the girder shall be monitored and controlled during construction of each segment, and change in the elevation of girder due to affection of temperature difference shall be taken into account • Shifting forward of the cantilever shall be symmetric, slow, and uniform, and the rear anchor point shall be timely anchored once the hanging basket is forward shifted to the position	monthly report	-	-	-

Table 13 (cont.) Construction method of box girder

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
3	Constructing structure system changing	Tension of prestressing tendon in prestressing work	• Stages for tensioning consists of pulling tendons, tension, tensing order, grouting. • Carefully pulling tendons is needed in order to prevent breaking of the corrugated pipes. • Tension of pre-stress tendon is a key working procedure in the pre-stress system. Both tension force and elongation of tendon shall be controlled, and tensing operation shall be done with a proper speed.	monthly report	-	-	-
4	Tensioning prestress tendon	Preparing grouting	• Before grouting, the pipe should be blown clean with compressed air and then wash clean with clean water. Grouting should be carried out slowly and cannot stop halfway.	monthly report	-	-	-

Table 14 Material used in box girder work

No.	Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Construction of closer and structure system changing	Prestressing work	• Shifting forward of the cantilever shall be symmetric, slow, and uniform, and the rear anchor point shall be timely anchored once the hanging basket is forward shifted to the position	monthly report	-	-	-
2	Raw material of concrete	Content of raw material	• Sand, aggregate, cement, and additive agents	monthly report	-	-	-

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Table 15 Equipment used in box girder work

No.	Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Construction of closer and structure system changing	Preparing of tensing devices in prestressing work	• The tensing jacks shall subject to inspection by skilled technicians organized, to ascertain if the jacks match their pressure gages, and oil pumps run properly. After passing primary inspection, jacks, oil pressure gages, and oil pumps should do the calibration before use.	monthly report	-	-	-
2	Tension of prestressing tendon	Preparing grouting	• A piston type of grouting pump used with controlled pressure at 0.5-0.7 MPa while grouting. The pump pressure can be adjusted higher if the ducts are long. The ducts should be full with cement paste and keep a certain period of time when the pump pressure reaching highest.	monthly report	-	-	-

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Table 16 Technology used in box girder work

No.	Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Installation of reinforcing bar	Construction of prestressing	• Have fourth steps, pulling tendons, tensioning, tensing order, and grouting • Pulling the tendon, part of the longitudinal tendons was pulled to position before concrete casting. • Tension of pre-stress tendon is a key working procedure in the pre-stress system. Both tension force and elongation of tendon shall be controlled, and tensing operation shall be done with a proper speed. • Tensing order, tensing was performed as the order in the drawing, and followed the principle to tense symmetrically. • Grouting, Longitudinal prestressing duct was grouting through one end • Before grouting, the pipe should be blown clean with compressed air then wash clean with clean water. Grouting should be carried out slowly.	monthly report	-	-	-

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Table 17 Construction method of installation of cable stay

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Installing of cable stay	Setting of the cable system	• A lifting platform, on which four 25t winches are set, and under which a tower top lifting device consisting of a 5-sheave, 10 chain polyspast is set along the bridge direction on the tower top. One end of the polyspast is hauled by the winch; another end is fixed with sling and hanger, to lift cable. The maximum theoretical lifting capacity of the lifting device is about 200t.	monthly report	-	-	-
2	Installing of cable stay	Winding off cables	• Cold cast anchors plus cables are made into cable reels in the factory and transported to the site by truck or ship • For short cables, berth the off cable ship under the bridge • The cable reels are placed on the off cable drum on the off cable ship • Open the cold cast anchor of the cable reel • Let the traction wire down through pulley at the girder end, then connect the traction wire with the cold cast anchor head on the ship through the anchor plug, and drag the cable up to the bridge surface using the winch on the girder surface. • Cable pulleys are placed in the interval of 20-30 m on the girder surface, the winch on the girder winds off cable. • When the anchor head at another end comes out of the reel and reaches the girder top, prepare to connect the anchor with the lifting system on the pylon.	monthly report	-	-	-

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Table 17 (cont.) Construction method of installation of cable stay

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
3	Installing of cable stay	Cable hanging	• For short cable, connect a tension connecting rod at the anchor head, directly lift it to the open of the cable sleeve in pylon top by using the tower crane or dropping the lifting rope from the pylon top, and then let the rope end of the winch out of the cable sleeve and connect with the tension connecting rod at the end of the cable, and drag it out of the rear end of the jack using a winch in the pylon • For hanging of medium long and long cables, first drag the cable to the bridge surface or lift the cable reels to the bridge surface using a bridge surface crane, and after completion of winding off cable and connecting the tension connection rod, and then start the cable hanging	monthly report	-	-	-

Table 18 Material used in installation of cable stay

No.	Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Anchor of cable stay	Location	• Anchored in the counterweight concrete block at bridge end, at the lower end of other cables, steel anchor boxes, composed of anchor plates, cushions, bracing ribs, and stiffeners, are all set for the cables in the main girders.	monthly report	-	-	-

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Table 19 Equipment used in installation of cable stay

No.	Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Vibration absorber	Function	• To control the vibration of cable, vibration absorber is placed in the cable sleeve, and the surface of outer HDPE sheath is set as bifilar helix.	monthly report	-	-	-
2	HCA damper	Position	• Located between cable stay and deck	monthly report	-	-	-

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Table 20 Construction method of floor system

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Constructing water proof coating on bridge deck	preparation	• The surface of primary level must be flat, solid, and clean prior to construction of the water proof coating layer. When its construction is in hot summer, shading measure shall be taken to prevent it from burning of sun.	monthly report	-	-	-
2	Constructing asphalt concrete pavement	Steps in the construction	• The construction consists of asphalt concrete mixing, transporting, paving, and compacting • Temperature control is very important during paving, and the compacting process may be divided into initial rolling, second rolling, and final rolling, to ensure quality of the pavement	monthly report	-	-	-
3	Constructing asphalt concrete pavement	Preparation	• The preparation includes bridge deck clearing, equipment adjustment, material preparation, mix ratio design. After the proper procedures and workmanship have been determined by paving a trial section, the pavement work can be started normally.	monthly report	-	-	-

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Table 21 Material used in floor system work

No.	Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Construction of closer and structure system changing	Prestressing work	• Shifting forward of the cantilever shall be symmetric, slow, and uniform, and the rear anchor point shall be timely anchored once the hanging basket is forward shifted to the position	monthly report	-	-	-
2	Raw material of concrete	Content of raw material	• Sand, aggregate, cement, and additive agents	monthly report	-	-	-
3	Pavement layer	The important thing	• Pavement layer is composed of wearing course with 5 cm thickness, and binder course with 5 cm thickness. Temperature control is very important during paving so it must be controlled. Temperature must be controlled so it can reach 1100- 1200	monthly report	-	-	-

Table 22 Equipment used in floor system work

No.	Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Concrete paver	Function	• For concrete pavement	monthly report	-	-	-

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Table 23 Technology used in floor system work

No.	Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Installation of reinforcing bar	Construction of prestressing	• Have fourth steps, pulling tendons, tensioning, tensing order, and grouting • Pulling the tendon, part of the longitudinal tendons was pulled to position before concrete casting. • Tension of pre-stress tendon is a key working procedure in the pre-stress system. Both tension force and elongation of tendon shall be controlled, and tensing operation shall be done with a proper speed. • Tensing order, tensing was performed as the order in the drawing, and followed the principle to tense symmetrically. • Grouting, Longitudinal prestressing duct was grouting through one end • Before grouting, the pipe should be blown clean with compressed air then wash clean with clean water. Grouting should be carried out slowly.	monthly report	-	-	-

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Pasupati Bridge Project

B.1. Bore Pile

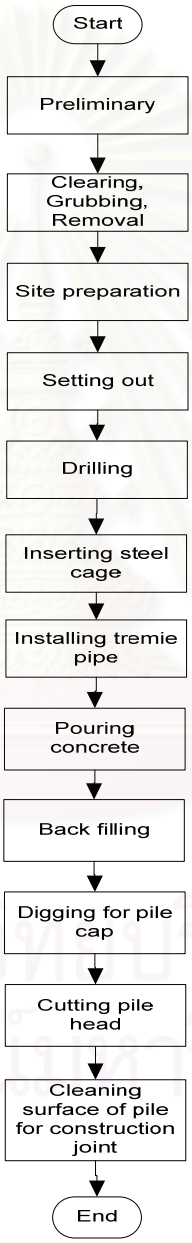

Figure 8 Work flowchart of bore pile

B.2. Pile Caps

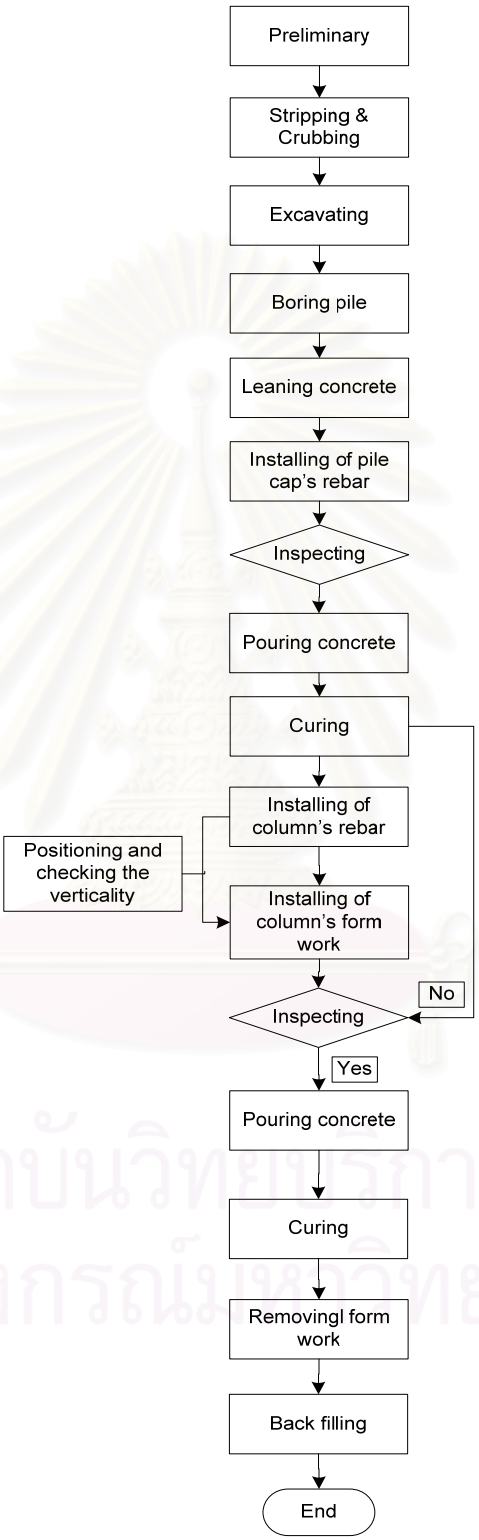

Figure 9 Work flowchart of pile cap

B.3. Pier

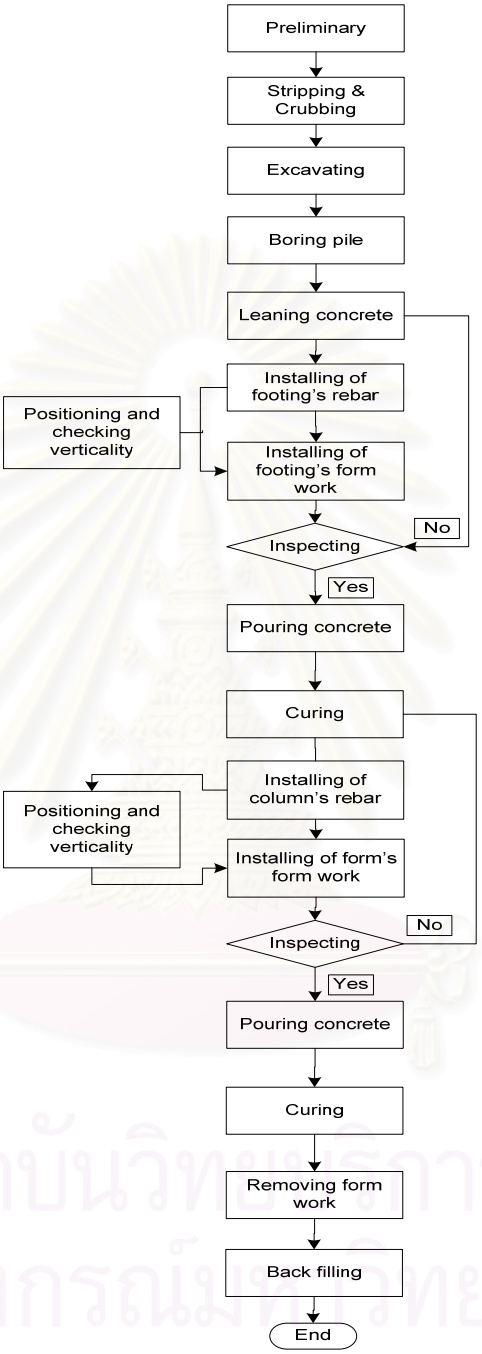

Figure 10 Work flowchart of pier

B.4. Retaining Wall

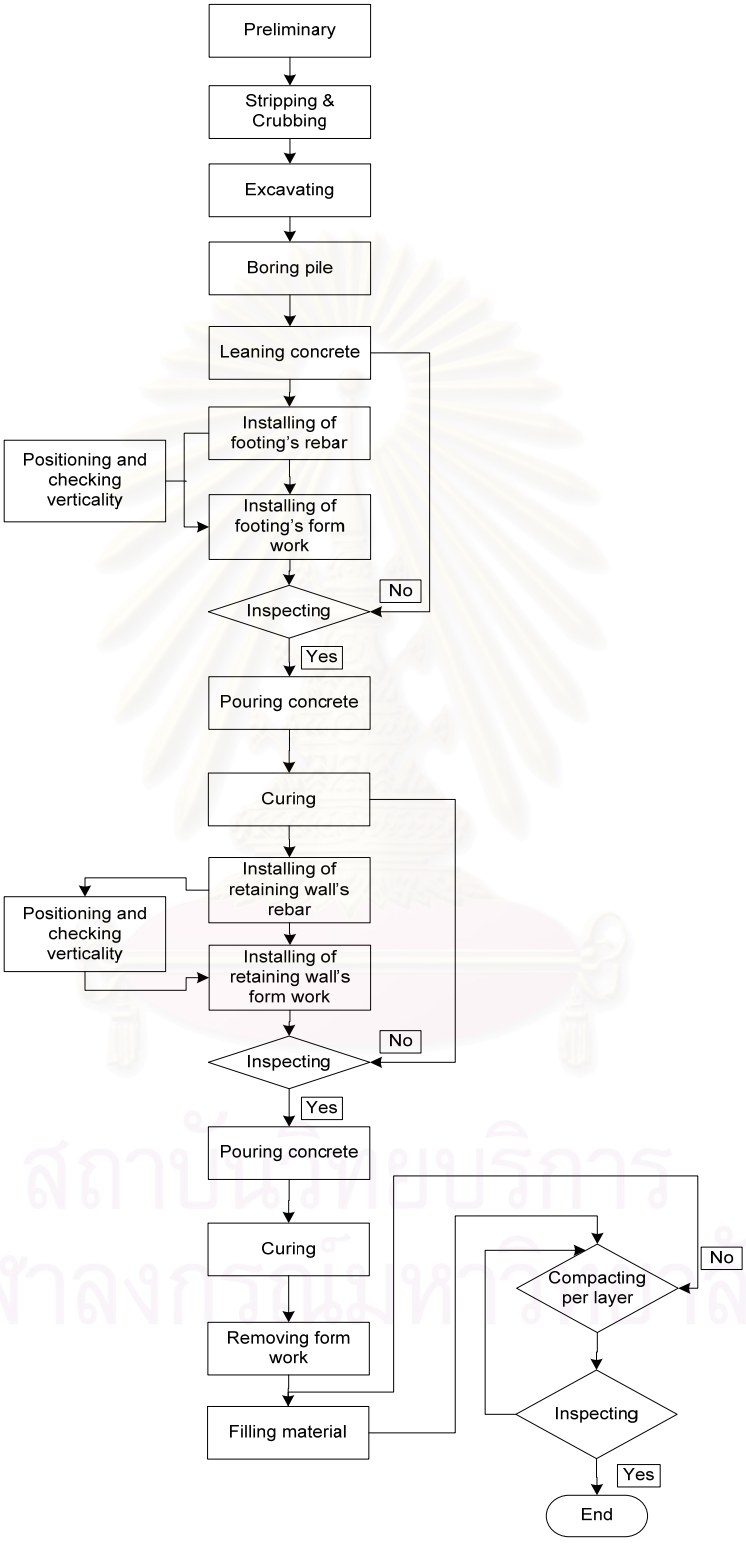

Figure 11 Work flowchart of retaining wall

B.5. Precast Concrete Segment Work

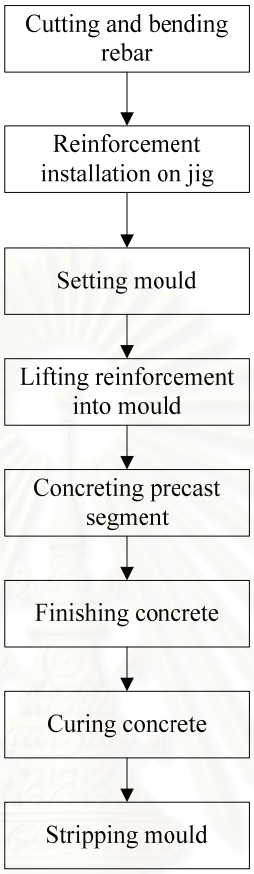

Figure 12 Work flowchart of precast concrete segment work

B.6. Installation of Cable Stay

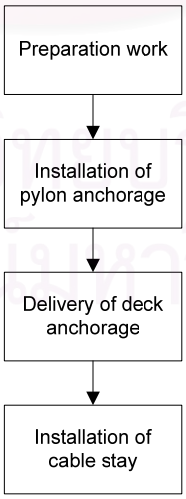

Figure 13 Work flowchart of installation of cable stay

B.7. Pylon

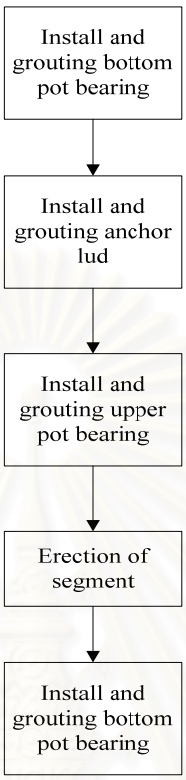

Figure 14 Work flowchart of pylon

Table 24 Construction method of bore pile

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Cast in place of concrete piling	Drilled holes	• All holes for concrete piles cast in drilled holes shall be drilled to the tips of piles • Drilled holes shall be protected from collapse by a water surcharge, by providing a steel casing. The stand casing pie shall be rigid and project at least 50 cm above ground level • The water level of the inside of the drilled hole shall be always kept approximately 2 m higher than the natural ground water level. Water supplied from a municipal water supply system or a river is allowed for this purpose	Monthly report	field engineer	meeting minutes	-
2	Bore pile execution	Stages of bore pile	• Steel casing to be installed until the elevation of stable layer of soil, length of casing to be determined • During boring, ground water shall be kept until top casing with tolerance 1m from top casing • During cleaning bucket operation, the bucket not taken up too fast avoid pressure of water inside a bore hole decreasing drastically • Sequence of boring shall be arranged in such a way that when bore hole in one location has not completely poured, the next bore hole will not be bored bellow bottom of the casing • Soil waste or mud from boring work should be placed on the bucket or temporary stock than removed out from site • Boring report and soil type monitoring. During bore execution, type of soil shall be sampling and recorded in bore log and describe it in boring report • Bore pile concreting report. Bore pile depth, depth to top of concrete, cumulative volume of concrete, timing of concreting, slump value.	Monthly report	field engineer	meeting minutes	-

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Table 24 (cont.) Construction method of bore pile

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
3	Bore pile	Setting out	• Drilling point is set up by surveyor, and then rig moved in to position. Position of rig controlled by surveyor for position and vertically of rebar. Drilling can be started only after surveyor satisfied with position and verticality.	Monthly report	field engineer	meeting minutes	-

Table 25 Equipment used in bore pile work

No.	Name of Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Equipment for piling micropile	Name	• Puncher must setting out for piling distance 1m2	daily report	field engineer	meeting minutes	-
2	Auger bit or bucket bit	Function	• Drilling spoil dumped beside the rig and disposed away.	daily report	field engineer	meeting minutes	-

Table 26 Material used in bore pile work

No.	Name of Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Material for piling work	Preparation of material	• For concrete, check material adequate and volume of concreting • Reinforcement cage, check with bore pile steel cage report	daily report	field engineer	meeting minutes	-

Table 27 Technology used in bore pile work

No.	Name of Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Piling micropile	Piling work	• Piling point with distance 1m • Piling, straight first monitored by guide pile and recorded by PDR (pile driving record) • Record total blow in every 0.5 m record quantity of piling blow • Joint of micropile must strong • Record final set. 10 latest piling blow/calendaring recorded by millimeter block • PDA test	daily report	field engineer	meeting minutes	-

Table 28 Construction method of pier

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Install formwork and reinforcement bars	The stages	• After pouring of pile cap, then install reinforcement bar for pier. Reinforcement bar used is steel bar deformed as such as specification. During install reinforcement bar, insert PVC for drainage rain water to coming out from deck. Position of hole drainage, anchorage bearing must be installed before pouring concrete. All of the position must be controlled by surveyor. Installing of formwork for pier, after reinforcement bar completely installed.	Monthly report	field engineer	meeting minutes	-
2	Pouring	The stages	• After clearing and joint inspection, pouring ready mix concrete pump. The concrete will be consolidated with approved mechanical vibrators operating within concrete. The way of pouring should be layer per layer.	Monthly report	field engineer	meeting minutes	-
3	Curing	The stages	• Immediately after formwork have been removed and finishing completed all concrete will be cured by wet sack • For top surface of pier concrete to be cured with water at minimum 7 days continuously	Monthly report	field engineer	meeting minutes	-
4	Formwork of pier (Setting panel)	Joint the front panel	• All bots are well installed (tight and firm) • Panels are installed with their pairs respectively • The joint is closed and put sealant	Monthly report	field engineer	meeting minutes	-
5	Formwork of pier (Setting panel)	Join side panels and install side recess panel as well	• All bots are well installed (tight and firm) • The gradient of side panel should be match with dimension of pier • Side recess installed rightly at position of poured side recess	Monthly report	field engineer	meeting minutes	-

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Table 28 (cont.) Construction method of pier

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
6	Pouring concrete	The stages	• Cleaning • Wetting the surface of construction joint with water • Clean and wet the concrete bucket • Prepare the pouring equipment such as vibrator • Install the half of PVC pipe diameter 5 cm at possible position as process for vibrator and concrete • Wetting the surface of construction joint with bonding agent , following dosage from manufacture • Getting the position of mobile crane, in order to get stable, so that bucket can be filled maximum and easy to lift up • Pouring concrete until determined elevation • Spray Rugosol C at construction joint surface • Spray the construction joint surface with water which connected to air compressor • Curing the construction joint surface with flooding or wet sack • Remove formwork • Curing the concrete surface using Antisol-S	Monthly report	field engineer	meeting minutes	-

Table 29 Equipment used in pier work

No.	Name of Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Drain hopper	How to install it during reinforcement of rebar	• Position of drain hopper as indicated in shop drawings • The installed drain hopper is firm and tight • The joint is closed and sealed to prevent concrete goes into pipe while pouring	daily report	field engineer	meeting minutes	-

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Table 30 Material used in pier work

No.	Name of Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Anchor	Function	• Block out is made of PVC pipe which will be removed after pouring • Diameter and length of PVC pipe as indicated in shop drawings • Position of block out bearing as indicated in shop drawings • The installed block out is firm and tight • The bottom of block out is secured and install pipe diameter 1 cm for air relief	Monthly report	field engineer	meeting minutes	-
2	Chamfer	Function	• Chamfer is made of steel plate or fiber nylon • Dimension of chamfer is 3x3x3 cm • Install chamfer tightly at the out edge of side panel • The joint between chamfer and side panel is closed	Monthly report	field engineer	meeting minutes	-
	Antisol-S	Function	• Curing the concrete surface using Antisol-S • Done after removing framework • Spray the entire concrete surface evenly with dose as recommended in brochure from fabric	Monthly report	field engineer	meeting minutes	-

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Table 31 Construction method of cable stay

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Preparation work	Installation of the anchorage in the deck	• The HDPE adjustable anchorages will be pre-assembled with their caps in the factors. Each anchorage will then be mounted in position ensuring that the assembly is aligned with centerline of the hole in the bearing plate	Monthly report	field engineer	meeting minutes	-
2	Preparation work	Installation of the anchorage in the pylon	• The pylon anchorages with the guide tubes will be pre-installed at the steel prefabrication yard. We have assumed that the yard will have handling facilities to allow us to fix the anchorage in an efficient and safe way.	Monthly report	field engineer	meeting minutes	-
3	Preparation work	Assembly of the DHPE outer protective pipe	• The HDPE pipe will be composed of 12 m length elements positioned on the deck and prepared for welding with an automatic fusion mirror-welding machine. The length of HDPE shall be welded until the required length of stay has been reached with consideration of geometry and thermal conditions.	Monthly report	field engineer	meeting minutes	-

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Table 31 (cont.) Construction method of cable stay

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
4	Installation of the cable stays	Installation of the HDPE pipe	• A known measured length of strand shall be threaded through the HDPE pipe temporarily placed on the deck, this is the reference strand • The ends of this strand shall be stripped, prepared and connected to the top end of the HDPE pipe with a special lifting clamp • An HDPE transition tube shall be positioned on each end of the HDPE pipe and a protective tube shall be positioned over the lower end of the pipe. The steel guide tube shall be installed on both deck and pylon anchorage • The assembly (pipe and reference strand) will be lifted using the tower crane if available or winched to positioned from the deck • When the HDPE pipe is in the required position, the reference strand will be threaded into the pylon and deck anchorages • The reference strand shall then be stressed to a required length using the isotension equipment.	Monthly report	field engineer	meeting minutes	-
5	Installation of the cable stays	Installation of the strand	• Adequate strand dispensers are installed on the deck, pulled through a cutting bench for strand ends preparation, and guided using a deviator wheel towards the HDPE pipe near the guide tube • The strand is fixed to a hosting shuttle, which is pulled with the main winch through the pylon anchorage. When the strand emerges at the top of pipe, the shuttle is tied and disconnect. • After the pylon anchor jaws are installed, the bottom end of strand is cut, prepared and threaded through the deck anchorage and the jaws fitted • The installed strand is then stressed from the deck anchorage using the isotension system	Monthly report	field engineer	meeting minutes	-

Table 32 Equipment used in cable stay work

No.	Name of Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Heavy Shoring	Function	• Used for temporary shoring deck of cable stayed bridge while casting concrete until stressing post-tensioning deck and installation cable stayed had finished. Because of project finishing must be accelerate, volume of heavy shoring increase from 70.000 m3 become 143.000 m3 heavy shoring. Heavy Shoring is imported from Taiwan.	daily report	field engineer	meeting minutes	-

Table 33 Material used in cables stay work

No.	Name of Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Galvanized parallel steel wire	Composition	• Galvanized parallel steel wires of D 7mm with high strength, and extruded with two layers of high density polyethylene, of which the inner layer is in black, and the outer layer in color.	daily report	field engineer	meeting minutes	-
2	Bearing		• 2 sets of earthquake-resistance steel spherical bearings are arranged under the main girders at each side pier of main bridge, of which one is moveable in two directions, and other is moveable in longitudinal direction and fixed in transverse direction. • Vertical supporting capacity of one bearing is 8000KN, and horizontal supporting capacity of the transversely fixed bearing is 6000KN	daily report	field engineer	meeting minutes	-
3	Cable guide tube		• After fabrication the tubes were hot dip galvanized	Monthly report	field engineer	meeting minutes	-

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Table 34 Technology used in cable stay work

No.	Name of Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Cable stay system	What is system used	• Cable stayd system used is Parallel Strand System that second generation of cable stayed technology. This system use seventh wire strand with diameter 15.7 mm that protected by galvanized, wax and HDPE. Each Cable stay (HDPE) consist of 19 strand (1 unit), 75 strand (10 unit), and 91 strand (8 unit) and done used stressing method	daily report	field engineer	meeting minutes	-
2	The isotension method	The principle of isotension	• The first strand is fixed to one of the anchorages, and its other end is threaded into the other anchorage, then cut and stressed to calculated force, which takes into account the foreseen deformations of the structure • The first strand is not yet wedged into the anchorage block, but anchorage in a special single strand anchoring device provided with a load cell, which gives a permanent reading of its tension • The second strand is then installed in a similar manner, cut and stressed directly in the anchorage knocks. The stressing is done, as for the first strand, with a mono strand jack equipped with a load cell identical to the one indicating the tension of the first strand. • As the second strand is stressed, the force in the first strand decreases, and the stressing operation is ceased when the reading of two cells are identical. The second strand is then anchored in the permanent anchor block. The two strands are equally stressed • The third strand is then installed and stressed until its force reaches the reading of the first strand (which decreases jointly with the force of the second strand)	Monthly report	field engineer	meeting minutes	-

Table 35 Construction method of retaining wall

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Install formwork and reinforcement bar	Method	• After pouring of pile cap, the install reinforcement bar for wall of retaining wall. Reinforcement bar used is steel bar deformed as such as specification. Install form work after reinforcement bar completely installed.	monthly report	-	-	-
2	Pouring concrete	Method	• After cleaning and joint inspection, pouring ready mix concrete by concrete pump. The concrete will be consolidated with approved mechanical vibrators operating within the concrete. The way of pouring should be layer per layer	monthly report	-	-	-
3	Curing	Method	• All concrete will be cured by wet sack or curing compound	monthly report	-	-	-

Table 36 Material used in retaining wall work

No.	Name of Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Joint Sealant	Function	• Plastic 99 from FOSROC was used as a sealant to the top surface joint between segments. It was important that the joint be cleaned thoroughly and the plastic be heated to a temperature of 200 0 C for it to bond to the concrete	daily report	field engineer	meeting minutes	-
2	Movement joint	Composition	• The expansion joints were installed using concrete K-450 with Cebex 100 as non-shrinkage additive	daily report	field engineer	meeting minutes	-

Table 37 Technology used in retaining wall work

No.	Name of Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Mattress & Install PC Mattress	How to do it	• Sand filling work (content of mud of sand < 6%, compacted by spray water, elevation sand filling) • Cut of pile work (elevation cut of pile, type 1 is less than 15 cm from top mattress elevation, type 2 is more than 5 cm from top mattress elevation • Cut of pile work • Lean concrete work • Position of PC mattress is head of micro pile jointed to cap of PC mattress and jointed between PC strand	daily report	field engineer	meeting minutes	-

Table 38 Construction method of concrete segment work

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Setting mould	Stages of setting bulk head	• Determine reference point or rotation point on bulk head • Tight and adjusted the right and left bolt • Setting the right and left trust • Tightened bolts between bulkhead and soffit table • Checked filler (rubber seal and sealant) inside bulkhead, wing form, and soffit table • Surveying dimension and elevation of bulkhead	monthly report	-	-	-
2	Setting mould	Stages of setting of soffit table with match cast	• Placed wet cast soffit table between bulk head and match cast for field segment • Removed match cast into concrete place, prepared space for wet cast soffit between bulk head and match cast • Install tie rod on pallet form • Lower geometry cart until match is support by soffit table • Sprayed the breaking bonding on to surface of match cast after mould has been set	Monthly report	field engineer	meeting minutes	-

Table 39 Equipment used in concrete segment work

No.	Name of Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Geometry cart	Function	• To support match cast • Place geometry cart under match cast, raised screw jack at the base of math cast so that the soffit table clear from the yard base slab by approximately 50 mm	daily report	field engineer	meeting minutes	-

Table 40 Material used in concrete segment work

No.	Name of Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Striking match cast segment	Effect	• In order to break the bond between the match cats and bulkhead, it is normal to release the rearward screw to allow segment to tilt back. This can cause damage to shear keys. Great care is needed with this operation. It may be necessary to try a few techniques depending upon the form mechanism.	daily report	field engineer	meeting minutes	-
2	Bonding agent	Limitation	• The surface of match cast can directly paint or spray with epoxy glue during erection, so that the material can adhesive with glue	daily report	field engineer	meeting minutes	-
3	Seal made from rubber	Function	• Install seal to prevent ingrains of adhesive of duct before erection	Monthly report	field engineer	meeting minutes	-

Table 41 Technologies used in concrete segment work

No.	Name of Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Identification and handling segment	Removed and identified segment (match cast) to be lifted	• The test of compressive strength has achieved 80% design strength	daily report	field engineer	meeting minutes	-
2	Transported segment to storage area		• The support points have space about 260-270 cm from center of segment both on lower layer and upper layer • The three positions of support are in one level	Monthly report	field engineer	meeting minutes	-

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Table 42 Construction method of pylon

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Install and grouting bottom pot bearing	Preparation installing and grouting pot bearing	• Surface of concrete shall be grouted, so that surface clean of cement water, clean from grease, mud and lose material, surface of concrete is saturated. • Elevation/level top bearing have been prepared from leveling and marking. • Pot bearing shall be installed as in drawing	monthly report	-	-	-
2	Application of grouting pot bearing	Execution of grouting	• Continue using pressure pump from one side until all of area full.	monthly report	-	-	-
3	Application of grouting pot bearing	Curing	• Closed by wet gunny least 8 hours.	monthly report	-	-	-
4	Erection of segment	Preparation of erection segment	• Access road below launching gantry must compacted and no settlement. • There should be enough room for maneuver of low bed trailer. • Traffic flow around erection location has to be arranged safely. • Position of winch for erection is in the save distance from pier column. • Low bed trailer position for erection must be in correct position. • Recheck all duct holes for permanent pre-stressing. • Recheck all inlet and outlet for top bearing grouting. • Install of steel bracket for top temporary pre-stressing and all bolts are installed well. • Set up tilting jack for alignment of viaduct and check the cross fall and gradient.	monthly report	field engineer	meeting minutes	-

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Table 42 (cont.) Construction method of pylon

No.	Construction method	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
5	Pre-stressing work	How to do it	• Moving and joint segment, still moved by gantry. • Stressing jack equipment. • PC strand and stress bar. • Stressing temporary pre-stressing top and bottom slab. • Surface of joint segment. Clean all epoxy laitance. • Install PC strand for permanent pre-stressing in correct location and number. • Permanent pre-stressing after one pair of segment is combined and then recording the stressing result including elongation.	monthly report	field engineer	meeting minutes	-

Table 43 Equipment used in pylon work

No.	Name of Equipment	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Equipment for grouting pot bearing	Type of equipment	• Pressure pump	daily report	field engineer	meeting minutes	-
2	Erection of segment	Type of equipment	• Launching gantry machine in function and safe. Function of this equipment is to lift and move the segment in proposed position	daily report	field engineer	meeting minutes	-

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Table 44 Material used in pylon work

No.	Name of Material	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Material of grouting	What kind of material use for grouting	• Mixing 1 bag (25kg) conbextra HF and 4.5 dm 3 water using hand mixer	daily report	field engineer	meeting minutes	-
2	Epoxy material	What kind of material use for epoxy	• Nitobond EC product, ready for sufficient volume	daily report	field engineer	meeting minutes	-

Table 45 Technology used in pylon work

No.	Technology	What knowledge	Description of knowledge	Sources (document)	Sources (people)	Sources (meeting)	Sources (others)
1	Pylon construction method	The stages of construction	• Manual concrete 1 segment with manual formwork • Erection tower crane • Erection climbing formwork outer and inner form with tower crane • Setting reinforcement bar • Setting formwork after reinforcements bar completely installed • Pouring second segment should be layer per layer with concrete bucket • Removal formwork • Lift up climbing form work • Inner panel must be change permanent bottom pre-cast, before pouring • The pylon anchorage with the guide tubes will be pre-installed at the steel prefabrication yard	monthly report	-	-	-

VITAE

Nofalia Andriyani was born on November 1, 1981 in Surabaya, Indonesia. She finished her elementary school to high school in Surabaya. In August 1999, she continued to study civil engineering in Gadjah Mada University, Yogyakarta, Indonesia. She spent 4 years to finish her bachelor degree and was honored cum laude from this university in November 2003. In April 2004, she got a scholarship from AUN/SEED-Net (Asian University Network / The Southeast Asia Engineering Education Development Network) JICA to continue her study to Master of Engineering Program in Civil Engineering, Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand.