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Engineering asset management - a case study on FAST project in Guizhou, China

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Abstract

Engineering asset management (EAM) is a new concept about inter-disciplinary field that combines technique issues of asset reliability, safety and performance with financial and managerial requirements. However, there are few literatures in research and application cases from industries.

This thesis takes the Five hundred meters Aperture Spherical Telescope (FAST) project as a case to explore how EAM was processed in large engineering projects. The aim of this study is to figure out the key elements of EAM in the projects like FAST and to develop an EAM model that is suitable for this kind of projects. FAST will be the biggest single radio telescope in the world, that being built in a natural Karst basin in Guizhou, China.

In this study, qualitative research and case study were adopted. The related knowledge of EAM was collected from the scientific literature, which helped access the initial theoretical framework. The details of FAST project, which includes the fundamental data and the first-hand information, are from the interviews and surveys.

By applying EAM to the project management of FAST, the shortcoming of existing EAM model has been noticed. The existing model mainly focuses on cost-saving and profit-achieving, while ignoring environment and risk management. In order to make EAM model more efficient and practical, this thesis provides a tailored EAM model that could be suitable for large engineering projects like FAST.

Key words: engineering asset management, environmental management, project management, EAM model

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Chapter 1 Introduction

This chapter starts with the background which introduces the basic information about EAM and FAST project. Secondly, purpose and research questions would be clearly manifested.

1.1 EAM

1.1.1 Background of EAM

EAM is an emerging inter-disciplinary field. It combines the technical issues of asset reliability, safety and performance with financial and managerial skills (Joe et al, 2010). It has been indicated that EAM would promise a suitable combination of skills to bear on solving the arguing issue of asset management since the last decades in 20th century. It covers a widely range from general management, operations, production arenas, financial and human capital aspects.

Asset management is a methodical, planned procedure including the entire life of physical assets. Therefore, the original supposition is that assets exist to maintain the organization's implementation strategies, and then involves a positive management approaching and proficiency from various organizational regulations (Lutchman, 2006).

In many organizations, physical assets are the basis for success and future growth. In order to achieve the overall success of projects, the efficient management method of these assets is indispensable for many organizations all over the world. Thousands of million dollars are used to manage assets. Nevertheless, with financial implication, the importance of asset management is rising and also affected by other factors. For instance, the common aging of assets; changing stakeholder and service conditions; increasing stress on public benefit; and gradually more severe obligations set by regulating bodies (Woodward, 1997). Organizations are recognizing such factors as becoming important to their functions and therefore seeming to frequently pick up their asset management performances. Conversely, amounts of literature being published by academic and practice fields.

1.1.2 Relationship between asset management and environmental management

An asset management framework is more disposed in the approach of running a life cycle, which mainly includes the infrastructure organizations (Schuman and Brent, 2005), such as utilities and transport. The approaches range consecutively from asset preparation, formation, operations, preservation, and performance measurement. These asset life cycle frameworks consists of risk, quality and environmental management (Joe et al, 2010).

In general, many organizations adopt the frameworks; asset and environmental management have been considered as proven risk management approaches by them. Asset management makes assets and infrastructure risks in order, and environmental management gives a general perspective for ordering environmental risks, which includes risks as of aging or inappropriately ran infrastructure (Schuman and Brent, 2005). Each framework creates approaches that depend on a nonstop development, to decrease risks by operational controls. Asset management and environmental management shouldn't considered as competitive relationship, the correct way is to combine them, because when use them together, it can make long-term sustainable development available (Lutchman, 2006).

1.2 FAST

1.2.1 Background of FAST

In order to accurately introduce FAST project, the following three paragraphs were adopted the original text from the official description of FAST, which composed by the chief scientist of FAST, Nan R D, and the research groups of FAST. We believe that can make readers understand the background of FAST more clearly than quote it in our own words.

"FAST is a project of five hundred meter aperture spherical telescope which was approved by National development and reform commission (NDRC) in 2007, and its foundation laying ceremony was held on the construction site in December of 2008. As planned, the construction will be finished by 2015. The conception of

FAST was firstly proposed in 1994, as a biggest single radio telescope in the world to be built in a natural basin Karst depression in Pingtang County, Qiannan Buyi-Miao Autonomous Prefecture, Guizhou, China. (Nan, 2006)"

"FAST is an Arecibo-type antenna with three outstanding aspects: the unique Karst depression as the site, active main reflector corrects spherical aberration on the ground to achieve full polarization and wide band without involving complex feed system, and the light focus cabin driven by cables and servomechanism plus a parallel robot as secondary adjustable system to carry the most precise parts of the receivers. (Nan, 2006)"

"As its name suggests, the size of FAST will be a big dish with a diameter of 500m. The area of FAST reflector dish is as large as about 30 football fields, and it will have 4,600 movable panels, the shelves of which are supported by the natural hollow of Karst. The telescope focuses through the focus cabin and simultaneously adjusting the shape of the illuminated reflector area. (Nan, 2006)"

1.2.2 Environmental conditions in FAST location

FAST is located in Jinke Village, Kedu Town, Pingtang County, Qiannan Buyi-Miao Autonomous Prefecture, Guizhou, China.

1.2.2.1 Ambient air

According to *Environmental control report in Qiannan Prefecture, November 2006* (Nan, 2006) which is provided by the Qiannan Environment Agency, the environmental condition from the three monitoring points on 27-29 November, 2006 was shown as *Figure 1*:

	TSP	**SO_2**	**NO_2**
Xinzhou	0.018mg/m^3	0.053mg/m^3	0.008mg/m^3
Entertainment Plaza	0.122mg/m^3	0.163mg/m^3	0.008mg/m^3
Longdong	0.045mg/m^3	0.047mg/m^3	0.008mg/m^3

Figure 1: The air conditions in Qiannan Prefecture

Source: Nan, 2006.

To compare with the second standard limit of GB3095-1996[1], the expected SO_2 emissions in Entertainment Plaza was better, so the results of all monitor points complied with China National Standard.

1.2.2.2 Water environment

The *Environmental control report in Qiannan Prefectur, November 2006* (Nan, 2006) also presented the result of water environment. On 27-29 November, 2006 the Environment Agency monitored the water temperature, PH, ammonia nitrogen, fluoride, five biochemical oxygen demand, potassium permanganate, dissolved oxygen, cyanide and etc. The monitor points include Longdong, Suoshapo, and Shizikou. The report indicates that the results complied with the second standard limit of GB3095-1996[1].

1.2.2.3 Acoustic environment

The main body of project covers the rural residential areas. The regional sound environment quality complies with the second standard limit of GB3096-1993[2].

1.2.2.4 Ecological environment

The project covers the rural ecological system with good vegetation and good ecological and environmental quality.

1.3 Purpose and Research questions

We want to explore how EAM could be processed in large engineering projects. The purpose is to figure out the key elements of EAM in large engineering projects and to tailor an EAM model that is suitable for this kind of projects.

Research questions:

-What are the key elements of EAM in large engineering projects?

-What could be the tailored EAM model that can be applied to large engineering projects?

[1] China National Standard, GB3095-1996: *Ambient air quality standard*.
[2] China National Standard, GB3096-1993: *Urban area environmental noise standard*.

Chapter 2 Methodology

This chapter presents how we carried on this study and how the data was collected. Finally, the validity and reliability of this research are also shown.

2.1 Research approach

To do this research, we have chosen one project as a case, which is FSAT, both large and complex. In this study, the qualitative and quantitative approaches have been used (Thomsona et al, 2011). The related knowledge of EAM was collected from books and journals in databases, which helped access the initial theoretical framework. When we searched for the articles, databases "ScienceDirect" and "Emerald" were preferred; and these are the main key words for searching: "engineering asset management", "environmental management", "project management", "risk management" etc. The details of FAST project, which include the fundamental data and the first-hand information, are from interviews and surveys. Before the interviews, a series of comprehensive questions were sent to the interviewees, who are the specialized managers in the project department. The content of interviews is recorded and organized as thesis documents, which will be verified after the interviews. The main content of this thesis is formed through the repeated discussions with the project managers and their feedback. The content of surveys is based on the modified theoretical model, and the collection of data will be analyzed by the model (Scapens, 2011). The results of the data analysis will be considered as template to evaluate the case. Meanwhile, some relevant documents are also used as an analytical basis for collecting. The questionnaire is designed to indicate the understanding level about EAM, FAST and asset standards. The questionnaire is answered by 15 staffs from different departments and different levels. It could represent the common situation in FAST.

2.2 Assess the stewardship performance

Assessment of stewardship performance is mainly based on the model of strategic infrastructure asset process (Too, 2010). This model assesses the organization by the aspects of capacity, option evaluation, procurement, maintenance, information and human. Based on this, follow the time-cost-quality theory of industrial project management (Munns and Bjeirmi, 1996), the model will be used to assess the plan and operation of the project. Meanwhile, it is combined with the soft model of change management (Voropajev, 1998), to compare the evaluation.

2.3 Classify the parts of management

Classify the precise data which provided by management department of the organization. Completely describe the internal situation of each subsystems and the mutual operation model. To learn the operation of these relevant departments will contribute to update the theoretical framework, which provides a new perspective for examining the operation of whole organization.

2.4 Design questionnaire

In order to effectively find out the use of EAM in real project, it is necessary to collect data with the ability to identify problems. The purpose of this stage is to explore and research, then constitute the structural questions with open mind. After data collection, the theoretical framework model of Too will be further applied, to generate a new view for managers. They will understand the relationship between each issue more deeply, and learn the relationship between case and theory.

2.5 Case study

The mainly research method is case study. In order to identify the common characteristics of projects through the learning of complex mechanisms (Scapens, 2011), especially infrastructure construction project, EAM has been considered as a development model in this kind of situation.

2.6 Validity

The questionnaire is established in order to know how much the staffs of FAST know about FAST, EAM and the related asset standards. The questionnaire is allocated to fifteen participants who are from the different levels and different departments in FAST. They are responsible for the different missions in FAST, and they get the same questionnaire to answer the questions. They could represent the general population and have an in-depth discussion. So it can be said with certainty that it is valid.

2.7 Reliability

The details of the interview are recorded by tape recorder. The interview events which included general description, question and answer, questionnaire, and visiting FAST project center lasted four days. Based on the interviews, there is a clear understanding about FAST science missions and specific requirements. The main content of this thesis is formed through the repeated discussions with the project managers and their feedback. Therefore, it could be said that this thesis is reliable.

Chapter 3 Theoretical framework

This chapter presents key concepts and related theories surrounding EAM and EAM model. For a better discussion in the following chapters, the concepts of environmental management, project management and risk management are also referred; and the key elements of existing EAM model were summarized in the end of this chapter.

3.1 EAM

3.1.1 Basic issues of EAM

EAM is a discipline of internal management that combines of operation and strategy (Too, 2010). As multi-disciplinary the EAM is, the scope of EAM focuses on something which doesn't include in finance asset, such as the aspects of inventory, equipment, land and buildings (Joe et al, 2010). In some articles, the characters of EAM could be summarized as a subject with all types of physical asset, information collection, human resources; for the different kind of objects, different measurement dimensions are needed like financial dimension and the capability dimension, the perspective goes from short to long term. The risk estimate needs to be consideration by statistic way. EAM is an organizational activity which is through the whole community includes all the staff.

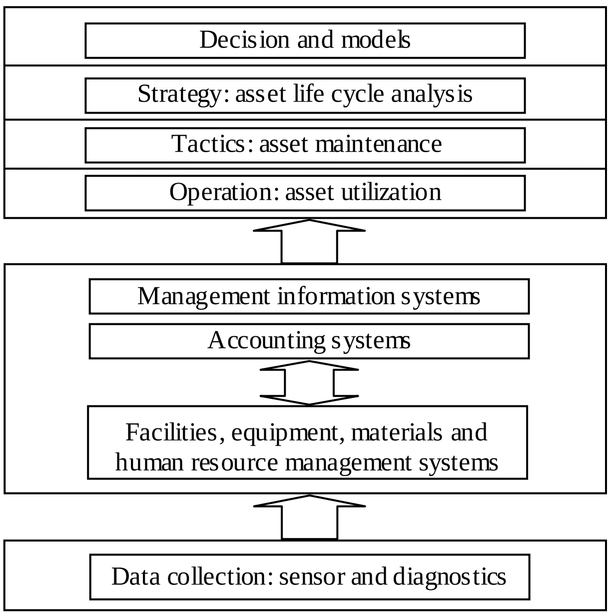

Figure 2: Issues related to the synergistic integration in EAM organization

Own construction adopted the EAM factors from Amadi-Echendu et al, 2007.

The characters mentioned above require EAM to involve skills like traditional engineering area. Decision making has to satisfy all levels in the organization from operational to strategic aspect. Human resource management will be the central part for EAM in terms of training and managing processes. Shown as *Figure 2*, synergistic integration in the organization includes physical asset, information collection and human factors (Amadi-Echendu et al, 2007).

3.1.2 Historical viewpoints of EAM

Figure 3 shows the development process of EAM in past decades. In general, EAM is a kind of management technique which has been developed since 1970s; its special value was fully recognized until 1990s. EAM is a method to manage complex activities, as a relatively new management method, it gained rapid development and continuous improvement (Hodkiewicz and Pascual, 2006).

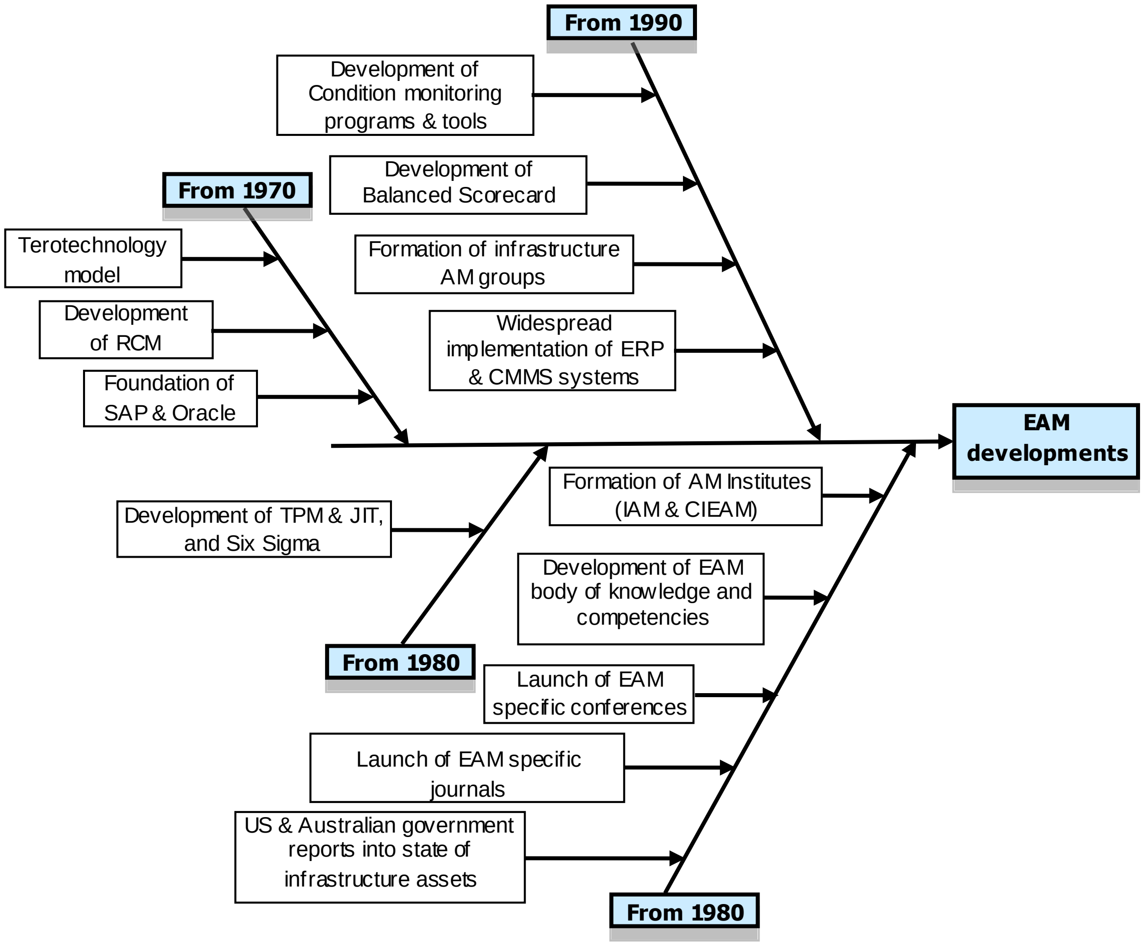

Figure 3: EAM developments

Source: Hodkiewicz and Pascual, 2006.

How to organize the management of large projects has become a big challenge around the world, some developed countries are investing heavily abroad to study and solve large engineering project problem by using EAM. Recently, some organizations of EAM have been founded like Institute of Asset Management in the UK, the Asset Management Council, and Centre for Integrated Engineering Asset Management in Australia. Generally, World Congress on Engineering Asset Management (WCEAM) is the most professional one of them, which has been held annually since 2006 commencing with the inaugural event on the Gold Coast in Queensland, Australia (Hodkiewicz and Pascual, 2006).

EAM with a broader vision built on ideas originating with terotechnology and supplemented by the practices embodied in Total Productive Maintenance (TPM) which was from the USA and developed in Japanese in 1970s. TPM is a maintenance process for improving production by making processes more reliable and less wasteful. After the Second World War, Japanese firstly imported the maintenance into the automobile electronic components manufacture in order to eliminate waste and pursue high effectiveness (Olofsson, 2010). To get the flexible manufacturing systems running effectively, total productive maintenance focuses on minimize equipment failure, reduce time for make-ready and equipment adjustment, eliminate equipment idling and minor stoppages, reduce running speeds, decrease defects in process and reduce equipment yield. The aim of TPM is zero product defects, zero equipment unplanned failures and zero accidents. According to these principles, eight pillars consist of the TPM (Pekka, 2000).

- Focused improvement. It is mainly about eliminate losses from downtime, speed and defect through small activities
- Planned maintenance. It focuses on reduce failure by predictive maintenance and corrective.
- Initial control. Based on a system to ensure manufacture and production system in order to make sure the operation.
- Education and training. Through educating and training leaders, operators and maintenance people skills and technique, format a knowledge team

- Autonomous maintenance. It means maintain through the cleaning activities in order to increase responsibility.
- Quality maintenance. For decrease defective products, machine conditions will be established to reach the zero defect
- Office TPM. Specialized departments established to support the efficiency manufacture and reduce losses.
- Safety, hygiene and environment. Set up a safe and healthy work place to ensure the production and prevent accident.

As a branch of TPM, the main purpose of EAM is to implement the lean manufacture by the evaluation of engineering assets in three aspects, which include life cycle, maintenance, and overall assessments (Pekka, 2000). EAM not only contributes to lean manufacture, but also considered as a sustainable discipline, but also achieve sustainable development. On the other hand, for most projects of infrastructure construction, the cost control and overall maintenance must be considered through a long-term perspective, unlike the purpose of commercial organizations. EAM comply with the principle of TPM which is a part of flexible manufacturing system. However, EAM is not just production and manufacturing but also utility, defense and local and national infrastructure asset.

From 1980s, development of TPM & JIT, and Six Sigma were taken in account. However, EAM was becoming widely adopted to use from 1990s. Development of Condition monitoring programs & tools, Development of Balanced Scorecard, Formation of infrastructure asset management groups and widespread implementation of Enterprise Resource Planning (ERP) & Computerized Maintenance Management System (CMMS) system were the main changes in EAM developing line. Since 2000, the increasing number of relevant articles, conferences and reports about EAM have been appearing like Formation of AM Institutes, Launch of EAM specific conferences, Launch of EAM specific journals and US & Australian government reports into state of infrastructure assets (Hodkiewicz and Pascual, 2006).

Some viewpoints in the literature about EAM could be summarized as the information and communication technology required in the management of data relating to asset and the way of EAM system to integrate and manages to inform decision-making about those assets. The physical assets are classified as non-current (includes tangible and intangible asset) and current asst (including inventory as stationery, consumables, materials & spare parts and stock) (Amadi-Echendu et al, 2007). To the tangible, there are movable assets like equipment, machinery, furniture, computer hardware and vehicles and immovable assets like property, land, buildings, infrastructure, heritage and mineral resources. To the intangible, there are some items like software, trademarks, licenses & patents and capitalized development costs. To the EAM, information system is the basic requirement to make an appropriate decision. In this way, the data could be provided to the managers who face to the change situation. On the other hand, it is necessary to reach the organization goals. Amadi-Echendu has discussed the relevant issues to EAM; the main view is taking the "value chain" into EAM theoretical (Amadi-Echendu, 2006). In order to achieve this requirement, the manager has to have a integrate perspective and approach plan to analyze the problems. Like the traditional asset management, accounting system is a part of this mix management. EAM as well needs accounting system to support their decision making. The significant advantage of this system is its coverage generality. To another addition problem, human factors are seen as a part of EAM issues as Townsend (1998) and Mitchell (2006) mentioned. It has been one of the big pictures of EAM life cycle as well as risk management and environment.

3.1.3 Related EAM models

EAM as a sub-branch of terotechnology and supplemented in TPM is suitable for the basic process model—the PDCA (Plan-Do-Check-Act) (Slack et al, 2006).

Plan: This phase is to all kinds of preparation about the evaluation and the maintenance planning, human resource planning and information management planning. There is a systematic view about the whole organization

Do: Put the planning into executing; monitor and control about the asset usage.

Check: According to the condition, analysis of the practicality of the planning; focuses on the appeared problem and possible risk and establish a new renewal plan.

Act: Execute the asset management.

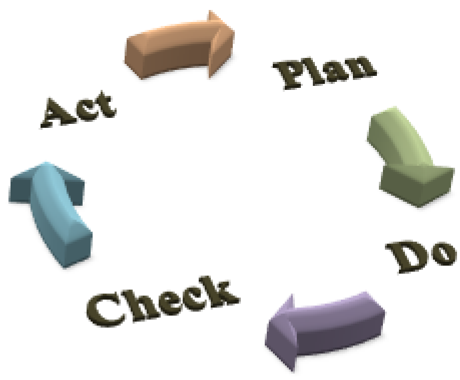

Figure 4: The PDCA model

Own construction adopted from the process model.

However, both the TPM and EAM is aim for reducing waste and improving effectiveness. EAM focuses on convert the asset value to business incomes through asset management. The essence of EAM is about decision making integration and better impact to the performance of asset by the consideration of the entire lifecycle incorporating, acquisition, maintenance, operation and refurbishment. The emerging strategic model of EAM consists of three phases which are asset planning, asset maintenance & operation and asset creation (Too, 2010). Asset planning pertains to establish the whole view about the missions, goals and needs. This step obtains two processes which are capacity process management and options evaluations process. The second phase called asset maintenance & operation like procure and delivery process will be connected with project management which associates with risk of time, cost and quality. The last asset operation & maintenance phase exists as the longest one in asset's lifecycle. Maintenance management and asset information management are included in this phase with the aim of improving its operational efficiency and effectiveness. The maintenance monitoring condition will be discussed in this part to reach the desired levels of service, conditions and performance of the asset. In the process of asset management, human resource management will affect the EAM result. Most parts of the process need to be controlled by human activities (Joe et al, 2010). The existing EAM model could be summarized as *Figure 5*. In the following part, the details of these processes will be further discussed.

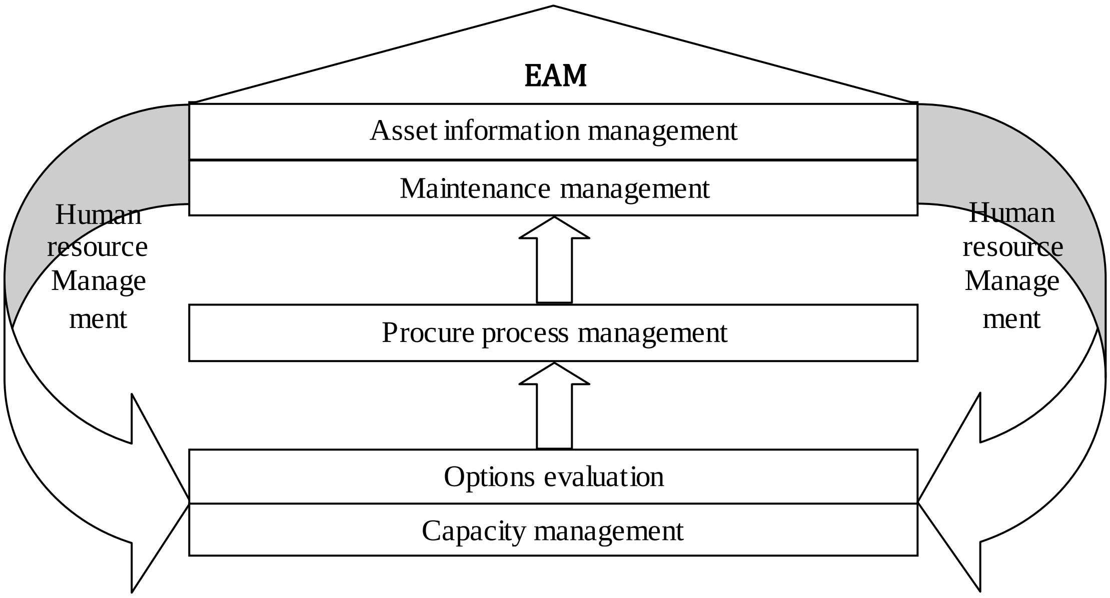

Figure 5: The existing EAM model

Own construction adopted the process of EAM from Joe et al, 2010.

3.1.3.1 Capacity process management

Capacity management is the process ensuring that adjustment of the capacity of a resource could meet the planned demand and reach cost-efficient outcomes. The function of capacity includes establishing, measuring, monitoring and adjusting all the manufacturing schedules. As this basic, the requirements of capacity management could be described as following points (Hsiao et al, 2011).

- Understanding the business missions. The full consideration about the business requirements will help the community summarize their job list correctly. According to the forward-looking process, the staff will avoid the surprise like running out of disk storage. Well preparation is important.
- Monitoring capacity based on service obligation. Take the business missions as foundation, capacity management will has the ability to service that missions and take the corrective actions to ensure the business running correctly. In order to better monitor capacity, talking to the rest of the business in necessary. The key point of the capacity management is not only well prepared to avoid surprise, but also keep away from waste. It is not meaningful that more capacity is the answer.

- Managing utilization. With the fully cognition about the asset, capacity management programs could take activities to ensuring the properly utilization.

In general, capacity management is a process used to manage information technology which complies with the process line like monitor demand, analyze, monitor performance and forecast. Whilst, three sub-processes consist with the capacity management are business capacity management, service capacity management and component capacity management (Irene et al, 1999).

- Business capacity management is aim for preparing the understanding about the future business requirements in order to analysis the current resource utilization.
- Service capacity management is responsible for controlling and predicting the performance of asset activities. It happened through the entire platform, all technology and cooperates with each level in the organization.
- Component capacity management focuses on the individual components of the community in order to support a particular service, monitor and measure the performance of IT service.

In data analysis, the first thing is to establish the normal standards. These standards are not only used to evaluate current asset performance, but also for predicting future resource usage. Some key metrics in capacity management include resource usage statistic, relative resource consumption and workload trends and forecasts etc.

3.1.3.2 Options evaluation process

In general, the integration evaluation processes include financial evaluation, technical evaluation, environment evaluation, safety evaluation and service quality evaluation (Too, 2010). Based on many capacity identified, the targets are established to evaluate in order to select the best options to the asset usage. The aim of options evaluation is maximizing asset life and benefit, whilst minimizing the life cycle cost through the multi-criteria approach. These approaches of investment, technology and technical development are satisfied both bottom line and the community, the environment and the economy.

For most business organization, financial return is the key need to be concerned. However, there are so many infrastructure constructions focusing on research and service to public with less pressure on benefit, the point of evaluation targets convert from the financial to the environment evaluation and safety evaluation. The management of risk will affect the economic service delivery, reduce uncertainty and cost during their useful life. Through the risk management, a more effective contingency planning is provided.

In the evaluation of environmental safety, asset location, asset value, asset condition and performance and asset approximate should be owned. The asset evaluation process could be summarized as *Figure 6* (Schuman and Brent, 2005).

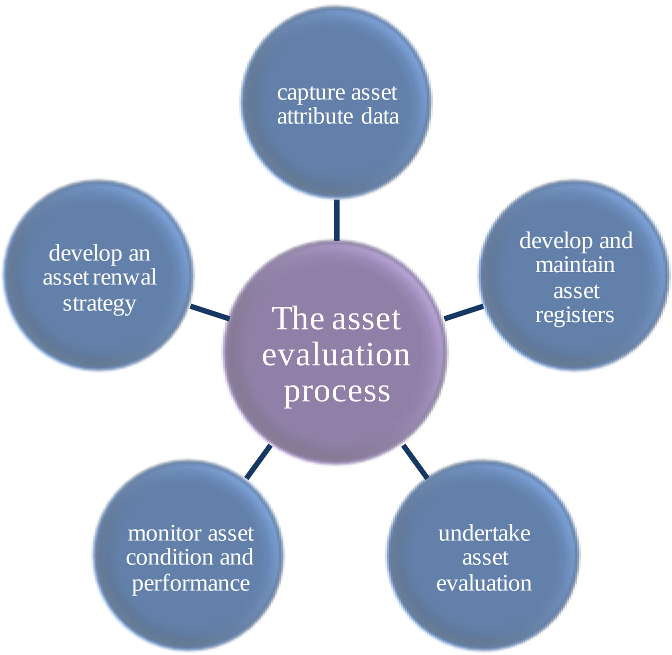

Figure 6: Asset evaluation process

Own construction adopted the asset evaluation process from Schuman and Brent, 2005.

- Capture asset attribute data

  In this phase, asset attribute data includes drawing and contracting documents, operation and maintenance manuals, inspection and measurement of asset should be determined. The schematic layouts could be developed based on these objectives in order to establish an appropriate hierarchical system.

- Develop and maintain asset registers

  After the data collecting and analyzing, asset detail information and related drawing which includes asset description, location, condition, residual life and value, will help handle the integration EAM.

- Undertake asset evaluation

  The principle in this phase complies with the preliminary-valuation-presentation-refinement. During the preliminary, communication lines and asset valuation policy should be established. Resources are allocated for determining the asset value. The evaluation result should be presented and refined in a certain period.

- Monitor asset condition and performance

  A method of evaluation which based on such issues is shown as *Figure 7*.

Asset	Typical asset condition

Sample decision matrix for prioritizing inspection

Preliminary condition rating	Asset importance level		
	Issue A	Issue B	Issue C
5			
4			
……			
1			

Figure 7: Qualitative condition rating

Source: Mba and Roe, 2009.

- Develop an asset renewal strategy

  The macro and micro strategy should be established and estimated in this process.

3.1.3.3 Procure process

Procurement in asset management aims for maximizing efficiency and effectiveness of organization resource, meeting customer expectations, whilst minimizing adverse customer impacts and adhering to project scope through considering outsourcing to achieve optimal solutions in terms of cost, time and quality (Duncan, 1996).

Asset procurement includes the design, construction and asset handover phase of the asset life cycle was adapted to most of government owned model from the only in-house resource and capabilities to outsourcing with considering both price and quality and delivery. In order to avoid lacking of trust, infrastructure organization has to select partner to help them reduce time to completion and improve cost effectiveness. The requirement is that the specialized expertise can ensure use in-house resource more effectively (Duncan, 1996).

In the procurement phase, some key issues should be prepared: The first is to develop and refine policies in order to minimize life cycle costs and clarify the requirements of external contractors and ensure a consistent approach to infrastructure development. These issues could be example as purchasing policy, policy on infrastructure delivery, design approval processes, design criteria and sizing of components, standard drawing, construction specifications and asset commissioning and handover procedures. The second is to determine the infrastructure delivery method. The options could be chosen based on the characters of assets. Some other issues are summarized as audit inspections during the construction phase, especially to the specified construction standards; integrate the whole project including scope, time, cost, quality, human resource, communication and risk; evaluate the procurement, like operation and maintenance manuals, asset register information, training of operation staff for specialist equipment (Duncan, 1996).

In general, procurement process for the large and complex infrastructure project, outsourcing from external provider gain the benefits including lower cost, improved service, and opportunities to leverage the expertise of private companies, overcoming in-house staff constraints and risk-spreading.

3.1.3.4 Maintenance planning

Maintenance planning is separately recognized as a fundamental requirement and a business objective for infrastructure organizations and asset managers. Maintenance management focus on investing the minimum levels of maintenance dollars to deliver the services desired by the organization, while meeting strategy obligations for the organization's risk management and pubic liability (Stephen, 2000).

A number of organizations adopt maintenance management to be an important business drive to all levels of the industry because of the increasing demand pressure on infrastructure asset. Maintenance management process can have a devastating effect on business operation. Jarrell & Brown 1999 supported this viewpoint and pointed out that maintenance planning could be used in the fields of efficiency, reliability and safety of the maintenance process. Maintenance planning requires fully monitoring data of the infrastructure assets and rigorous review. According to analysis of the data, ensure the maintenance activities successful.

In maintenance planning, the property could be organized and maintained in a systematic way; asset could be monitored to assist their efficient use; the standard and presentation of the property can be maintained; subjective decision making and emergency corrective maintenance are minimized. That maintenance could be classified into three groups which are corrective maintenance, planned maintenance and emergency corrective maintenance (Stephen, 2000). In order to decide an appropriate maintenance policy, a plenty number of information should be gathered includes details of plans, location of all elements and construction, maintenance requirements, local council requirements and so on.

Generally, according to Stephen G D, the main maintenance planning has two steps. Firstly, maintenance activities are planned on the basis of some rules and standards. “This is a process that can be used to first set up and then adjust maintenance procedures and activities based on projected and observed fielded system performance”, says Stephen. Secondly, maintenance is affect by the risk of asset failure including abrasion, fatigue, longer response times and degradation caused by exposure or storage. “The ability to sustain that initial maintenance planning and refine maintenance plans as required, throughout the life of a system, depends on an adequate resource commitment to gather and analyze data cost-effectively and intelligently through the life of the system. (Stephen, 2000)”

3.1.3.5 Asset information management

Like the requirements of maintenance management and the increasing pressure on operating results emerging from globalization, costly resource, tighter regulations and changing demographics force companies to continuously innovate and achieve excellence in all lifecycle phase of mission critical, information management is essential to all levels of the organization. In addition, information on current asset are needed by a wide range of aspects includes physical (e.g. location and condition) financial (e.g. service potential, risk and liabilities) and performance (both service performance and asset performance) (Too, 2010). With this information, the organization could provide the basis for projecting future lifetime availability and make predictions on how the asset is performing whether anything need to be changed. According to the information, condition could be monitored about asset breakdown and expected usage and decide the capacity whether need to be done something else or refurbish it.

Because the maintenance management is from the traditional time-based-maintenance to condition-based-maintenance approach, the condition monitoring has to utilize more modern technologies (Too, 2010). The technologies used should depend on the type of infrastructure assets and there are a lot of diagnostic tools currently available to assist asset manager in determining the maintenance regime required to deliver the appropriate levels of service at an accepted level of risk. Some significant technical asset information includes process and instrumentation diagrams, specification sheets, standard operating procedures, calculation sheets and other asset related documentation that contributes to the operating result.

In the asset information management, solutions are based on four main objectives within the asset lifecycle which are described as following: Firstly, comply with legal and safety regulations. Then, avoid unplanned productions. Thirdly, multiple projects for plant optimization need to be managed as day to day maintenance; it relies on as-built information. For some highly skilled outsourced engineering work, the data exchange should avoid the chance for error and out-of-data record left (Middleton, 2007).

In general, information management includes not only entire plants and production line, but asset structures and data on different objects that are performing in the plant. Especially the complex project consists with some independent lifecycle assets. The information management should manage all of their independent maintenance history and other documentation. In this way, through the information management, maximum the return on investment and use asset strategically.

3.1.3.6 Human resource process

EAM focus on provide benefit to satisfy the continuum of constraints imposed changing business strategy, economy, ergonomic, operational and technical integrity and regulatory compliance. However, the greatest challenges for EAM are changed. In many studies, failure of implementation is most often caused by lack of human training and indoctrinating of staffs about relevant knowledge (Mills and Waterhouse, 2008).

As the multiple decision-making like EAM, manager own four main types of thinking, analyzer, energizer synthesizer and humanizer. However, with the EAM stepped into a more information age, managers changed their mind into synthesizing and humanizing thinking styles (Mills and Waterhouse, 2008). The most important is how to adapt and align traditional behavioral preferences towards the new mental processing modes and attitudes demanded by the era of innovation, knowledge and learning economy. Therefore, it is a big challenge to develop a consistent knowledge base, with organization refocusing on the asset, plus commitment to re-aligning education and training towards effective human resource development.

3.2 Environmental management

Environmental management is a kind of management of interaction by the modern societies and in return to impact upon the environment. The main issues involve politics, programs and resources. Like other kind of management, there are effective management tools, standards and systems used by environmental management. The ISO14001 standard is the most widely used standard for environmental risk management. By environmental assessment and evaluation, organization will clear the interaction between environment and project asset (AEPA, 2009).

In the environmental management system, five dimensions consist of the whole system (Carin et al, 2003).

- Policy. Environmental policies are the foundation of the EMS which is issued by the relevant government department and local regulations.
- Planning. The EMS identifies the research, physical plant, maintenance, and office operations that have an impact on the environment. The identified environmental aspects could be classified as *Figure 8*.

1, Activity/ process	2, Environmental aspect	3, Environmental impact	4, Environmental effect

Figure 8: Categories of environmental aspects

- Implementation and operation. This plan will achieve reduction in environment impacts. It will provide targets and recommend.

- Checking and corrective action. Environmental audits are major component of EMS since they determine how environmental concerns and non-conformances are handled, investigated, corrective, preventative actions are implemented and completed. Records included non-conformance and corrective actions, environmental incidents with follow-up, inspection and maintenance records and environmental monitoring data are required to demonstrate compliance with any EMS.
- Management review. This document must be periodically reviewed to ensure the effectiveness of the EMS.

3.3 Project management

In the project management, there are four most important methods (scope, time, cost and quality), close relationship with the project environment (context, stakeholders, project clients), and ability to deal with changes for the project team (risk and uncertainties) (Munns and Bjeirmi, 1996).

The traditional development phases of an engineering project shows as *Figure 9*.

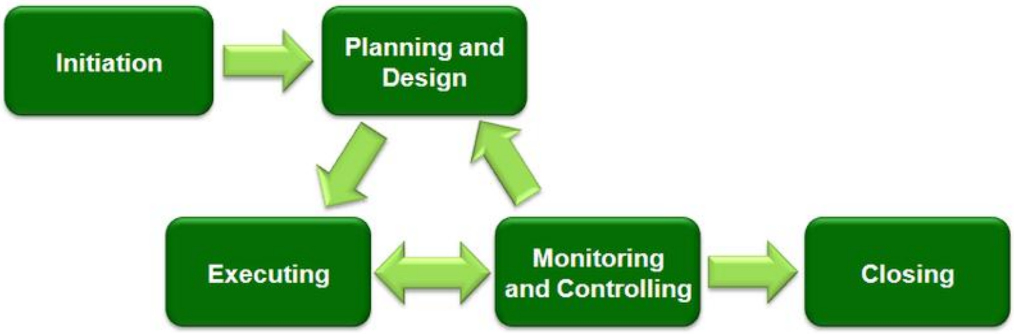

Figure 9: The traditional project management process

Source: Own construction adopted the project management process from Munns and Bjeirmi, 1996.

- Initiation. In this stage, the key project controls need an understanding of organization needs, the current operations, financial analysis of the costs and benefits.
- Planning and design. In this stage, the main purpose is to balance the relationship of time, cost and resource adequately. The main process consists

of selecting the planning team, estimating the resource requirements for the activities, risk planning, developing the schedule and so on

- Executing. Execution process involves coordinating people and resource in order to follow the project planning.
- Monitoring and controlling. In this stage, identified the potential problems in a timely manner and corrective action can be taken. It includes measuring the ongoing project activities, monitoring the project variables against the project management plan and the project performance baseline and identifies corrective actions to address issues and risks properly.
- Closing. Project closing means all activities and processes have finished and the administrative activities include the archiving of the files and documenting lessons learned.

3.4 Risk management

Risk management aim for coordinating and minimizing the resource through monitor and control the probability impact of unfortunate events. The main ways are risk identification, assessment and prioritization. Risk management is used vary widely includes project management, security, engineering, industrial processes, financial portfolios, actuarial assessments and so on (Neville, 2005).

According to Neville (2005), the main processes of risk management could be summarized as following points:

- Identity the threats, especially to the critical assets

In this phase, the manager should identify and name the risks by using a combination of brainstorming and reviewing of standard risk list. There are different sorts of risks need to be decided on the basis of project.

- Determine the risk and the possible consequence

Risk need to be quantified in two dimensions. The first is the impact and the second is the probability of the risk occurring. Each one could be rated on 1 to 4 scales by using the matrix, shown as *Figure 10*.

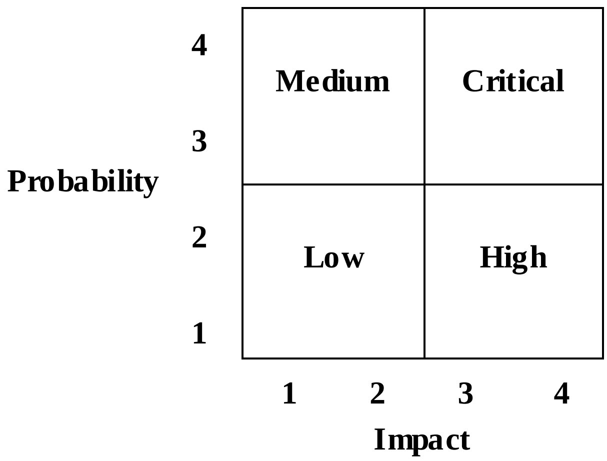

Figure 10: The matrix for identifying the risk quantification

Source: Neville, 2005.

- Find out the ways to resolve the risk

For different types of risks, the response is different. However, the main strategy could be described as: avoid the risk, transfer the risk, mitigate the risk and accept the risk.

- Risk monitoring and control

The purpose is to identify the change in the status. It is best to hold regular risk reviews to identify actions outstanding, risk probability and impact and identify new risks. Risk management is a continuous task, it is better for an organization to establish a folder management to record all the relevant documents and training their staffs to establish their sense of risk.

3.5 Summary

This chapter has shown the key elements of existing EAM model, which are:

- Capacity management
- Options evaluation
- Procure process
- Maintenance management
- Asset information management

Until when we write this thesis, we have not found any article or research about how to tailor the EAM model for large engineering projects.

Chapter 4 Result

In order to present the details of FAST, especially in environmental management, most of the information which we obtained from the interviews and questionnaires was organized in this chapter.

4.1 General description

The research result has been obtained after the data collection. As most business organization, FAST project organized as three parts: engineering, technology and science (Nan, 2006). The initiator of project choose this kind of organization, just because FAST is a high-tech project, unlike general business project or common infrastructure construction with plentiful experience. Project construction, aiming at scientific research such as radio telescope, has little experience before and the security and reliability lack index to compare with. To some extent, FAST is a pioneer, not only because of it adopts some new materials, but also due to it focuses on the effect on environment. The philosophy of environment protection will enormously affect the accuracy and stability of each fluctuation in FAST.

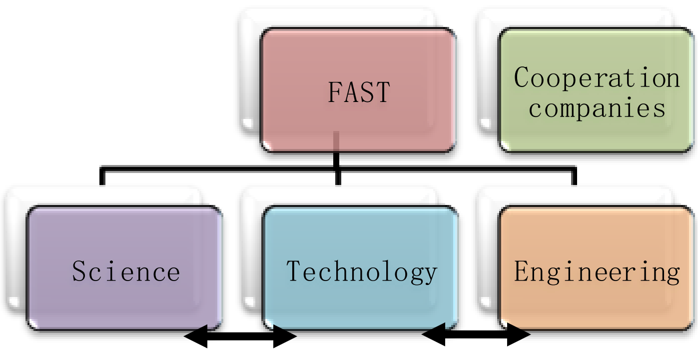

Figure 11: The organization structure of FAST

Source: Nan, 2006

In FAST, all activities are based on engineering plan which proposed by science department. Experts from science department offer construction requirement according to scientific target set by FAST. They spread scientific knowledge to people in every department containing engineering and technology, in order to enable staffs to know what significant effect will be caused to the final science research by construction quality. According to the request of science department, technology department works on the experiment and breakthrough of technology, assess its reliability and security, repeatedly tests integral operation and ensures technical security and construction quality. Engineering department is responsible for location choosing, environment estimating, and relative problem solving (Gan et al, 2005). In primary simulation model, the engineering department could be interacting with technology department. Under the circumstance, especially in order to complete the high-quality project before deadline and fulfill the property optimization, coordination among the three departments is very important.

4.1.1 Science

As a large engineering project, FAST has been through a long scientific investigation and assessment, exhaustive requirements were put forward at the preparation period (Nan, 2000).

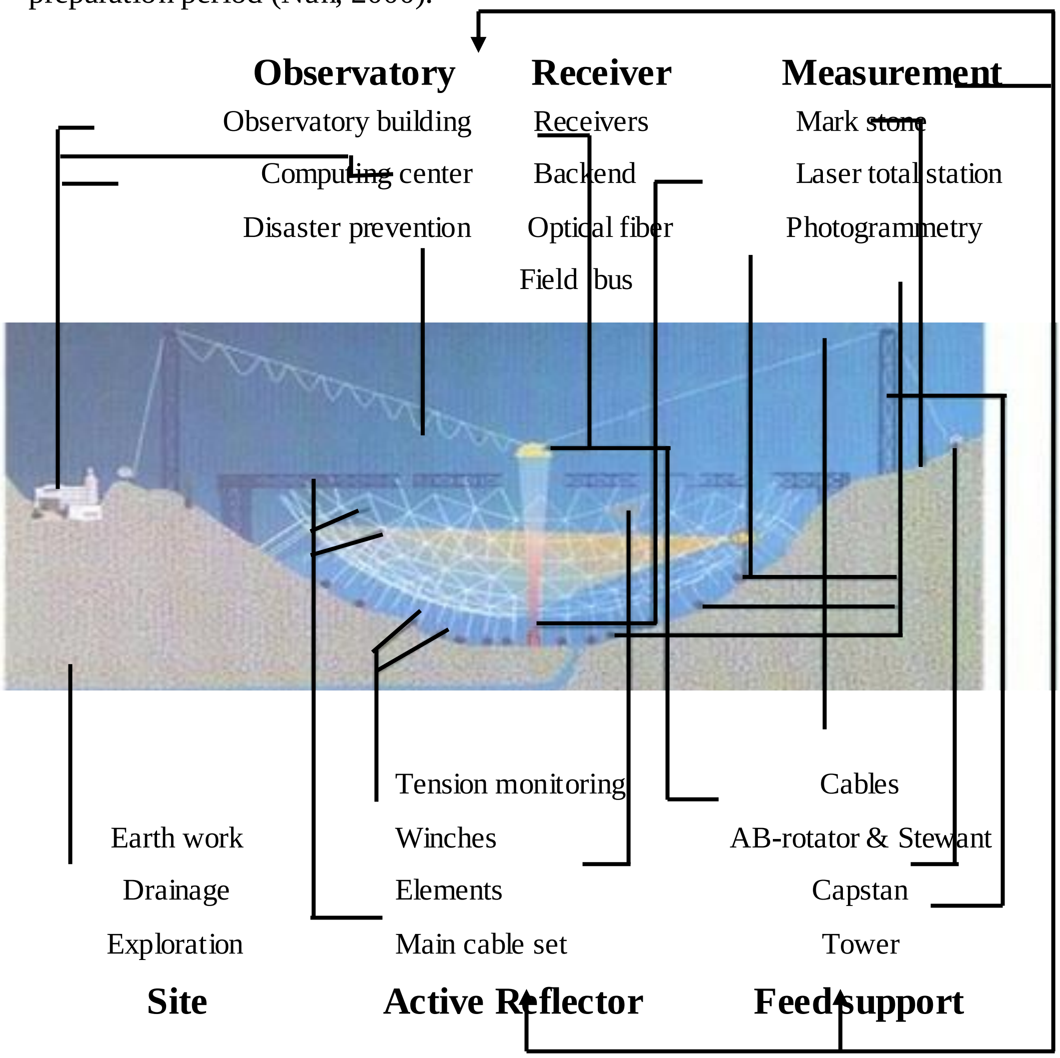

Figure 12: The sub-system of FAST

Source: Nan, 2006.

As *Figure 12* shows, FAST project is divided into six systems. They are site, active reflector, feed support, measurement, receiver and observatory. For different sub-systems, each of them bears different scientific tasks, and each one takes different risks.

Site in survey and excavation: FAST project mainly observe the universe through radio technology, which depends on pulsar observations, using neutral hydrogen to research the history of universe and execute a very long baseline interferometer network. And carry on the study of molecular line; also look for the extraterrestrial civilizations (Gan et al, 2005). Different from ordinary telescopes, FAST uses longer wavelength radio wave to carry on study. Because of this, the location of radio telescope should pay more attention to the area which is quiet and in less electromagnetic interference environment, rather than a place that has clear sky and less clouds. Therefore, the Karst landform in Pingtang, Guizhou becomes the best choice. It is surrounded by mountainous, that makes the region a natural barrier to shield from radio interference of all parties. Furthermore, the place has only a very small group of residents, so the migration of villagers involves 12 households only, which benefits FAST a lot. However, there is a plenty of rain in this area in summer, and the stratum is soft. Many uncertainties could cause problems in this construction project, so before the project oriented forward, it needs a local environmental assessment, especially in the aspect of geological structure (Nan, 2006).

Active reflector system: active reflector is one of three independent innovation projects in FAST project; thousands of pieces of units compose a 500-meter coronal active reflector, which is laid in the potholes. According to the feedback of distance control system, the cable is zipped up and down to change the shape of the reflector and correct the spherical aberration, which will help observation. Another innovative project is to use nearly 7000 light cables to support the cable net, zip up and down through 2400 of them connecting to the actuator. Each of these light cables will share the weight of platform, which is more than 10,000 tons (Nan, 2006).

Feed support system: feedback cabin suspension system is one of the most difficult engineering problems of FAST project, in order to ensure the feasibility of the design; FAST engineering team cooperates with some famous universities all over the world, which includes MT Mechatronic, Xi'an University of Electronic Science and Technology, Tsinghua University, and Darmstrad. They carried out simulation to evaluate system optimization results obtained demonstrate, through the cable-driven adjustment of control, the displacement of the control cabin within a few centimeters (Gan et al, 2005). After carrying out this, the adjustment of stable platform for the position precision control can reach a few millimeters.

Measurement system: this system is the most important part of FAST, the signal receiving system run through a flexible support and the signal reflecting surface no rigid connection between their co-ordination, which depends on precise time synchronization and relative position (Nan, 2006). Therefore, the accuracy and reliability of the system will have a significant impact, which requires a good definition in an accurate reference frame which can provide fast and long-distance remote monitoring. It also requires technical departments to focus on the technical indicators corresponding to strict monitoring (Gan et al, 2005).

Feedback and receiving systems: in the entire receiving system, scientists suggest that needing to run 9 different sets of receivers, make the band covering from 70MHz to 3GHz. If the band is higher than 1GHz, it will use the corrugated horn feed; higher than the 0.5GHz, the receiver will be cold deeply, and the IF signal is passed down through the fiber to the observatory (Gan et al, 2005). For different bands, the National Observatory, Jodrell Bank Observatory and the ATNF have a long-term cooperation between the plans together to complete the preliminary design of the receiver.

4.1.2 Technology

The technology department is mainly responsible for the technology researches which are pointed out by the science department. What is more, this department is looking for the external company to help them resolve the technology problems. Most of related professions are organized by the technology department to evaluate the possible risk.

4.1.3 Engineering

The details of project management are outsourced to a company named Beijing Zhongyuan. Each part of project is outsourcing to the professional and experienced construction companies. For example, the support system is outsourcing to a company major in building tower (Gan et al, 2005).

4.2 Data analysis

4.2.1 Environment evaluation

In the preparation period of FAST, an investigation and assessment of local environmental impact was carried on by Guizhou Provincial Environmental Science Research and Design Institute, and an official certification[3] was issued, which mainly includes eight phases.

- The basic situation of project

FAST's location, area occupied, facilities, main content and layout have been determined. Then, the total investment and construction cycle would be estimated. According to the result, the pollution situation could be evaluated.

- Construction in the natural and social environment
- Environmental quality of FAST location
- Clarify the standard reference works of FAST

The construction must be in accordance with the environmental quality standards, pollutant discharge standards and emission control standards. These requirements will be demonstrated as figures in following parts.

- The possible pollutant emissions during the construction of FAST are shown as *Figure 13*.

[3] Guizhou Province Environmental Protection Science Research and Design Institute. *Environmental Impact Assessment Certification No. 3302*, January 2008.

Content	Emission source		Pollutant	Concentration of pollution before management		Emission concentration	
Atmospheric pollutant	Construction period	Land preparation	Dust, Automobile exhaust	Few		Few	
	Operation period	Kitchen lampblack	Lampblack	Concentration (C)mg/m^3 13	Quantity (Q)kg/a 140.4	C 5.2	Q 65
		Automobile exhaust	NO_2 CO HC	Quantity kg/a 19.15 2.45 2.23		Q 19.15 2.45 2.23	
Water pollutant	Construction period	Domestic sewage	COD SS BOD_5 NH_3-N TP	C mg/L 220 180 100 25 4	Q t/a 1.72 1.40 0.78 0.20 0.03	C mg/L 150 150 30 10 1	Q t/a 1.17 1.17 0.23 0.078 0.008
	Operation period	Domestic sewage	COD SS BOD_5 NH_3-N TP	220 180 100 25 4	3.01 2.47 1.37 0.34 0.05	150 150 30 10 1	2.06 2.06 0.41 0.137 0.014
Solid waste	Construction period	Engineering construction	Stones	1800000 m^3		All transport to a designated container	
		Building to decorate	Construction waste	200 m^3			
	Operation period	Household garbage	Household garbage	46.8t/a		All transport to a designated container	
Noise	(Construction period) Construction machinery noise 90dB(A)-100dB(A) (Operation period) Air conditioning, water pump, fan equipment noise 60dB(A)-80dB(A)						
Others	None						

Figure 13: The possible pollutant emissions

Source: China Environmental Impact Assessment Certification No. 3302, January 2008.

➢ Environmental impact analysis

In construction and operation period, environmental impact analysis provides the evaluation and prediction in atmospheric, water, sound, solid waste, and general environmental impact. On this basis, the project need to be taken by control measures, the expected effects are shown as *Figure 14*.

Content	Emission source		Pollutant	Measures	Prediction outcomes
Atmospheric pollutant	Construction period	Materials transport	Dust, Automobile exhaust	Wet spraying Closed transportation	Little impact
	Operation period	Kitchen lampblack	Lampblack	Special flue	Little impact
		Automobile exhaust	NO_2、CO、HC	Nature ventilation	Little impact
Water pollutant	Domestic sewage		SS、COD、BOD_5、NH_3-N、TP	Agricultural irrigation or greening after sewage treatment	GB5084-92[4]
Solid waste	Engineering construction Building to decorate		Construction garbage	All transport to a designated container	Little impact
	Household garbage		Hint household garbage	Unified collect, regularly to keep up	
Noise	Machine noise when construction		Noise	Apply for construction noise permit	GB12523-90[5]
Others	Ecology: 1. Avoid high fill deep cut, little earth-gathering, abandon soil, construction waste etc should be timely to designated yard or landfill Guiyang, do not get optional dumped in the road, affects the city environment health and landscape. 2. The building materials should be accomplished during properly stockpiling, in order to reduce the influence of soil and water loss caused by construction 3. This project is completed, the afforestation helps to improve around 30% of the ecological environment				

Figure 14: The control measures and expected effects of FAST

Source: Source: China Environmental Impact Assessment Certification No. 3302, January 2008.

[4] China National Standard, GB5084-92: *Irrigation water quality standard*.

[5] China National Standard, GB12523-90: *Construction noise standard*.

➢ Public Participation Survey

Through the issuance of 120 questionnaires, for the residences in project location region, Dawohan of Liushui village, Kedu Town, Pingtang County, investigating individuals and groups, to master the understanding, coordinating and assessment situation in different ages and education levels.

4.2.2 Risk evaluation

In order to achieve the optimization of key technology in engineering, FAST project built the first general model called Miyun 50-meter model (Nan, 2006), focus on the possible risk analysis, forecasting, and solutions

4.2.2.1 Anti-corrosion

Through the environmental assessment of FAST project, the management also found a set of data: in the site area, the average annual rainfall is 1218 mm, annual temperature is 16-18 C^o, the total annual evaporation is 1295 mm, the average relative humidity is 80%, the annual hail rate is 0.6 times a year, the annual snowfall are 5.4 days, frost days are 59, hail days are 2.6 (Nan, 2006). It shows this area has adequate annual rainfall, some of them may be acid rain, and the humidity in the air is high. In addition, FAST is located in pothole, withstand long-term invasion of acid rain and condensation water, air, so there is often a condensation phenomenon. The devices of FAST may undergo erosion with the temperature changes and condensation water alternating.

According to ISO 9223[6], made by International Organization of Standardization Committee, classifies the corrosivity of an atmosphere based on various measurements. Based on these measures an atmosphere is classified as being in one of five categories. Meanwhile, in order to assess the environmental impact of corrosion, the external and internal factors are listed by each corrosion hierarchies, shown as *Figure 15*.

[6] ISO 9223: Corrosion of metals and alloys - Classification of corrosivity of atmospheres.

Corrosion type	The loss of quality on unit area In the first year after exposure to lose		The typical temperature climate environment	
	Mild steel		External	Internal
	Mass loss (g/m^2)	Thickness loss (μm)		
C1 Very low	≤10	≤1.3	-	Heating building inside like school, office, etc
C2 Low	10-200	1.3-25	Air pollution is low, mostly in rural areas	Not heating place with condensation like warehouse, gym
C3 Medium	200-400	25-50	In cities, SO_2 pollution, low salinity sea areas	High humidity and some production place like food company.
C4 High	400-650	50-80	High salinity of industrial and coastal areas	Chemical plants, swimming pool, ship factory.
C5 - I Very high (Industrial)	650-1500	80-200	High salinity and bad atmosphere of industry area	Place with condensation and high humidity
C5 - M Very high (Sea)	650-1500	80-200	High salinity coastal and offshore areas	Places under high humidity and high pollution

Figure 15: Corrosion hierarchies and environmental impact

Source: Own construction adopted the classification from ISO 9223

Under the analysis of local humidity, SO_2 and salt particle concentration, the steel structure of FAST project is considered to be in a strong steel corrosive environment. In accordance with ISO 12944[7], the environmental corrosion is

[7] ISO 12944: Corrosion protection of steel structures by protective paint systems.

higher than C2, close to C3; therefore, the corrosion protection is very important for FAST.

The durability of anti-corrosion coating systems is divided in three ranges by the relevant staff of FAST.

No.	Durability	Design life (year)
1	Low	Below 5 years
2	Medium	5~15 years
3	High	Over 15years

Figure 16: Coating system durability range

According to the preliminary design, the painting system should be used in at least 15 years. Research of painting for relevant departments show that 6 different structural units, including large steel structure (supporting tower, beam and support), small Steel Structure (flange, cable anchor), high friction parts (ear board, cable Nodes) and aluminum structure (panel, purlin) need to carry out anti-corrosion anticorrosion program design, according to ISO 12944[7], the corrosion protection program of structure.

Corrosion environment	Service life	Thickness of dry film (DFT)
C2	Low Medium High	80 150 200
C3	Low Medium High	120 160 200
C4	Low Medium High	160 200 240 (with Zinc) 280 (without Zinc)
C5 - I C5 - M	Low Medium High	200 280 320

Figure 17: ISO 12944 requirements in service life and DFT

Source: Own construction adopted the requirements from ISO 12944

FAST anti-corrosion structures were recognized as *Figure 18*.

Corrosion environment	ISO 12944[7] C3		
Anti-corrosion requirements	High durability≥5 years		
Structure	Measures	Product name	DTF
Steel structure	Coating	Epoxy zinc rich primer	40
		Penguard Midcoat MIO	100
		Polyurethane surface or Fluorine carbon surface or polysiloxane surface	60
Small steel structure	Hot-dip zinc + coating	Hot dip galvanizing	55-85
		Etch primer	10
		Polyurethane surface or Fluorine carbon surface or polysiloxane surface	40
High friction structure	Thermal spray hard wear-resisting alloys	Thermal spray tungsten alloy, molybdenum alloys or nickel alloy	
Aluminum structure	Electrochemical oxidation	Normal anodizing	
	Coating	Etch primer	10
		Polyurethane surface or Fluorine carbon surface or polysiloxane surface	40

Figure 18: FAST anti-corrosion structures

Source: Own construction adopted the requirements from ISO 12944

4.2.2.2 Support system

As one of the key technologies, feedback supporting technology, based on the cooperation of Tsinghua University and Chinese Academy of Sciences. They organized a "FAST moving car - feed stable platform 50-meter model coupling system" (Nan, 2006). Through a period of two years of theoretical study and model tests, the mechanical analysis has been used to establish similar situation that provided an axial bearing cable tension, weight, inertia of transverse vibration. It is the innovative ways to meet similar laws and requirements of elasticity and inertia in cable system. On this basis, an experimental model for the control system can be passed from the laser tracker then point to the motor encoder. Cable tension sensor and other measurement data, on-line calculation of motor control output 18 devices to achieve the feed coordination support system testing model control. Meanwhile, the development of the inertial measurement unit and laser tracker measurement system integrated and applied to flexible support of Stewart platform position and orientation controlled trial. Fourthly, experimental model system is 50-meter test model, which is the spatial orientation of the feed platform, and the root means square error is from 0.36 to 0.45 mm; the wind speed based on the similarity of the prediction in FAST is from 0 to 2 meters/s in observed working conditions (Nan, 2006). The root means square error is the positioning which can reach 4 to 7 mm. To point to the root, means square error is up to 1 to 2 mill radians, it can basically meet FAST work requirements.

4.2.2.3 Active reflector system

The active reflector is composed by more than 2,400 pieces small sphere in the field (Nan, 2006). Each panel has some support points, each point supports adjacent panels. The position of each panel can be adjusted in real time in the direction of the sphere center, in order to achieve spherical reflector illuminated part of the real-time synthesis of a transient. Each point includes an actuator can be used to changing the height; an appropriate connector and a control system for complete the control requirements of the actuator. Thereby, the panel can be adjusted by the movement of actuator.

However, due to the wet field environment, complex terrain, it's difficult to maintain the 2,400 control points. The technical part of FAST is in the development, installation, operation, maintenance, a reliable superiority of field bus and considerable technology (FCS), to achieve all-digital, full-open, full-spread, high quality control and cost-saving. FCS uses LonWorks[8] system, which uses LonTalk[9] to complete various tasks in support of a wide range of communications media and twisted pair, power lines, and support for reliable mind, to provide predictable response times, support for mixed media and any connectivity between mediums and nodes.

4.2.2.4 Human factors research

Questionnaire is the main method of this research. The participants include 15 people from different levels in three departments of FAST. The aim of our questionnaires is to figure out whether the staff comes from different levels in each department can have the consensus of the project; and whether they have enough vertical or horizontal knowledge about FAST; finally, whether they can work together well and know something about EAM.

- Knowledge level about FAST

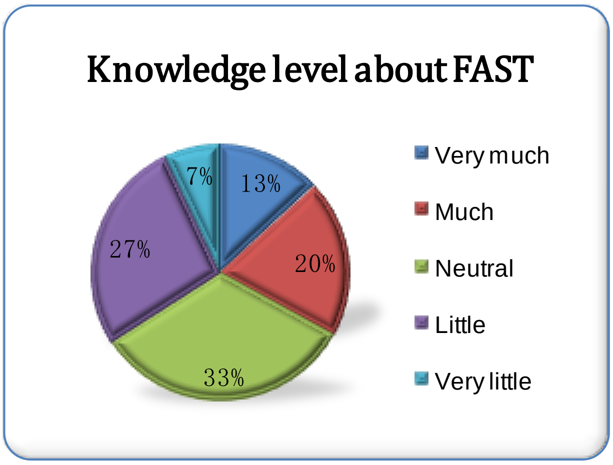

Figure 19: Knowledge level about FAST

Obviously, in questionnaires of this part, people from department of science know more about goal and needs of FAST project relatively, but they are not

[8] LonWorks: a networking platform specifically created to address the needs of control applications.

[9] LonTalk: a protocol optimized for control created by Echelon Corporation for networking devices over media.

acquaint of structure of it and related legislation. However, staffs from department of technology and engineering concentrate on technical problem in engineering. There is a difference among the knowledge of three departments and each has its own capabilities.

➢ Knowledge about EAM

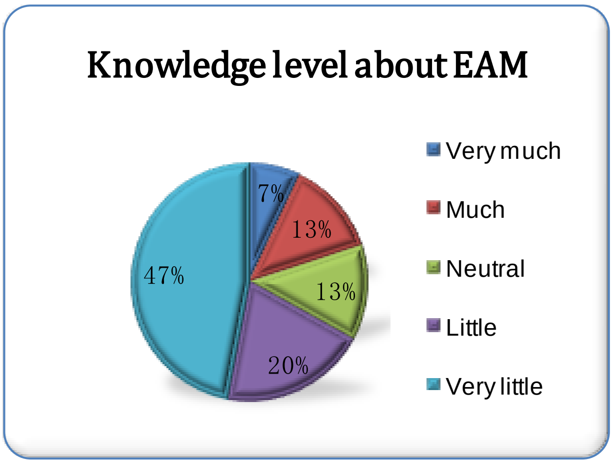

Figure 20: Knowledge level about EAM

Through simple enquiry about EAM, we find that knowledge about it of staffs of the three departments is still on primary level. They just know a little about several branch questions, which is not systematical. While most of them have never or rarely heard about the concept, only several administrators set foot in this area to some extent.

➢ Knowledge about asset standards

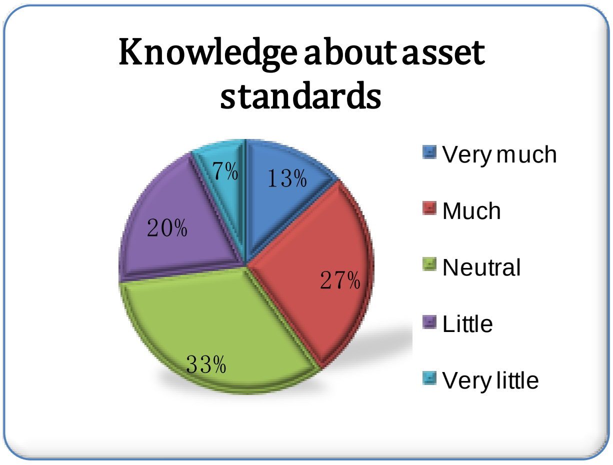

Figure 21: knowledge about asset standards

For the acquaintance of asset standards, generally, most staffs know them. In this area, the grasp of department of science is relatively bad; the staffs just know it broadly, and even some leaders in this department cannot point out the asset standards clearly.

- Others

Though using some method such as conferences and workshop to impart related knowledge and communicate, there is a knowledge gap among different departments, through the analysis of questionnaires. More specific, the extent and content of knowledge grasp in department of technology and engineering, while what in department of science have a gap compared with the other. Within independent departments, macroscopic control of the management is powerful, but the transmission between management and employees is weak and as a result, it is hard to complete demand of project detail accurately. The grasp of related knowledge about FAST's solutions, asset details and EAM are not systematical.

4.3 Future plan

4.3.1 Maintenance management

There is no an existing maintenance planning because the project is not done. However, there is a basic philosophy on maintenance which is based on time. The maintenance planning will strictly comply with the asset regulations.

4.3.2 Human training

FAST has already established a training plan in order to educate more university students who are interested in FAST. The purpose is to make students have a better understanding about asset. The training covers many subjects include computer, mathematic, management and astronomy. The training will last when the students graduate and they will take part in the project as soon as possible.

Chapter 5 Discussion

This chapter combines the theoretical framework with the result to discuss the shortcomings of the existing EAM model, as well as propose the key elements of EAM in large engineering projects, that give responses to the research questions we set in the beginning.

5.1 Shortcomings of the existing EAM model

In the interview and observation in FAST project, it could be easily found that FAST project is converting from the planning and designing stage to the executing stage. The preparation of project establishing is 5.5 years, and the main task is environmental evaluation and land preparation as so far. At the same time, a huge number of relevant universities, organizations, and companies are taken part in the project in order to research the relevant issues including management and technologies. However, limited by the long term of complex project construction, some shortcomings come out.

5.1.1 Lack of time management

As the project management requires, it is important to balance time, cost and quality. FAST project is one of the National key projects which receive national financial and local financial allocation. On the other side, scientists from all levels and organizations cooperate with each other to resolve the technical difficulties. However, because of less preparation, lots of emergency happened without sufficient planning. For example, Karst caves was discovered when land preparing. It extended the time schedule and increased the difficult of project executing.

5.1.2 Lack of communication

As FAST staff said, FAST project involves a wide range of fields, which include science, technology and engineering. Most of staffs are not clear to how much the construction situation would affect the future operation and control. This is due to the construction project was outsourced to a professional management company, which instead of them.

5.1.3 Lack of information integration

In the interview, it is difficult to gather information from the professional department. Instead, the documents and relevant information have to be asked for from the specific department manager. It is important for EAM to manage the information in order to better handle the asset situation. Even at very beginning of the project, the preparation of information management should be done. This is one of the reasons why there are too much surprises when the project executing.

However, the limitation is inevitable because FAST project is a groundbreaking project without enough relevant experience. The result is that there are many unexpected events appearing. Unlike other business project and normal infrastructure construction, the character of FAST is a kind of project with high science requirements. The different majors of participants are too difficult to be easily understood by each other. On this situation, EAM needs to be redefined.

5.2 Key elements of EAM in large engineering projects

Large engineering projects need to be processed by EAM in the initiation stage. For project management, there are five important stages, which are: initiation, planning and design, executing, monitoring and controlling, and closing. The normal sense for engineering is when the project has been in monitoring and controlling stage, or after the project has been running. However, for large engineering projects like FAST, all the issues should be combined with environmental management and risk management in all stages. These could be the key elements of EAM in large engineering projects.

5.2.1 Data collection

In this period, when the project is still in the planning stage, all of the data should be collected. The most important thing is identify the organization's mission. For the business organizations, their aim is to gain profits and increase asset utilization. For the normal infrastructure construction, the aim is to provide service to public and increase asset utilization. For the large engineering projects like FAST, it focuses on the science outcomes and increase asset utilization. It could be easily found, there is a same thing to increase asset utilization. In order to reach this goal, the asset management department has to clarify the organization's missions and asset requirements. Such as FAST project, assets are affected by the environment like earthquake, nature of soil, electromagnetic interference and etc. After the management handled this information, the responsibility could be allocated. The sub-system department will understand what they should do, what they can offer, what they can help others. According to that, ensure the coming actions corrective.

5.2.2 Options evaluation

Based on the defined organization's mission and strategy, asset attribute data could be laid out. The next is to set out to do a series of evaluations. According to the project description, location, condition, residual life and value, relevant evaluations should be arranged. These evaluations include financial evaluation, technical evaluation, environment evaluation, safety evaluation and service quality. Take FAST project as an example, the asset requirement combined the environment evaluation, technical evaluation and safety evaluation. The point is that asset utilization will be affect by the local environment. Based on link the requirements of environment and asset attribute data, the technical requirements could be got. The risk evaluation has to take environment and technical requirement as basic. However, to most business organization, the evaluation should take cost into account. The final option decisions are across decision. There is no doubting that the safety evaluation is basic to each kind of project. The organization could rank the asset importance level in order to establish a niche targeting renewal strategy.

5.2.3 Procure process

The organization could make a decision about whether they can complete the project with other companies and which kind of cooperation style they could choose. Based on their renewal strategy, result of each kind of evaluations, the organization will clear about their strength and weakness. Consider with the price and service quality, the organization could outsourcing some weak objects to the other companies in order to maximizing efficiency and effectiveness of organization's resource, meeting the organization's mission, and at the same time minimizing adverse impact. If the organization decides outsourcing to other companies, establish a close relationship necessarily. Based on the trust and the evaluation about the outsourcing company, organization will not worry about their core value especially for the business company. For example, FAST is outsourcing their management to a professional management company named Zhongyuan. They will help the organization do most of the issues include construction and management. However, the communication between the two even more companies is important. Both sides must ensure that they can get the dynamic information as soon as possible to avoid the communication gap. On the other side, the outsourcing company must have a fully understanding about the project needs, requirements and missions to avoid risk.

5.2.4 Maintenance planning

No matter who manage the whole organization, there should be a maintenance planning. For the asset, maintenance is an essential part to minimize the risk. With the asset utilizing, the asset residual life is shorter and shorter, the real time monitoring is necessary to get hold of the asset condition. At first, relevant staff should have an understanding about the asset standards and requirements. The organization should provide safety learning to all the staffs. It is better to establish an emergency plan to deal with the emergency events. However, in this stage, most of organizations always formulate the time-based-maintenance plan. This is a kind of plan relying on the asset age. However, the engineering asset consumes the function by the practical situation and it will be affected by the environment conditions. A new philosophy like condition-based-maintenance plan should be taken into account especially for large engineering projects.

5.2.5 Information management

As we mentioned above, the evidence as basis for projecting future lifetime availability and make predictions on how the asset is performing whether anything need to be changed. As the requirements like maintenance planning, the condition-based-maintenance plan will be accepted by more and more companies, this condition-based-maintenance planning need the sufficient information as a foundation. In risk management and emergency plan, the asset information could help the decision making. At the same time, the documents like environment evaluation and technical evaluation need to be update. The information is changing with the current situation. From another side, all the information should be provided to the staffs in order to make sure everyone understand the asset going and project going.

5.2.6 Human resource management

Human factors affect to the asset management vastly because both data collection and information analysis are based on human action. The staffs understand how much about EAM directly affect the asset performance. Training is the efficient way to resolve the human problem. The training not only means the asset safety and standards education for the new staffs but also when the project beginning. The technology cooperation between project department and universities make FAST run well. FAST project trains their future staffs when they were young and have interest in their project. The education lesson includes taking part into the project before it established. FAST project's philosophy is that the students, who will participate in this project, should be better understood where the standards come from, and why the rules are formulated like this. Therefore, the students' majors include a wide range of disciplines, such as mathematics, astronomy, engineering and computer. The science construction give a new guideline to other kind of projects that the EAM begins from it was planned, rather than all the asset is running. The related work need to be fully considered, rather than resolve when it comes out.

Chapter 6 Conclusion

This chapter combines with the discussion in previous chapter to provide the answers to the research questions.

6.1 What are the key elements of EAM in large engineering projects?

Based on the study, a tailored EAM model has been developed as shown in *Figure 22*. This model combines the original EAM theory with the key elements of EAM in large engineering projects. The key elements are:

- Data collection
- Options evaluation
- Procure process
- Maintenance planning
- Information management
- Human resource management

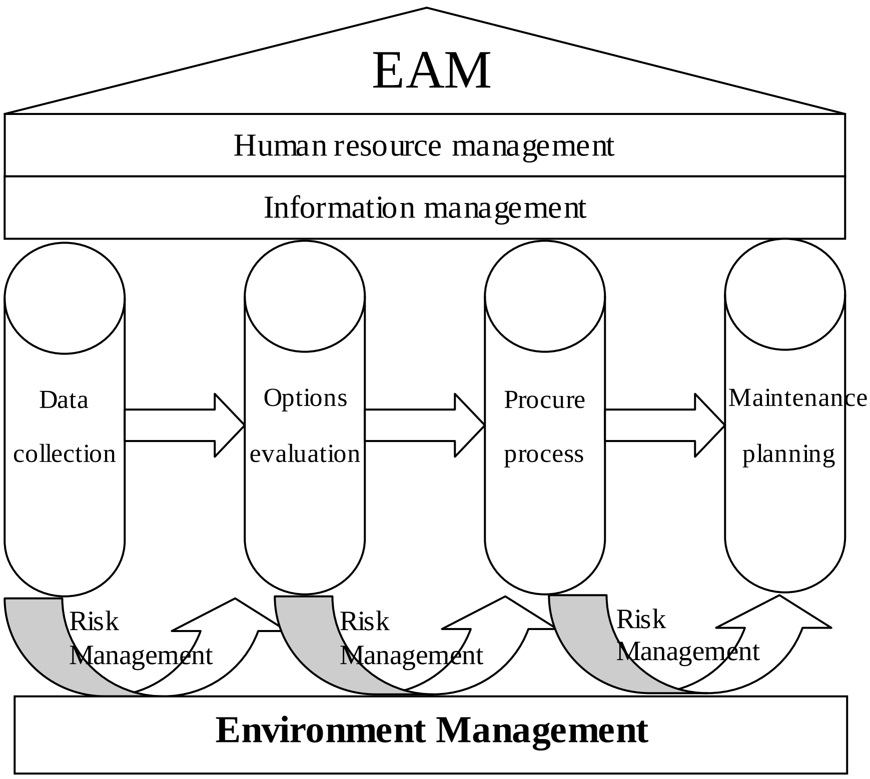

Figure 22: The tailored EAM model

Source: Own contruction tailored from the exiting EAM model in *Figure 5*.

6.2 What could be the tailored EAM model that can be applied to large engineering projects?

As shown in *Figure 22,* the tailored EAM model gives a guideline to resolve the possible problems which are caused by the external and internal influences. This model focuses on the foundation of environmental management. That means the activities of EAM should base on the environmental evaluation. In the process of data collection, the interaction between asset consumption and environment influence should be under control. Moreover, risk management could be operated through the decision making, which includes procure process and maintenance planning. The related information is used for human training and future assets monitoring. In general, the tailored EAM model requires the organization to put EAM into the initiation stage of project, rather than in the intermediate stage or the final stage, and to convert the asset management from time-based to condition-based.

Compared with the existing EAM model, the tailored model is more suitable for the projects like FAST. The key issues are science result and the relationship between project and environment. In FAST project, there is a large numbers of preparatory works of environment control before the real beginning of whole project. Then, based on the confirmation of the environmental requirements, the missions of project could be determined. Furthermore, the risk management doesn't aim the asset operation stage in the tailored EAM model. Instead, the risk management is set into the data collection and the maintenance planning. The reason is to avoid time consuming by the "happened" issues. In addition, human resource management tends to be more goal-oriented, because the information management is developed in a specific way. In the project team, each department and administrator knows about "what we will deal with", "what will happen" and "we should… if things go like that". The advantage is to give more possibility to collect more resource, which can be used to resolve the core problem. FAST is an iconic project which associates with many different areas to achieve the unfamiliar goals. All of the activities must be based on sufficient communication and quantized management.

The tailored EAM model provides a different measure for the projects that wants to achieve the lean manufacture. Specifically, for most of the construction project of large scientific facilities, the asset performance will be highly affected by the environmental factors. In normal business projects, the additional evaluation is financial safety, which contributes to the business goals. However, no matter what kinds of project, the key is to minimize the possibility of asset failure and to maximize the utilization of asset. Therefore, different needs could be unified in EAM, and large construction projects are no exception, the tailored EAM model could be suitable for them.

6.3 Further research

Our research in this thesis is narrowed to the implementation of EAM in FAST. FAST is the unique case study for exploring how EAM could be processed in large engineering projects. However, further research could review the achievement of the tailored EAM model.

Based on *Figure 22*, researchers can analyze the implications of the tailored EAM model in other engineering projects or other types of project. From the perspective of project managers, researchers can study how EAM could be more suitable, what EAM models could be used, and how to take advantages of EAM to enhance executive capabilities.

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Appendix

UNIVERSITY OF GÄVLE

Department of Industrial Engineering and Management

Master Programme in Logistics and Innovation Management

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Survey Guideline:

Engineering asset management (EAM) is a burgeoning concept which is widely used in Australia, Europe and USA, especially in infrastructure construction. However, in China, there are still very few literatures and application cases in relevant academic researches and industrial practitioners. Only few organizations adopt EAM to project management.

The purpose of this survey is to collected information from the participants in FAST covers most of departments. We would like to know how people's knowledge is in FAST about EAM. Some key issues relevant with EAM will be put forward in the questionnaire. The interviewee could choose the most appropriate answer or write down their opinion.

1. What is your position in FAST? ____________

2. How long have you engaged in your professional? _____________

3. How do you know about FAST

	Very little	Little	Neutral	Much	Very much
Project structure of FAST	○	○	○	○	○
Science goals of FAST	○	○	○	○	○
Needs of FAST construction	○	○	○	○	○
Related legislation and requirements on environmental when FAST is running	○	○	○	○	○

4. How much do you know about engineering asset management?

○ Very little

○ Little

○ Neutral

○ Much

○ Very much

5. Which one do you think will mostly effect to FAST running? (Score each ones with 1 to 5, with 1 indicating the mostly effect, 5 indicating the least effect)

Geography ☐

Climate ☐

Engineering construction ☐

Social environment ☐

Radio interference ☐

6. How much do you know about the most of asset standards?

- ○ Very little
- ○ Little
- ○ Neutral
- ○ Much
- ○ Very much

7. What do you think about maintenance to FAST

8. What is the most risk to your department? How will you deal with it?

9. Could you describe the way you sharing the currently asset information?

10. What limitation do you think exists in the organization?

Thank you for your cooperation!