CHAPTER 2

Literature Reviews

2.1 Overview

Business success is increasingly competitive global markets depends on the alignment of the business strategy, IT strategy, organisational structure and processes, and IT infrastructure and processes. The alignment of business and IT strategies has been utilized by organisations to create and improve efficiencies, reduce costs, create barriers to entry, improve customer and buyer/supplier relationships, and to create new products and business solutions (Erasmus et al., 2012).

2.2 IT Planning

According to the theory, organisation goals determine strategies which is determined by objectives and supported by budget and planning. In reality, the service behaviours are different and thus depend on motivation and returns. It is thus not surprising to see different budgets in different objectives of each strategy. Plans can contain politics more than strategies and project may not be a part of planning. Kaplan and Norton (1996) stress the importance of guidelines and popularity in budget and strategy, flexibility of goals, and future prediction. Finally, the order of objectives and budget depend on the control, and the order of strategy and plan depend on the operation plan.

IT strategy is important in the planning process in the sense of market position and competition. The tools for measuring strategies do not develop the vision in creating value. Companies need to develop business strategy that has IT to create value for shareholders (Altemimi et al., 2012). However, IT will normally support organisation or business goals at the best. Therefore, successful companies will use CIO in drafting the plan and frequently laying the business strategy in which IT will be included not just as a concept.

The process of quantifying/ scaling is important to ensure that the strategies and target are applicable and can be achieved. To emphasis on a distinctive competitive advantage necessary to develop effective performance measurement systems linking firm strategy to operating decisions toward measuring the performance of IT achievement (Rouse and Putterill, 2003.

The consideration of company requirements will be an updating business model including supply chain. The appropriate system will show harmonious combination of processes and strategies. Return and profit form market will increase if the best idea is distributed and created from simple idea to response industry which will determine the competitive edge.

IT strategic planning for the future should be done with confidence and complied with business strategies. However, the operation of new investment needs the profound recognition of IT. The service system and investment must be planned in agreement with the present structure for decision-making and business driving. The inventory of operation asset and project should have TCO (Jamison and Lowenstein, 2011), age, technology standard, and limitation. Knowledge of present status of information file will facilitate the beginning to new IT. The exchange wants to combine short and long-term goals. The IT files should be adjusted to conform to the objectives of new strategies. This is the symbol of exchange rate of the hidden values of future company. At the same time, the company can adapt itself to the future.

The change from present to future takes years. It requires complicated planning, from short to long-term consideration. The final condition in an ideal case will be to determine the new technology structure which will compromise the short-term business requirement and state limitations. The investment should put an order to the depreciated asset by ensuring that the infrastructure and operation system will be a sustainable investment. Therefore, the outsourcing or the management will accommodate the out-of-classroom knowledge and the capability that can be used at all times and paid through the operation cost. When the life cycle of technology is short, it should focus on open structure and shared operation, which will facilitate the design flexibility and alternatives. The control of change should be divided into two or four parts so that the examination or new direction determination can be facilitated.

The IT investment at the present or in the future depends on the present operation system. The design, development, and implementation of IT investment will be successful depends on the reliability of IT process, resource, and technological tools. Often, IT operation is not enough and becomes an obstacle to investment progress. Nevertherless, many companies still need new investments in feasible directions by separating from IT operation systems. The management thus needs to invest in the same way.

2.3 IT Investment

Iinvestment's in information technology (IT) can improve firm performance as enable for improved organisational efficiency and competitiveness (Kohli and Devaraj, 2003; Wade and Hulland, 2004). A firm's IT capabilities represent the application of physical or intangible IT resources such as technology, knowledge, practices, relationships, management skills, business process understanding and human resources to further organisational goals (Bhatt and Grover, 2005; Sandberg et al., 2014). Strategic planning and IT investment must be in agreement. If the investment is in the same direction of planning, there is a possibility that the investment will result in values clearly. Companies should earn benefits from managing business and IT by supporting the management appropriately and clearly. They should assign liability in the future and have equality in the procurement procedures by biding to principles of fair profits.

IT programs should have plans that are consistent with the business plan, appropriate to organisation goals. IT projects should realize the expected values. The objectives are the optimisation of the value creation for IT investment. The right project planning can be used in the appropriate time and budget and for the desired business and quality. This reduces the consumer, operation, finance, technology, and control risks.

IT investment is about more than assets on the balance sheet, it is about the ability to drive business to shift older technology investment into information investment, where the focus is on value from information (the information ('I') in 'IT', and information ('I') in 'CIO'). Today, IT investment creates business efficiency as opposed to being a solely money saving activity.

IT assets represent between 2% and 12% of total company income, and at the end of 2008, Gartner suggested that global IT investment was approximately 2.6-3.0 trillion dollars. Of this, more than half was spent on communication and the remainder on IT hardware, software, and services. Putting this into perspective, the yearly expenditure compares to the GDP of England or France and is almost three times that of India.

2.3.1 Importance of IT Investment

Investing in IT may be the most important decision business firm will face. Unfortunately, investment in IT is not as easy as common financial investment decisions. To make good decisions on IT today requires the use of variety of investment methodologies (Schniedejans, Hamaker, and Schniederjans, 2010). IT investment has continuously grown and from the emergence of the modern computer era in 1940, IT has expanded from the basics of a computer and telecommunication infrastructure to state enterprise systems including data and management of large organisations and private sector services. The Internet began in 1969 and in 1973 was followed by computers connected via ethernet (Leiner et al., 2009). The change of mode and function of the Internet resulted in computer communications standards, enabling international connections. The subsequent increase in personal computers and communication applications led to the growth of globally connected networks. The introduction of Mosaic in 1993 is regarded as the origin of connection protocols currently used in integrating whole equipment, for example, the audio in mobile phones and social network communities such as Facebook. Commercial applications have been realized through software, e.g. SaaS (software as a service) and service management.

IT investment has grown significantly from 1950 in terms of technology progress from the first-generation computer to global IT investment, increasing from 10 million USD in 1950 to 2.6-3.0 million USD in 2008. Between 1950 and 1990 average global IT investment doubled, with this change mainly due to the expansion of the

Internet, beginning in 2001. In 2000 there was constant growth in IT investment of approximately 2.5-5% but this growth was variable in developing countries. Despite such variability, IT investment continues to grow and increased from nearly 2 trillion USD at the end of 1990 to 2.6-3.0 trillion USD in 2008. According to Gartner, almost one-third of global IT use occurs in North America, Western Europe, and Japan. Growth in IT investment continues while capability, market evolution and competition expands.

IT consists of investment in both existing and new technology. That is the integration of available hardware and software with investment in IT management (such as support and service). Labor costs can increase or decrease the value of technology. However, continuous support and service is not a common part of the investment. Evidence from humans (intellectual property) is a more crucial asset than tangible assets, and should be maintained as part of the IT investment. IT costs and related accounting must therefore include this intellectual property when considering the IT investment. There should also be a consideration of the difference between existing and new technologies.

IT investment will increase the value of both tangible and intangible assets for organizations as mention by Kleis, Chwelos, Ramirez, and Cockburn (2011) suggests that IT is vital to intermediate processes such as those that produce intangible output. According to traditional practices, IT investment depends primarily on tangible capital and benefits. Today however, intangible assets represent 85-90% of shareholder value in IT investment, focusing on strategic knowledge, business data, database programs, and experimental support. Intangible assets related to IT can be managed and explained by evaluating returns. However, the management tools and evaluation strategies are not well established. It is understood that data is important but data investment is another subject. Where is the overwhelming knowledge against the operating system? The obstacles are the data that are inherent but there is no change in them or happens of new knowledge. At the time of 60 years ago, it should be called the database era not the IT one. The available database helps understanding and facilitates the management of business system in the same direction. Yet, it creates the suitability or arguments in integrating databases. The owner or IT supporters must implement it for the business development and the creation of visible intellectual capital and of value in invisible assets.

IT investment is vital both for the short-term benefit of supporting business operation and in the long-term for shareholder returns, including new business opportunities. Short-term IT investment focuses on limited capital and the control of strategy development. Challenges include the cost reduction of IT in basic operations and the transformation of cost into appropriate strategies for business growth, such as cost reduction in networking and basic computers, new investments in developing a customer relationship management system (CRM), or how to manage knowledge in a knowledge management system. Competition has become more intense due to increasing innovation and change within companies, which is often realized through IT. Investment in technology and human resources is therefore critical to respond appropriately to this competition, and to increase capability, growth factors, and ultimately. Moreover Bagheri et al., (2012) emphasize that IT can create a sustained competitive advantage for the firm.

2.3.2 Trend in IT Investment

In 5-10 years IT investment will receive significant interest from organizations and the value of IT in developing countries will expand. Organizations will have access to less costly IT supplies and will become more flexible with their outsourcing. Common computing languages and standard operating systems that are protected by the World Wide Web Consortium (W3C) and Organization for the Advancement of Structured Information Standard (OASIS) result in appropriate protection and reduce exploitation of changing IT. Effective IT investment strategy should include improvement of infrastructure, development of effective business processes, the storage of goods, use of Windows and UNIX systems, network creation, networked databases, web services, as well as continuous ownership, which are important factors providing companies with speed and agility when entering the market.

Service-Oriented Architecture (SOA) and Web 2.0 are growing in their acceptance and usage in commercial programs. Web 2.0 is the business revolution in the computer industry caused by the move to the internet as platform and easy to build better applications for more people to use them. The new version of web 1.0 are flexible web design, creative reuse, updates, collaborative content creation and the most outstanding features of web 2.0 is to support collaboration and to help gather collective intelligence rather web 1.0 (Aghaei, Nematbakhsh, and Farsani, 2012).

From the 1980s to mid-1990s, SOA focused on the programs that connect computers, for example the data transfer (API) under the J2EE standard. From the end of the 1990s, SOA received attention from businesses and was equipped with web service messaging (context rich) as well as the registration for the picture download business (UDDI). SOA is often considered as devaluing the design of architecture; however, SOA is a considerable driver of IT in organizations. This depends on business-standard operating systems and databases in terms of diagrams, assessment of the highest and lowest points, focusing on data change, or possibly compromising to meet the middle point and focusing on the Enterprise Service Bus (ESB) which concentrates on service integration, service quality and its acceptance, security, messaging procedures, modeling, communication, ESB management, and infrastructure.

The challenge of web services is the division of main duties among main assets or the development of systems that connect computers. These computers can then transfer data among each other with the possibility of reuse. Consequently, the combined media or services will constitute a system connecting computers that can transfer data between them. For businesses or databases in web service, the fundamentals of the business include the main IT assets and their capability in terms of implementation. With appropriate IT implementation, websites that gain popularity will be user friendly and accessible by consumers. These services are comprised of personal data storage, blogs, Wikipedia, online network connections, peer-to-peer networking (method of computer network management that assigns each computer in the network to act as a client or server). This means that each computer has programs or files for itself. Management makes it possible to use these programs or files from any computer rather than using only file servers. Another type of network management is known as client-server, which assigns one computer to be the file server or the program and provide file storage. The computers in this network setup cannot use their programs or files from other computers; they must call from the server only.

Database is one of the most important components of information system and stores all information for web applications (Yan et al., 2014). The benefits from the change in IT are the opening and widening of service database modes including:

- Better returns, decreasing investment in capex and open
- Individual customer service, maximum life value, continuous purchasing, extended purchasing
- Just-in-time business, having independent decisions
- Authenticated and reliable data, best service level
- Low operation and technology cost, paying as one wants and being the best cost of owners
- Time in entering the market and earning profit, speed in system development and readiness in competition for the business prospect
- Agility and flexibility of business, capability in purchasing, capability in reliability measuring, and just-in-time management
- Security system and insurance, low risk from change
- Compliance to control, law, monitoring, and consumer protection
- Technology leadership, first in introducing advanced technology to market

IT changes are enabling everything from IT organisation to infrastructure, with IT connectivity being possible and the associated networks efficient. Important infrastructures and the operational costs will be outsourced with the whole cost to owners becoming the communication systems. IT represents more than goods or commodities and IT outsourcing seems to be an alternative and cost effective management method.

Systems and procedures in outsourcing continue to grow, which changes the working procedures both inside and outside of companies. The main objective is accumulation of profits, and in terms of business competitiveness, IT departments will become key collaborators with outside companies such as IBM and HP. Company growth in outsourcing to India, China, and Romania consumes more than 50% of the whole IT sector in the financial systems industry. Outsourcing will increase and replace the assets system.

During the 1970s the nature of the computer infrastructure or procedures was rigid due to the comparatively high cost of the computer. In large businesses, servers and SANs, effective infrastructure and flexibility in program support, and IT service are currently making continuous progress. Access to the organisational management system will be controlled from the central database system. Large competitors like Microsoft and VMware have significant progress in the number of desktop computer users. From Gartner's report, it was found that the production of desktop computers increased from 5 million in 2006 to 660 million in 2011.

The IT management is considered to be a foundation and important direction of future business. Information system needs to be harmoniously integrated to business but the future is not deterministic. The expectation of projects or returns thus is uncertain. Therefore, IT investment should be flexible or changeable for the convenience in adjusting alternatives. In addition, there should be clear understanding of one's own IT necessity for the clarity of future work. Lack of such an understanding will make such an investment a short-term investment because of alternative nature of work.

2.3.3 IT Investment Strategy

Ideally with no constraints on the budget, investment in IT should be easy and straightforward. The senior IT officials offer a very mixed assessment about the effectiveness of various institutional investments in IT (The Department Chair, 2013) and many environmental variable are related to IT investment strategy (Ravichandran and Liu, 2011). Business alignment to new market or industry is another challenge of companies because they have to review their business models. Some procedures need to be redesigned to be aligned with the prospect market. When there is a rapid change, IT executives are often blamed by the partner. CIO needs to control the situation by expecting the direction of the jumping business.

The strategy of company is on the flexibility and agility because no matter of information or system investment the company should catch up with and be designed openly for the least change. This will be a reduction in system and complexity when there is future change. However, the design should be based on the standard business process and carried out according to main assumptions. CIO thus requires practice for the sake of competitive benefits.

Successful companies have always had clear objectives in IT investment. The highest objectives are the harmonious combination of IT system and business and efficiency in working. Although IT strategies will not ensure that the strategies will make the business successful, the complexity and dynamics of organization are all contributed to its success including culture, politics, experience, and influences from behaviors. These have impact to the organization decision. Therefore, the strategies should be announced immediately after their preparation.

The investment in IT strategy is for the opportunity in new business, service, and customers. These are all challenging. For example, the bank industry tries to increase its return from Internet transactions. Such an activity is considered a big problem. However, Wells Fargo, the leader of online banking can make profit to a certain extent. US bank is also successful in driving using that channel. Customers turn to use the online bank service more and more. It also increases the service of the customer accounts, for example, the online cheque payment.

2.4 IT Evaluation

2.4.1 Asset Evaluation

Universally accepted method for the evaluation of the IT investment is not evident (McShea, 2009). Acceptable evaluation methods for IT investment are not generally found. However, there are hundreds of tools that can be used in the evaluation. The tools are divided into two parts: finance and organization. In each part there exists basic methods, new techniques, and tools. The basic methods will evaluate the IT investment as an asset whereas the new technique will look at IT as the value storage. In this chapter, the basic method of strategic planning and conventional financial methods will be of interest. New techniques will be considered later.

The basic methods have been accepted and supported generally in the research of strategic planning, conventional accountancy, and financial return from investment. The financial tools are: NPV IRR ARR Payback and Budget. The management tools include the strategic planning, business objectives, position, decision-making, and planning.

2.4.2 Conventional Financial Methods

Financial technique is usually used in the evaluation of asset from investment. It uses ROC as the standard in the evaluation. Apart from this, there are techniques of restructuring, break-even analysis, unnecessary cost removal, time saving, and/or valuing techniques. The analysis of capital benefits visualizes the investment return and cash flow. Those tools are understood and widely used in professional financial analysts. It is convenient to measure the performance of investment based on accountancy principles and financial management models. Profits are the important part from the investment. Therefore, ROI will be a tool for measuring the investment efficiency. In addition, DCF (deducted by risk) will make the financial managers understand the cash flow from the investment. However, DCF is not used in all situations. Only 50% of general organizations used it compared to NPV and IRR for the project evaluation.

Presently the budget and capital planning is the basic method for management of IT investment. This technique is useful for budgeting as well as collaboration planning, future planning, and efficient budgeting. The effects from budgeting and alternative evaluation can build strong organizations. Normally, IT operation will depend on some financial aspects like percentage of sale, cost, and /or asset management as these factors can reduce the cost. When the business condition is changed, however, executives need to delay the budget that cannot be realized first.

IT mechanisms that affect business plan and unit cost can increase the vision and business operation although it is not enough for budget management. The business research and investment analysis are used in the evaluation of IT investment. ROI and DCF are used in selection of projects whereas IRR or Cost of capital will be used in risk assessment. Challenges lie in the determination of benefits to be received, especially non-financial. The examination of business plan and study should include clear financial assumptions and environmental changes.

Project plan is created as the prototype for business study. Committee for investment examination and executives will be chosen to evaluate different projects, depending on business plan, objectives, and expected return. The study can be approved, rejected, or changed.

Conventional tools of management and IT investment evaluation are not evident. Strrasman (1985) questions about the appropriateness of tools in evaluating performance/productivity of IT. Use of ROI in the evaluation will lead to wrong resource allocation not consistent with economic value. ROI employs the past data to forecast the investment that is uncertain and does not include the evaluation of remained value from future investment. Normally, the remained value will be more than 50% of market value. DCF is thus more suitable for the IT evaluation, but not in strategic investment.

However with regards to the IT asset, there is no direct relation between IT investment and the company's revenue (Ferguson and Hadar, 2011). The above financial methods may lead to inappropriate or most of the time incorrect investment decision on the IT assets. IT strategic investment can lead to many results. Each result has a different probability. The more complex it is, the higher the numbers of parameters in the evaluation must be. There is a survey finding that only 8% that use ROI in the evaluation.

The present accountancy principles cannot be used as standards in reporting cost and investment of IT. Therefore, IT spending cannot be officially examined. It results in the inability of measuring stability in IT investment and productivity performance or values of shareholders. There are thus variations in definitions, categorizations, and investment records including spending levels among companies. Therefore, there is a definition to compare the standard of each IT industry.

The depreciation depends on the life of the investment. The return rate will be the same as in cost and return.

Organizations need to create management systems for measuring the organization values. The examination based on financial and accountancy standards reflect short-term value and take long time. They are thus used for evaluating past operations. These measurements depend on the form of evaluation, which is applied in the past to investment. The key of IT investment is the evaluation in the future not at the present.

2.4.3 Budget Planning

Budget planning is the basic method of IT investment. The problem of budgeting is the planning uses the former years as the basis. This is no different from using small sale percent or cost and/or management for planning. It makes most cost reduce sale and there is no profit, which leads to hiding of cost and bad behavior in transfer the cost to an account which cannot be examined and thus results in erroneous allocation of IT resources. Frequently, budget for IT resources is allocated more than the actual cost. The established and used budget did not consider the capability of the company and lead to frequent mistakes in management. As a result, budget executes business instead of the vice versa. If the business condition changes, the management will delay the budget that cannot be used. In addition, the budget department does not compare such a return for the shareholders. There is delay in reporting to the shareholders. A CIO thus proposes that it is time to change from the old budgeting method and increase the speed in approving the budget.

Strassmann (1985) suggests that IT budget should be equal to the cost in company utility plus sale, profit after tax, computer number, worker knowledge number, then minus by personnel. Strassmann defines that budget and IT investment should consider the asset values of IT (like hardware, software, development and training). In other words, it is the centralized consideration of budget that contains cost and possible investment from estimated quartile sales and pays attention in things that create values for customers.

However, bad business management process will affect IT investment in the detrimental way and increase the cost of sale. Therefore, the inactive updating of conditions is unacceptable and leads to bad cost management.

2.4.4 Benefit Realisation

Clear identification of benefits from IT investment to be direct or indirect ones is a challenge. This is especially when using common infrastructure. There have been attempts in separating cause and results from IT investment. It is not trivial when there are other activities or investments. The benefits come from technology, procedures, or personals. When the investment is complete, there can be one factor superior to the others. Technology is claimed to realize things which requires change in driving the business. Therefore, understanding of the interested party will be always used in making decision about IT investment due to its difficulty in benefit measuring. Accordingly, the decision is made without covering whole value of business or it may overestimate. There are ways to indicate benefits from IT. The easiest one is to measure benefits from the whole including persons and investment processes. Other forms contain fish-bone analysis and cause-and-effect. The assessment and value realization are founded by Thorp and DMR by using indirect relationship which connects revolution steps, design and development of IT investment. Due to its application, it is influential to organization performance. From the related parts of output and outcome, the assets have transformed such as the transformation of CRM investment by using IT to increase returns. Remenyi and Sherword-Smith (1998) propose active benefit realization (ABR) which defines outcome space. It explains the benefits from IT investment. The investment is defined as the efficient development (automate), the data development for better decision or the improved efficiency (informant), change in business operation, better driving, and product or market (transformate). Several methodologies that are used for analysis of the investment and returns are applied for the IT investment. Deterministic or stochastic methods are used in the evaluation. Stochastic method or risk analysis is used when there is a high uncertainty.

2.4.5 Total Cost of Ownership

The concept of Total Cost of Ownership or TCO is suggested by The Gartner Group in 1980. It means the total cost of personal computers in terms of thousand computers per year that the companies must provide. TCO overlooks the fixed thing due to the complexity in cost analysis. The best reduction in TCO is to review the organizations. Capital, and cost used in a single project are considered a new investment and continuous support. Maintenance is defined as the operation cost. However, there exist typical cost but not included like technical cost and user practice, the reduction of efficiency, the security penetration, the recovery from failure, and the energy usage. Understanding technological cost is not only related to the investment of new business but also the limitation of operation cost, in which the constant IT cost is not included.

The use of common infrastructure and systems needs continuous development. The new development is included to make it complete. The transfer system plays an important role in business operation which leads to low investment and effects on production, higher limitation, and lower efficiency. This results in the increase of operation cost.

The present IT architecture should be evaluated for the resistance of standard measurements in industries, the inventory management of necessary assets, and cost planning. The future architecture planning is prepared for the business path. The determination of opened architecture for common operation and complete connection will reduce the ownership cost. Efficient IT protocol, efficient workers as well as the IT plan are necessary for freedom in technology decision. Otherwise, the ownership cost will increase.

2.4.6 Loss Values

The management in IT investment does not only handle the capital and time schedule, but also the value addition to companies, the IT justification, and the evaluation including the share impacts. It also defines the steps that result in the risk adjustment of economic values which is more appropriate than DCF, ROI, cost saving, or ownership reduction. The conventional procedures may not cover the benefits of intangible values. Bad investment decision such as wrong positioning or neglecting values which are necessary happen frequently. It is clearly seen that the conventional methods and IT investment management need to combine the whole benefits not just as a financial aspect.

2.5 Risk Management

Since information technology investments involve un- certainties that must be carefully managed, the relative importance of various risks should be addressed (Wu and Ong, 2008). And risk management is a wide topic but applicable to IT investment because it is necessary to have a risk perception both controllable and uncontrollable, existing and new investment. Controllable risk includes the cost risk (import, variables related to cost), benefit risk (output and ROI), operation risk (of existing things), structural risk (changing HR), project risk (in-time budget) and technology risk (reliability and performance). Therefore, investments should take into account of these risks.

Hagen, Albrechtsen, andHorden (2008) mentioned that the risk-management perspective takes into account that failures of information security, economic perspective, legal perspective, and cultural perspective. IT investment always computes the organisation risk. Such a risk is considered a required risk for controlling the investment budget. New investment cannot generally negotiate to obtain privileges. IT investment should address the risk and reward in advance because the cost may increase but it is a way of risk reduction and helps prepare to treat the risk timely.

The uncontrollable risk is the financial risk (interest rate and cost), legal risk (approval and limitations), market risk (price and demand), industry risk (logistics), and competition risk (new market enters and differences). Such as Bojanc et al., (2012) presented mathematical model for an optimal security-technology investment evaluation by used the return on investment (ROI), the net present value (NPV), and the internal rate of return (IRR). When considering an investment, the uncontrollable variables should be considered first because they are important. CIO needs to understand important definitions, competitive positioning, and connections in organization development including their feasibilities. The failure rate of IT investment is considered high when the business environment constantly changes. The uncontrollable variables that are often found are politics and competition, which are important variables in IT risk management.

Generally acceptance of profit is the crucial factor for business, and hence it is convenience to measure the investment from the accountability using the financial methods. And some scholar mentioned that IT asset is no direct relation between IT investment and the organisation's revenue (Ferguson and Hadar, 2011). Change in technology, economic conditions, and fluctuation of market environment make IT investment risky. IT project risk depends individual factor and cannot be distributed. There are a significant number of researchers who are in doubt of the conventional investment and financial measures. They are not robust, flexible, and have possibility of deviation. The conventional ones like DCF and ROI cannot limit the value that is flexible for the unstable IT projects. The instability in IT investment and flexibility of value in management results in high non-financial values. The flexibility is efficient in the upper part whereas in the lower part it is limited. Efficient risk management is highly required in evaluating IT investment.

It is clearly seen that new techniques seem to be alternative techniques, especially when the investment has a natural investment character and high potential, high uncertainty, and indirect return. The real alternative is the investment in potential and human resource which will bring the future. Real analysis will make the theoretical selection become alternatives under uncertainty. The real alternative thus is used for the cost estimation and strategic decision because it can handle the values sensitive in the future when the external factors are uncertain. The evaluation in new dimension is needed in strategic investment and evaluation of IT more than the conventional methods. Tools for modern financial management are necessary for evaluating IT investment. It is proposed for the cost estimation and strategic decision because it can measure future values that are sensitive under uncertain external factors.

2.6 Challenges in IT Management

IT is a key source of competitive advantage in business environment. The importance of strategies, organizational spending on IT applications is rising rapidly. And IT has become a dominant part of the capital budgets in many enterprise. So the managing IT investment is a crucial challenge task for most CIO, because the costs and benefits have been hard to quantify (Chen et al., 2009). Moreover, IT investment has more different definitions than ordinary investment in computer hardware and software. There are varieties of software that can be bought, rent, lease, or brought to service. In addition, outsourcing incurs additional costs which increases the spending in balance sheet. In conclusion, the contractor and labor in internal works related to design, build, and tests will be included to the final value of goods and assets. However, the main cost due to personnel operation will be the cost that does not create benefits. This cost is the largest IT cost like in bank business where almost one out of five of personnel are IT professionals. It is the largest proportion in every industry. As the management cost is concentrated at the IT utility or in the non-profit lists, IT investment can increase the non-financial value from service improvement, upgrading system, knowledge creation, supply chain development, efficient business process, and business cycle. Therefore, IT investment is complicated nowadays and not limited to only organisation evaluation

2.7 Asset Management

In the previous chapters, the evolution of Information Technology has been explained. This IT evolution has gradually been adopted and integrated by organisations to create competitive advantage and enhance management. As with other types of assets, IT requires organisations to spend, and the IT asset itself has a specific life cycle. However, IT investment is typically regarded as a sunk cost, with no corresponding cost recovery in the form of revenue. This often results in unjustifiable investment. Hence, in order to systematically manage IT assets, an asset management framework is applied in this research and discussed in this chapter.

2.7.1 Definition of Asset Management and Related Terms

Pundney (2010) described Asset Management (AM) as "an organisation's coordinated multidisciplinary practice that applies human, equipment and financial resources to physical assets over their whole life cycle to achieve defined asset performance and cost objectives at acceptable levels of risk whilst taking account of the relevant governance, geo- political, economic, social, demographic and technological regimes". Many countries have adopted the concept of asset management, with each often defining their own terminology. It is therefore necessary to investigate the accepted definitions of asset management. In its broadest sense, asset management is the management of any physical assets. These include for example, the selection of specific assets, as well as the associated inspection and maintenance (including repair and replacement). Many realise that asset management not only requires a systematic and scientific approach, but also depends on human judgement, which some refer to as the art of management. Together, the 'art' and 'science' of investment help the organisation to make the correct decisions and systematically optimise the relevant processes. More specifically, during the period concerned with managing the asset, asset management allows visibility and management of risks associated with the asset, both in the short-term and long-term. If planned and undertaken well, asset management could assist in balancing all issues, especially costs, which are typically hard to predict and assign a value.

The asset management industry is a vital source of economic growth as intermediary in the savings-investment channel and achieve their investment goals (Walter, 2011). Historically, strategic investment decisions were made in the head office by top-level management, while local decision making processes to solve daily problems were undertaken by local/frontline workers. This was because local/frontline workers had a clearer understanding of what was going on in the field. However, as the business and asset management system grow in complexity and capability, top-level management is obliged to have a greater understanding of the situation in the field in order to grasp the opportunity and manage risk. Some might therefore conclude that asset management has become more centralised in terms of control. Others have argued that this is not the case, as the local/frontline workers might not fully appreciate the consequences of what they do in the field, especially in terms of the benefits to the organisation as a whole. Furthermore, top level management must balance asset management functionality with costs and complexity.

In relation to the discussion above, practitioners interested in asset management established the UK's Institute of Asset Management (IAM). These include for example, individuals from industry, consultants, academics and/or government personnel. IBM (2009) presented the PAS 55 asset management standard gives guidance and best practices on asset management and is typically relevant for all asset-intensive industries. PAS 55 defines asset management as "systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their lifecycles for the purpose of achieving its organisational strategic plan." (p. 2)

Campbell et al., (2011) summarise, the previous definition of asset management indicates that asset management focuses on costs, performance and associated risks. The overall objective of the asset manager is to make strategic decisions with respect to the asset lifecycle while simultaneously balancing costs, performance and associated risks. Other objectives can be given as follows:

- Improving equipment reliability
- Minimising downtime through integrated planning and scheduling and enhanced maintenance/monitoring techniques
- Maximising component life by avoiding conditions that reduce life
- Maximising equipment performance
- Minimising maintenance, through life costs and potential for conflict

In other words, the objective of effective asset management is to minimise the overall costs for the whole asset lifecycle. Furthermore, asset management is a continuous processes where the asset manager improves his/her decision making outcome each time a decision is made. This relates to the Deming Cycle; Plan, Do, Check, Act (PDCA) (Deming, 1986). Asset lifecycle processes generate, process, and analyse enormous amount of data on daily basis. Asset lifecycle management can be viewed as a combination of data based informed decisions associated with strategic, planning, and operational levels of the organisation (Haider. and Haider, 2013). Hence, it is important that the asset manager understands the asset lifecycle, which is shown in Figure 2.1.

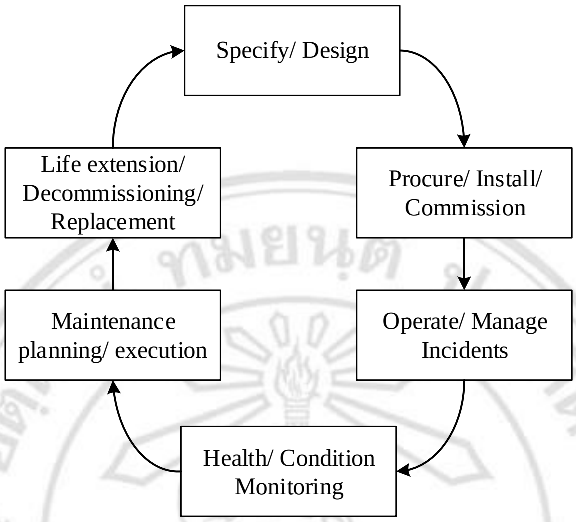

Figure 2.1 Asset Lifecycle (adapted from Minnaar et al., 2013)

Minnaar et al., (2013) mention that both PAS 55 and ISO 55001 require an organisation to set up a life cycle management plan. The plan should consider the complete life cycle of the asset, from acquisition, to utilisation, to maintenance, and finally to the disposal of the asset. Figure 2.1 illustrates the asset lifecycle, which is central to the concept of asset management. The lifecycle of each asset can generally be categorised into six states. These include specify/design, which involves identifying the required asset and is considered as the first state of the asset lifecycle, as exemplified in Figure 2.2.

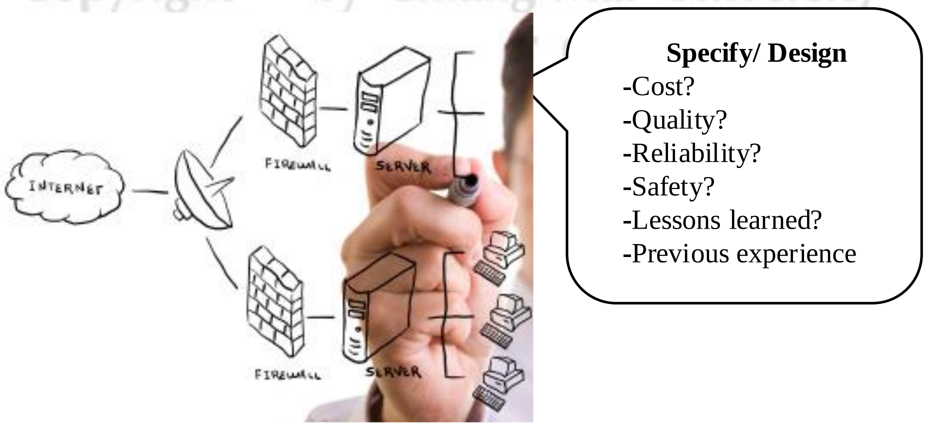

Figure 2.2 The first stage of the asset lifecycle: specify/design

The second state is procure/install/commission, which involves how to acquire the required asset, the installation of this asset at the predefined location, and the commission of this asset. This second state of the asset lifecycle is illustrated in Figure 2.3.

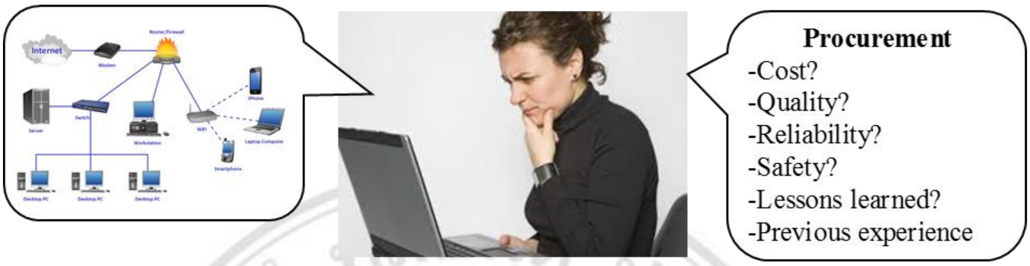

Figure 2.3 The second stage of the asset lifecycle: Procurement

The third state is operate/manage incidents, which involves the periods where this asset is being operated. The third state of the asset lifecycle is illustrated in Figure 2.4.

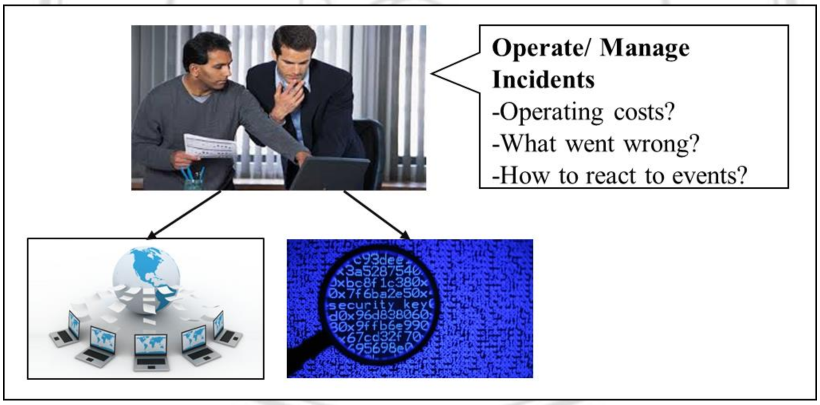

Figure 2.4 The third stage of the asset lifecycle: Operate/Management Incidents

The fourth state is health/condition monitoring which involves receiving data regarding the asset condition and making a decision whether as to whether any action is required. The fourth state of the asset lifecycle is shown in Figure 2.5.

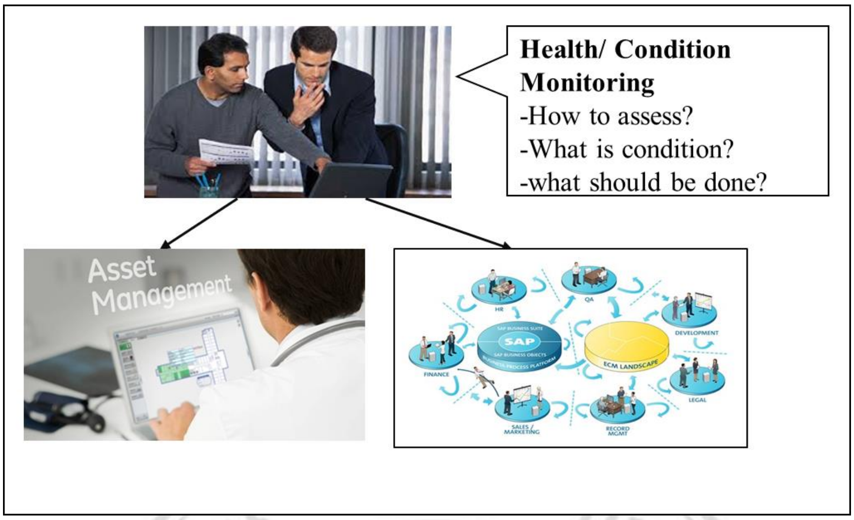

Figure 2.5 The fourth stage of the asset lifecycle: Health/Condition Monitoring

The fifth state is maintenance planning/execution, which involves keeping the asset state at an appropriate level where it can operate safely and efficiently. The fifth state of the asset lifecycle can be illustrated in Figure 2.6.

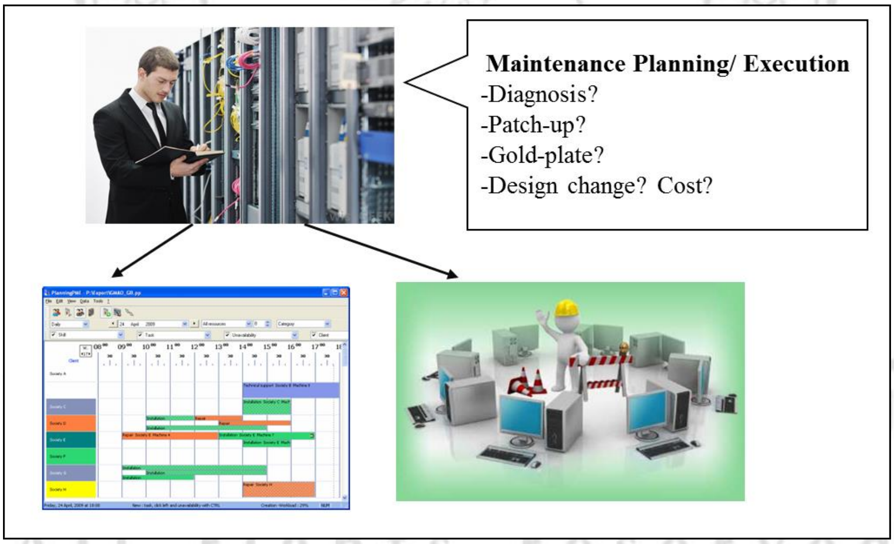

Figure 2.6 The fifth stage of the asset lifecycle: Maintenance Planning/Execution

The last state is life extension/decommissioning/replacement, which represents strategic action on the asset depending on the asset condition and the organisation’s overall objectives. This can be shown in Figure 2.7.

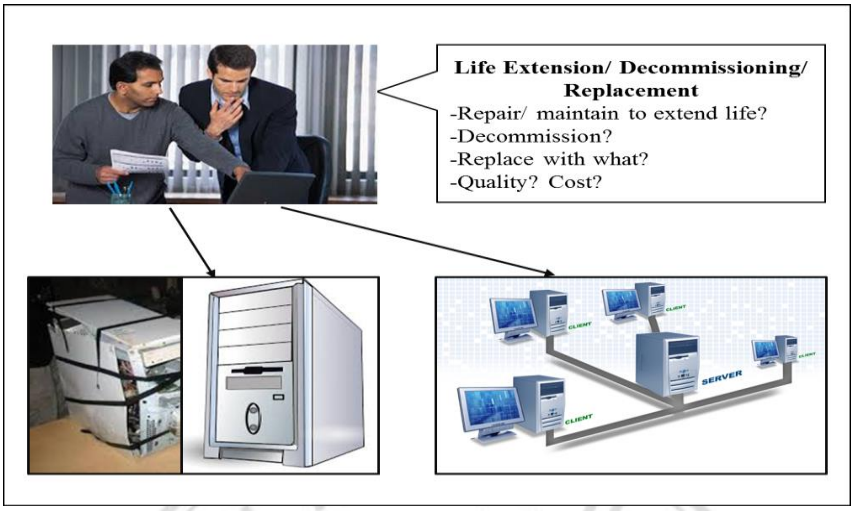

Figure 2.7 The sixth stage of the asset lifecycle: Life Extension/Decommissioning/Replacement

The example above replicates the decision making activity of just one car (one asset unit). However, in a business context, this would be significantly more complicated and would certainly present top-level management and the asset manager with difficulties. The greater the number of the assets within the asset system, the bigger the differences in capital and operating costs, different models/specifications, different reliability, and different maintenance requirements. Moreover, assets are usually operated in different environments with differing utilisation levels, constraints and requirements for safety.

In summary, an appropriate definition of asset management and its related terms can be given as follows:

- **Asset(s)**: plant, machinery, property, buildings, vehicles and other items that have a distinct value to the organisation
- **Asset management**: systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organisational strategic plan (IBM, 2009) p.2.
- **Asset management information**: meaningful data relating to assets and asset management. Examples of asset management information can cover asset registers, drawings, contracts, licences, legal, regulatory and

statutory documents, policies, standards, guidance notes, technical instructions, procedures, operating criteria, asset performance and condition data, or all asset management records.

- **Asset management objective(s)**: specific and measurable outcome or achievement required of asset system(s) in order to implement the asset management policy and asset management strategy; and/or detailed and measurable level of performance or condition required of the assets; and/or specific and measurable outcome or achievement required of the asset management system.
- **Sustainable**: Achieving or retaining an optimum compromise between performance, costs and risks over the life cycle, whilst avoiding adverse long-term impacts to the organisation from short-term decisions

2.8 The Asset Management System

The Asset Management system is how a company delivers its business goals (Woodhouse, 2007). The definition of asset management given in the previous chapter indicates that an effective asset management system requires good quality data/information with the necessary availability to support complex decision making activities. Advances in IT mean the introduction of a modern information system can be very simple, and in this sense is often described as “either requiring someone with great vision or becoming a huge disaster”. The only question is which comes first. The asset management system is no exception to this quotation.

Asset Management needs accurate data and information. However, it is universally agreed that the full body of appropriate data and information is nearly impossible to obtain and usually very costly. Hence, it is very important to achieve the right balance between what is needed and cost. The key issues when considering the information requirements of the asset management system are as follows:

- Strategic: at the level required to support ‘strategic objectives’. For example, this includes measures of corporate business, drivers of safety, performance, environment, etc.

- Tactical: to support ‘technical policy development’ (e.g. data and information to support analysis of maintenance intervention policies)
- Operational: to deliver asset related work through the efficient scheduling of resources (e.g. location data to perform work on site)
- Physical asset data: what assets are owned and operated as well as their technical characteristics
- Location and spatial links: where is the asset and how does it relate to other assets?
- Work management data: what work has been and/or will be performed on this asset?
- Performance data: how does this asset contribute to serviceability targets?
- Condition data: what is the residual life of the asset?
- Cost data: how much does the asset cost to buy and operate?
- Frequency of use: how often is the information needed in order to support business processes?
- Type: the asset type
- Specific attributes and units: the age of an asset in years
- Precision and accuracy: how exact measurements need to be and to what extent can inaccuracy be tolerated

2.9 Application of Asset Management in the Utility Industry

Asset management is concerned with making both the correct short and long term decision to efficiently manage the asset and potential costs over its lifecycle. This concept is very popular in asset intensive industries such as utilities where every aspect of business relies heavily on effective, reliable functioning of the asset systems. In the utility industry, asset management is applied to predict and manage future performance of the assets owned by the utility. Consequently, this could lead to a prediction of funding requirements and provide potential options for the future to change the way operation and maintenance are conducted. This method represents a move from passive actions to more active actions (reactive to proactive way of conducting operation and maintenance). Similar to most organisations in other industrial sectors, the utility business is concerned with and influenced by many stakeholders. These include top level management of the utility itself, the regulatory body, and the general public. All of these stakeholders usually have different perspectives on how the utility runs its business and these perspectives are often conflicting. Thus, it is crucial that a utility can justify and support its funding requirements with a definitive explanation and associated evidence.

Within the utility industry (though, not limited too solely to the utility industry), the importance of asset management arises from key issues concerned when running the business. These are as follows (Norris, 2013):

- Risks: real and acceptable levels.
- Costs: Cost of failure, enhancement and renewal costs, funding requirements and affordability.
- The availability of data and information. This refers to lesson learn data and information previously in people's heads and in various disjointed sources.
- Functions, data and required information. Create a plan to monitor, maintenance activities, equipment and spare parts.

In response to these issues, the asset management capability model has been introduced within the utility industry. Deadman (2010) suggest his model plays an important role in bringing together critical issues which usually arise during conflict among stakeholders. The key objective of the asset management capability model is to strategically decide on the type of asset management system needed, the organisational structures, and the cultural approaches suitable for its implementation. The asset management capability model is illustrated in Figure 2.8.

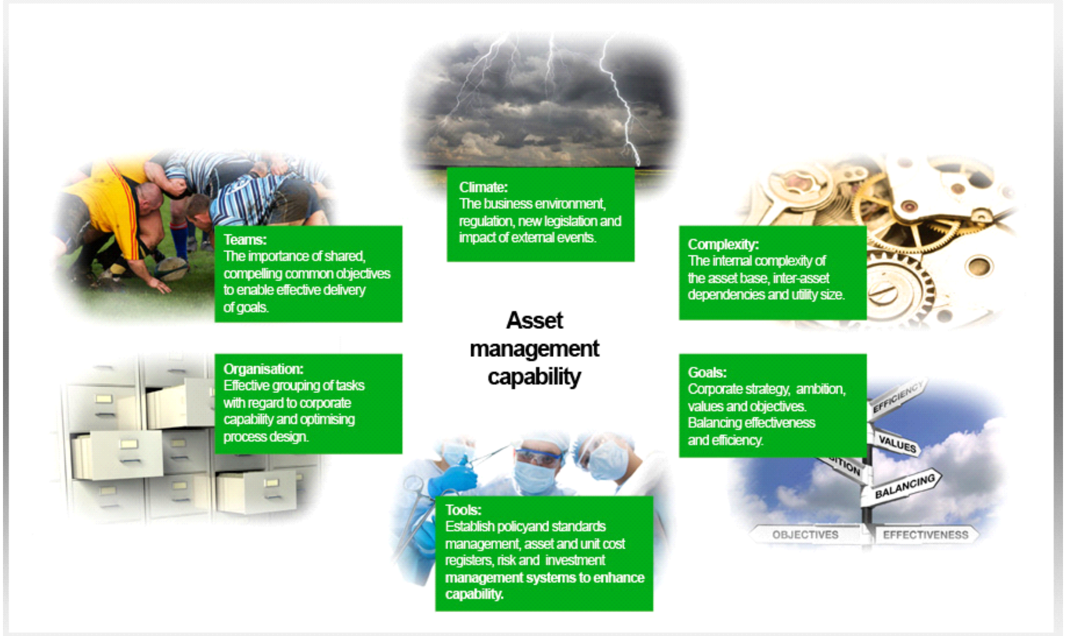

Figure 2.8 The asset management capability model (Deadman, 2010)

The asset capability model shown in Figure 2.8 comprises of three economic and commercial factors. These are climate, complexity and goals. Together these factors determine the asset management system and how the utility should undertake its asset management. A further three factors are then defined, which are tools, organisation and terms. These factors are essential elements for top level management and the asset manager when structuring and organising their business to ensure the asset management system can deliver the required business performance. With clarification and consensus of these factors, the utility receives the support it needs to develop and utilise the asset management system as well as having greater confidence in its overall performance and efficiency.

Examples of failures to implement an effective asset management system can also be seen in the utility industry. In New Zealand, the central business district (CBD) of Auckland was left without electricity after the failure of the last of four 110 kilovolt (kV) cables bringing power into the city centre. It was over two weeks before one cable was repaired, restoring a limited power supply and requiring a further two months before full power was restored. Furthermore, there was also only one 22kV reserve cable available for operation. However, this one remaining reserve cable was used to support emergency services, thus resulting in many businesses and services being forced to close or relocate.

Another example of poor asset management also occurred in New Zealand in 1998. This was known as the Mercury Power Crisis (MPC) in Auckland, which lasted for six weeks. Consequences can be summarised and given as follows:

- Severe disruption to all services and businesses in the affected areas.
- Short-term economic losses to industries and businesses operating in the affected area, in particular to the retail and hospitality industries, and industrial sectors.
- Long-term economic losses to many industries and businesses in the affected area, with an estimated long-term economic impact equivalent to 0.1-0.3% of GDP.
- The Mercury Power Crisis forced vacation of 54% of business premises, affecting 70,000 workers and 7,500 residents.
- 400 businesses failed.

One example of asset management implementation from an organisational perspective is the Office of Gas and Electricity Markets (OFGEMS) in the United Kingdom (UK). OFGEMS, is the UK regulator for electricity and gas, and proposed a three layer model to place asset management into context within utility organisations as follows:

- Asset owner (responsible for 'business strategy')
- Asset manager (responsible for 'asset strategy')
- Service provider (responsible for managing one or more parts of the 'asset lifecycle')

This three layer model proposed by OFGEMS for the facilitation of the asset management framework within utilities can be illustrated in Figure 2.9.

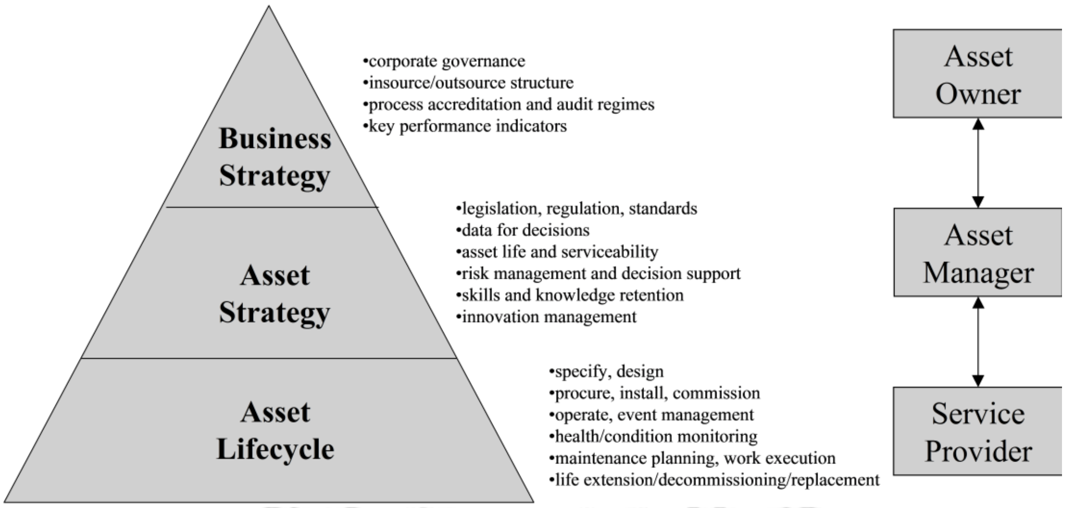

Figure 2.9 The proposed OFGEMS asset management model

The model proposed in Figure 2.9 comprises of three layers for the implementation of asset management within the utility. Each layer indicates specific responsibilities. Some responsibilities may be shared to alliances, partnerships and others. However, this requires effective planning and management. Within the utility industry, 90% of transmission companies have separated the roles of asset manager and service providers, while 50% of transmission companies have separated asset manager from asset owner. The precise allocation of each function can vary from organisation to organisation, or even industry to industry. Some organisations may adopt a 'thick' asset management function which includes many functions including the 'asset worker' layer. Others may opt for a rather more 'thin' approach to asset management which involves only the core decision making personnel. Once again, alliances and partnerships are often formed to execute some of these functions.

In summarising the factors influencing the implementation of asset management within the utility industry, the key factors are:

- Regulator: This ensures that competition exists and the consumer receives a fair deal. The interests of the consumer (and the general public) are protected in the medium to long term. Regulation itself (particularly through price controls) often represents a controversial topic
- Consumers' requirements: increased levels of supply continuity and quality are required. Consumer devices which depend on an

uninterrupted, high quality power supply are increasing in number. This consequently places greater pressure on the utility to deliver a “better” product (in terms of improved power quality and reliability of supply) than was previously demanded (or necessary).

In summary, this section has reviewed the application of asset management implementation in the utility industry and given examples of effective and ineffective asset management. The asset management model is presented and can be divided into three layers. These three layers differentiate the responsibilities accordingly.

2.10 Asset Maintenance Strategy

In the previous chapters, the definition of asset management was explored. As discussed earlier, the overall objective of the asset management framework is to minimise costs for the whole lifecycle of the asset. This results in an investigation of general asset lifecycle. To briefly summarise the asset lifecycle, it covers activities from specification/design, procurement, operation and management of incidents, health/condition monitoring, maintenance planning and execution, and life extension/decommissioning/replacement. Each of the activities mentioned has its own importance to the overall management of the asset. However, this thesis focuses primarily on the maintenance planning and execution of the asset as strategic decisions made at this stage have impacts on the overall lifecycle of the asset, and inevitably other stages as well. For example, instead of repairing the asset, replacing it with new might be a better option. Other options may be a change of function, relocation, refurbishment, and/or replacement. Hence, the following subsections are dedicated to the concept of asset maintenance.

2.10.1 History of Maintenance

In the past, skilled craftsmen conducted maintenance activity in order to repair equipment as required. Repairs usually required construction of new parts or salvation of the broken parts. This maintenance or repair activity was possible since the parts of the equipment were originally designed to be very durable. This was in part due to the fact that the evolution of equipment design was driven by close observation of in-service failures and problems. Once repairing broken parts became unfeasible, replacing them with new parts was an obvious solution. This led to the typical decision to keep spare parts in stock. These spare parts required a very accurate and repeatable construction process in order to ensure compatibility without any modification to the existing overall system. Spare parts meant that any maintenance activity required less craftsman skill and increasingly relied on diagnosis and visual inspection. This was supported by the increased complexity of the equipment being maintained.

Another influencing factor was the quality control and automation of the manufacturing processes which ensured the quality of products and reduced production costs. This resulted in the whole product becoming cheaper to replace than repair. This was especially true where special fit parts or expensive skilled craftsmen were required. Consequently, an unavoidable scenario occurred where there was shortage of skilled workers. Lesser skilled workers could still undertake maintenance tasks, but not all of the work. From a wider perspective, this influenced the asset design from being repairable to non-repairable. Ultimately, maintenance strategy and policy within the organisation were adapted to rely on engineering judgement/experience instead of vendor recommendation.

The history of maintenance can be summarised and illustrated in Figure 2.10.

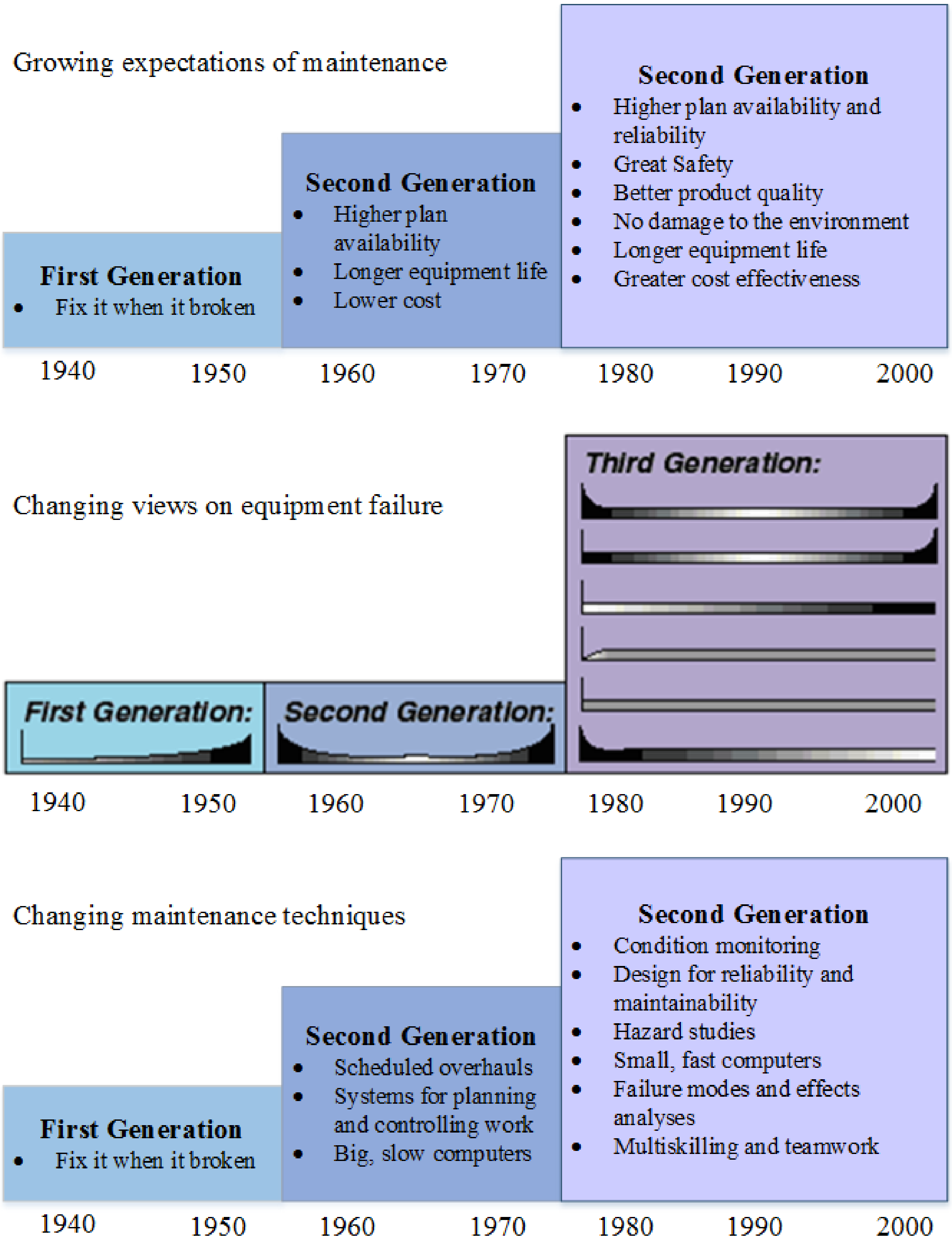

Figure 2.10 Summary of maintenance history

Figure 2.10 illustrates the summary of maintenance history from three perspectives. The first is the growing expectation of maintenance from simple corrective action. The First Generation, the things are fixed either after failure or during failure (Moubray, 1997). This maintenance type is emergency, repair, unscheduled and remedial tasks (Mobley, 2004). This method has been a major part of the maintenance operations since the first manufacturing plant was built.

The second perspective represents the evolving views on equipment failures from just one view to multiple possible scenarios. The last is the changing maintenance techniques, again resulting from simple corrective action to complicated decision making solutions depending on various factors.

2.10.2 Maintenance Strategy

Traditionally, the purpose of maintenance activities is to ensure that the equipment performs its function accurately and satisfactorily. Salonen and Deleryd (2011) stated that the large part of the organisations operating budget are constituted by maintenance and investments in machinery and equipment. Maintenance represents 10-40% of the production cost in a company, however it is further argued that some figures believes it might be as much as 15-70% of the total production cost. Onwards, about 30 % of maintenance costs are related to unnecessary expenditures, due to bad planning, overtime, unmet preventive maintenance, etc.

This would then reduce the overall costs incurred by repairing the asset prior to its deterioration, thus avoiding greater critical damage beyond possible maintenance. Finally, maintenance is done in order to avoid unexpected outages which could result in higher overall costs and risks to the systems. These maintenance strategies and activities could then be divided into corrective action to resolve the failure, preventative action to avoid future damage, and predictive action to monitor critical parts of the equipment or the system. This can be summarised in Figure 2.11.

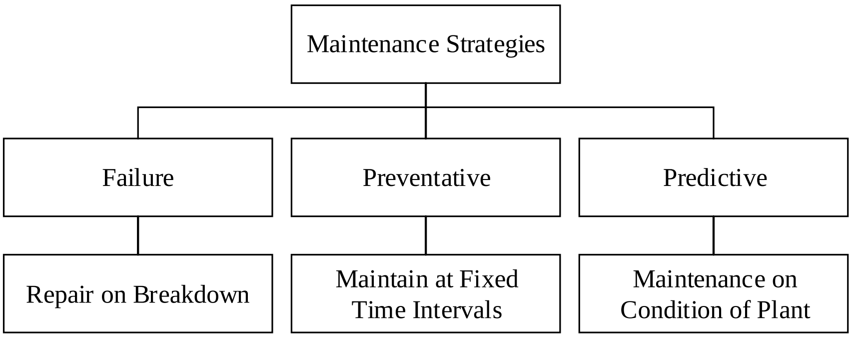

Figure 2.11 Maintenance strategies (adapted from Mobley, 2004)

The maintenance strategies shown in Figure 2.11 include correction, prevention and prediction. Corrective action represents maintenance activities based on failures only when and where a breakdown occurs. Mobley (2004) refer that preventive action represents maintenance activities at fixed time intervals. Sometimes this preventive action is referred as calendar based maintenance. This preventive action is done to avoid possible failure using the past knowledge/experience gained from the corrective actions. The predictive action represents maintenance activities based on the condition of the equipment or the systems. For example, when the reliability of the system is compromised or where the risk is high. Hence, sometimes this predictive action is referred to as condition based maintenance.

The key points of the failure/reactive maintenance (corrective action) can be summarised as follows:

- "If it isn't broken, then don't fix it"
- A survey showed that >50% of the major industrial companies are still operating in this mode.
- It continues to be the predominant method of maintenance in many domains.
- The benefits of a failure based maintenance regime include:
    - relatively low costs
    - requires low staff levels (although staff problems and/or resource problems could be experienced if several items of equipment fail at or around the same time)

- allow equipment to run until breakdown – maximum life of equipment is always utilised

- simple approach - very effective where consequences and costs are low

The drawbacks of a failure based maintenance regime include:

- increased costs due to the unpredictable nature of activities – unplanned outages
- increased labour costs – overtime working hours may be required
- inefficient use of maintenance staff resources – peaks and troughs
- inventory problems - difficult to plan requirements
- consequential damage - e.g. oil pump failure causes engine seizure, breaker failure causes large amounts of system isolation
- safety considerations

Key points of the periodic/preventive maintenance approach can be summarised as follows:

- Preventive (also known as periodic and calendar-based maintenance) maintenance is concerned with detecting, precluding, or mitigating degradation of a component or system with the aim of sustaining or extending its useful life.
- (Should) reduce unexpected failures – this is expanded upon later.
- Represents a step forward from reacting to breakdowns to preventing breakdowns.
- Maintenance activities within a preventive maintenance programme are usually based on specific time intervals.
- These intervals can be defined in terms of calendar days, equipment run time or duty (e.g. 2 days at 50% full load = 1 day at 100%), etc.
- Downtime in an automobile plant assembly line is at a onetime cost of $10,000 per minute. Relating this to lost production time, an automobile manufacturer reported that the establishment of a PM

program in their 16 assembly plants reduced downtime from 300 hours per year to 25 hours per year.

- Traditionally based on the concept of the bathtub curve.
- Unfortunately, reliability centred maintenance is based on research conducted by United Airlines and the rest of the aircraft industry showed that very few non-structural components exhibit bathtub curve characteristics. Their research showed that only about 11% of all components exhibit wear-out characteristics, but 72% of components do exhibit infant mortality characteristics.
- This probably applies to many items of utility plant

Key points of predictive maintenance can be summarised as follows:

- Referred to as predictive maintenance (or as a type of predictive maintenance technique)
- Maintenance is scheduled based on the analysis of data collected on the condition of the machine or equipment, not necessarily on any set schedule
- To be effective, the equipment being monitored must have sufficient instruments to obtain meaningful data
- An automated means of collecting, storing and analysing the data is also helpful
- In some cases, technology has been allowed to drive this philosophy and this has resulted in the development of several costly systems that are not economically justifiable
- Care must be taken to ensure that technology is applied effectively
- Systems may be advisory or executive in nature (e.g. automatically removing the plant from service upon the detection of certain conditions – this is where the boundaries between monitoring and protection can become less clear)
- Clear relationship between observables and condition
- Knowledge of failure modes (and pre-failure/indication of incipient failure) and effects must be available

- System must respond quickly enough to provide adequate warning of deterioration/impending failure
- No (or a minimal number of) ‘false alarms’ should be generated
- Data measurement & recording infrastructure must exist
- Benefits must outweigh implementation and running costs
- Data and knowledge relating to the equipment being monitored/maintained must be available

From the maintenance strategies discussed above, maintenance options can then be summarised into breakdown (run to failure), periodic or preventive action, condition based action and reliability centred maintenance. Generally speaking, the organisation usually adopts preventive action or sometimes the breakdown (run to failure) option for non-critical assets. Condition based and reliability based maintenance are used extensively in airline and military applications where the consequences of failure are much higher and cause significant impact to the general public.

This section has provided an explanation of the asset maintenance strategy, which is central and essential to the overall asset lifecycle. The maintenance scheme has moved from repairs using skilled craftsmen to more sophisticated action with diagnostic and analytical knowledge. Currently, several maintenance schemes and techniques are available, and sometimes the basic technique represents the best option. The selection of an appropriate maintenance scheme and technique depends on the understanding of asset performance, failures modes, and/or failure curves. Hence, data and knowledge are important elements. As seen from the development of the maintenance scheme, it is crucial to ensure that effective basic understanding is achieved before investigating more advanced options.

Moreover, maintenance management comprises several aspects. Such as Wireman (2010) presents 16 different aspects which contribute to an understanding of the maintenance function within a company. For example, maintenance organisations, maintenance training, planning and scheduling, preventive maintenance, reporting, etc.

2.11 Asset Management Methodology – PAS 55

In previous chapters, a discussion on the concept of asset management was provided. This begins with an investigation of the definition of asset management, and considers the application of asset management in the utility industry, and asset maintenance strategies. This chapter now explains the methodology developed to facilitate the implementation of asset management within the organisation. This methodology is known as ‘Publicly Availability Specification’ or PAS55. The details of PAS55 are discussed in the subsections below.

2.11.1 Background of PAS55

The Institute of Asset Management and the British Standards Institute (BSI) worked together to develop strategies to help reduce risks to business- critical assets. This project resulted in the Publicly Available Specification (PAS) 55-1: 2008: Asset Management standard, first published in 2004. This new standard is the culmination of the latest thinking in terms of best practices in asset management systems (IBM, 2009). PAS55 is sponsored by the industry, passed on to many review panels for quality control and industrial compatibility, and could become BS, ISO, CEN or IEC by using one language and common terminology. PAS55 was first published in 2004 as the British Standard for Industry (BSI). The very first sector adopting this framework was the electricity and gas industries in the UK represented by OFGEMS. As a regulator of electricity and gas industries, OFGEMS asks companies doing business within the electricity and gas industries to adopt PAS55 to ensure transparency and highlight good governance. Today, all companies in the UK electricity and gas industries are compliant with PAS55. In 2008, the updated version of PAS55 was published and comprises a 28 point requirements specification. This updated PAS55 can be divided into two parts. Part 1 provides a glossary and terminology for asset management, while part 2 provides guidance for asset management implementation within the organisation.

2.11.2 Overview of PAS55: 2008

In this thesis, the updated 2008 version of PAS55 is utilised and is fundamental to the development of the ITAM proposed in this research. This updated 2008 version of PAS55 is referred to in this thesis as PAS55: 2008. As noted previously, there is a 28 point requirements specification in PAS55: 2008. These requirements are to ensure the effective and appropriate processes are conducted within the organisation. Consequently, this requires the organisation to show evidence of what is being done and the rationale behind the actions. How the asset management is conducted is left to the organisation to decide and could vary widely from organisation to organisation. Due to the development principles, the PAS55: 2008 is not attached to any specific industry, nor it is attached to any specific asset types, asset distribution and/or asset ownership structure. Furthermore, the location of the asset in the system does not matter. The important aspect is the alignment of an organisation's objectives with what is being done in the field. Hence, it can be said that PAS55: 2008 requires the organisation to indicate competence in asset management, and focus on good practice.

Benefits to an organisation adopting the PAS55: 2008 can be summarised as follows:

- Enhanced customer satisfaction from improved performance and control of product or service delivery to the required standards
- Improved health, safety and environmental performance
- Optimized return on investment and/or growth
- Long-term planning, confidence and performance sustainability
- The ability to demonstrate best value-for-money within a constrained funding regime
- Evidence, in the form of controlled and systematic processes, to demonstrate legal, regulatory and statutory compliance;
- Improved risk management and corporate governance, and a clear audit trail for the appropriateness of decisions taken and their associated risks
- Improved corporate reputation, the benefits of which may include enhanced shareholder value, improved marketability of

product/service, greater staff satisfaction and more efficient and effective procurement from the supply chain

Apart from the glossary, terminology and implementation guideline, PAS55: 2008 also identifies other elements crucial to the successful implementation of asset management within the organisation. These are organisational structure, staff awareness and adequate information and knowledge. These are shown in Figure 2.12.

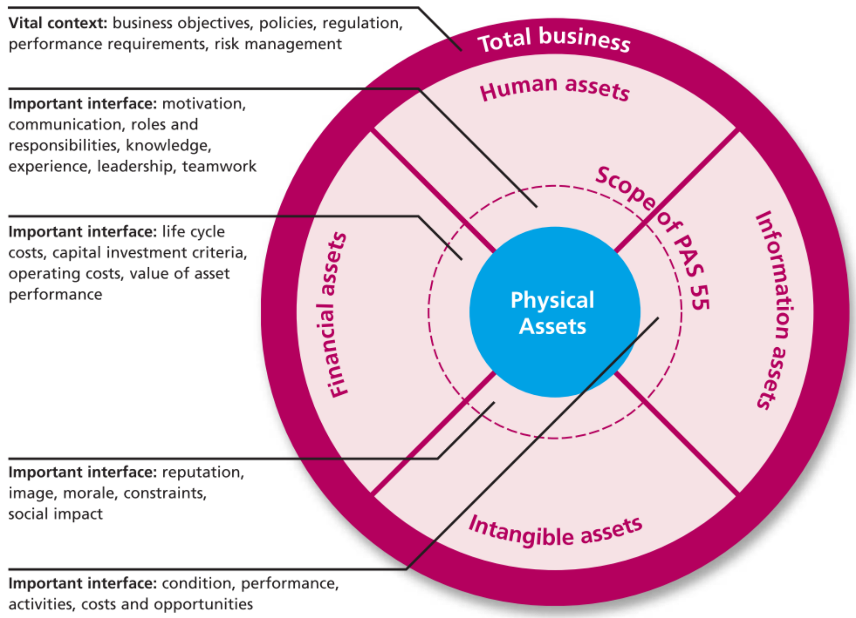

Figure 2.12 The focus and business context of PAS55 (IAM, 2004 and IBM, 2009)

Figure 2.12 illustrates the focus and business context of PAS55: 2008 in relation to other asset categories. The organisational structure is considered important to facilitate the implementation of asset management with clear authoritative leadership. Staff awareness as well as competence and commitment are fundamental to successful implementation as staff operate the assets. This is usually cross functional. Last but not least, adequate information and knowledge regarding the asset condition, risks, costs and performance is crucial.

2.11.3 Overall Structure of PAS55: 2008

As mentioned previously, there is a 28 point requirements specification in PAS55; 2008. These requirements are to ensure that the organisation indicates its asset management competence. These requirements can be summarised and illustrated in Figure 2.13.

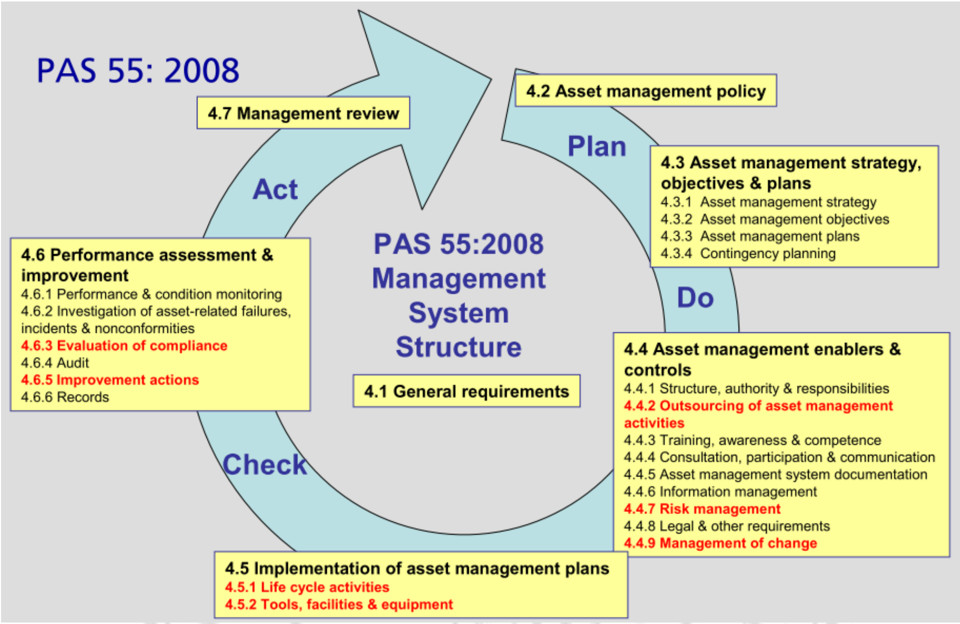

Figure 2.13 Overall structure of PAS55: 2008 (IBM, 2009)

Figure 2.13 illustrates the 28 point requirements specification which forms the overall structure of PAS55: 2008 or the asset management system. This overall structure emphasises that asset management is a continuous processes and the outcome of the decision making activities improves every time a decision is made. In other words, these requirements can be categorised into subsets according to the Plan-Do-Check-Act (PDCA) of the Deming cycle. A detailed explanation of each subset based on PAS55: 2008 part 2 is given as follows:

Asset Management Policy

- The organisation's top management shall authorize an overall asset management policy
- The policy shall:

- be derived from, and be consistent with, the organisational strategic plan
- be appropriate to the nature and scale of the organisation's assets and operations
- be consistent with other organisational policies
- be consistent with the organisation's overall risk management framework
- provide the framework which enables the asset management strategy, objectives and plans to be produced and implemented
- include a commitment to comply with current applicable legislation, regulatory and statutory requirements and with other requirements to which the organisation subscribes
- clearly state the principles to be applied, such as health and safety or sustainable development
- include a commitment to continual improvement
- be documented, implemented and maintained
- be communicated to all relevant stakeholders
- Be reviewed periodically

<u>Asset Management Strategy, Objectives and Plans</u>

- The strategy shall:
    - be derived from, and be consistent with, the asset management policy and the organisational strategic plan
    - be consistent with other policies and strategies
    - identify and consider the requirements of relevant stakeholders
    - consider the life cycle management requirements of the assets
    - take account of asset-related risks and criticalities
    - identify the function(s), performance and condition of existing asset systems and critical assets

- state the desired future function(s), performance and condition of existing and new asset systems and critical assets, on timescales aligned to those of the organisational strategic plan
- clearly state the approach and principal methods by which assets and asset systems will be managed
- provide sufficient information, direction and guidance to enable specific asset management objectives and asset management plan(s) to be produced
- include criteria for optimizing and prioritizing asset management objectives and plans
- be communicated to all relevant stakeholders, including contracted service providers
- be reviewed periodically to ensure that it remains effective and consistent with the asset management policy

- Asset management objectives
  - be measurable (i.e. quantified and/or capable of being demonstrated as achieved through objective assessment)
  - be derived from, and consistent with, the asset management strategy
  - be consistent with the organisation's commitment to continual improvement
  - be communicated to all relevant stakeholders, including contracted service providers
  - be reviewed and updated periodically
  - consider legal, regulatory, statutory and other asset management requirements
  - take account of asset management related risks
  - consider improvement opportunities including new technologies and asset management tools, techniques and practices

- Asset management plans
    - creation, acquisition or enhancement of assets
    - utilization of assets
    - maintenance of assets
    - decommissioning and/or disposal of assets
    - include tasks, responsibilities
    - be communicated and reviewed
    - maintenance also includes inspection, condition monitoring, functional testing, repair, refurbishment, and/or life extension of assets
    - replacement of individual assets may also be considered as maintenance of asset systems
    - asset management plan(s) can be for individual assets, asset types, asset systems, whole asset portfolios and/or the overall asset management system
    - essential that the plans are clearly linked to the asset management strategy and objectives that they are intended to achieve
    - the development of asset management plan(s) and life cycle activities shall include consideration of the impact of actions in one life cycle phase upon the activities necessary in other life cycle phases
    - the asset management plan(s) shall be optimized and the actions prioritized. Multiple plans (for example, covering a portfolio of asset systems or assets) shall be jointly optimized and prioritized (many more details)
- Contingency planning
    - Establish, implement, and maintain plan(s) and/or procedure(s) for identifying and responding to incidents and emergency situations, and maintaining the continuity of critical asset management activities

    - Plans should include all risks, mitigations, responses, personnel, processes, recording of information, essential personnel, communication plans, provision of resources
    - Must be reviewed and tested regularly

<u>Asset Management Enablers and Controls</u>

- Structure, authority and responsibilities
    - Clear structure, roles, responsibilities
    - Evidence of commitment from top management
    - Promotion of asset management
    - Visibility
    - Ensure compliance with asset management policy, strategy and plans throughout the organisation
    - Communication and processes in place
- Outsourcing
    - Organisation must retain control and visibility of all activities and their consequences
    - Processes must be documented and scoped
    - Must be fully integrated with asset management activities
    - Boundaries, sharing of information
- Training and competence
    - All staff (core and contractors/outsourced) must be demonstrably competent
    - All staff must have training and information to ensure that they understand risks, asset plans, roles procedures, consequences of deviation from stated activities
    - Use of competency frameworks
    - Regularly reviewed
- Risk Management
    - The organisation shall establish, implement and maintain documented process(es) and/or procedure(s) for the ongoing identification and assessment of asset-related and asset

management-related risks, and the identification and implementation of necessary control measures throughout the life cycles of the assets

Implementation of Asset Management Plans

- Implementation
    - Ensure processes are followed and implemented for creation, acquisition or enhancement of assets; utilization of assets; maintenance of assets; decommissioning and/or disposal of assets
    - Tools and equipment must be fit for purpose - calibrated, maintained

Performance Assessments and Improvement

- Performance assessment
    - Identify trends, risks of non-conformance, under-performance
    - Monitor effectiveness of the asset management system
    - Identify improvement opportunities
    - Audits and records are important
    - Communication to all stakeholders

Management Review

- Top management shall review at intervals that it determines appropriate the organisation's asset management system to ensure its continuing suitability, adequacy and effectiveness. Reviews shall include assessing the need for changes to the asset management system, including asset management policy, asset management strategy and asset management objectives.
- Lots if input data/reports required – danger of overload
- Important to produce concise statistics
- This process should be visible to stakeholders (including regulators)

2.12 Knowledge Management

Knowledge is regarded as one of the key factors with potential to provide significant competitive advantage to any organisation. While this concept is not new, recognition of the importance of knowledge has gained momentum, especially in the current global economy, where information plays an important role in every organisation's strategy. As a consequence, a certain amount of an organisation's annual budget is allocated for the sole purpose of acquiring relevant expertise and improving the competency of the knowledge workers within the organisation. However, in contemporary business environments and the existing economy where capital is allowed to move freely, this has also posed concern to the organisation. This is due to the fact that knowledge workers and expertise are categorized as human capital. Hence, this could also fall into the same scenario as other types of capital, where the organisation and its knowledge workers part ways when their objectives no longer match. This resulting staff turnover can be a very damaging issue as knowledge workers take valuable experience with them, often including knowledge relating to major critical tasks. Knowledge retention activities are therefore required to leverage this valuable knowledge within the organisation and avoid the dependency on individual knowledge workers. This has seen many organisations employing the knowledge management discipline, either implicitly or explicitly, to manage organisational knowledge in order to develop, retain and reuse such knowledge in a way that sustains the organisation's competitive advantage.

Knowledge management (KM) can typically be categorized into three perspectives. The first is the business perspective where focus is on the business framework and organisation productivity resulting from KM implementation. The second is the behaviour perspective, where focus is on the learning behaviour of the knowledge workers within the organisation and on facilitating an appropriate learning environment. The last is the information technology perspective where focus is on the management of the information to best suit the organisation's objectives. As a result, the implementation of KM would allow the organisation to fully utilize its knowledge assets by applying the most suitable KM perspective. Since the rapid advance and wide adoption of IT within organisations, IT has become essential, acting as a major enabler for effective KM implementation. This is universally known as a knowledge management system (KMS). However, without the right knowledge being available to share and use, the KMS becomes merely another IT system in the organisation. Hence, the knowledge/information contents of the system are considered the most important component. The acquisition of the required knowledge, and the subsequent interpretation and dissemination becomes very important, and it is in these aspects that knowledge engineering (KE) plays an important role in the KMS implementation. KE provides a method and methodology to design and construct knowledge systems. The activities include capturing, analyzing, validating and modeling a domain of knowledge. Several knowledge engineering approaches have been developed over the previous decades, but the most universally accepted is CommonKADS, which offers a set of guidelines for knowledge analysis and data structuring as well as the design and implementation of knowledge systems. CommonKADS has been widely applied in many domains where there are problems with data availability for decision making activities, and human judgment becomes essential.

2.13 Knowledge and Knowledge Management

In the past, the economy was influenced by economies of scale where bigger was generally better. However, with more complexity added to the economy, and specific customer requirements, the result has been a shift to an economy depending more on the speed of decision making. This is also known as the economy of speed, where production must ensure products reach the market faster than competitors. Customers' requirements need to be responded to quickly and specifically. The implication is that the organisation needs to change the way it runs its business. Every resource, including human capital, needs to be fully utilized to its maximum level. Failures are no longer acceptable meaning unnecessary time and costs and are no longer affordable. In order to compete in this economy of speed, organisations require more than tangible, financial assets; they also need appropriate intelligence to utilize these financial assets in the most suitable way. This is where KM has a useful role and as such, it is important to discuss and define 'knowledge', which is a fundamental term used in this research.

Figure 2.14 shows the relationship among related terminology, including knowledge.

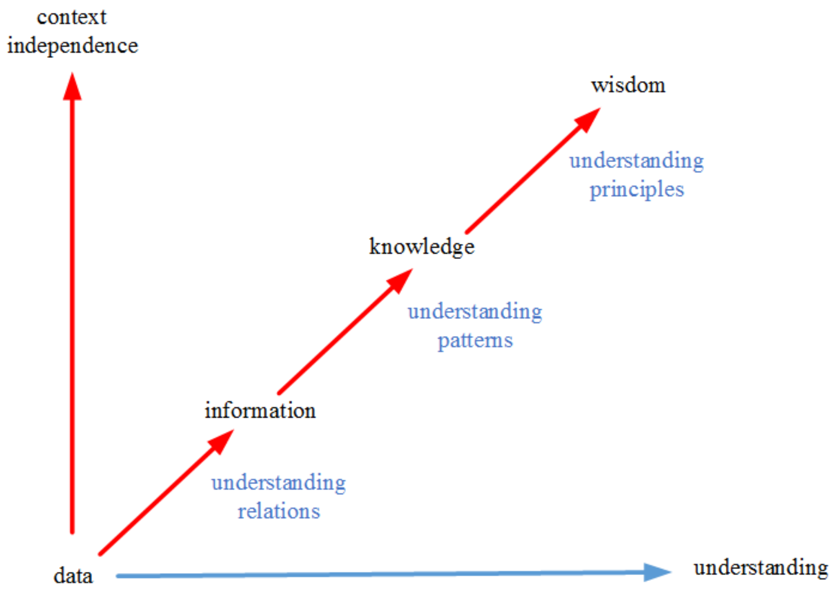

Figure 2.14 The relationship between related terminologies

Data, information and knowledge are three often-encountered words and are frequently used interchangeably [38]. However, in the context of knowledge management and knowledge engineering, these terms represent different meanings in their own right. Data refers to un-interpreted signals received by sensory devices. These include for example, human sensory organs (i.e. eyes, ears, or nose), or hardware sensors (i.e. thermometer, clock, or measuring devices typically used in people's daily living). Hence with this definition, data is raw, simply exists, and could be in any form. Whether data is usable or not does not matter, since it data has no intrinsic meaning. Once this data is interpreted into patterns by visualization or basic statistical analysis, it provides some meaning. Hence, this raw data is transformed into information. The meaning can be useful, though not necessarily. When this information is used practically in any situation, the cause and effect of utilizing this information is perceived thorough reasoning. From a human perspective, knowledge is often referred to as knowledge workers, while from an IT perspective, knowledge is often referred to as information for action. Once the organisation accumulates many collective knowledge sets, it gains wisdom which can be used where and when appropriate. There usually no difficulty in collecting data, which is easy and straightforward. This can be undertaken via reading sensors or measuring devices. Interpretation of data to obtain useful information may require an understanding of the subject or some training. But to possess knowledge, people need workplace learning and job experiences.

People use knowledge to solve problems and during decision making activities. The level of knowledge usage depends on the complexity of the problems and the level of expertise of the knowledge users. Peter Drucker (2002), the well-known philosopher, coined the term '*knowledge worker'* by characterizing knowledge workers *as* those who have high levels of education and specialist skills and combined with the ability to apply these skills to identify and solve problems. In this context, managing knowledge is like managing people who have such knowledge.

There are several lucid and effective definitions of knowledge management (KM) given by philosophers, but the meaning given by Newman and Conrad (1999) is simple and easy to understand. Newman and Conrad proposed the general knowledge model for organizing knowledge flows into four primary activity areas. These are knowledge creation, retention, transfer and utilization. The graphical representation of this model is shown in Figure 2.15

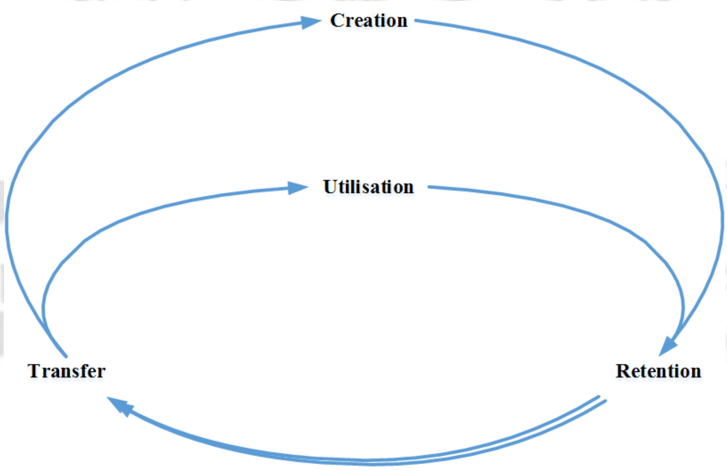

Figure 2.15: The general knowledge management model (Newman and Conrad, 1999)

The description of the each knowledge activity in this model is as follows (Newman and Conrad, 1999):

- *Knowledge Creation*: this comprises activities associated with the entry of new knowledge into the system, and includes knowledge development, discovery and capture.
- *Knowledge Retention*: this includes all activities that preserve knowledge and allow it to remain in the system once introduced. It also includes those activities that maintain the viability of knowledge within the system.
- *Knowledge Transfer*: this refers to activities associated with the flow of knowledge from one party to another. This includes communication, translation, conversion, filtering and rendering.
- *Knowledge Utilization*: this includes the activities and events connected with the application of knowledge to business processes.

Apart from the definition of knowledge management mentioned above, there is also a significant body of literature that explores and investigates the field of knowledge management in depth. However, the most well-known and cited are publications from David A. Garvin (2000), Ikujiro Nonaka and Hirotaka Takauchi (1995), and Peter M. Senge(1990). This literature provides the fundamental constructs for creating, retaining, transferring, measuring and utilizing knowledge. As Bhagavad-Gita says “the wise see knowledge and action as one” meaning that knowledge cannot be obtained without actions. Garvin (2000) introduced the concept of the learning process of people to acquire knowledge where the key concept is not to get people out of the field to train in the classroom or training session. Instead, the focus is to create opportunities for people to transform their usual daily tasks into learning opportunities. This has led to the term ‘learning in action’. Garvin indicates that the most important aspect is not what people learn, but how to learn. He continues by outlining the processes of acquiring knowledge and emphasizes the importance of team leadership. Argyris (1973) proposes double loop learning theory, which pertains to learning to change underlying variables (governing variables) and assumptions. An important aspect of the theory is the distinction between an individual's ‘espoused theory’ (what they would like others to think they do) and their ‘theory-in-use’ (what they actually do). Bringing these two into congruence is a primary concern of double loop learning. The focus of the theory is on solving problems that are complex and ill-structured. The improved effectiveness in decision-making and better acceptance of failures and mistakes are the most expected end results of the double loop learning concept. Senge (1990) emphasizes the role of human components of the company. Not only do people cultivate their limited territory and privileges, but they also have to work together and take responsibility for their shared future. That is to work on creating maximum synergy and maximum ability to deal with the whole situation. As previously mentioned, the human is the crucial ingredient in cultivating KM and Senge lays down the foundation of the human role and how to tap and exploit the knowledge residing within people. Ikujiro Nonaka (1995) proposes the means to manage both explicit and tacit knowledge from the individual to organisational level. The SECI model is proposed by Nonaka and provides a mechanism to tap organisational knowledge and embed it within the processes and products of the company. He also advises the enabling conditions and five-phase model of the organisational knowledge creation process. Finally, Edvinsson (1997) explores knowledge management from a slightly different perspective. He considers intellectual capital primarily as the hidden values constituting the gap between market value and book value. To leverage these intangible assets, the organisation must know relative to others in the marketplace, what the staff know and how this provides the organisation with a competitive advantage. He proposed the framework to structure, and measure these intangible assets in the form of intellectual capital within the organisation. This is also known as the Skandia Model, which is basically a guide for management and knowledge worker activity. It also helps orient objective setting and guides the performance of knowledge workers in terms of five focus area: financial, customer, human, process, and renewal/development. Table 2.1 provides a summary of the knowledge management frameworks given by knowledge management gurus mentioned above.

Table 2.1 Knowledge management frameworks

Framework	Concept	Feature	Organisation
Double-Loop Learning (Argyris, 1973)	Balance How with Why	Prevent human Error from Defensive Routine	Teaching the Smart People How to Learn
The Fifth Discipline (Senge, 1990)	System Dynamics for Changes	Prevent Snow Balling, Balance Operating Parameters	Develop learning skill during Changes
Knowledge Creating Company (Nonaka, 1995)	Knowledge Creation Process	Create Innovation	Knowledge production
Intellectual Capital (Edvinsson, 1997)	IC measurement	Market value control	High IC public company
Learning in Action (Garvin, 2000)	Action to Learning Opportunity	Develop learning skill at work	Critical tasks or core business line

Table 2.1 summarises the key concepts of each knowledge management theory. Each theory focuses on tackling knowledge worker problems from different perspectives. Any organisation wishing to implement knowledge management must select the most suitable theory according to its nature, culture and expected productivities.

2.14 Knowledge Engineering

While knowledge management focuses on overall business outcomes and organisational productivity with the use of IT, knowledge engineering provides a method and methodology to design and construct knowledge systems. Its methodology includes capturing, analysing, modelling, validating and storing a domain of knowledge. Knowledge engineering is the process of codifying an expert's tacit knowledge and experiences in such a form that can be stored, accessed and processed by a computer system. It helps organisations transform tacit knowledge residing in people's head into an explicit form in order that the knowledge can be stored and disseminated easily among users.

Some recognize knowledge engineering's similarity with software engineering where activities cover requirements analysis, design and implementation. This is also true since the end product of knowledge engineering is often the IT based knowledge management system. Knowledge engineering was originally developed as part of the artificial intelligence (AI) domain, with the objective of providing methods and tools for constructing knowledge based systems in a systematic and controllable way. It involves integrating knowledge into computer systems in order to solve complex problems normally requiring a high level of human intelligences. At present, knowledge engineering refers to the building, maintenance and development of knowledge-based systems.

The core element in the knowledge engineering process is concerned with how to acquire both tacit knowledge residing in knowledge workers and explicit knowledge usually in the forms of documents or IT systems. Over the years, a variety of methods and techniques have been developed and introduced by scholars and experts in the industry to facilitate the knowledge elicitation process. The principles having been laid out for such efficient and effective acquisition rely on the following:

- Recognize that there are different types of knowledge; e.g. declarative and procedural knowledge, static and dynamic knowledge, tacit and explicit knowledge, or abstract and specific knowledge.
- Recognize that there are different types of experts and expertise, depending on their training and experience.
- Recognize that there are different ways of representing knowledge.
- Recognize that there are different ways of using knowledge.
- Use structured methods.

2.14.1 Knowledge Elicitation

Knowledge elicitation is the process of acquiring the data/information/ knowledge/experience needed prior to the modelling of knowledge. There are a number of elicitation techniques such interviewing, protocol analysis, laddering, concept sorting and repertory grid. The application of each technique depends on the type of knowledge, the type of expertise, or the methods of knowledge representation mentioned above. However, the most commonly used is the interview method. By interviewing, both elicitors (knowledge engineer) and knowledge providers can engage naturally and freely by interacting with each other. The interview method can be divided as follows:

- Unstructured interview: no agenda set by either interviewer or expert, but this does not necessarily mean there is no goal for the interview. The goal is clearly defined between both parties, but the detail for conducting knowledge elicitation is dynamic and adapted to the situation.
- Structured interview: this has the advantage that it provides structured transcripts that are easier to analyze and control in terms of interviewing time. However, it might prevent experts freely revealing their knowledge. Experts do not work through a particular scenario extracted from the domain by the interviewer, rather the experts generate their own scenarios as the interview progresses.
- Semi-structured: a compromised technique between unstructured and structured would be most suitable.

As mentioned above, each interview technique has its own advantages and disadvantages. An effective way to perform knowledge elicitation using interview is to start with an unstructured interview to allow experts to freely express how they would solve a problem. This would provide an opportunity for the knowledge engineer to feel familiar to the knowledge subject. After a general outline of the task is described and some key concepts are identified, a structured interview can then be used to focus on some specific issues that exist and to induce another concept. In addition, the structured interview also assists the knowledge engineer in obtaining information about key concepts and their relations. During the structured interview, it is however helpful to limit the elicitation interview to a set of question probes, each with a specific function. This is to prevent the interview from broadening to and becoming irrelevant. Table 2.2 contains a list of probing questions which were applied to get insightful information.

Table 2.2 Probes to elicit information in structured interviews

Probe Code	Question template	Effect
P1	*Why would you do that?*	Converts an assertion into a rule
P2	*How would you do that?*	Generates lower-order rules
P3	*When would you do that?* *Is<the rule>always the case?*	Reveals the generality of the rule and may generate other rules
P4	*What alternatives to <the prescribed action/decision> are there?*	Generates more rules
P5	*What if it were not the case that <currently true condition>?*	Generates rules for when current condition does not apply
P6	*Can you tell me more about <any subject already mentioned>?*	Used to generate further dialogue if expert dries up

The pitfall of the interview method is that the expert can articulate only the knowledge which can be explained. If there are non-verbalized aspects in the domain, that is the expert knows how to solve the problem but is unable to explain it, the interviewer will not cover them. To remedy this problem, the supplemental technique of protocol analysis can be applied to an interview. The expert is asked to carry out his real job and explain how and why he is making each major decision while processing the task. The protocol is then later analysed to identify the structure of the reasoning process and knowledge components.

In this research, the main sources of knowledge are the executives of the organisation responsible for IT investment, the IT technician, and the key users. The most suitable elicitation technique used in this research is the interview method, particularly the semi-structured approach.

2.14.2 Knowledge Engineering Concept

The main concept underlying the foundation of knowledge engineering is the systematic framework to translate and explain tacit knowledge into exchangeable knowledge with clear modelling techniques. In the past, knowledge engineering was considered as simply transferring knowledge from an expert into a knowledge base.

This resulted in failure and usually produced no added productivity to the organisation. One explanation is that with this perception, knowledge is only transferred into different types of unusable knowledge. As previously noted, there are different types of knowledge and expertise. Experts are often unaware of experiences they use to solve their problems, hence, crucial pieces of knowledge are not directly accessible and need to be constructed and structured during the knowledge acquisition phase. From the viewpoint of codifying an expert's knowledge and experience into a manageable form, the knowledge acquisition process is therefore a model construction process. On the other hand, the construction of a knowledge-based system often refers to the realization of a computer model with the aim of achieving problem-solving capabilities that are comparable to a domain expert.

There are two major notions developed in the knowledge engineering community: the notion of problem solving methods (PSMs) and ontologies. These two concepts provide the backbone for building structured and reusable knowledge models. Ontologies are concerned with static domain knowledge, such as basic understanding of the domain or relationship among concepts, whilst problem solving methods deal with dynamic reasoning knowledge usually in the form of knowledge mapping. PSMs and ontologies can be seen as complementary knowledge components to construct knowledge systems.

The notions of PSMs and ontologies have been reflected in various modelling frameworks such as CommonKADS, MIKE, and PROTÉGÉ. Further details of these two notions are discussed below.

2.14.2.1 Problem-Solving Methods

Today, problem solving methods (PSMs) are recognized as valuable components for constructing knowledge based systems (KBS). The notion of PSM is presented in leading knowledge engineering frameworks including Common KADS. PSMs describe the reasoning process of a KBS in an implementation and domain independent manner. A PSM defines a way of how to achieve the goal of a task, usually in the form of knowledge mapping. It has inputs and outputs and may decompose a task into subtasks. In addition, a PSM specifies the data flow between its subtasks. Control knowledge determines the execution order and iterations of the subtasks of a PSM.

A PSM may be characterized as follows:

- A PSM specifies which inference steps have to be carried out for achieving the goal of a task.
- A PSM defines one or more control structures over these steps.
- Knowledge roles specify the role that domain knowledge plays in each inference step. These knowledge roles define a domain-independent generic terminology. There are two types of roles: static roles describe the domain knowledge needed by the PSM; dynamic roles form the input and output of inference steps.

How to develop problem solving methods is a principal question that the knowledge community tries answer. One way to do this is by analysing human problem-solving behaviour and representing this behaviour computationally. Another option is to perform reverse engineering of existing expert systems. These two ways of developing PSMs essentially involve a creative activity, for which no methodological support exists.

2.14.2.2 Ontologies

Ontologies have become a popular research topic and have been investigated by several artificial intelligence research communities. These include for example knowledge engineering, natural-language processing and knowledge representation. Ontologies aim at capturing domain knowledge in a generic way and provide a commonly agreed understanding of a domain, which may be reused and shared across applications and groups. An ontology can be represented in many different forms depending on the knowledge and utilization. These include for example, common vocabulary, jargon used by domain experts, principal theories used in the domain, and the relationship between domain concepts. Ontologies are usually organized as taxonomies and typically contain modelling primitives such as classes, relations, functions, axioms and instances. Popular applications of ontologies include knowledge management, natural language generation, enterprise modelling, knowledge-based systems, ontology-based brokers, and interoperability between systems.

The role of ontologies in the knowledge engineering process is essentially to facilitate the construction of a domain model. Over time, a wide range of methodologies have been proposed to build ontologies. Apart from minimal differences relating to domain and application constraints, ontology engineering methodologies usually introduce an iterative process consisting of the following phases:

- Domain analysis (including requirements analysis and knowledge acquisition);
- Conceptualization of the domain knowledge;
- Ontology implementation,
- Ontology population (i.e. generation or integration of ontology instances),
- Ontology evaluation,
- Ontology refinement, and
- Ontology maintenance.

All the ontology development programs more or less follow this generic framework in building ontologies.

2.15 Propose Solution for IT Asset Management

In this research, an IT Asset Management (ITAM) framework is proposed and tested. College of Arts, Media and Technology (CAMT) within Chiang Mai University is selected as the primary source of information and acts as the case study. The focus of this thesis is on the management of the IT resources within CAMT including investment and maintenance. The concept of asset management to balance among costs, performance and risks is applied to form the foundation of the ITAM. Although PAS55:

2008 provides guidelines for the implementation and a 28 point requirements specification, it leaves ‘how to’ to the organisation themselves to decide. Hence in order to construct the ITAM, this research constructs three decision models based on costs, performance and risks. The first model is the governing factor controlling risk. ISO27000 is applied for this risk model in the ITAM. The second model assists in decision making activities regarding the economic performance. Rather than relying solely on data/information, this research utilises the knowledge and experience of experts to construct an economic performance decision model. Hence, CommonKADS based on the asset management framework is applied to elicit relevant knowledge and construct a knowledge model. This is discussed in the next chapter. The last decision model is the IT service performance model, which indicates satisfaction among stakeholders. In this research, IT service performance is performed by ‘functions divided by requirements’.