CHAPTER 4

FINANCIAL AND KNOWLEDGE BASED MODELS

4.1 Chapter Overview

In the previous chapter, a general description of proposed model was given. The financial and knowledge based models, and components of the proposed decision model, are explained in this chapter. A review of existing financial metrics is undertaken in this chapter to select the most appropriate metric during decision making in the context of the power transformer. This chapter provides the economic value added (EVA) modeling of the power transformer to evaluate its net profit over its life cycle and the terms used in the modeling of EVA are described.

The other part of this chapter starts with the importance of knowledge based model for the power utilities. It also discusses the existing knowledge engineering (KE) methodologies to choose a suitable methodology for designing knowledge based model. The hidden knowledge of the power transformer is defined and explained. Then, it presents the methods for constructing the knowledge based model of the power transformer to utilize the hidden knowledge. The results are presented in the later section of this chapter to demonstrate the suitability of both models.

4.2 Financial Model

The power utility authority does not have complete financial knowledge about the status of an individual power transformer within its life cycle. So, the financial decision on individual asset is based on financial metrics of whole assets on the network with limited calculations. The other existing financial models cannot accurately compute the opportunity cost and stock keeping cost of power transformer while not supplying energy to the consumers. In this regard, this thesis proposes an alternative financial model to the power utility that provides financial measures of an individual power transformer with the inclusion of net profit during decision making. The net profit of each power transformer is determined with the modeling of EVA in the context of the power transformer. Moreover, the payback period of each power transformer can be determined with this model based on its initial investment.

4.2.1 Review of Existing Financial Measures in Decision Making

This section briefly reviews the widely used financial measures in decision making.

Net Present Value (NPV): It is the present value of the future cash flows returned by a project, minus initial investment. It is used for evaluating investment opportunities and can be expressed as [Z. Lu, 2006]:

$$\text{NPV} = \sum_{t=1}^{N} (\text{ACF}_t \,/\, (1\text{-k})^{N}) - \text{IO} \tag{4.1}$$

Where ACF_t is the annual cash flow in year t; k is discount rate; IO is the initial investment amount and N is the project's expected life.

Ostergaard et al. have used the NPV method to assess the condition of components for replacement or not [J. Ostergaard, 2001]. It has been used to determine the reinvestment options in equipment maintenance [G.J. Anders, 2005]. It is basically focused on cash flow rather than accounting profits.

Benefit-Cost Ratio: It is the ratio of the present value of benefits to initial investments. In general, it is used in comparisons of alternatives investment plans [G. J. Anders, 2005].

Marginal Cost: In economics and finance, marginal cost is the change in total cost that arises when the quantity produced changes by one unit. It is the cost to continue to use and keep the asset operational one more time unit or year. Marginal costs are a yearly estimation of the costs to own and operate an asset for that year. Mathematically, it can be represented as [M.S. Bowman, 2003]:

Marginal Cost = Decrease in Book Value + Cost of Invested Capital + Operating Cost (4.2)

It is widely used in the electricity market to determine the market price [S. Stoft, 2002].This is mainly applicable to mature, older existing equipment with increasing operating costs rather than to new equipment.

However, the methods described above concentrate more on operation and maintenance cost of the assets. Traditional profit is determined in the income statement from revenues subtracting costs and expenses missing the opportunity cost. The EVA has considered opportunity cost of equity capital in order to determine the net profit. Hence, EVA has been used in this thesis to determine net profit of a power transformer and is explained in the later section.

4.2.2 Economic Value Added

In this thesis, the net profit of the power transformer is computed by modeling the economic value added (EVA). The net profit is applied in decision rules to choose better decision on power transformers during load violation.

EVA is a registered trademark of the consulting firm of Stern Stewart and company and originated in the 1980s. It indicates the monetary worth added by an alternative to the corporation's bottom line. It has gained more attention in recent years from both businesses and academics as a primary equity valuation tool. It is found that there is a significant improvement in stock performance with the adoption of EVA [B. J. Yu, 2001]. It can reflect the accurate financial performance of enterprise [Y. Tong, 2009]. The main advantage of EVA compared with traditional profit metrics is that it incorporates the opportunity cost of equity capital [Y. Tong, 2010]. In addition, it can measure a company's true economic profit more accurately than conventional measures [C. Tseng, 2006].

The annual EVA is the amount of the net operating profit after taxes (NOPAT) remaining on corporate books after removing the cost of invested capital during that year. The basic formula of EVA [L. Blank, 2002] [J.L. Grant, 2003] is given below:

$$\begin{aligned} EVA &= NOPAT - \text{Cost of Invested Capital} \\ &= NOPAT - (\text{after-tax interest rate})^* (\text{Book Value in year } t-1) \\ &= NOPAT - ((1 - \text{tax rate})^* \text{ interest rate})^* (\text{Book Value in year } t-1) \end{aligned} \tag{4.3}$$

Finally, the EVA at year t can be modeled in the context of a power transformer presented in equation 4.4.

$$EVA_t = GR – OC – Depreciation – MC – Taxes – Cost\ of\ Invested\ Capital \quad (4.4)$$

Then the net profit of the power transformer without utilization of hidden knowledge costs is determined using the equation 4.5.

$$\text{Net Profit} = \sum_{t=1}^{n} PV(EVA_t) \quad (4.5)$$

Where, n is the total number of years, GR is gross revenue, OC is operation and maintenance cost, and MC is mortgage cost.

4.2.3 Financial Terminology

Gross Revenue (GR): It is the income or revenue generated by each power transformer each year after selling energy to the consumers. It is expressed as:

$$GR = \text{Average tariff rate} * 8760 * \text{Load in MVA} * PF * WC * 1000 \quad (4.6)$$

The average tariff rate is the average charge paid by domestic consumers for the consumption of electricity. The WC referred to as wheeling charge is explained in the next section.

Wheeling Charge (WC): It is defined as a use of utility’s transmission facilities to transmit power for other buyers and sellers. It is the amount or percent charged by one electrical system to transmit the energy of, and for, another system or systems [W.J. Lee, 2001]. The cost of transmission and distribution contributes significantly to the total cost of providing electricity to the consumer [I. Wangensteen, 1990] The supply contributes only 18% of its domestic electricity bill [P. Williams, 2001] and the power transformer contributes about 60% of the total investment in the supply [D. J. Woodcock, 2000] [A. Naderian, 2008]. Hence, the wheeling charge of power transformer is given below:

WC = Contribution of supply costs to the electricity bill * Contribution of power transformer (4.7)

Acquisition Cost (AC): It is the cost associated with acquiring the power transformer before supplying energy to the consumers [D. Braun, 1994] [J.L. Goudie, 2002]. For a new power transformer, it is equivalent to the asset price and is determined from the contract documents. However, the acquisition cost of the existing power transformer is the sum of transportation cost, installation cost, operation and maintenance setup, visual inspection learning, corrective maintenance learning, preventive maintenance learning, training cost and commissioning cost.

Operation and Maintenance Cost (OC): The power transformer is required to operate and sustain in order to maintain its condition during operation and maintenance stage. It includes administrative personnel and repair costs [D. Braun, 1994]. The personnel are required to facilitate the operation and maintenance tasks of the power transformer. The cost of testing equipment and spare parts are included in the repair cost [C. E. Ebeling, 1997]. The operating cost is achieved via interviewing senior engineers of the power utility working in substation.

Depreciation: It is the reduction in value of an asset. It is used by a corporation or business for internal financial accounting. Straight line and declining balance methods are most commonly used to determine book depreciation of an asset [L. Blank, 2002]. In this research, the straight line depreciation method is used to compute depreciation of a power transformer because the selected power utility for this study has adopted this method in its accounting. In this method, the asset is depreciated by same amount each year. It is determined from the accounting practice of the power utility. In equation form, straight line depreciation is expressed as:

$$\text{Depreciation} = (\text{Asset Price} - \text{Salvage Value})/\text{FDL} \quad (4.8)$$

Where FDL is financial designed life of power transformer.

Book Value (BV): It is the value at which an asset is carried out in a balance sheet. Initially, the book value is equal to an asset price. In other words, it represents the remaining, un-depreciated capital investment on the books after the total amount of depreciation charges to date have been subtracted [L. Blank, 2002]. The basic formula of BV is given below:

$$BV_t = BV_{t-1} - \text{Depreciation} \quad (4.9)$$

If the existing power transformer is moved to another location in year t, the book value of this power transformer in that particular year is determined using the following equation:

$$BV_t = (\text{Asset price} - (FDL - (EFDL - RI + 1)) * \text{Depreciation})) \quad (4.10)$$

Where RI is the year when the power transformer is reinstalled in a new location and EFDL is the estimated financial designed life which is represented as follows:

$$EFDL = IY_E + FDL - 1 \quad (4.11)$$

Where IY_E is the first installation year of the existing power transformer on network. Similarly, the actual financial designed life (AFDL) of power transformer is expressed in equation 4.12.

$$AFDL = EFDL + NS_A \quad (4.12)$$

Where NS_A is the number of years that the power transformer is already kept on stock and is less than or equal to (FDL – (Stock Keeping Year - IY_E)).

Mortgage Cost (MC): It is the cost to be paid each year for borrowing the soft loan to procure the power transformer. In this research, it is assumed that utilities receive money as a soft loan for the period of financial designed life. It is determined using the PMT function in spreadsheet cell [L. Blank, 2002]. The format is given below:

$$MC = PMT(\text{Soft loan interest}, FDL, \text{Asset Price}, -\text{Salvage Value}) \quad (4.13)$$

Opportunity Cost: The opportunity cost is the cost of any activity measured in terms of the best alternative forgone and it exists when the provision of a product prevents the provision of another product with a higher value [J. Sloman, 1999][OC, 2011]. Lost opportunity cost is paid to generating units that are backed down from the accepted values in the energy market and participate in the reserve market with a capacity equal to their reduction in the energy market [K. Afshar, 2007][D. Gan, 2002]. For the simulation selection problem, opportunity cost is the difference between the unknown mean of the selected system and the unknown mean of the actual best system. It penalizes bad choices more than the slightly incorrect selections [D. He, 2007]. For example, it may be better to be wrong 99% of the time if the penalty for being wrong is $1 (an expected opportunity cost of 0.99 x $1 = $0.99) rather than being wrong only 1% of the time if the penalty is $100 [S.E. Chick, 2001]. It is useful when the performance of each alternative is measured in financial terms as opposed to other engineering measures [D. He, 2007]. In this research, lost opportunity cost is paid to the power transformers that are not accepted for supplying energy to the connected consumers during load violation. It is represented as LOE and is presented in chapter 5.

4.3 Knowledge Based Model

The decision becomes infeasible from a financial perspective as decisions are mainly focused on the cheapest price of any assets available in the market without any consideration of investment budget and with limitations thinking only of the technical aspects rather than financial aspects [M. Shahidehpour, 2005]. Utilities must make optimal decision on the power transformer considering both financial and technical constraints. The engineering and financial requirements can be fulfilled with the utilization of reusable knowledge embedded within the power transformer over its life cycle. However, the available knowledge is unstructured and often in tacit form which cannot be utilized. Hence, this thesis aims to offer knowledge engineering and management framework to develop knowledge based system for an effective life cycle assessment of a power transformer in order to maximize its utilization during its life cycle. It is the repository of hidden/or reusable knowledge of the power transformer.

4.3.1 Knowledge and Knowledge Engineering

Knowledge is the complete body of data and information which enables people to generate action for carrying out tasks and creating new information [G. Schreiber, 2000]. "*Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms*" [T.H. Davenport, 1998]. There is still a philosophical debate with Plato's formulation of knowledge as "justified true belief". The confidents understanding of a subject with the ability to use it for a specific purpose is also referred to as knowledge. Knowledge can be classified into two categories: explicit knowledge and tacit knowledge Tacit knowledge is embedded in a person's memory and is difficult to extract and share with others. Tacit knowledge is more valuable because it gives context for people, places, ideas, and experiences. Explicit knowledge on the other hand is knowledge that can be seen, shared and communicated with others. Explicit knowledge resides in manuals, documents and procedures either in electronic or paper forms [M. S. Abdullah, 2004]. There is a requirement to convert tacit knowledge into explicit knowledge in order to manage it. This knowledge conversion can be done through the process of socialization, externalization, combination and internalization [I. Nonaka, 1995].

Knowledge engineering (KE) evolved from the late 1970s onward, from the art of constructing expert systems, knowledge-based systems, and knowledge-intensive information systems. It is an engineering discipline that involves integrating knowledge into computer systems to solve complex problems. KE is not simply a means of extracting knowledge from the expert's head. Now it is considered as a modeling activity. It includes methods and techniques for knowledge acquisition, modeling, representation and utilization [G. Schreiber, 2000]. KE means the building, maintenance and development of a knowledge-based system. It is important to understand the working procedures of a model within a knowledge based system [G. Boch, 1999]. The development of a knowledge based system considers the knowledge modeling as a central activity. Modeling is the understanding of the source of knowledge, the inputs and outputs, flow of knowledge and identification of other variables [T. H. Davenport, 1998].

The main principles of KE developed by knowledge engineers to improve the process of knowledge acquisition and ordering are listed below [N. Shadbolt, 1999]:

❖ There are different types of knowledge.

❖ There are different types of experts and expertise.

❖ There are different ways of representing knowledge.

❖ There are different ways of using knowledge and

❖ Knowledge engineers use structured methods for increasing the efficiency of acquisition process.

In this thesis, the common knowledge engineering methodologies (i.e. MOKA, SPEDE and CommonKADS) are briefly reviewed in the later section.

4.3.1.1 Knowledge-Based Engineering (KBE) Lifecycle

KBE life cycle is a general model of knowledge engineering to select a suitable methodology for constructing knowledge based model for hidden knowledge from a power transformer. The well-known knowledge based engineering lifecycle proposed by Preston is used in this thesis [S. Preston, 2005]. It focuses on six phases: identify, justify, capture, formalize, package and activate. The KE methodologies provide tools to support a KE project lifecycle.

4.3.1.2 Knowledge Engineering Methodologies

MOKA: It is a methodology for developing knowledge based engineering applications. It is aimed at capturing and applying knowledge within the industries of the design of complex mechanical products [MOKA, 2011]. It has two recognized models in the KBE application development lifecycle: the informal model and formal model. It has emphasized manufacturing context and has not given more attention to the network and culture of organization [P. Sureephong, 2009].

SPEDE: It provides knowledge acquisition tools that permit quick elicitation of business process improvement requirements, structured acquisition of heterogeneous process information and validation of captured information. It assists company know-how to establish links to organizational memory and knowledge management resources. It gives a demonstration environment to facilitate organizational change. It also reduces the effort in the creation and use of business process models. It is mainly applicable to business process improvement within an organization [N. Shadbolt, 1999].

CommonKADS: The CommonKADS methodology [G. Schreiber, 2000] provides a structured approach based on a few basic principles achieved through experience over the years. It is the de facto standard for knowledge modeling. The methodology explains principles, techniques, methods and document structure to support the construction of knowledge based system in three stages; context level, concept level and artifact level. It provides a CommonKADS model suite to create requirements specifications for knowledge based system, as given in figure 4.1.

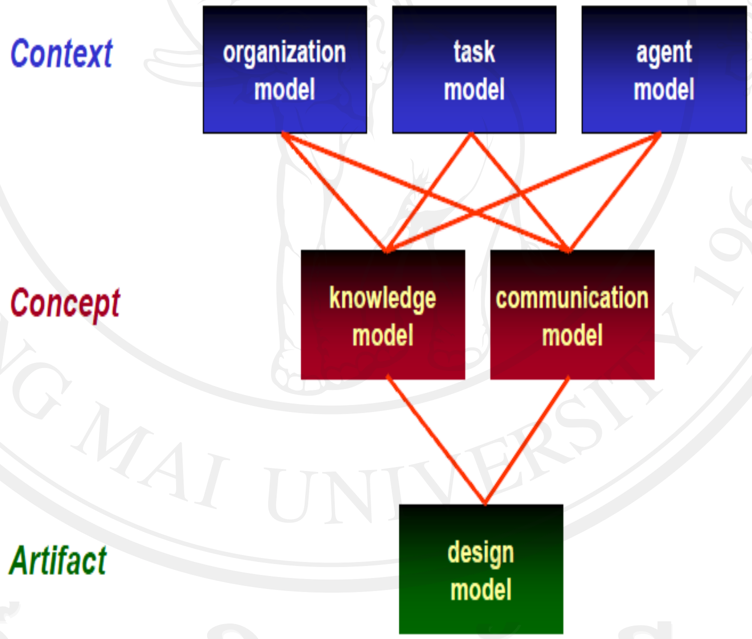

Figure 4.1 The CommonKADS Model Suite [G. Schreiber, 2000].

At the context level, it focuses on the organization that will use the system, describing the business processes, resources, and knowledge assets of the organization and its impacts on the system. This level of analysis helps to demonstrate the feasibility of knowledge based system to the organization adopting it.

At the concept level, it specifies the knowledge and reasoning requirements of the prospective system. It is a tool to clarify the structure of a knowledge- intensive information- processing task. It provides a specification of the data and knowledge structures needed for the application. The construction of a knowledge model consists of three knowledge categories; task knowledge, inference knowledge and domain knowledge. Each knowledge category has its own components to construct the model.

At the third design level, the methodology is used to construct the requirements specification for the knowledge system. This methodology includes all knowledge activities: create, store/retrieve, share, and representation. Also, it emphasizes more on knowledge sharing methods. CommonKADS has been widely applied in different domain such as medical, legal, engineering, business and social sciences [M.S. Abdullah, 2002].

4.3.2 Selection of Suitable KE Methodology

CommonKADS and SPEDE provide tools to support processes from identification to packaging of the KBE lifecycle, however MOKA does not. SPEDE is used to improve the performance of the organization at the process level where as CommonKADS is used to improve knowledge intensive tasks at the practice levels. In addition, CommonKADS provides models and templates in each level of the framework. These templates facilitate the knowledge engineer to elicit the knowledge embedded in both analysis and synthesis tasks. Hence, this technique can be used in different types of knowledge problems [P. Sureephong, 2009]. CommonKADS methodologies include structured systems analysis and design, object orientation, organization theory, process reengineering, and quality management [G. Schreiber, 2000]. Thus, CommonKADS is selected in this research for construction of a knowledge based system for the power utility to share within the organizational context. Moreover, it is a widely accepted methodology. The hidden knowledge of the power transformer and its implementation with the use of CommonKADS are described in the next section.

4.3.3 Hidden Knowledge

Hidden knowledge is the tacit knowledge possessed in knowledge workers or engineers who have been operating on power transformers. It can also be available within documentation relating to the power transformer. Hidden knowledge is identified with the construction of the life cycle of the power transformer. The cost associated with the hidden knowledge is determined by interviewing senior engineers of the contractor and is verified with experts from the manufacturer of the power transformer. The list of hidden knowledge from the power transformer is explained below.

Engineering Knowledge: This is the knowledge required to understand the detail design specifications of the power transformer during the manufacturing process including drawings, test reports, etc. It is utilized in the existing power transformer or a new transformer during relocation or procurement, and to determine the designed safety margin in order to operate further beyond its financial designed life. This is located by the head of the manufacturer's experts and on relevant documents. The engineering cost (EC) is expressed as [Bharat Heavy Electricals Limited, 2003]:

EC = function (Design drawings, General layout drawings, Testing reports) (4.14)

Transportation Knowledge: It contains dispatch, receiving on site and handling knowledge. This knowledge is needed before installing the existing or new power transformer on the network. It is on the supervisor's head and inside the instruction manual. The transportation cost (TRC) is represented as [Bharat Heavy Electricals Limited, 2003]:

TRC = function (Freight Charges, Custom Clearance, Crain Charge, Supervisor cost per day, etc.) (4.15)

Installation Knowledge: Knowledge of location and mounting, site arrangement, erection, testing, oil filling, etc. are required for installation. The supervisor is needed for the proper supervision of the installation process. This knowledge can be achieved through the supervisor and the installation manual provided by the contractor. The total installation cost (IC) is comprised of the following [Bharat Heavy Electricals Limited, 2003]:

IC = function (Supervisor cost per day * Installation Duration, Erection Cost, Labor Cost, Testing equipments, etc.) (4.16)

Commissioning Knowledge: This knowledge includes the concept of energizing, measurements and observations, etc. It is embedded within the supervisor and instruction document. This commissioning cost (CC) is comprised of the following [B. Hochart, 1987]:

CC=function (Supervisor cost/day * Commissioning duration, Testing equipments, Labor Cost, Accessories, etc.) (4.17)

Operation and Maintenance Setup (OMSC): It provides the complete guidelines, procedures and methods to do proper operations and maintenance of the power transformer as well as safety precautions in the written form [J.H. Harlow, 2007].

Corrective Maintenance Learning (CML): This is the knowledge required for the operation and maintenance workers to diagnose and investigate the failure of the power transformer during operation [IEEE Std., 1991]. It is learnt with the help of operation and maintenance expert during the acquisition phase.

Preventive Maintenance Learning (PML): It includes the learning of regular inspection, testing and reconditioning of power transformer ensuring correct operation [IEEE Std., 2007]. The operation and maintenance workers can learn from the operation and maintenance expert.

Visual Inspection Learning (VIL): This learning provides the knowledge about internal and physical inspections of the power transformer to the operation and maintenance workers [IEEE Std., 2007]. They can learn from the operation and maintenance expert of the contractor.

Planning Knowledge: This knowledge includes the concept of design specifications, tender preparation and bidding selection. It is needed at the time of procurement of the power transformer. This knowledge can be gained through the expert's planning and the operation department of the substation.

Training Knowledge: This knowledge is required to train operation and maintenance workers to become familiar with the operating and maintenance, safety and protection aspects of the power transformer every five years. This can be achieved from supervisor/or trainer of contractor.

$$TrC = \text{Supervisor cost per day} * \text{Training duration} \quad (4.18)$$

The total cost (TC) incurred at the year of power transformer acquisition is given below when the hidden knowledge is not utilized:

$$TC = PC + EC + TRC + IC + CC + TrC + OMSC + VIL + PML + CML \quad (4.19)$$

Similarly, the total operating cost of power transformer is determined by the following equation in case of no utilization of hidden knowledge during the operation and maintenance stage:

$$TC = TrC + OC + VIL + PML + CML \quad (4.20)$$

The knowledge embedded within the documents and experts such as drawings, test reports, supervisors, etc. can be reused. In addition, it can provide technical knowledge of the power transformer for maintaining its engineering requirements. The above mentioned knowledge can be utilized within the power utility by constructing the knowledge based system.

4.3.4 Construction of the Knowledge Based Model

Knowledge engineering is used to capture, model and utilize knowledge systematically. CommonKADS (Common Knowledge Acquisition and Design System) is adopted because it supports structured knowledge engineering techniques. It also offers some useful inference templates to create a knowledge framework and these templates provide useful guidelines for interviewing, analyzing, modeling and utilizing knowledge [G. Schreiber, 2000]. The construction of knowledge based system is divided into three levels; organization model (context level), knowledge model and key ontology (concept level) and support tacit knowledge (artifact level). Firstly, the overall tasks associated with the life cycle cost of the power transformer, referred to hidden knowledge, are presented in the organization model. Secondly, the knowledge model and key ontology diagram are used to conceptualize the particular task. Finally, the support tacit knowledge diagram explains the problem solving structure of all existing tasks. The knowledge elicitation processes is completed with the use of available knowledge templates shown in tables 4.1, table 4.2 and table 4.3 and the organization model worksheets. It is represented by a knowledge map (K-Map).

In addition, the hidden knowledge presented in the knowledge based system will become obsolete due to the advancement of technologies and practices. Hence, an expert is hired every five years, according to general practice to update and maintain the knowledge based system in order to understand the obsolescence rate.

4.3.4.1 The Context Level

The context level includes the CommonKADS organization model to discover problems and opportunities for the knowledge based system. It can be constructed using organization model worksheets. This level provides the scope and crystal view of the power transformer's hidden knowledge implementation.

4.3.4.2 The Concept Level

This level conceptualizes the hidden knowledge of the power transformer. The CommonKADS Knowledge Model provides the type and structure of the knowledge used in performing a task in detail.

Table 4.1 CommonKADS Model Suite [G. Schreiber, 2000].

Model	Composition of Model
Knowledge Model	Task Knowledge (Goal and Sub Goal)
	Inference Knowledge (Reasoning)
	Domain Knowledge (Specification)

The key ontology template [K. Khankasikam, 2010] also describes various sources from which the knowledge is elicited and formalized in terms of an ontology.

Table 4.2 Key Ontology Template [K. Khankasikam, 2010].

Composition of Model	
Who	Experts
	Knowledge Workers
	Community of Practice
	Knowledge Portfolio
Document	Manual
	Book
	Standards
	Working Procedures
	Drawings
	Control/Protection/Information System
	Checked Sheets
	Measuring Point List
	Cases
Information	Updated Information
	Link to Database
Abstract	The Short Description of Work

4.3.4.3 The Artifact Level

This last level contains support tacit model. The algorithms and tools required for implementation are included in this level. It describes the structure of the software system needed to implement the knowledge and communication models. Table 4.3 [K. Khankasikam, 2010] depicts the details of support tacit knowledge.

Table 4.3 Support Tacit Knowledge [K. Khankasikam, 2010].

Model	Composition of Model
Support Tacit Knowledge	Precautions/Cautions
	Advantages/Disadvantages/Alternatives
	Methods/Strategy to Solve the Problem/Control /Maximize/Minimize/Optimize
	Condition/Criteria
	Guideline Techniques/Recommendation/Ensure
	Requirements/Objectives/Needs
	Limitations
	Assumptions
	Examples

4.3.4.4 Implementation

To utilize the knowledge framework by constructing the knowledge management system, the captured knowledge models are implemented using Microsoft Share Point [MSP, 2011]. This software is selected as it enables people to make better-informed decisions and also connects people, information and expertise.

4.4 Case Study

Nepal Electricity Authority (NEA) is used for the case study to confirm the applicability of financial and knowledge based models within one MVA power transformer. Knowledge elicitation was undertaken using structured interviews with senior operation and maintenance engineers/or supervisors from the grid operation department of NEA, the manufacturer and supplier of the power transformer. Knowledge was also captured from the documents related to life cycle cost of power transformer. The financial designed life of the power transformer is 20 years since the depreciation rate of distribution system assets is 5% [NEA, 2007b].

4.4.1 Parameters

The total asset price of one MVA power transformer is about 200,000 US Dollars. For operation and maintenance of the power transformer, the total fiscal budget is approximately 2% of its asset price per year. Both are determined from interviewing senior engineers of the grid operation department of NEA who have been working with power transformers. The soft loan interest rate is obtained from interviewing senior officer of national planning commission of Nepal, which is about 2%. The discount rate is taken as 8% in this research because it was taken as 10% in 2004 [NEA, 2004], when the normal interest rate was about 10%, but has now reduced by 2% [NEA, 2008]. Through interviews with the senior supervisor of Nepal Hydro (supplier of power transformers) and senior engineers of the Provincial Electricity Authority of Thailand, the following data was obtained:

Operation and Maintenance expert cost Man-day = 3000USD

Supervisor cost Man-day = 1000 USD Installation duration = 5 days;

Training Duration = 2 days Commissioning duration = 2 days

Power factor = 0.80 [NEA, 2007b] Load factor = 52.20% [NEA, 2007a]

Warranty period = 1 year [Grid Operation Department, 2006]

Average tariff rate = 0.10 USD [NEA, 2007b]

Finally, the designed load demand of the power transformer is obtained from the senior planning engineers of the grid operation department and is presented in table 4.4.

Table 4.4 Designed Load Demand of One MVA Power Transformer.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Load (MVA)	0.2	0.23	0.26	0.30	0.35	0.40	0.46	0.53	0.61	0.65
Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Load (MVA)	0.71	0.73	0.74	0.76	0.77	0.79	0.80	0.82	0.84	0.85

4.4.2 Results and Discussion

The following results are obtained using the data and parameters presented in section 4.4.1. The results are categorized into two contexts: the financial model and the knowledge based model.

4.4.2.1 Financial Model

The mortgage cost and depreciation of a power transformer having capacity of one MVA are determined using equation 4.13 and 4.8 respectively. The results are presented in table 4.5. The utility has to pay $12,231.34 to the soft loan provider each year until the end of financial designed life. Initially, the book value of power transformer is $200,000, which is equivalent to the price of the power transformer. However, this value declines each year by $10,000 after it has been put into operation and finally, it is zero at the end of its financial designed life. The book value of the power transformer in 2015 can be computed using equation 4.10.

Table 4.5 BV, MC and Depreciation of Power Transformer.

BV in Year 2015 (USD)	Mortgage Cost Each Year (USD)	Depreciation Each Year (USD)
1,50,000.00	12,231.34	10,000.00

The gross revenue and EVA of this power transformer over its financial designed life are calculated with the help of equations 4.6 and 4.4 respectively and are shown in figure 4.2. The value of the EVA is negative until 2015 due to low-load demand and high initial cost of invested capital. Finally, the net profit of this power transformer is $28,581.67 based on the designed load demand and is determined using equation 4.5.

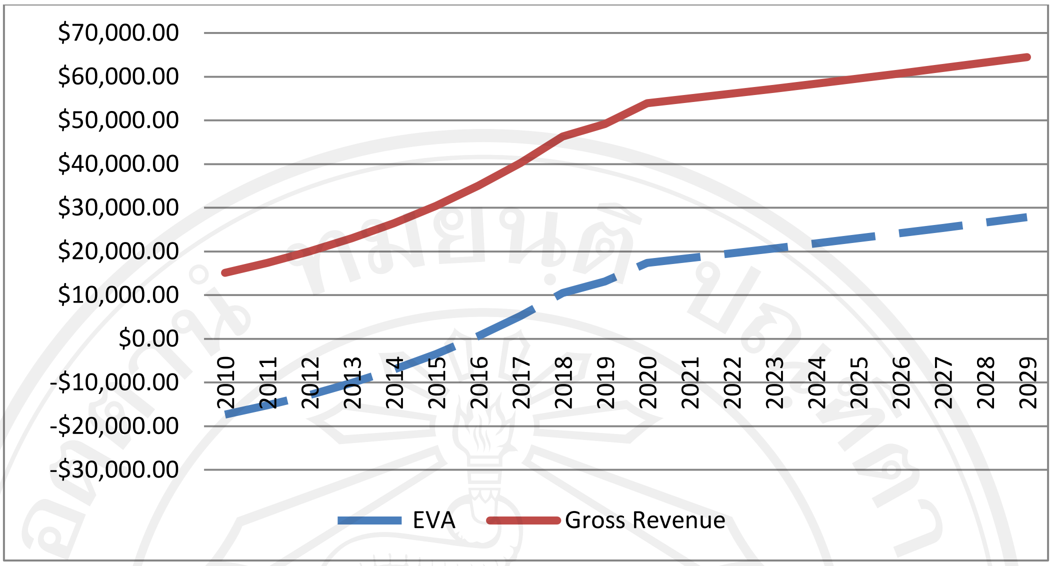

Figure 4.2 Gross Revenue and EVA of Power Transformer.

From figure 4.3, it can be speculated that this power transformer can return back its initial investment approximately 18 years after its installation. It is determined by plotting the cumulative cash flow each year considering the discount rate. The total amount paid by the utility including total interest amount is $244,626.87 for acquiring the power transformer. The curve increases from negative to positive because the power transformer slowly begins to generate revenue after it has been put into the network.

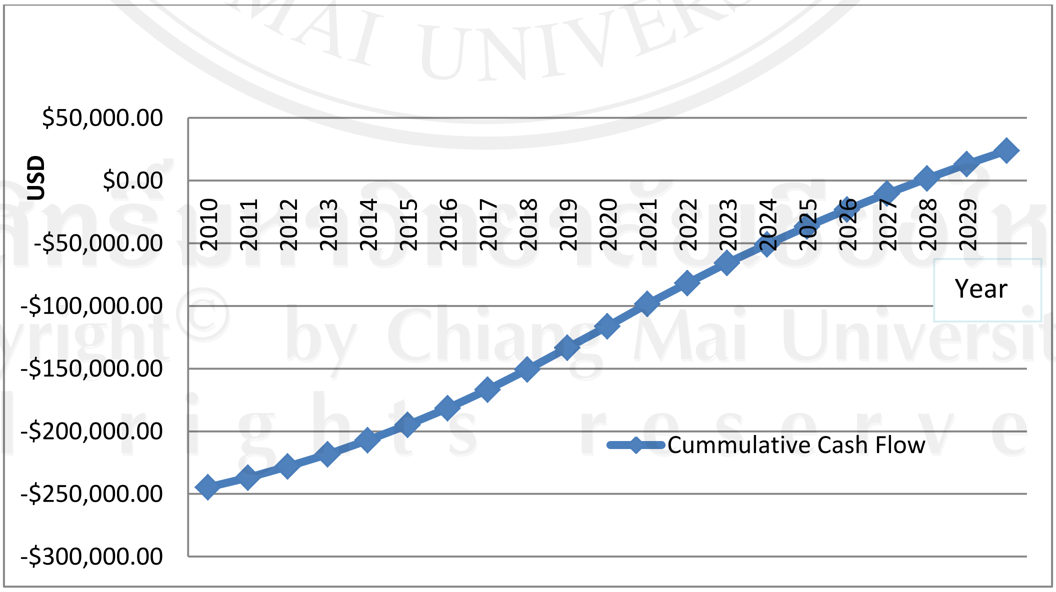

Figure 4.3 Payback Period of Power Transformer.

The payback period of the power transformer can be shortened by the utilization of hidden knowledge. It is illustrated in the next section.

4.4.2.2 Knowledge Based Model

This section provides the results attained from the construction and utilization of the hidden knowledge of a power transformer.

4.4.2.2.1 Construction

It presents the results obtained from the construction of knowledge based model using CommonKADS model suite. The results show that the hidden knowledge implementation of the power transformer consists of organization model worksheets, conceptual level and artifact level diagrams.

Table 4.6 Identifying Knowledge Oriented Problems and Opportunities.

Organization Model	**Problems and Opportunities Worksheet OM-1**
Problems and Opportunities	• Not fully utilization of PT without the utilization of hidden knowledge. • Unstructured and in tacit form
Organizational Context	• Enable people to utilize the hidden knowledge possessed within the experts. • Provide both technical and financial values from the utilization of hidden knowledge
Solution	• Implement Knowledge Management System to disseminate and fully utilize the hidden knowledge within the organizational context

Firstly, the context level of the power transformer hidden knowledge is shown by constructing the CommonKADS organization model. It is represented in tables 4.6 to 4.8. Table 4.6 provides the necessities of hidden knowledge implementation for the organizational context using worksheet OM-1 template. By adopting worksheet OM-2 template, the involvement of employees, existing resource and required knowledge for the power transformer life cycle management are identified and presented in table 4.7.

Table 4.7 Description of Organizational Aspects Affecting BY KMS.

Organization Model	**Variant Aspects Worksheet OM-2**
People	• Senior Planning Engineers • Operation & Maintenance Engineers • Technicians
Resource	Power Transformer Data Inventory System
Knowledge	• Planning Knowledge • Engineering Knowledge • Transportation Knowledge • Installation Knowledge • Commissioning Knowledge • Operational and Maintenance Setup • Corrective Maintenance Learning • Preventive Maintenance Learning • Visual Inspection Learning • Training Knowledge

The different tasks or activities involved in each phase of the life cycle of power transformer are categorized based on the followings aspects using worksheets OM-3 and OM-4 as template, as shown in table 4.8.

- Who perform the tasks?
- Where is the task performed?
- What is the knowledge required to perform the tasks?
- What is the contribution of each task in terms of financial?
- Where is this required knowledge used in?

Table 4.8 Description of Tasks and Knowledge Components.

Organization Model			Process Breakdown and Knowledge Assets Worksheets OM-3 & OM-4		
Task	Performed By	Where	Knowledge Asset	Significance	Used In
Bidding Preparation	Senior Planning Engineer	Acquisition Stage	Planning Knowledge	0.25% of Asset Price	Relocation & Procuring
Detail Design Drawings	Engineers of Manufacturer	Acquisition Stage	Engineering Knowledge	3.0% of Asset Price	Relocation, Procuring & Operating
Dispatch & Receiving	Supervisor of Contractor	Acquisition Stage	Transportation Knowledge	10.0% of Asset Price during procurement 2.00% of Asset Price during relocation	Relocation of PT & Procuring
Installation & Energizing	Supervisor of Contractor	Acquisition Stage	Installation & Commissioning	5% & 3% of Asset Price	Relocation of PT & Procuring
Operation & Maintenance	O&M Expert	O&M Stage	CML; PML; VIL and O&M Setup	O&M Expert one-Man day/year for learning and 10 Man-Day for Set Up	Operating the PT
Training of Employee	Trainer of Contractor	O&M Stage	Training Knowledge	About 1% of Asset Price	O&M Stage

Secondly, the concept level diagrams are shown in figures 4.4 to 4.6 along with the key ontology diagram. The CommonKADS knowledge model is represented in figures 4.4 to 4.6 showing the relationships among task knowledge, inference knowledge and domain knowledge. Similarly, figure 4.7 shows the key ontology diagram of the ratio test of the power transformer. Thirdly, figure 4.8 presents the artifact level diagram of the ratio test which provides the steps or processes for conducting particular tasks of power transformer.

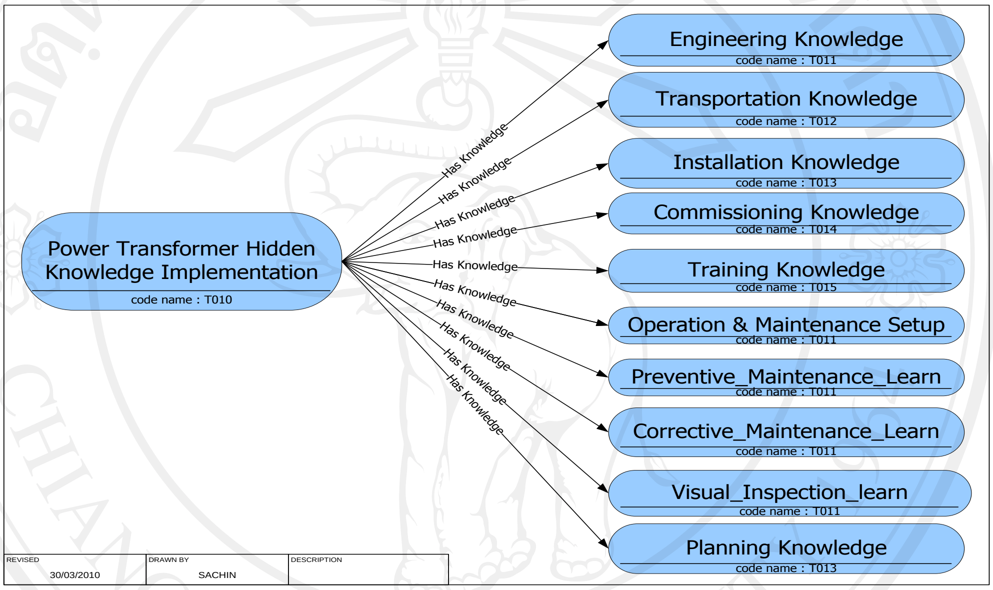

Figure 4.4 Task Knowledge Diagram.

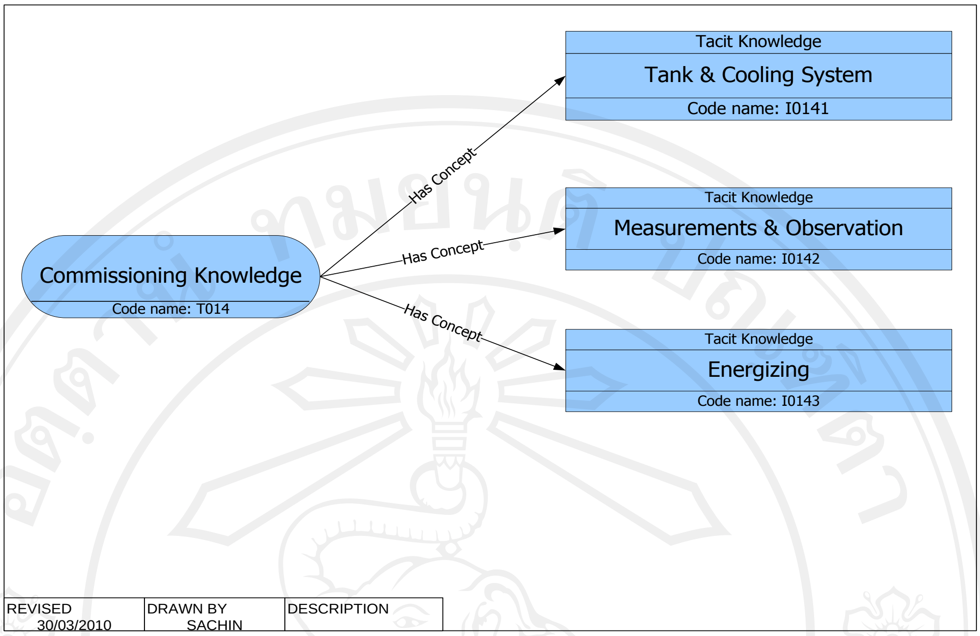

Figure 4.5 Inference Knowledge Diagram.

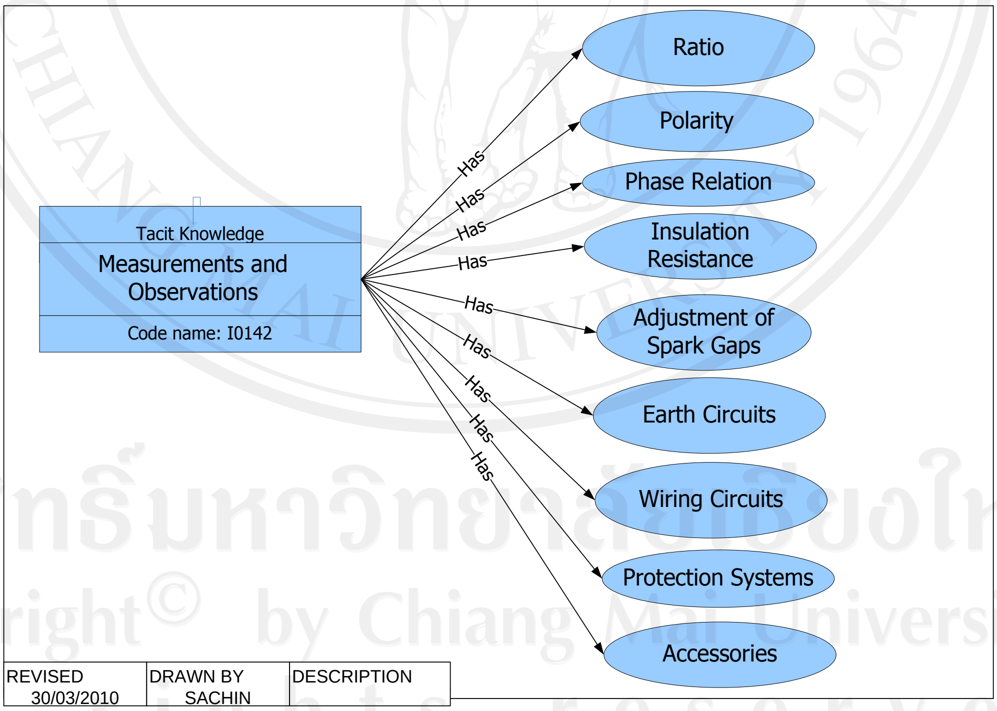

Figure 4.6 Domain Knowledge Diagram.

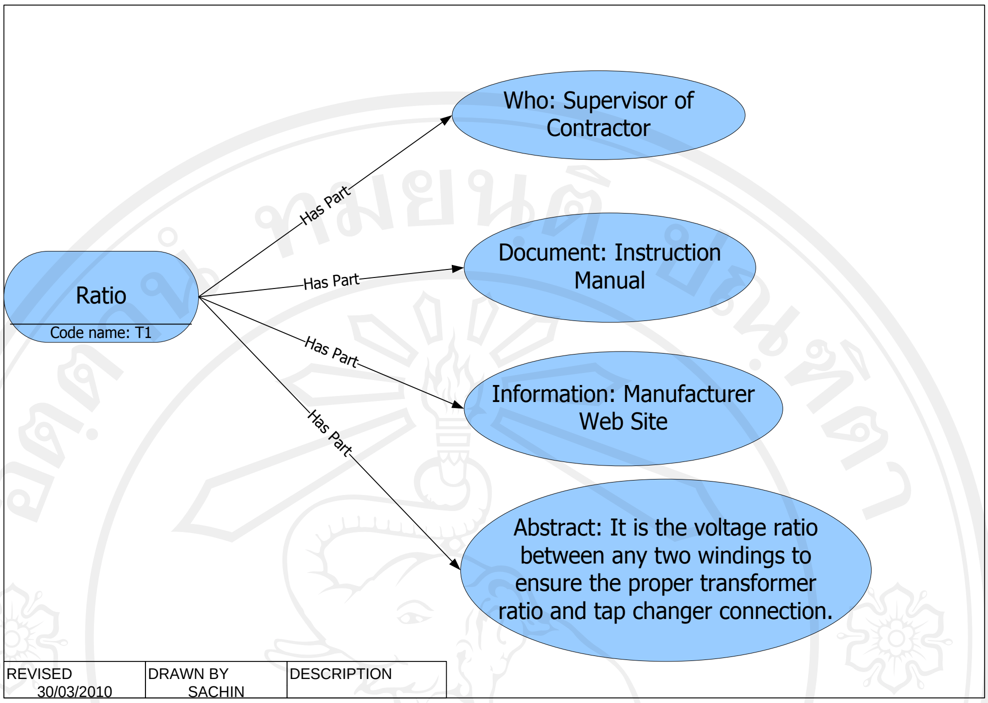

Figure 4.7 Key Ontology Diagram.

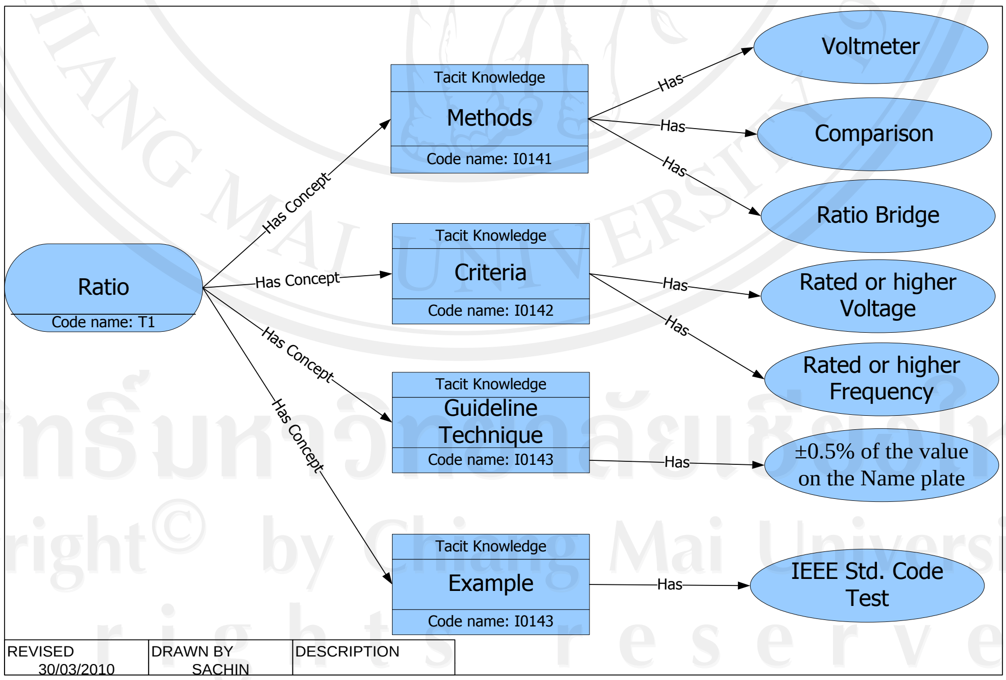

Figure 4.8 Support Tacit Knowledge Diagram.

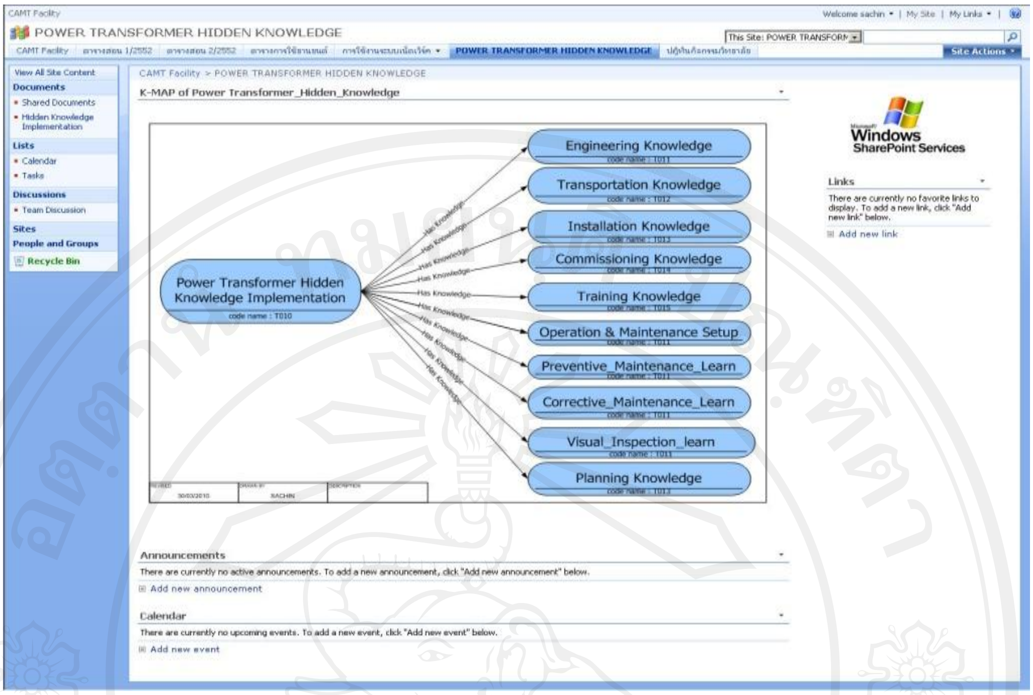

Figure 4.9 Implementation in Microsoft Share Point.

The example of hidden knowledge implementation using Microsoft Share Point is shown in figure 4.9. The embedded knowledge is updated and maintained every five years by hiring an operation and maintenance expert for one day.

4.4.2.2.2 Utilization

The importance of hidden knowledge in terms of financial values is given in this section. Table 4.9 compares the cost of hidden knowledge in both cases: before and after utilization. In the previous section of table 4.8, the contribution of hidden knowledge in its asset price is formulated and is applied to estimate their individual cost in case of no utilization. When the power transformer is reinstalled in another location, the hidden knowledge can be utilized and its individual cost is presented in table 4.9. In this case, the transportation cost is about 2 % of its asset price due to the savings in custom charges and freight charges and is achieved from the experience of planning engineers of the power utility. With the reuse of design drawings, general layout drawings and testing reports, the total engineering cost can be reduced. Similarly, OM set up cost is zero because operation and maintenance set up documents can be reused. The installation, commissioning and training costs can be determined through deducting the total supervisor cost in equations 4.16, 4.17 and

4.18 respectively. During the installation, commissioning and training of the power transformer, the total supervisor costs are $5000, $2000 and $2000 respectively. Visual inspection learning, corrective maintenance learning and preventive maintenance learning include only the hiring cost of the operation and maintenance expert. So, these learning costs become zero. Finally, the planning cost is also zero due to the savings in the preparation of tender cost.

Moreover, table 4.9 shows the importance of utilizing the whole hidden knowledge in terms of financial value (net savings), which is about 35.25% of its asset price. To update and maintain knowledge of the power transformer in knowledge based model, it costs about $15000 as there is a requirement to hire an operation and maintenance expert five times over its life cycle. Hence with the practice of obsolescence rate, the net reusable hidden knowledge is about 27.75% of its asset price.

Table 4.9 Hidden Knowledge Cost.

S.N.	**Hidden Knowledge**	**Before Utilization**	**After Utilization**
1.	Transportation Cost	$20,000	$4,000
2.	Engineering Cost	$6,000	$0
3.	Installation Cost	$10,000	$5000
4.	Commissioning Cost	$4,000	$2,000
5.	OM Set up Cost	$30,000	$0
6.	Visual Inspection Learning	$3,000	$0
7.	Corrective Maintenance Learning	$3,000	$0
8.	Preventive Maintenance Learning	$3,000	$0
9.	Training	$2,000	$0
10.	Planning	$500	$0
Total Hidden Knowledge Cost		$81,500	$11,000
Net Reusable Hidden Knowledge		$70,500	
Updating & Maintaining Knowledge Cost		$15,000	
Net Reusable with Practice Obsolescence Rate		$55,500	

Figure 4.10 illustrates the importance of utilizing the hidden knowledge during its life cycle. The graph is plotted over its financial designed life through the calculation of the total cost during acquisition and operation and maintenance periods with the help of equations 4.19 and 4.20 respectively. At the installation year, there is a significant difference between two cases because the complete hidden knowledge is utilized. Then, the difference is constant throughout the life cycle except in year 18 where the utility needs to provide training to operation and maintenance personnel every five years after installation. During the operation and maintenance period, the cost difference is not as significant as it can save only visual inspection learning, corrective maintenance learning, preventive maintenance learning and training cost. Thus the net acquisition cost can be reduced significantly by 85.92% with its utilization. It means that the cost of hiring the experts can be saved and other costs remain the same.

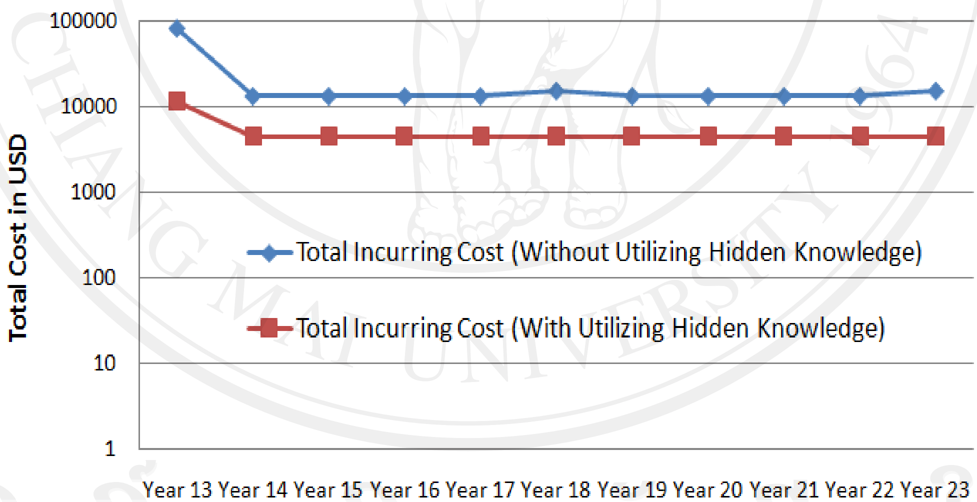

Figure 4.10 Utilization of Hidden Knowledge over its Life Cycle in Case of Relocation.

The results are verified with the help of the expertise of the Nepal Electricity Authority and Nepal EKARAT Engineering Co. Pvt. Ltd. Finally, results are validated with the expertise of the Metropolitan Electricity Authority of Thailand. The knowledge becomes well structured and more manageable. The results show that the CommonKADS methodology provides a structure to systematically identify, capture, model and utilize the knowledge involved during the life cycle of the power transformer. Moreover, the visual inspection, corrective maintenance, preventive maintenance and engineering knowledge facilitate engineers/or technicians to undertake better operation of transformer maintenance based on the technical requirements. Some portion of financial savings can be achieved with the utilization of hidden knowledge each year and can be used to meet technical requirements.

4.5 Chapter Summary

This chapter has explained in detail, the two components of the proposed life cycle assessment model i.e. financial and knowledge based models. The EVA is selected and modeled in the context of the power transformer in order to apply decision rules for decision making. The decisions rules are explained in the next chapter. The aim of the knowledge based model is to support utility companies in managing the knowledge they currently possess, and to focus their operations towards knowledge reuse. By using the CommonKADS Model Suite, hidden knowledge embedded within the power transformer is characterized, modeled, and utilized within the power utility and consequently implemented for sharing and dissemination. Hence, the utility can fully leverage the hidden knowledge to achieve both financial and technical values.