ENERGY MODEL AS A SUSTAINABLE FUNCTION IN BUILDING DESIGN DECISIONS

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ABSTRACT: New buildings display an increasing awareness of sustainability but invariability assume a level of technical sustainability an concentrate on economic and social sustainability, as opposed to environmental sustainability. This paper presents an approach and study to describe and modeling energy as a sustainable function in building design decisions. The object study is a big mall (under pre construction-delayed) in a new district in Surabaya, Indonesia. With the cost of energy rising and availability decreasing the need to provide energy-efficient design become more important. As a proponent of increased value, our knowledge of energy must be expanded. Source of energy and the availability of energy must be understood. This is a consideration to the design life of project, consumption rates, equipment efficiencies, system design and other factors that contribute to waste energy. A means of accounting for the energy uses for the construction and operation of building and plant facilities is needed. More specially, it is necessary to know the areas within a building which are energy consumer and to learn how much energy a building uses as a comparison to the amount of energy that a building should use. Commencing at the design and planning stage, the technical, social, economic and environmental sustainability of building energy of a mall development needs to be considered. The decision building design consists of three sustainability functions that are economic sustainability, environment and social sustainability and technical sustainability. Combining of three functions have built a set of decision hierarchy in a model of Analytical Hierarchy Process (AHP). Analysis from decision process revealed model of energy in the project.

Keywords: energy model, sustainability, building, decision

1. INTRODUCTION

Business competitiveness means sustained growth and earnings through building customer loyalty by creating high values project in very dynamic global markets. There are five main sources that is resulting the complexity of the project development: (1) inherent project complexity; (2) process complexity, (3) team cooperation and communication complexity (4) computer and network complexity and (5) a maze of specifications including international regulations and safety. In the last few years we have seen rather dramatic changes in our perception of the vision of the built environment project of the future. This vision was created as a way to satisfy the market demands for shorter project times, precise delivery times, and flexibility in project Varian and so on, ensuring a better global competitiveness. These are important factors influencing creating a built environment project with a future.

The need to provided energy-efficient design becomes more important. This is especially true in relationship to the design life of project. A means of accounting for the energy uses for the construction and operation of building is needed. At times it is difficult to quantify and qualify the importance of values other than those relating only cost. Criteria for evaluating value are initial cost and energy cost as the LCC, return in profit, functional performance, reliability, and maintenance ability. This paper focuses on a methodology of design decision that can more effectively align the design and performance evaluation with user expectations and economic imperatives. If reducing costs results in an inferior solution then it is possible that this solution will be of significantly less value. Therefore value should be the main consideration when choosing a solution.

2. LIFE CYCLE MODEL

Life Cycle Management

Life cycle management consists of 2 issues that are risk management and six aspects. These aspects are: increased product life, calculation of revenue loss, managing continuity, configuration management, managing revision change and incorporated lessons learned. Here is the example of configuration management.

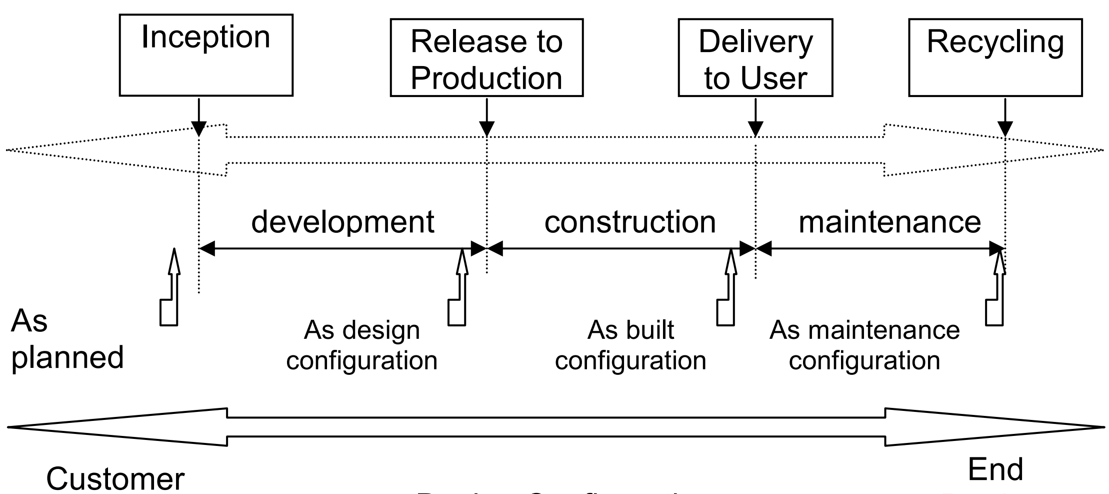

Figure 1:Configuration of Life Cycle Management (Flanagan,1987; Leo,1993; Kezner, 2005)

Life Cycle Cost Drivers

The goal of the life-cycle cost is to maximize the value of a project, while containing its cost to the developer, the user and society.

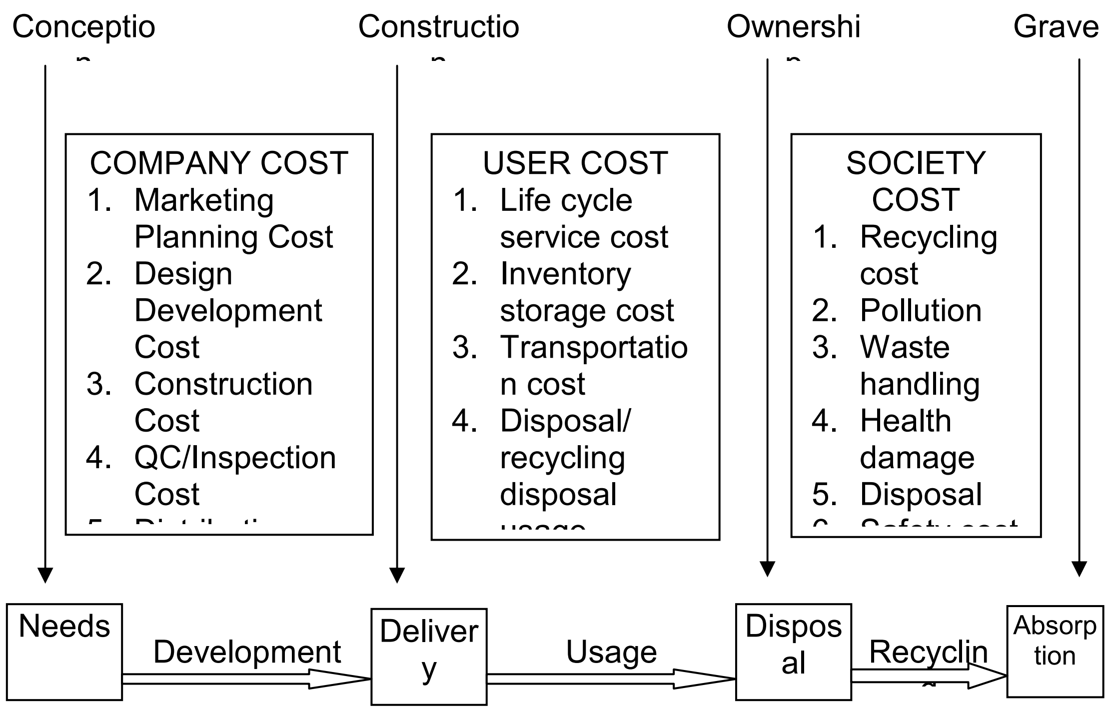

Figure 2: Life Cycle Cost Drivers (Flanagan, 1987; Leo, 1993; Kezner, 2005)

Usually, project cost calculations only cover design and construction costs as well as overhead costs. Consist for disposal/recycling or usage was not considered. It will be necessary to develop models that can describe all the costs related to a project that is total life cycle costs, so that it will be possible to compare different project alternatives. How the costs are share among the company, user and society, is mainly a political issue. A life cycle cost model will be a necessary tool and in the criteria function it may become possible to set a measure for life cycle costs of project.

Life Cycle Design

When designing a project, the design group normally starts its development work based on a set of specifications. These specifications are based on an assessment of a need recognized in the market. The specifications are seen as the 'goal' that the development work is based on a criteria function containing elements like company policy, project properties, construction properties, land condition, material supply and cost. Neither the specification nor the criteria function contains environmentally issues, that is, internal and external environmental protection. For example, the costs for disposal are ‘hidden in our taxes’ and not visible as they should be for the individual product. Not a single one of developer had sanitary land fill. All of them use municipal drainage and other municipal infrastructure which were paid from public taxes. If the disposal costs were visible they would force a necessary development toward more life-cycle economical projects. Life cycle design is illustrated in the phases a project through: need recognition, design/development, construction, usage and maintenance, disposal/recycling. The selection possible solutions are guided by a criteria function contained elements like: environmental protection, occupational health, resource optimization (energy and material), construction, and company policy and life cycle costs.

Life Cycle Methodologies and Tools

Some of the methodologies/tools that have to be developed (Leo, 1993) are; (a) a general methodology for the design function on how to incorporated environmental, occupational health, resource utilization, life cycle costs and so on into design procedure in a natural manner; (b) a procedure/paradigm for establishing environmental, occupational health, resource utilization, life cycle costs specifications alongside with and similar to the specification set up as a goal for the project development; (c) material flow analysis, keeping track of all material input in all phases from construction through disposal/recycling; (d) effects model to assess the effects on the environment as well as on occupational health; (e) risk analysis to cope with accident, fire, hazardous release of materials, energy and so on; (f) resource optimization in a life cycle context. Moreover, it can be used methodologies that are always practice in quality management like: systems integration, quality function deployment, customer satisfaction and concept of selection material.

Life Cycle Cost

The term life cycle cost (LCC) means (Kirk and Dell’Isola, 1995; Barringer, 2003) process for evaluating the total economic worth of a usable project segment by analyzing initial costs and discounted future costs, such as maintenance, user costs, reconstruction, rehabilitation, restoring, and resurfacing costs, over the life of the project segment. Life Cycle Cost is an essential design process for controlling the initial and the future cost of building ownership. LCC can be implemented at any level of the design process and can also be an effective tool for evaluation of existing building systems. LCC can be used to evaluate the cost of a full range of projects, from an entire site complex to a specific building system component. As defined earlier, Life Cycle Cost is the total discounted cost of owning, operating, maintaining, and disposing of a building or a building system over a period of time. LCC equation can be breakdown into three variables: the pertinent costs of ownership, the period of time over which these costs are incurred, and the discount rate that is applied to future costs to equate them with present day costs (Fabrycky and Blanchard, 1991; Bull, 1993).

As the total cost of ownership of machinery and equipment, including its cost of acquisition, operation, maintenance, conversion, and/or decommission, LCC are summations of cost estimates from inception to disposal for both equipment and projects as determined by an analytical study and estimate of total costs experienced in annual time increments during the project life with consideration for the time value of money (Bull, 1993; Kirk and Dell'Isola, 1995, Woodward, 1997). Figure 3 present key factor in LCC. The objective of LCC analysis (Barringer, 2003) is to choose the most cost effective approach from a series of alternatives to achieve the lowest long-term cost of ownership. LCC is an economic model over the project life span. Usually the cost of operation, maintenance, and disposal costs exceed all other first costs many times over.

For calculation of LCC, the following equation is used.

$$\begin{aligned} \text{PW of LCC} = \ & \text{Investment cost} \\ & + \text{PW operation cost} \\ & + \text{PW maintenance cost} \\ & + \text{PW energy cost} \\ & + \text{PW replacement cost} \\ & + \text{PW salvage value} \end{aligned} \qquad (1)$$

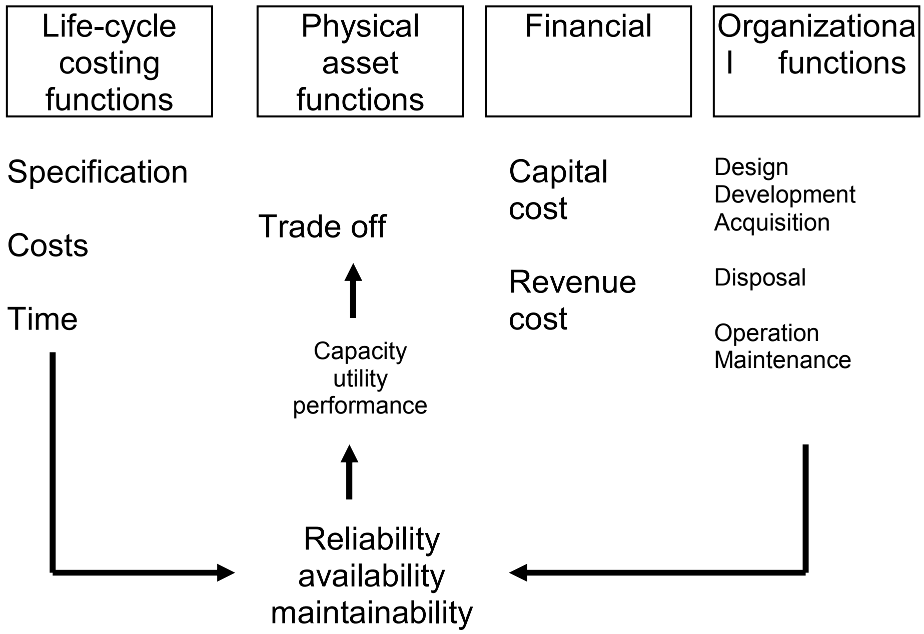

Figure 3: Key factors in Life Cycle Costing (Woodward, 1997)

Present worth (PW) can be calculated using theory of time value of money

$$P = F\left[\frac{1}{1+i}\right]^{N} = F(1+i)^{-N} \quad (2)$$

$$P = A\left[\frac{(1+i)^{N}-1}{i(1+i)^{N}}\right] \quad (3)$$

Where P = present value; F = future value; A = annual value; i = rate per period (year); N = number of time periods (years).

Based on the equation (1) four cost drivers of building were calculated, here salvage value was not calculated because it was not practice in Indonesia. Table 1 and figure 4 present LCC and the proportion for each category; initial cost (including investment cost), energy cost, operation and maintenance (O&M) cost and replacement cost. O&M cost and energy cost have annual basis, so they use equation (3) to calculate. Equation (2) was used for replacement cost that has variability in period.

Table 1. Life Cycle Cost of a Commercial Mall (Million USD)

Cost category	Present Worth (Million USD)
Initial	45
Energy	90
Operation & Maintenance	60

(O&M)	
Replacement	30
Total Cost	225

In the calculation of LCC of the mall project, it is essential that the risk and associates with statistical parameters such as discount rate be properly considered. As a commercial building, two most important variables must be considered for sensitivity analyses, which are discount rate and minimum attractive rate of return (MARR). Sensitivity analysis is a technique for evaluating how stability of the result or outcome depends on the variation in various input parameters.

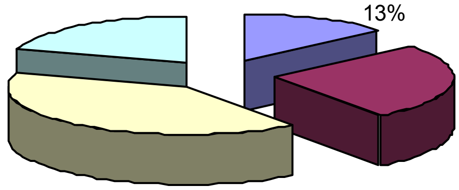

Figure 4. Life Cycle Cost of a Commercial Mall

3. ANALYTIC HIERARCHY PROCESS (AHP)

The AHP (Saaty, 1996) is a powerful and flexible decision making process to help people set priorities and make the best decision when both qualitative and its quantitative aspects of a decision need to be considered. AHP is an approach to decision making that involves structuring multiple choice criteria into a hierarchy, assessing the relative importance of these criteria, comparing alternatives for each criterion, and determining an overall ranking of the alternatives (Knott, 2006). By organizing and assessing alternatives against a hierarchy of multifaceted objectives, AHP provides a proven, effective means to deal with complex decision making. Indeed, AHP allows a better, easier, and more efficient identification of selection criteria, their weighting and analysis.

The same opinions indicate that AHP is appropriate for the task of selecting components when several criteria must be considered (Cangussu, et al., 2006). AHP provides the framework to view the problems in an organized but complex framework that allows for interaction and interdependence among factors and still enables the decision maker to think about them in a simple way (Pandejpong, 2002). The general concept of AHP is about decomposing a problem into sub problems and then aggregating the solutions of all the sub problems into a conclusion (Chantrasa, 2005).

The basic tool in AHP is a matrix number, representing the judgment of pairwise comparisons. Consider the elements C1, C2, ...,Cn of some level in a hierarchy. Weights of influence w1, w2, ...wn on some element in the next level. Denote aij as the number indicating the strength of Ci, when compared with Cj. The matrix of these number aij is denoted A, or A = (aij). aji = 1/aij, that is the matrix A is reciprocal. If judgments is perfect in all comparison, then aik = aij . ajk for all i, j, k and the matrix A is called consistent. Then the mathematic formulation is:

aij = wi/wj ; i,j = 1,2,…n (4)

And thus $$a_{ij}.a_{jk} = {w_i}/{w_j} . {w_j}/{w_k} = {w_i}/{w_k} = a_{ik}$$

The matrix equation A . x = y , where $x = (x_1,...,x_n)$ and $y = (y_1,..., y_n)$ is a shorthand notation for the set of equations.

$$\sum_{j=1}^{n} a_{ij} x_i$$ where i = 1,… n

From equation (4) $$a_{ij} . {w_j}/{w_i} = 1$$ i, j = 1, …, n

And consequently i = 1, … n

$$\sum_{j=1}^{n} a_{ij} . w_j . 1/{w_i} = n$$

Or $$\sum_{j=1}^{n} a_{ij} . w_j = n w_i$$ i = 1, …, n

Which is equivalent to Aw = n w (5)

$$\begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \cdots & \cdots & \cdots & \cdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}$$

In matrix theory, the above formula expresses the fact that w is an eigenvector of A with eigenvalue n. The aij are not based on exact measurements, but on subjective judgments. Thus, the aij will deviate from the “ideal” ratio wi/wj, and therefore equation (5) will no longer hold. But, there are two matrix theory, the first of is, if $\lambda_1,...,\lambda_n$ are the numbers satisfying the equation $Ax = \lambda x$, i.e., are the eigenvalues of A, and if aii = 1 for all I.

Therefore, if equation (5) holds, then all eigenvalues are zero, except one, which is n. Clearly then in the consistent case, n is the largest eigenvalue of A. Second is if one changes the entries aij of a positive reciprocal matrix A by small amounts, then the eigenvalues change by small amounts. It will results the diagonal of a matrix A consists of ones (aii = 1), and if A is consistent, then small variations of the aij keep the largest eigenvalue, $\lambda_{\max}$ close to n, and the remaining eigenvalues close to zero.

4. DESIGN DECISION

In addition to each process that may offer an alternative solution, there are several possible implementations for each of these modeling and evaluating. Because of the potential in the number of possible realizable solutions for each function, a hierarchical approach to evaluation is needed, and it is important to eliminate unsuitable solutions at the highest level of abstraction as possible.

Some functions it may decided that a set of generic process are needed to perform the function, each of which will give rise to an associated set of possible specific processes. The solution to how a particular function will be performed will generally take the form of some process (or procedure). In this research there are three function of sustainability, that are technical, economic, and social (presented in level 3 figure 5) as the basis for alternative priority. By evaluating a number of alternative solutions, every sustainability decision has own alternative priority. Figure 5 shows a model of decision hierarchy of sustainable function for a commercial mall project in Indonesia. Each of the objects in this model contains attribute representing their various properties and different preference. In this model, energy building system is used as object study. The model has been test to the decision in a mall project. A paired comparison is held to determine the weighing to be given to each attribute.

Based on decision hierarchy in figure 5, calculation matrix for each level of hierarchy that are: weighing factor of each criteria, 0.053989 (initial cost), 0.364125 (return in profit), 0.05341 (reliability), 0.153315 (functional performance), 0.15329 (maintenance ability), 0,193935 (energy cost). Table 2 and 3 indicate that every sustainability function have their own preference priority. Using 100% government sources for energy system was chosen as first priority for technical and economic sustainability function. Different priority presents in social sustainability. This function put green technology in the highest priority.

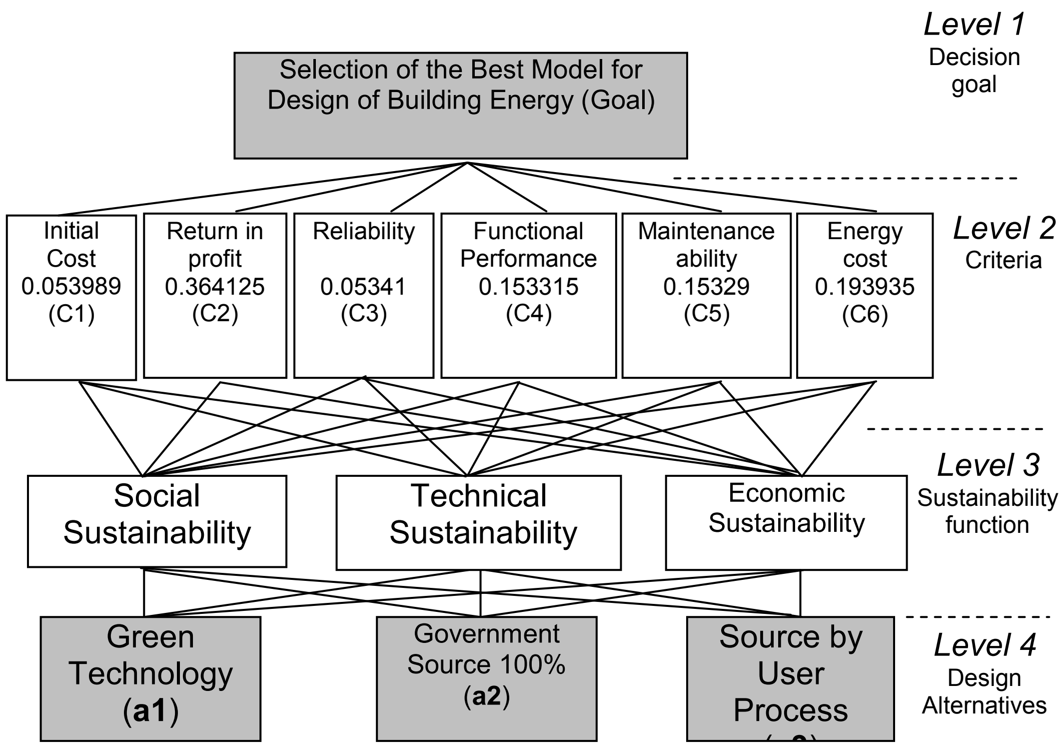

Figure 5. Decision Hierarchy Model

Table 2: Synthesis of Analytic Hierarchy Process

Weight of alternative	*Weight of criteria (Consistency Ratio =0.091865)*					
	C1 0.053989	*C2* 0.364125	*C3* 0.05341	*C4* 0.153315	*C5* 0.15329	*C6* 0.193935
Social sustainability						
a1 0.419094	0.03789	0.03990	0.03383	0.07519	0.09392	0.13836
a2 0.230976	0.01065	0.11257	0.00567	0.04783	0.01809	0.03619
a3 0.321994	0.00545	0.21165	0.01391	0.03029	0.04128	0.01939
Technical sustainability						
a1 0.217825	0.02833	0.02913	0.02797	0.01681	0.01403	0.10156
a2 0.423381	0.01802	0.13967	0.00919	0.08912	0.10839	0.05899
a3 0.330857	0.00764	0.19532	0.01625	0.04739	0.03087	0.03338
Economic sustainability						
a1 0.316265	0.00284	0.09562	0.00747	0.09819	0.09156	0.02059
a2 0.364122	0.03126	0.11987	0.01529	0.03156	0.04329	0.12283
a3 0.291678	0.01989	0.14863	0.03064	0.02356	0.01843	0.05052

Table 3: Each Alternatives for each Decision

Priorities	Decision Alternatives to Function		
	Social Sustainability	Technical Sustainability	Economic Sustainability
1	By green technology	By government source	By government source
2	By government source	By user process	By green technology
3	By user process	By green technology	By user process

Since the decision priority is different for each sustainability function, further method can be used for optimization such as goal programming or advance method in artificial intelligent. In this case, design by 100% government source was decide for the mall project. This decision based on qualitative synthesis of LCC analysis and the AHP result by the owner and designer.

5. CONCLUSION

The implementation results demonstrate a process to select priorities each alternatives to each decision. Life cycle cost and function analysis lead to effort in the initial design process and an increased active in the evaluation stage. However, given that implementation is the part of the development process that requires the greatest effort, and in many case accounts for the largest proportion of development costs. It further emphasizes the importance of performance evaluation in the design process, and provides a focus for future research into performance evaluation techniques and their application. Follow up research is particularly required, primarily a study of decision support system and expert systems, and artificial intelligent such as Multi Agent System

6. REFERENCES

Barringer, P. (2003). A life cycle cost summary. *International Conference of Maintenance Societies.*

Bull, John W. (1993). *Life cycle cost for construction*, 1st ed., London: Blackie Academic & Professional.

Fabrycky, W. J & Blanchard, B.S. (1991). *Life-cycle cost and economic analysis*, New Jersey: Prentice-Hall.

Kirk, S. J. & Dell'Isola. (1995). *Life cycle costing for design professionals*, 2nd edition. New York: McGraw-Hill, Inc.

Woodward, D.G. (1997). Life cycle costing-theory, information acquisition and application. *International Journal of Project Management* 15(6): 335-344.

Alting, Leo (1993) *Life-cycle Design of Product: A New Opportunity for Manufacturing Enterprises in Concurrent Engineering: Automation, Tools, and Techniques*, edited by Andrew Kusiak. John Wiley & Sons.

Flanagan, R, *et al* (1987) Life Cycle Costing and Risk Management. *Construction Management and Economics Journal*

Knott, C.L. (2006) *A New Approach to Estimating Non Sampling Errors Using The Analytic Hierarchy Process.* PhD. Dissertation. The George Washington University : United States.

Kezner, H (2005) *Project Management: A System Approach to Planning, Scheduling, and Controlling*. 9th Edition. John Wiley&Sons Inc.

Cangussu, J.W. Cooper, K.C. and Wong, E.W. (2006) Multi Criteria Selection of Component Using The Analytic Hierarchy Process*. Journal of Lecture Notes in Computer Science*, pp 67-82.

Chantrasa, R. (2005) *Decision Making Approaches for Information Sharing In A Supply Chain.* PhD. Dissertation. Clemson University. United States.

Pandejpong, T. (2002) *Strategic Decision: Process for Technology Selection in The Petrochemical Industry.* Engineering Management of Technology. Portland : Portland State University.

Saaty, T.L. (1996). *The Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process*, volume IV of AHP Series. RWS Publications, Pittsburg.