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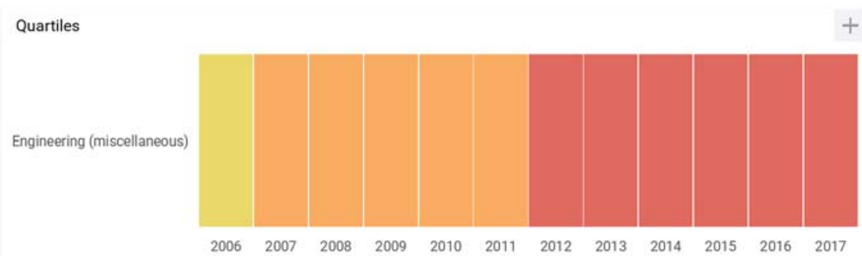

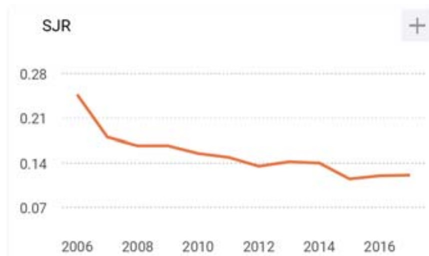

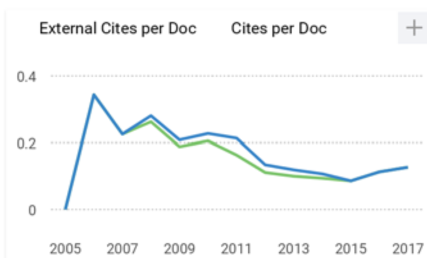

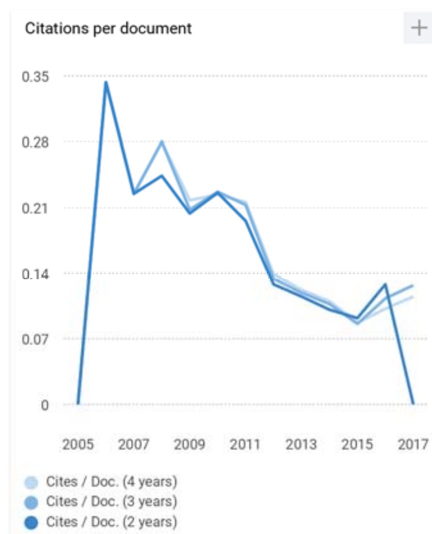

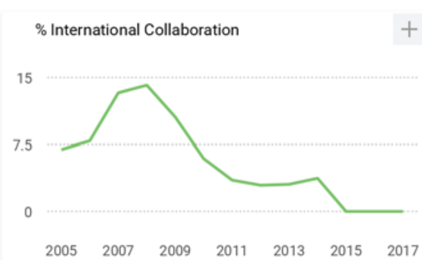

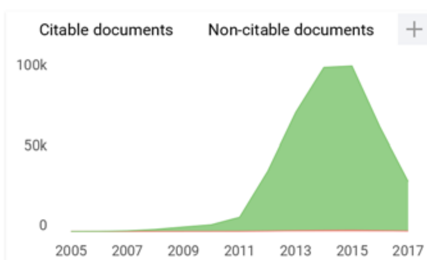

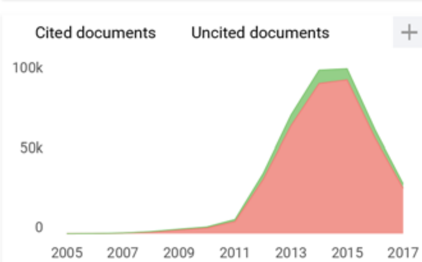

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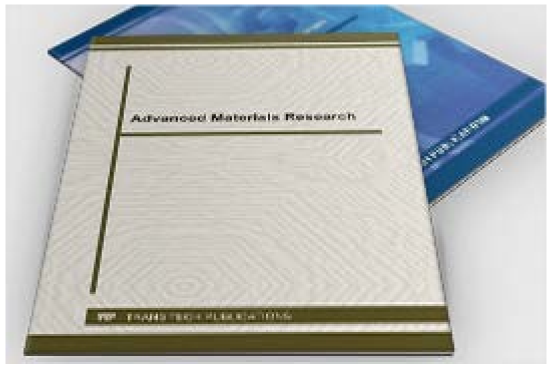

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A Framework for Life Cycle Cost Estimation of a Product Family at the Early Stage of Product Development

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Keywords: Life Cycle Cost, Cost Estimation, Product Family, Early Design Stage.

Abstract. A cost estimation method is required to estimate the life cycle cost of a product family at the early stage of product development in order to evaluate the product family design. There are difficulties with existing cost estimation techniques in estimating the life cycle cost for a product family at the early stage of product development. This paper proposes a framework that combines a knowledge based system and an activity based costing techniques in estimating the life cycle cost of a product family at the early stage of product development. The inputs of the framework are the product family structure and its sub function. The output of the framework is the life cycle cost of a product family that consists of all costs at each product family level and the costs of each product life cycle stage. The proposed framework provides a life cycle cost estimation tool for a product family at the early stage of product development using high level information as its input. The framework makes it possible to estimate the life cycle cost of various product family that use any types of product structure. It provides detailed information related to the activity and resource costs of both parts and products that can assist the designer in analyzing the cost of the product family design. In addition, it can reduce the required amount of information and time to construct the cost estimation system.

Introduction

To provide customized product at reasonable cost in a shorter lead-time, mass customization is the most widely implemented approach. Mass customization is defined by Pine (1993) as variety and customization through flexibility and quick responsiveness [1]. The aim of this approach is to deliver a variety of product that fulfils customer needs while keeping mass production efficiency [2]. However, it is not feasible to develop all product variation because of some of the limitations within and outside the manufacturing companies. Simpson (2004) proposes that an effective means to providing a variety of products in a cost effective way is through a product family design [as cited in 3]. In general, product family is defined as "a group of related products that is derived from a product platform to satisfy a variety of market niches" [4].

To ensure the success of mass customization approach (in this case, designing a product family) in a product development chain, a rapid and accurate cost estimation and control system is needed [5]. The cost estimation system should consider not only pre production and production cost (design, manufacturing, and assembly) but also post production cost (customer use, support, and end of life). Therefore, a cost estimation method is required to estimate the product life cycle cost of the product family at the early stage of product development in order to evaluate the product family design.

Various cost estimation techniques have been suggested to estimate the cost of the product family. However, there are difficulties with these techniques in estimating the life cycle cost for a product family at the early stage of product development. This paper proposes a framework to solve this problem. In the next section, an analysis of various cost estimation techniques for a product family

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and a description of their weaknesses in estimating life cycle cost for a product family at the early stage of product development are provided. In Section 3, a framework to estimate the life cycle cost of the product family is presented. Conclusions are drawn and described in the last section.

Life Cycle Cost Estimation Techniques for a Product Family

Existing cost estimation techniques can be classified into four classifications, which are intuitive, analogy, parametric, and analytic techniques [6]. Many researchers propose using various analytic techniques in estimating cost of a product family. A cost index structure combined with generative and variant cost estimation methods is proposed by Tu, Xie, & Fung (2007) to estimate cost in mass customization [5]. The technique covers only production cost and is problematic in estimating post production cost.

Park & Simpson (2005) develop an activity based costing framework for a product family, which consists of allocation, estimation, and analysis stages [7]. Later, they refine the framework by developing cost modularization in the activity based costing system [3]. Related to the activity based costing technique, Chen & Wang (2007) propose a generic activity definition in order to simplify and catalyze activities based costing especially in high variety production [8]. To use an activity based costing technique, low level information related to required activities and resources in producing all products should be available. Other research by Johnson & Kirchain (2010) proposes process based cost modeling as cost modeling methodology to estimate fabrication, assembly, and development costs of the product [9]. Similar to an activity based costing technique, process based cost modeling also requires detailed information in order to estimate the cost.

In general, existing analytic techniques are difficult to implement at the early stage of product development because they require detailed and complete information as their input. Meanwhile, the available information in the early stage of product family development is high level information. This difficulty also is faced in existing parametric techniques because it requires parameters to be identified before performing cost estimation.

To solve the problem, several types of analogy technique are suggested to estimate cost at the early stage of product development. An analogy technique can estimate cost using high level information as the input. Seo, Park, Jang, & Wallace (2002) develop a cost estimation system that employs artificial neural networks to estimate life cycle cost in conceptual design [10]. Seo, et al. (2002) do not specifically develop cost estimation for a product family but this system can be used to estimate the cost of all product variants of a product family at the early stage of product development. This cost estimation system provides fast estimation but poses difficulties if the product structure changes due to a new design. In addition, an artificial neural network functions as a black box in cost estimation and does not provide detailed information related to various factors and their influence on the cost. Therefore, this system cannot be used in analyzing the cost of a product family and evaluating its design.

Intuitive technique is used by Shehab & Abdalla (2002) in modeling the cost of a machining component and an injection molding component [11]. In their research, they propose an intelligent knowledge based system with hybrid knowledge representation techniques. Intuitive technique is mostly used to estimate cost for a single part because it requires a large volume of information and extensive time to construct the cost estimation system [12, 13].

Accordingly, existing analogy cost estimation techniques can be difficult to use for life cycle cost analysis at the early stage of product development. In addition, they cannot be used if the product family structure changes due to a new design. Furthermore, existing intuitive techniques require much more information and time to construct a cost estimation system for a product family compared to that for a single part because a product family consists of various parts.

As a single technique has difficulties in estimating the life cycle cost of a product family at the early stage of product development, a hybrid technique raises the possibility of solving the problems [14-16]. Liu, Gopalkrishnan, Ng, Song, & Li (2008) build an intelligent system to estimate the product life cycle cost at the early design stage. This research applies activity based costing and machine learning technique to define and estimate various life cycle cost elements [17]. An artificial neural network or support vector regression is applied if available activity and resource information are insufficient. An activity based costing is applied if there are sufficient activity and resource information. This intelligent system can only estimate the cost of a product family that use a certain product structure and it cannot be used to analyze the cost of a product family.

Other existing hybrid technique is proposed by Xu, Chen, & Xie (2006) [18]. They propose to use case based reasoning to buid a new product model and activity based costing to calculate the life cycle cost of a product. However, the framework cannot be used to estimate the life cycle cost for each product family level (platform, product variant and product family). As a result, the framework cannot be used to analyse the cost of a product family.

Life Cycle Cost Estimation Framework

According to Park & Simpson (2008), activity based costing is an appropriate technique to estimate the cost of a product family because it is able to allocate indirect cost more accurately to each product variant in the product family [3]. This ability is important because applying a product family approach increases product variety and production volumes. As a result, overhead cost becomes larger than total production cost and does not proportionally increase with production volumes. However, as described above, an activity based costing technique requires detailed activity and resource information and can be problematic to implement at the early stage of product development. For that reason, a method to provide the required information at the early stage of product development should be developed and then combined with the activity based costing.

This paper proposes a framework that combines a knowledge based system and an activity based costing techniques in estimating the life cycle cost of a product family at the early stage of product development. In this paper, the early stage of product development refers to the stage after product planning and before product embodiment. The framework will apply an expert system and a case base reasoning to solve the problem in generating the required activity and resource information at the early stage of product development. Then, the generated information will be used as an input of the activity based costing technique to estimate the life cycle cost of a product family at the early stage of product development.

The aim of the framework is to provide a tool for estimating the life cycle cost of various product families, which have various types of structure, by using available high level information at the early stage of product development. The inputs of the framework are a product family structure and its sub functions. The sub function is represented by the use of the function taxonomy of Hirtz [19]. The information related to the sub function consists of its type, market segment, input, and output. The type classifies each sub function into a base or variant sub function. The market segment explains its product segment, performance, and production volume. The input and output describe input and output material, energy, motion, and signal of each sub function. Based on the input, the framework will generate life cycle cost information of a product family as its output that consists of all costs at each product family level and the costs of each product life cycle stage (research and development, production, logistic, usage and end of life).

The framework consists of five steps as shown in Figure 1 below. The first step is to retrieve and select a concept that could satisfy each required sub function. First, each sub function is mapped to at least one appropriate concept that can satisfy the sub function and then designers select the best concept for each sub function based on their expertise. Case based reasoning is used to find the appropriate concepts from previously developed concept database. Each selected concept inherits the type and market segment information of the related sub function.

The next step is to break down each selected concept into its assembled parts and to provide information related to the type, market segment, procurement type, design, logistics, physical, after sales and end of life attributes of each assembled part. The type and the market segment information of each part are inherited from the related concept. The procurement type determines whether the part will be manufactured inhouse or outsourced. The physical attributes of part could include quantity, material, shape, main dimension, specific features, and required tolerance. The procurement type and the five attributes information are required to generate data on all activities and resources performed at each product life cycle stage. Case based reasoning is used to determine the assembled parts and their related information.

The third step is to generate activity and resource information for each part, which are required or consumed from the design stage up to the end of life stage of product life cycle. The activity information consists of all required activities consumed by each part. The resource information describes all resources consumed by each activity. First, each assembled part is categorized according to its procurement type. The activities and consumed resources information related to the outsourced parts are generated differently compared to the inhouse parts. The activity information of an inhouse part comprises process related and non process related activities. Meanwhile, no manufacturing process activity is required for an outsourced part. Therefore, the activity information of outsourced part comprises only all activities that are not related to the manufacturing process. Then, the process required to manufacture each inhouse part is determined by the use of the expert system. Next, all process related activities for the inhouse part are generated by the use of the case based reasoning. The activity information of non related part is also generated by using case based reasoning. Finally, all resources required in conducting each activity are determined by using case based reasoning. Because a knowledge based system is used to generate general activities and resources information that can be applied to all parts, the amount of information and time in constructing the cost estimation system are not as great as generating cost information for each part.

Next, all activity and resource information required to produce all product variants of the product family are then generated. Product structure that describes the hierarchical relationships of all parts is used to determine the required activities. The sequence of assembly/disassembly process and the parts that are assembled/disassembled are determined by the use of the expert system. Then, all the resources consumed in conducting each activity are generated. This step uses a similar technique to generate activity and resource information for parts. Because the product structure is used as the input, the proposed framework makes it possible to estimate the life cycle cost of the product family that have any types of product structure.

The last step is to calculate the life cycle cost of the product family by the use of an activity based costing. Activities and resources information for a part, operational data (i.e. working days, hours per day, etc.), and financial data (i.e. material cost, labor wage, etc.) are used to calculate the life cycle cost of each part. Parts that require similar activities are grouped and the resources that they consume are identified. Then, the usage of the resources consumed is calculated and summed. The total usage of the resources consumed is used to calculate resource consumption rates. The resource consumption rate is equal to total resource cost divided by the total usage of the resource consumed. Each activity cost of a part can be calculated by multiplying the resource consumption rate with the resource usage of the activity. The life cycle cost of each part can be calculated by adding all costs of the activities consumed by the part and then divide it with the production volume of the part.

Activities and resources information for a product, operational data, and financial data are used to calculate the activity costs for a product. It is similar to calculate the activity costs for a part. The life cycle cost of each product can be calculated by adding all activity costs for a product divided by the production volume of the product and the life cycle cost of all of its parts. The life cycle cost can be calculated for each product family level and for each product life cycle stage.

Conclusions

The proposed framework provides a life cycle cost estimation tool for a product family at the early stage of product development using high level information as its input. The framework makes it possible to estimate the life cycle cost of various product family that use any types of product structure. It provides detailed information related to the activity and resource costs of both parts and products that can assist the designer in analyzing the cost of the product family design. In addition, it can reduce the required amount of information and time to construct the cost estimation system.

By using the proposed framework, manufacturing companies will be able to estimate all costs throughout the product life cycle of all product variants (platform and variants) of various product families, analyze the profitability of a product family design, and perform tradeoffs between the benefit and the cost in designing a product family.

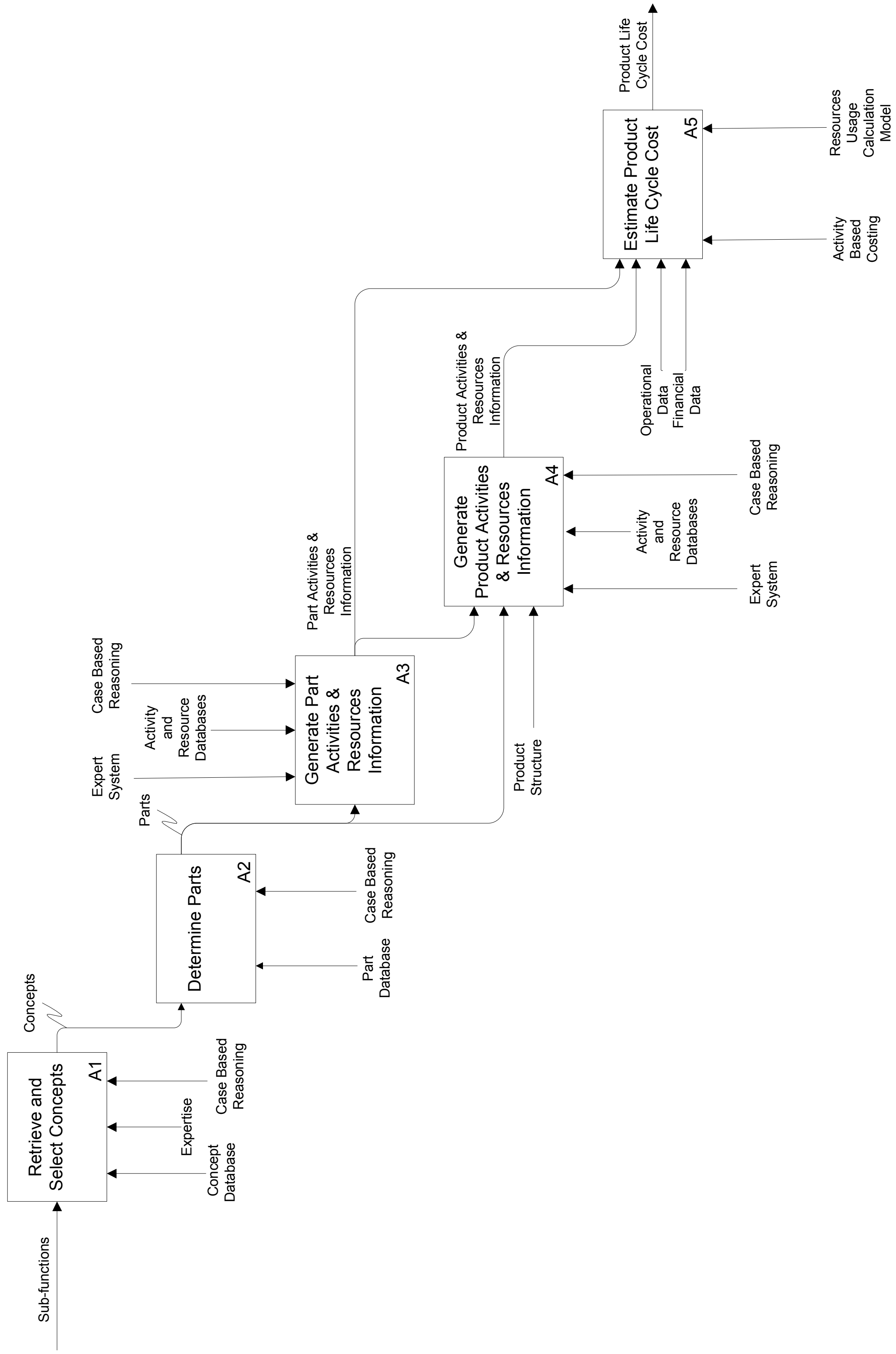

Fig. 1 Proposed Cost Estimation Framework

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References

[1] B.J. Pine, *Mass customization: the new frontier in business competition*. (1993), Boston, Mass: Harvard Business School Press.

[2] J. Jiao and M.M. Tseng, *A methodology of developing product family architecture for mass customization,* Journal of Intelligent Manufacturing. **10**(1) (1999) 3-20.

[3] J. Park and T.W. Simpson, *Toward an activity-based costing system for product families and product platforms in the early stages of development,* International Journal of Production Research. **46**(1) (2008) 99-130.

[4] T.W. Simpson, Z. Siddique, and J. Jiao, *Product platform and product family design: methods and applications*. (2006), New York: Springer-Verlag.

[5] Y.L. Tu, et al., *Product development cost estimation in mass customization,* IEEE Transactions on Engineering Management. **54**(1) (2007) 29-40.

[6] A. Niazi, et al., *Product cost estimation: Technique classification and methodology review,* Journal of Manufacturing Science and Engineering-Transactions of The ASME. **128**(2) (2006) 563-575.

[7] J. Park and T.W. Simpson, *Development of a production cost estimation framework to support product family design,* International Journal of Production Research. **43**(4) (2005) 731-772.

[8] Z. Chen and L. Wang, *A generic activity-dictionary-based method for product costing in mass customization,* Journal of Manufacturing Technology Management. **18**(6) (2007) 678-700.

[9] M.D. Johnson and R. Kirchain, *Developing and Assessing Commonality Metrics for Product Families: A Process-Based Cost-Modeling Approach,* IEEE Transactions on Engineering Management. **57**(4) (2010) 634-648.

[10] K.K. Seo, et al., *Approximate Estimation of the Product Life Cycle Cost Using Artificial Neural Networks in Conceptual Design,* International Journal of Advanced Manufacturing Technology. **19**(6) (2002) 461-471.

[11] E. Shehab and H. Abdalla, *An Intelligent Knowledge-Based System for Product Cost Modelling,* International Journal of Advanced Manufacturing Technology. **19**(1) (2002) 49-65.

[12] H. Wang, X.Y. Ruan, and X.H. Zhou, *Research on Injection Mould Intelligent Cost Estimation System and Key Technologies,* International Journal of Advanced Manufacturing Technology. **21**(3) (2003) 215-222.

[13] K.H. Ko, K. Pochiraju, and S. Manoochehri, *An embedded system for knowledge-based cost evaluation of molded parts,* Knowledge-Based Systems. **20**(3) (2007) 291-299.

[14] F.T.S. Chan, *Application of a hybrid case-based reasoning approach in electroplating industry,* Expert Systems With Applications. **29**(1) (2005) 121-130.

[15] P. Duverlie and J.M. Castelain, *Cost Estimation During Design Step: Parametric Method versus Case Based Reasoning Method,* International Journal of Advanced Manufacturing Technology. **15**(12) (1999) 895-906.

[16] R. Chougule and B. Ravi, *Casting cost estimation in an integrated product and process design environment,* International Journal of Computer Integrated Manufacturing. **19**(7) (2006) 676-688.

[17] H. Liu, et al., *An intelligent system for estimating full product life cycle cost at the early design stage,* International Journal of Product Lifecycle Management. **3**(2/3) (2008) 96-113.

[18] X. Xu, J.L.Q. Chen, and S.Q. Xie, *Framework of a Product Lifecycle Costing System,* Journal of Computing and Information Science in Engineering. **6**(1) (2006) 69.

[19] J. Hirtz, et al., *A functional basis for engineering design: Reconciling and evolving previous efforts,* Research in Engineering Design. **13**(2) (2002) 65-82.