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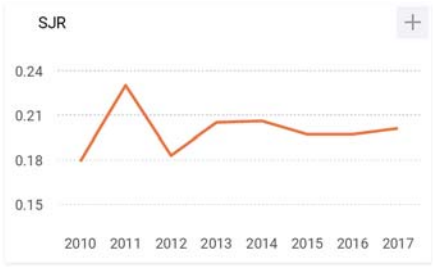

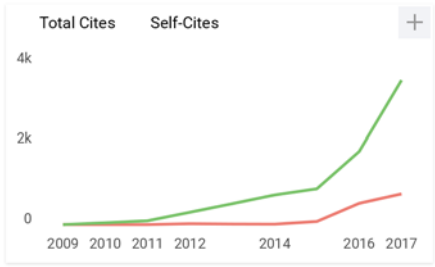

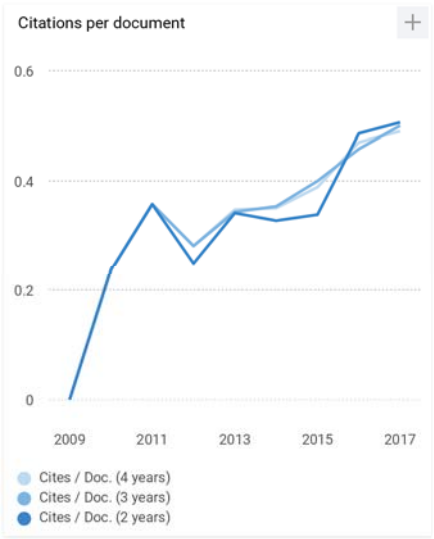

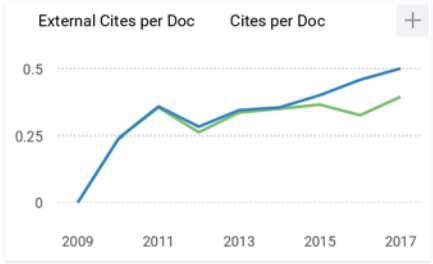

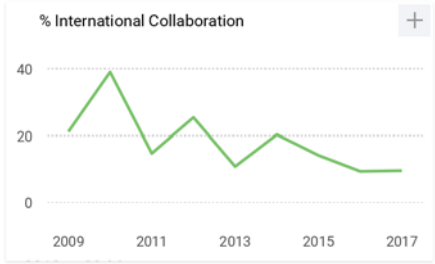

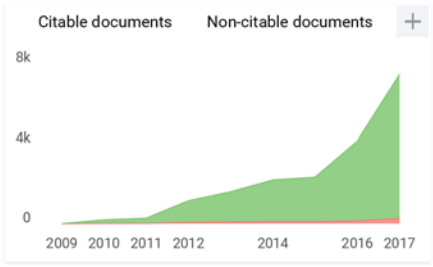

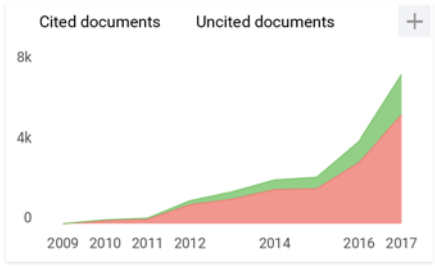

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Welcome Remarks, Chair of the Steering Committee

Welcome to Bali! Welcome to our very first International Conference on Informatics, Technology and Engineering (InCITE) 2017 held by Faculty of Engineering Universitas Surabaya (Ubaya), in collaboration with University of Wollongong (Australia), Solar Energy Research Center – Dalarna University (Sweden), Suranaree University of Technology (Thailand), and National Taiwan University of Science and Technology (Taiwan).

This international conference will be enlivened by a series of keynote speeches and parallel sessions delivered by scholars, researchers, practitioners and academicians who are coming from 5 different countries and more. More specifically, it is hoped that InCITE may link researchers and practitioners from various branches of engineering disciplines from around the world. This year's conference theme of Sustainable Technology and Innovation – Opportunities and Challenges will bring you to the critical awareness of what we have done and what we should contribute to our sustainable environment, society and economy, through the applied technology and innovation. All participants will disseminate information on the relevant and recent research and practice in engineering-based sustainability.

We would like to say thank you to all keynote speakers, presenters, and reviewers/scientific committees for the generous supports. In addition, our thank you to the Ubaya Foundation, Rector of Ubaya, Dean of Faculty of Engineering Ubaya, OC Chairman and members, SC members, and all InCITE committees.

We wish you a very pleasant and memorable stay and research networking event in InCITE 2017 Bali. We are looking forward to seeing you again at the 2nd InCITE 2019! Thank you very much. *Matur nuwun sanget.*

Assoc. Prof. Ir. Markus Hartono, Ph.D., CHFP, IPM

Welcome Remarks, Chair of the Organizing Committee

Rector of University of Surabaya: Prof. Dr. Joniarto Parung,
Dean of Faculty of Engineering, University of Surabaya: Dr. Amelia Santoso,
Honorary Keynote Speakers: Prof. Dr. Suksun Horpibulsuk, Prof. Dr. Nai-Wei Lo, Prof. Dr. Mats Rönnelid, and Prof. Dr. Willy Susilo,
Fellow Participants, Distinguished Guests, Ladies and Gentlemen:

First of all, welcome to Bali, Indonesia, and welcome to the first International Conference on Informatics, Technology and Engineering (InCITE) 2017!

It is still vivid in my memory, one and a half year ago, when some colleagues and officials of our Faculty of Engineering discussed the possibility of organizing an international event, to substitute national seminars that some of our study programs held annually or bi-annually. The call for an international event is a necessity given 30 years of Faculty of Engineering's existence, and the dawn of University of Surabaya's Silver Anniversary next year. Such a level of maturity prompts us to contribute more to a larger scale. An international event will have greater exposure to international community, and consequently greater impact to us all.

The following process, however, was far from easy. We were inexperienced, but we were faithful to our mission. It took us some time until we were able to formulate the conference theme, found prominent scholars in the selected theme, and negotiated with them. We are very grateful that all four speakers whom we approached are here with us today, to deliver their insights on opportunities and challenges in sustainable technology and innovation. Let's give our big hands to them!

Sessions beyond those with our invited speakers will deliver four sub-themes, namely: *sustainable design & innovation*, *sustainable manufacturing & processes*, *sustainable energy & earth resources*, and *the role of IT in sustainable enterprise*. We are glad to inform you that our conference has attracted 67 papers from the first round of acceptance. After careful selection by a panel that consists of high-profile international reviewers around the world, we passed 50 papers. We are thankful to our international reviewers who worked very hard providing feedback to the submitted papers. We are indebted to such great service that they have given.

I sincerely hope that the exchange of knowledge throughout this event, be it from within the substance of academic papers or during the conference time, will enhance our professional network and benefit us in the long run. Thank you to all our speakers, reviewers, participants, and most of all my committee members who have been hand-in-hand with me in this long journey! You all have made our dream come true!

We hope you will have a wonderful conference and memorable stay in Bali this week. We are looking forward to seeing you again in the next two years!

Assoc. Prof. Eric Wibisono, Ph.D.

Conference Photographs






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Estimating life cycle cost for a product family design: The challenges

IOP Conf. Series: Materials Science and Engineering **273** (2017) 012026 doi:10.1088/1757-899X/273/1/012026

Estimating life cycle cost for a product family design: The challenges

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Abstract. A cost estimation system is required to assist in designing a product family. The aim of this paper is to identify the requirements and the problems in estimating the life cycle cost of a product family. Then, this paper also presents the state-of-the-art and the research challenges in developing a life cycle cost estimation system for a product family design. As the conclusion, the life cycle cost estimation process for a product family still needs to face the challenges to determine the end of life strategy of each sub module of a product family, to integrate the end of life strategy to estimate the life cycle cost of a product family, to estimate the life cycle cost of each component level of a product family for design purposes and for different technologies and approaches, to reduce the required time and effort for updating process in estimating the life cycle cost for different structures of different product families, and to transform the available information into the required information in order to estimate the life cycle cost of a product family at the early stage of product development.

1. Introduction

Manufacturing companies are now under pressure to provide a variety of products in a shorter lead-time and in a cost effective way, without sacrificing product quality and environmental considerations, to be competitive in the market. Simpson (as cited in [1]) proposes that an effective means of fulfilling the requirements, to provide a variety of products in a cost effective way, is through a product family design. The implementation of a product family design is not only beneficial at the manufacturing and supply chain stages but also at the end of life stage. In general, a product family is defined as "a group of related products that is derived from a product platform to satisfy a variety of market niches" [2]. Derived from various definitions of a product platform as cited by Simpson et al., the groups of products are related because they share common functions, features, components, technologies, processes, knowledge, people and/or relationships, which form a product platform [2].

In this research, a product family is divided into five levels of components, which are part, product platform, variant, product variant, and product family level. Each component level is related to each other by its market segment. A product family consists of more than one product variant that share common things. Each product variant is developed to satisfy customers from a certain market segment. Each product variant consists of product platform and variant. A product platform consists of several parts that form a common structure. A variant is a part or a collection of parts that differentiates one

member of a product family from other members. A part is the lowest level component of a product family. Each part inherits the market segment attributes of the product variant to which it belongs.

The growing implementation of a product family design has led to the need for a product family design support system especially the cost estimation system. However, most of the product family design methods provide a limited support for the cost estimation process [3]. Therefore, the aim of this paper is to identify the requirements and the problems in estimating the cost of a product family. In addition, this paper also presents the state-of-the-art and the research challenges in developing a cost estimation system for a product family design.

The next section describes all the requirements in estimating the cost of a product family. Then, various problems in implementing the product family approach especially in estimating the cost of a product family are explained. In section 4, existing cost estimation systems are reviewed in order to fulfill the requirements and solve the identified problems for estimating the cost of a product family. Next, the requirements and the problems in estimating the cost of a product family and how the existing techniques handle the problems are discussed. Finally, the challenges in estimating the cost for a product family design are concluded in the last section.

2. Cost estimation system requirements for a product family

A cost estimation system is required to assist in estimating the profitability of the product family design, performing an economic evaluation of the technical choices design, and controlling other processes in the product family design. It is also useful in performing the trade-off between the benefit and the complexity in optimizing the product family design. As a product family has five levels of components, the cost estimation of each level of component is required. Therefore, an appropriate cost estimation system is required to estimate the cost of each component level in order to assist in evaluating the design of a product family.

A product family could have various structures. Even different product variants in the same product family could use different structures. The product structure defines how the functions or components of a product are arranged in a hierarchical structure. It describes the relationship among functions or components of a product. Different product family structures will influence the product family cost differently. Therefore, the product family structure must be taken into account in estimating the cost of a product family.

The product family approach has been implemented by various types and sizes of companies. As various types and sizes of companies exist in the world, the cost estimation system must be able to be applied in different types and sizes of companies that implement different technologies and approaches. In addition, as technology is changing rapidly, the cost estimation system must be able to accommodate the changes or it will become unreliable. For that reason, the cost estimation system for a product family must be able to be implemented in different situations and take into account any changes.

The cost estimation system must be able to estimate the life cycle cost of a product family. It involves all the incurred costs during the product design, the production, the product use, the support, and the disposal or recycling stage [4]. The life cycle cost is important to be used as an engineering tool for providing decision support in the design process. Many researchers have proposed a variety of cost estimation techniques. However, the majority of the cost estimation techniques are proposed to estimate the cost incurred at the pre-production and the production stages. The estimation of the post-production costs, especially the end of life cost, is becoming important in performing an evaluation of the product family because the end of life cost now has a significant influence on the total cost of a product. The influence of the end of life cost is becoming significant because the costs of product take back, product recovery, and product disposal are now being imposed on manufacturers as a result of the increasing environmental awareness and the stricter regulations related to the environment. The estimation of the end of life cost is also important in understanding the potential benefits in remanufacturing and refurbishing.

The life cycle cost estimation of a product family should be performed at the early stage of product development. The early stage of product development refers to the stage after product planning and before the product detail design stage. According to Nevins and Whitney (as cited in [5]), it is important to estimate the life cycle cost at the early stage of product development, because at least 70% of the product life cycle cost is committed at this stage. By performing the life cycle cost estimation at this stage, the cost could be adjusted as early as possible and as a result, decisions can be more easily made. In addition, it is more feasible to reduce the cost at the early stage of product development without resulting in many difficulties caused by late modification.

3. Cost estimation problems

Although the implementation of a product family approach could bring various benefits, it could raise the complexity at all stages during the product life cycle, including the estimation of the life cycle cost of a product family. The implementation of a product family approach increases the range of products. The increased range of products increases the number of indirect activities, which benefit more than one product. As a result, it enlarges the portion of the indirect cost to the total cost. The increased portion of the indirect cost creates a significant error in estimating cost for product family by using a traditional volume-based cost estimation technique. The error becomes significant because a volume-based cost estimation technique assumes that the indirect cost is proportional to the volume of the product. In fact, the indirect cost does not always vary with production volumes. The assumption causes under costing for certain types of products and over costing for other products. To reduce the error, the cost estimation system must be able to allocate the indirect cost properly.

In addition, the implementation of a product family approach is more difficult compared to the implementation of multiple products because there are sharing components, processes, resources, etc. between or among members of a product family. The sharing component, process, resource, etc. between or among members could result in difficulty in allocating the cost of each member. It makes the cost estimation process for a product family much more difficult and could generate more errors than for an individual product and for multiple products. For that reason, the cost estimation system must be able to allocate the life cycle cost for each product variant of a product family. As the life cycle cost estimation of each component level is required in evaluating the design of the product family, the cost estimation system must also be able to allocate the life cycle cost of each component level of a product family.

Another problem that arises in estimating the cost of a product family is that different product structures will result in different costs. As the cost estimation system must be able to estimate the life cycle cost of different structures of different product families, the system could require extensive time and effort in estimating the life cycle cost of various structures of a product family. In addition, it is required to store complete information for each product platform, variant, and product variant. To avoid this, the cost estimation system must be easily updated for different structures of different product families.

The cost estimation system must be able to be applied in different types and sizes of companies [6]. It must also be able to accommodate the trend of technology and reflect any change inside the company or it will become unreliable. The implementation of the cost estimation system in different situations could require extensive time and effort in adapting process. Therefore, the cost estimation system for a product family must be easily adapted to reflect any changes.

In addition, the life cycle cost of a product family is influenced by the end of life strategy of the product family. The end of life strategy of a product determines the end of life recovery process that will be conducted after the product is taken back. It is not realistic to determine the end of life strategy on product level because a product consists of more than one component that could have different attributes and end of life strategies. It is also not practicable to determine the end of life strategy on part level because it is usually less economical to disassemble a product into parts. The factors that can be used to determine the end of life of a sub module could be different compared to a product or a part. Various factors are used to determine the end of life strategy of a product that is at the end of its life

[7, 8, 9]. Other researchers have proposed other factors to determine the end of life strategy of a part [10, 11]. For that reason, the cost estimation system must consider various factors that influence the end of life of a sub module in estimating the life cycle cost.

Furthermore, the need to estimate the cost at the early stage of product development results in another problem in estimating the life cycle cost of a product family. As a product family is represented by several attributes, then these attributes influence the life cycle cost of a product family. Not all attributes required to design a product family are available at the early stage of product development. At the conceptual design stage, geometry and material of the product are not yet known. According to Pahl, Beitz, Feldhusen, and Grote, the available product information is identified problems, required functions, working principles and structure [12]. In addition, Zha describes that the available product information at the beginning of the conceptual design is functional requirements and relevant production requirements [13]. Then, during the conceptual design stage, the information is transformed into critical design requirements. Based on the studies by Fixson, Simpson, et al., and by Park and Simpson, the available product family attributes at the early stage of product development are market segment, production volume, product family structure, and product family function [1, 14]. In order to estimate the cost of a product family at the early stage of product development, the cost estimation system must be able to use the market segment, the production volume, the product family structure, and the product family functions as its input.

4. Life cycle cost estimation techniques for a product family

A large number of systems for estimating the cost of a product have been proposed by many researchers. The techniques used by the existing cost estimation systems can be divided into four classifications, which are intuitive, analogy, parametric, and analytic techniques [15].

Intuitive cost estimation techniques use past experience to generate a body of knowledge related to the cost. This knowledge is then used to provide the required information to estimate the cost. These techniques allow the cost estimation of different product families at the early stage of product development. These techniques provide a transparent estimation process which can assist in cost analysis. However, these techniques heavily rely on past data and previous experience to develop the cost estimation system. They have become unreliable because technology is changing rapidly. In addition, they are mostly used to estimate cost of an individual part or product because they require a large amount of information and time to develop the system. Estimating the cost of various product families that consist of a large number and various parts requires much larger amounts of information and time than estimating an individual part.

Analogy cost estimation techniques estimate the cost based on the historical data of products with known cost. The historical data are used to establish a relationship between the cost and the values of certain selected variables. After that, the relationship can be used to estimate the cost of a new product. These techniques are able to estimate the cost using conceptual and not detailed information as their input. In addition, this does not require a lot of data. These techniques are able to estimate the cost of a new product when the extensive database is not available. Therefore, these techniques could provide quick and easy life cycle cost estimation for a product family at the early stage of product development. However, the application of analogy cost estimation techniques is limited to those product families that have the same structure, because they use historical data of a certain product family. Analogy cost estimation techniques function as a black box in cost estimation and do not provide detailed information related to various factors and their influence on the cost. As a result, analogy cost estimation techniques cannot be used to assist in analyzing the cost of a product family and evaluating its design.

Parametric cost estimation techniques use statistical methodology to develop a cost estimation model. Then, the parametric cost model estimates the cost using certain critical parameters of the product. These techniques can be used in estimating the cost estimation of a product family at the early stage of product development. These techniques are able to estimate the life cycle cost of a product family as long as all critical parameters that influence the life cycle cost are identified. However, as

they require and use previous data of a certain product family, they are not able to estimate the cost of different product families with different critical parameters. In addition, the accuracy of the technique is very low because they specify a complex product family with only a limited number of parameters.
Analytical cost estimation techniques estimate the product cost by summing the cost of all the decompositions of the product. This method requires detailed information about the decomposition of the product to estimate the cost. These techniques require detailed information and are difficult to be implemented at the early stage of product development.

The existing cost estimation techniques have been analyzed in order to estimate the life cycle cost of a product family at the early stage of product development. In order to assist in evaluating a product family, the cost estimation system must be able to estimate the life cycle cost of different structures of a product family, allocate the life cycle cost of each component level of a product family, be implemented at the early stage of product development, be adapted and updated easily. Each cost estimation technique has its own strengths and limitations in estimating the life cycle cost of a product family. The result of the requirement analysis is summarized in Table 1.

Table 1. Analysis results.

Requirements	Intuitive	Analogy	Parametric	Analytic
Able to estimate the life cycle cost of different structures of a product family	Yes	No	No	Yes
Able to allocate the life cycle cost of each component level of a product family	Yes	No	No	Yes
Able to be implemented at the early stage of product development	Yes	Yes	Yes	No
Able to be adapted and updated easily	No	Yes	Yes	Yes

One of the analytic cost estimation techniques, the activity-based costing technique, has been proposed by several researchers to estimate the cost of a product family. The activity-based costing technique is considered as a potential costing method for estimating the cost of a product family. Even though the activity-based costing technique can solve some difficulties in estimating the life cycle cost of a product family, it still has several disadvantages. Although this technique is able to estimate the life cycle cost of different structures of different product families, it requires an extensive time and effort to estimate the life cycle cost of different product families and is difficult and costly to be updated in order to reflect any changes. This technique also has difficulties in evaluating the life cycle cost in different types and sizes of companies because the consumed activities and resources will be different from one company to another company that use different technologies and approaches. Then, an activity-based costing technique is difficult to be implemented at the early stage of product development because detailed information related to consumed activities and resources should be available in using an activity-based costing technique. Last, the original aim of this technique is to estimate the cost of a product family for accounting purposes. It will need an adaptation to suit the purpose as a design support system.

5. Discussion

In this section, the requirements and the problems in estimating the cost of a product family are discussed. In addition, how the existing techniques handle the problems is also discussed.

The end of life strategy has a significant influence in the end of life cost of a product family. The existing studies have determined the end of life strategy on the product or part level. As it is not feasible to determine the end of life strategy on the product or part level, the end of life strategy must

be determined on the sub-module level. In addition, the factors that can be used to determine the end of life of a sub-module could be different compared to a product or a part. Considering this fact, there is a need to investigate various ends of life strategies of a sub module, to develop a new method in order to determine the end of life strategy of each sub module of a product family, and to integrate the end of life strategy for estimating the life cycle cost of a product family.

The existing cost estimation techniques have their own difficulties in fulfilling the requirement of estimating the life cycle cost of each component level of a product family. To solve these difficulties, the activity-based costing technique has been proposed as a potential costing method for estimating the cost of a product family. However, this technique still experiences some difficulties in estimating the life cycle cost in different types and sizes of companies that use different technologies and approaches because they consume different activities and resources. In addition, it is not intended for design purpose. Therefore, there is a need to develop a novel technique that can be used to estimate the life cycle cost of each component level of a product family for design purposes and can be adapted easily for different technologies and approaches.

The existing techniques require extensive time and effort to estimate the life cycle cost of different structures of different product families. They need to store complete information for each product platform, variant, product variant, and product family. Therefore, it is important to develop a new method that can reduce the required time and effort for updating process in estimating the life cycle cost for different structures of different product families.

Last, the available product family attributes at the early stage of product development, which is the market segment, the production volume, the structure, and the function, cannot directly be used to estimate the life cycle cost of a product family. How to use these available attributes of a product family to estimate the life cycle cost at the early stage of product development has not been studied yet. In addition, most of the existing systems do not provide detailed information related to various factors and their influence on the cost. As a result, they cannot be used to assist in analyzing the cost of a product family and evaluating its design. For that reason, it is important to find a way to transform the available information into the required information in order to estimate the life cycle cost and evaluate the design of a product family at the early stage of product development

6. Conclusion

A cost estimation system is required to estimate the life cycle cost in order to evaluate the design of different product families at the early stage of product development. The existing techniques do not provide satisfying answers for the identified problems. Therefore, the life cycle cost estimation process for a product family still needs to face and solve the challenges below:

1. A new method is required to determine the end of life strategy of each sub module of a product family and to integrate the end of life strategy for estimating the life cycle cost of a product family,
2. A novel technique needs to be developed to estimate the life cycle cost of each component level of a product family for design purposes and can be adapted easily for different technologies and approaches,
3. A new method is required to reduce the required time and effort for updating process in estimating the life cycle cost for different structures of different product families,
4. It is important to find a way to transform the available information into the required information in order to estimate the life cycle cost of a product family at the early stage of product development.

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