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The adaptation of product cost estimation techniques to estimate the cost of service.

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The adaption of product cost estimation techniques to estimate the cost of service

This paper presents an approach to ascertain whether product cost estimating techniques can be adapted for use in estimating the costs for providing a service. The research methodology adopted consists of a critique and analysis of the literature to ascertain how current cost estimation techniques are used. The analysis of the cost estimation techniques provides knowledge of cost estimation, in particular for products and service with advantages and drawbacks defined. This leads to the proposition of applying product costing methods to services. Hence, proposals on how product costing approaches can contribute to the service industry are presented as the focus of this paper. Gaps and challenges for service costing are identified and corresponding future direction is suggested.

Keywords: Product; Service; Product Cost estimation; Service Cost Estimation

1. Introduction

Within this research, the role of costing in various domains, especially in aerospace and defence areas, has been examined and is viewed as an approach which can assist costing knowledge and information through the entire product or service life cycle. In order to further assist the costing industry, the research presented in this paper places emphasis on estimating the cost for the provision of a service.

Cost is the expenditure that has to be paid regardless of how much the company has gained or lost unless its business is bankrupt. Thus, cost perhaps has the most influential impact on determining what the end product or service would be. In essence, keeping cost at a minimum whilst maintaining quality at a sufficient level is crucial for many companies' survival in today's competitive market place. Research shows that companies which fail to estimate the cost of a product or service accurately at the conceptual design stage have a higher probability of schedule delay or increase cost at a later development stage, than those that complete cost estimation successfully (Hoult *et al.* 1996). It has also been found that customers are not only considering product costs but also the cost of after-sale services that companies provide, e.g., what companies services options are available and how the product should be disposed after use (Xu *et al.* 2006).

The current trend shows companies are moving from selling and providing spare parts to offering customised service solutions, such as availability and capability (Huang *et al.* 2009). As an example, Rolls Royce recently has won a $350m order, at list prices, for Trent engines to power five Airbus A330 aircraft for Turkish Airlines (Rolls-Royce 2009). The contract includes long-term TotalCare service support and aircraft deliveries started in 2010. Another typical example is the MoD which has moved to contracting for availability (a subset of capability), i.e. the contractor has to provide a service (Gray report, 2009). This indicates that the service costs (i.e. operation and support) has become an important part of the total life cycle costs of a product or a service. Hence, it is important for service-based companies to adapt and apply appropriate cost estimating methods. To achieve this it is necessary to ascertain the most appropriate way to estimate the cost of a service. In this paper current approaches are analysed and the challenges of using product cost estimating techniques to estimate the cost of a service are presented.

2. Costing Review

Based on the Association for the Advancement of Cost Engineering (CET 2010), cost estimation aims to determine the quantity and predict the costs of constructing a facility, manufacturing goods, or delivering a service. Product cost estimation is often involved in estimating the cost of producing and selling a physical good, such as a car, which includes the costs of research and development, designing, manufacturing, marketing and distribution, and customer service (Park *et al.* 2002). In comparison, service cost estimation commonly deals with the life cycle cost of delivering an intangible service (CMMI 2009), such as a telephone helpline for healthcare problems.

The following section presents a summary of the definition of product and service cost estimation, which is used within this research.

2.1. Product Costing

Since, the twentieth century, research in the field of product cost estimation (PCE) has been undertaken (Clark 1985, Ostwald 1991, Blocher *et al.* 2005). Examples include cost estimation of standard or customised components, general or specific cost optimisation techniques, and estimation techniques applied at the different life cycle phases (Niazi *et al.* 2006). In addition, PCE techniques have been categorised using certain specifications by numerous researchers, e.g. Niazi et al. (2006), and Asiedu and Gu (1998). The latter classify PCE approaches into parametric, analogous, and detailed methods and later, Ben-Arieh and Qian (2003) extended the scope of PCE techniques into intuitive, analogical, parametric, and analytical based. Similarly, Shehab and Abdalla (2001) categorises PCE methods into intuitive, parametric, variant-based, and generative without defining them clearly. They later develop the PCE methods used at the design stage into knowledge-, feature-, function-, and operations-based approaches. In contrast, a different way to classify PCE techniques is to separate them into traditional detailed breakdown, simplified-breakdown, group-technology-based, regression-based, and activity-based (Zhang *et al.* 1996).

Although there are many different ways to classify PCE approaches, a comprehensive hierarchical classification of the estimation techniques was not fully developed until 2006 (Niazi *et al.* 2006). Niazi and his colleagues categorised the PCE techniques into qualitative and quantitative. The fundamental idea of qualitative cost estimation techniques is to identify whether a new product has any similarities with previous products. The identified similarities can then be implemented to help to build the new product, which greatly reduces the time and effort compared with estimating the cost from scratch. The key requirements of implementing these types of techniques successfully are historical design and manufacturing data, and/or previous cost estimating experts' experience. Qualitative cost estimation techniques can be further categorised into intuitive and analogical techniques which will be discussed in detail elsewhere.

However, rather than relying on the past data or an estimator's knowledge, focusing on a detailed analysis of a product design, its features, and corresponding manufacturing processes are the major characteristics of quantitative cost estimation techniques (Roy *et al.* 2001). By applying these types of techniques, costs are usually estimated by using mathematical formula, taking different product or resources parameters during a whole product life cycle into account. This approach would generally obtain more accurate costing results than the qualitative method; however, the latter one helps to obtain quick and rough estimates during the early conceptual design stage of a product.

Hence, qualitative techniques are more appropriated to implement when the estimating time is limited, past data or experts' knowledge is available, and the estimating accuracy requirement is moderate (Roy *et al.* 2001). In contrast, quantitative techniques are preferable when the estimating time is sufficient, relationships of different cost variables are identified, and the estimating accuracy requirement is comparably high. Moreover, quantitative cost estimation techniques can be further categorised into parametric and analytical techniques which will be discussed in detail elsewhere (Niazi *et al.* 2006).

Previous discussed cost estimation techniques have been summarised and illustrated as a tree diagram shown in Figure 1 (Niazi *et al.* 2006). It is these techniques which are used for the analysis within this paper. The bottom row of Figure 1 illustrates how each technique can be sectioned into more specific systems or cost models, which will be discussed in detail in section 3.

Insert figure 1 about here

2.2. Service Costing

Throughout the review of cost estimating approaches, there was minimal findings in terms of service cost estimation (SCE). The concept of delivering a service has been researched since the twentieth century and widely applied in numerous sectors such as aerospace, information technology (IT), health care, finance, civil construction, and defence areas (Jian and Hong-fu 2004, Ward and Graves 2007, Tan *et al.* 2009). The delivery of a service can, for example, include training, logistics, maintenance, consulting, auditing, human resources, financial management, health care and IT services (CMMI 2009). Although services have been exploited in a broad context, the cost estimation of maintenance is one of the few SCE areas which has been researched, especially in the aerospace industry. For instance, the project-evaluating method and the cost-estimating relationships (CERs) approach, such as the grey model are designed specifically for forecasting airplane maintenance costs (Deng 1982, 1989). In addition, other SCE areas including contracts for spares or preventative maintenance, fixed price repairs, component management and stock exchanges have also been investigated within the aerospace domain (Ward and Graves 2007).

Based on the existing literature review, there are gaps within SCE and it should be exploited in areas other than aerospace. There was also limited literature relating to SCE, although there was some research on maintenance and contracting (Bowman and Schmee 2001, Partha and Rajkumar. 2010).

To ascertain the way forward in modelling service costs the following sections present various PCE techniques and how these methods can be applied to services.

This is the focus of the paper. This analysis then leads to presenting how these PCE techniques can be used to estimate the cost of service.

3. Applying Product Cost Estimating to Service Cost Estimating

This section provides a detailed analysis of PCE techniques and presents how they could be applied to SCE. Each section is presented as follows. The PCE technique is described in relation to the current literature. The authors then present their views on how the technique could be used for SCE.

3.1. Intuitive Cost Estimation Techniques

The intuitive cost estimation techniques are primarily dependent on past experience i.e. a cost estimator's expert knowledge is the key to their success. Their experience can be applied either directly or through some forms of storage, such as rules, decision trees and judgements, to generate cost estimates for components and assemblies (Niazi *et al.* 2006). Table 1 summarises the intuitive cost estimation techniques which can be categorised into case-based systems and decision support systems, each having advantages and drawbacks which are now analysed.

Insert table 1 about here

3.1.1. Case-based Reasoning

Case-based systems are also known as cased-based reasoning (CBR). This approach is designed to estimate the cost of a product by assuming that similar products have similar costs. Figure 2 illustrates the overview of the CBR process (Aamodt and Plaza 1994). It starts by identifying problems for a new case followed by outlining this new component or product's design specifications based on the closest design match from the knowledge base of previous cases. The process then incorporates modifications either by retrieving similar attributes from the design database or by designing new ones altogether. The adapted solution of a new design then conforms to the outlined design specification when all the necessary changes are adapted in a similar way. This solution can either be a quick cost estimation result or be ready to verify for a more accurate and detailed cost estimation. If it is the latter, the new design solution will be stored in the knowledge base and tested to provide a final design solution. One of the major drawbacks of this technique is that it is heavily dependent on past data and models although it often generates an innovative design. Therefore, applying this approach to products which have limited historical information or relevant cost data may not be possible.

Insert figure 2 about here

How CBR could be used for SCE:

By applying the same concept, this approach could also estimate the cost of a service by assuming that similar services have similar costs. For example, if a company estimates leasing a car to person A costs X at one occasion, it is likely on the next occurrence that the company estimates a similar amount for leasing the same car to person B, providing the service condition are the same. However, in reality, comparing new service conditions to previous occurrences is more complex than comparing new products to previous products. This is because service is generally intangible having no physical attributes to make the comparison. Also service delivery is usually a dynamic and flexible process, which makes it more complex and time-consuming to build up the knowledge data base.

Using the example of estimating the cost for the car leasing business, not only are factors related to the car, such as its age, maintenance record, mileage considered, but more importantly, factors related to for example driver's driving experiences, temper, driving history and the weather also require to be considered. Therefore, one of the greatest challenges for applying CBR to service is to understand how to identify and estimate differences and similarities between new services and existing services.

3.1.2. Decision Support Systems (DSS)

The main purpose of Decision support systems (DSS) is used to help a cost estimator to select the most appropriate design solution by utilising information from the knowledge database. Figure 3 shows the processes of implementing a DSS approach in PCE. A car example is provided to illustrate the concept of this DSS process. If someone wants to purchase a car, they could select their own specification from the seller by selecting the model type, the colour for the main body, the wheel and seat types. Then the car manufacturer would design a product specification based on the customer's requirement. Based on this specification, the manufacturer would select the most appropriate design methodology and production process to build this car. After deciding these, an estimated cost for manufacturing this car is generated. Other costs, such as marketing costs, sales costs, and some pre-determined profit margin are added on top of the production costs to offer a price for the customer. If the customer is dissatisfied with the offer, they could either reject the offer or negotiate with the dealer. If the customer accepts the offer, a deposit is paid and an order for manufacturing and delivering the car has been executed.

Table 1 shows that decision support techniques can be separated into rule-based systems, fuzzy logic systems and expert systems，which will be discussed in detail in the next section.

Insert figure 3 about here

a. Rule-based Systems

The core idea of this approach is to establish a set of design and/or manufacturing constraints to help manufacturers to select the more appropriated manufacturing processes in order to calculate the product cost. Gayretli and Abdalla (1999) developed a rule in the form 'If premises Then conclusion' to help select a certain type of production processes to estimate process time and cost based on parts features. This means that a product can be separated into different components and features, with each being through a similar process to calculate the cost. Then the total cost of a product can be generated as a sum of the costs of different parts. The advantage of this technique is that it is capable of providing optimised solutions by adopting the most appropriate product processes, however, the limitation of this approach is that it is time-consuming as a product could have countless parts and features to be evaluated.

<u>How Rule-based Systems could be used for SCE:</u>

In comparison, although the intangibility characteristics of service appear inappropriate to apply the rule-based system approach, the concept of this technique might be possible to adopt. In order to apply this technique, a rule in the form 'If premises Then conclusion' is designed based on the characteristics of services. For instance, the service task is to deliver flowers to a customer at a required time. If the time to reach the customer's place can be estimated in advance, the delivery person and transport are made available within working hours then the cost for this service can be estimated by adding up the costs of labour, fuel and flowers. However, this estimation is probably not accurate in reality as it neglects the important role of uncertainty. For example, during delivery, the delivery man might be sick; the traffic could be particularly busy; the transport may breakdown or the weather condition might be severe etc. Alternatively, high customer demand of requesting orders for flowers might occur around the same time, such as on Valentine's Day, exceeding the capacity of the delivery team. All these potential factors could cause delay or failure of delivery, which add extra cost not only for the refund or compensation fees for customers, but also for hiring part-time employees as a result of a staff shortage. Therefore, challenges of applying this technique for service cost estimating are not only the creation of logical rules, but the importance of uncertainty and risk in the process of SCE. The drawback of this approach is that it could be time-consuming and has high initial research costs. However, the greatest advantage is it is capable of generating an optimised service offering for customers.

b. Fuzzy Logic Systems

A fuzzy logic system is a decision table which provides system rules and indicates the relationships between the input and output variables of this system (Niazi *et al.* 2006). The main focus of this technique is used to handle uncertain knowledge in PCE. Shehab and Abdalla (2002) developed a fuzzy model based on this approach by following several steps. These steps are fuzzification of inputs, fuzzy inference based on a defined set of rules and finally defuzzification of the inferred fuzzy values. Moreover, they have illustrated their model by giving an example of estimating the machining cost of drilling a hole. One set of rules from the decision table for hole making would be if the hole depth is large presented by an X value, the hole diameter is medium presented by a Y value, and the required surface finish, e.g. polish, presented by a Z value, then the machining time is high presented by a T value which is deduced from the relationship between X, Y and Z. Consequently, the machine cost for drilling this hole equals this machining time multiplied by the unit time cost. By applying the same concept, this fuzzy model is capable of estimating a product cost and an assembly cost. The benefits of this fuzzy logic system are competent at handling uncertainty and providing reliable estimate results. However estimating the costs of products with complex features using this approach is often time-consuming and tedious.

How Fuzzy Logic Systems could be used for SCE:

In contrast, this approach is not applicable for SCE as service generally has no tangible features to estimate. However, the fundamental concept of fuzzy logic systems may be modified and adopted in services. This could be achieved by creating a fuzzy logic model to handle uncertainty in services based on their characteristics. The greatest challenge is to create a decision table for different service tasks by setting standards, such as giving rating scores for service providers' performance and customers' responsiveness, similar to supplier ratings in the 1980s (Park *et al.* 2001).

c. Expert Systems

This technique transfers experts' knowledge through rule-based programming into a knowledge database and then selects the relevant data to infer a quicker, more consistent, and more accurate cost estimation (Datta and Roy 2010). This approach is ideal for minimising human errors, such as different cost estimators, providing different results due to their own experience and subjective opinions. However, the noticeable drawback of this technique is that complex programming is often required. Another major limitation is that the expert system applied to PCE which has been developed is largely based on the theoretical techniques from textbooks rather than from the industry (Niazi *et al.* 2006).

How Expert Systems could be used for SCE:

This technique may be applicable for use in estimating the costs of services. Imagine if the expert system is capable of storing service experts' knowledge in a database, then services can be estimated in a similar way as products. To achieve this, the research question is how intangible service factors can be transferred, such as level of co-operation between service providers and customers, into tangible criteria in the form of a standard or rating table. Therefore, the potential gap is to identify and evaluate the commonality between different types of services and hence, develop a framework to estimate them. It is worth noting that the programming behind this concept could be comparably complex but may provide more accurate and consistent estimation efficiently.

Based on the summary of PCE techniques and their advantages and disadvantages and the views presented relating to the possibility of applying intuitive PCE techniques to services, Table 2 summarises authors' view of the way forward and possible solutions/approaches to estimate the costs for services.

Insert table 2 about here

3.2. Analogical Cost Estimation Techniques

Analogical techniques utilise the similarity of products by assuming similar products have similar costs (Roy and Kerr 2003). The method identifies the similarity and differences between products before adjusting differences to produce a valid and reliable estimate. This is generally achieved by the cost estimators' experience or historical databases of products. Based on Table 3, analogical cost estimation techniques have two types of models, namely regression analysis models and back-propagation neural-network. The following sections describe these methods in detail.

Insert table 3 about here

3.2.1. Regression Analysis Models

Although this method applies the same concept of analogical approach, it is only able to forecast the cost of a new product based on a linear relationship between past cases and the values of certain selected variables (Niazi *et al.* 2006). Hence, if a new product has non-linear or irregular relationships with similar products, the regression analysis model is not appropriate. Nonetheless, Hundal (1993) has illustrated that product costs can be estimated efficiently and relatively accurate based on the similarity principle, while Galorath Inc. has adopted this technique to assist the cost estimation of the airframe components (Lewis 2000).

<u>How Regression Analysis Models could be used for SCE:</u>

This technique can be modified and adapted to the service environment. The challenge of applying this method to service is to establish a linear relationship between the final service cost and the service cost factors. For example, the length of the queue is likely to have an impact of determining whether someone selects a fast food outlet. Customers could observe the queue length in response to demand at a fast food outlet. Therefore, it is important for fast food companies to understand how the length of the queue affects their business. In terms of service-oriented companies ascertaining whether there is any linear relationship between their historical service costs and certain variables could be used to identify relationship for forecasting the future service costs. If this idea could be achieved, then the advantages would save time for cost estimation from scratch and at the same time capable of producing a relatively reliable result. However, the drawback of this is limited to resolve linearity issues.

3.2.2. Back Propagation Neural Network (BPNN) Models

In recent years, artificial intelligence (AI) has been developed progressively for application to PCE (Bode 1998, Smith and Mason 1997). In particular, AI has been adapted for use in cost estimation through the application of neural networks (NNs). AI allows the NNs model to store and process data like the human thought processes so that this model is capable of inferring answers to new questions without historical data (Villarreal 1992). This indicates that such models are particularly effective for dealing with uncertain cases and non-linear conditions (Niazi *et al.* 2006). One of the most common types of NNs models is the back-propagation neural-network (BPNN) model. Zhang and his colleagues have used the BPNN techniques to estimate the cost of packaging products by establishing a relationship between cost and cost-related features of packaging products (Zhang *et al.* 1996). This method not only can deal with nonlinear cases, which overcomes the limitation of progression analysis approach, but also requires less detailed data for cost estimation, which solves the common problem of traditional breakdown approaches. Although the BPNN model has several significant advantages over other methods, the major limitations are heavily dependent on available data rather than experience and generally have a higher establishment cost (Niazi *et al.* 2006).

<u>How BPNN Models could be used for SCE:</u>

Although the current BPNN models cannot be applied to services, the concept of making a computer program learn the effect of product-related attributes to cost may be modified and adopted for services. To achieve this, the initial task could be to find the relationship between service costs and service-related attributes. Based on this, cost estimation software can be created which can apply the approximated function obtained from the past data to predict a cost value.

Using the summary in table 3 and the views presented relating to the possibility of applying analogical PCE techniques to services, Tables 4 summarises the author's view of the way forward and possible solutions/approaches to estimate the cost for services.

Insert table 4 about here

3.3. Parametric Cost Estimation Techniques

The parametric approach focuses on the characteristics of the product without describing it completely to estimate its cost (Duverlie and Castelain 1999). The main principal of a parametric model is utilising the cost estimating relationship (CER). In aircraft the CER normally used is the weight of the aircraft, when weight increases, the relevant production and utilisation cost rise. This relationship can be presented by some forms of mathematical equations, such as $Y = aX+b$ (Roy and Kerr 2003). Within the relationship described, it is then possible use the formula to predict the cost of a future aircraft based on its weight alone. This is a simplistic example demonstrating the core idea of parametric estimating. The benefit of applying this method is utilising cost drivers effectively by considering more parameters, which overcomes the limitation of a regression analysis model (Niazi *et al.* 2006). However, this approach does have a few down sides; for instance, CERs are sometimes too simplistic to forecast costs, affecting the accuracy of the estimation. They also rely on statistical assumptions concerning the cost driver relationships to cost, neglecting the importance of common sense, and estimators' knowledge and experience (Roy and Kerr 2003).

How Parametric Techniques could be used for SCE:

However it is the author's view that the principal of the parametric method can be modified and adapted to services. The questions here would be how to identify and establish the CERs for service-based businesses and especially how to transfer the intangibility characteristics into some form of tangible formula or common rules.

Table 5 shows a summary of the key advantages and disadvantages of parametric PCE techniques (adapted from Niazi *et al.* 2006). Based on Table 5 and the previous discussion, the author's view on how parametric PCE techniques could be used to model services is summarised in Table 6.

Insert table 5 about here

Insert table 6 about here

3.4. Analytical Cost Estimation Techniques

Another approach that can be applied is the analytical approach, which is a quantitative cost estimation technique. The principal of this approach is to decompose the work into elementary tasks in order to estimate the product cost (Duverlie and Castelain 1999). Another more precise definition of this method is to separate a product into elementary units, operations, and activities that represent different resources consumed during the product's life cycle and deducting the final cost as a summation of all these components (Niazi *et al.* 2006). These analytical techniques can be further classified into five different categories, which are operation-based, break-down, cost tolerance, feature-based and activity based cost models. Each will be discussed in detail as followed (Table 7).

Insert table 7 about here

3.4.1. Operation-based Cost Models

This approach is designed to estimate the manufacturing costs of a product based on the summation of costs associated with production time, non-productive time, and setup times (Jung 2002). Because this type of cost model requires detailed design and process planning data, it is generally used at the later design stage of a product (Niazi *et al.* 2006). Nevertheless, this method is able to obtain optimised estimation by evaluating alternative process plans, such as the mathematical model created by Feng and his colleagues (Feng *et al.* 1996). Their cost model includes geometric features such as chamfer, rectangular blocks, holes and flat surfaces and hence, an algorithm is developed for estimating the minimum production cost of a standard part.

How Operation-based Cost Models could be used for SCE:

As this technique is specially designed for estimating the manufacturing costs of a product related to machining, it is not clear how it could be applicable for estimating service costs.

3.4.2. Break-down Cost Models

Unlike the operation-based approach, focusing on the manufacturing costs related to machining, the break-down method tends to consider all the costs incurred during the product's lifecycle. This means that costs could be associated with material, labour, and overhead costs and not just the machining. This requires even more detailed information than the operation-based approach. In addition, the break-down approach is also limited as in general it is more applicable at the final stage of product design processes, when more detail is available. However, the greatest advantages of this method are having a wider costing scope than the operation-based approach and relatively easier to apply without further training in computing or other software programs.

How Break-down Cost Models could be used for SCE:

In comparison, although the break-down approach is designed to estimate the total product costs through its lifecycle, service costs can also be calculated by adopting the principal of this method to some extent. In order to create a break-down service model, the current challenge would be to find out all the costs incurred during the lifecycle of a service. If the service is to provide an aeroplane to customers whenever they require and also to make sure the plane is working at a prior agreed period, then the service companies should consider all the factors affecting the final service cost. Such factors could be questions such as how often the aeroplane requires maintenance check; what the weather condition is on the plane's working day; has the pilot had enough experience of controlling the plane correctly and safely; what the relationship between flying mileage and plane's lifespan is? Some of these relationships can be presented by either linear or non-linear mathematical formula, but others might require a rating standard or logical deduction based on experience or historical data from the industry. The greatest challenge in applying the Work Breakdown Structure (WBS) approach is obtaining original data from industry as cost data is generally case-sensitive and not always available. To overcome this obstacle, the project could focus on construction or other commercial industries rather than defence or aerospace domains or generate original data while keeping the information related to the data provider confidential.

3.4.3. Cost Tolerance Models

This type of techniques focuses on the design tolerances of a product to determine the product cost (Lin and Chang 2002). It is based on obtaining the optimal tolerances before setting up the allowable boundaries for the design variables to meet certain criteria. The theory behind this tolerance cost model is primarily based on mathematical equations, closely linking the design variables and the manufacturing process. The advantage of this methodology is that cost effective design tolerances can be identified, whereas, the drawback is detailed design information is required.

How Cost Tolerance Models could be used for SCE:

As this approach relies on the design tolerances of a product, it is highly unlikely to apply to services.

3.4.4. Feature-based Cost Models

This approach to cost modelling identifies a product's cost-related features as a fundamental ground for determining their associated costs (Niazi *et al.* 2006). Taking the advantages of the fast growth of 3D modelling tools, feature-based approaches have become more popular and commercial (Roy and Kerr 2003). Therefore, a broad range of scholars have attempted to estimate the cost of products through their design, process planning and manufacturing process by using this method (Catania 1991, Qu-Yang and Lin 1997). It is found that products consist of standard features in terms of holes, edges, flat faces, flanges etc; hence, the lifecycle costs of the product can be determined by the summation of the cost of each feature with respect to its corresponding manufacturing process (Gayretli and Abdalla 1999). There are several significant advantages of applying this approach to PCE. It not only allows product providers to design and manufacture parts based on design-for-cost target, but also costs related to standard parts can be re-used for new products. This means that it is likely to produce an optimise product within the budget and estimate the product cost more efficiently and effectively. However, one of the greatest obstacles for using this approach for the product costing process is difficult to estimate parts with complex or very small geometric features, especially if manufacturing processes are required to produce these features (Niazi *et al.* 2006).

<u>How Feature-based Cost Models could be used for SCE:</u>

However, as this approach estimates cost based on product's cost related features, it is suggested that the concept might be applicable for services. Because services also have cost-related 'features' that could be estimated to determine their associated costs if sufficient data is obtained. The challenge of adapting this concept to SCE is that how to tangiblised intangible service features? The proposed work could be to identify different types of cost-related service factors and hence to find out the relationship between these factors and their associated costs.

3.4.5. Activity-based Cost (ABC) Models

According to Blocher and his colleagues (2005), ABC is defined as a costing approach that focuses on estimating the costs incurred on performing the activities to manufacture a product. Each activity within the company is first identified with an associated cost and then the total cost of producing a product is a summation of all these related costs (Roy and Kerr 2003). The main benefits this approach brings to companies are better profitability measures, better decision and control, and better information for controlling capacity cost (Blocher *et al.* 2005). Because the ABC approach is able to provide more accurate and informative product costs, this would help companies to better estimate the product profitability, improve product design and manufacturing processes, and identify and utilise any unused capacity. Although this approach has several advantages, the main problem is that not all costs have a clear activity which they can be allocated with, such as the costs of a manager's salary, property taxes and facility insurance. Another issue is that it has the probability to neglect some of the product costs during the product's lifecycle, such as the costs of marketing, advertising, and research and development.

<u>How ABC Models could be used for SCE:</u>

The ABC methodology has been applied for SCE, such as the service blueprint technique created by Shostack (1984, 1987). This technique estimates the service costs based on identifying all the activities or processes of delivering a service and the associated execution time. Detailed information about the service blueprint has been mentioned elsewhere. Applying the ABC approach to service has the same benefits and limitations of applying it to a product. Service companies could design an optimised service within the target cost and maximise any spare capacity but might neglect some of the service costs which hard to allocate or not include in the service activities. They also have to devote a considerable amount of time and effort to establish and monitor the ABC system, requiring high investment costs and relevant experts. The challenge of improving this technique for the service costing purpose is to consider all the activities under different conditions through lifecycle of a service.

Based on Table 7 and the views presented relating to the possibility of applying analytical PCE techniques to services, Table 8 summarises authors' view of the way forward and possible solutions/approaches to estimate the costs for services.

Insert table 8 about here

4. Conclusions

The first sections of this paper introduced a review of the literature in terms of researchers view of what product cost estimating and service cost estimating actually mean. This provided a background to present the research being undertaken by the authors. The core contribution of this paper focuses on an assessment and analysis of how four key product cost estimation techniques namely; intuitive, analogical, parametric and analytical could be enhanced/adapted to estimate the service costs for a product/system. The contributions are summarised in four tables (2, 4, 6 and 8) where the authors have identified the advantages and challenges of using traditional/current product cost estimation techniques and enhancing/adapting these techniques to estimate the service costs.

These tables present the authors view on whether the technique would be applicable for estimating the cost of a service, and which modelling approaches within these techniques could be used. The author identified advantages, challenges and future work required are then summarised in each of the tables.

The analysis of these various techniques and their application in estimating the cost of products and services identified several key findings. Using the qualitative and quantitative classification shown in figure 1, the fundamental concept of qualitative product cost estimating techniques (Intuitive and Analogical techniques) can be adapted to estimate the cost of a service (with the exception of the fuzzy logic method). However, the approaches used in quantitative techniques (Parametric and Analytical) are generally not applicable for use in estimating the costs for a service, with the exception of both feature-based and activity-based cost modelling approaches.

This analysis provides the future research direction in identifying cost estimating techniques to predict the cost of a service.

5. Future Research Activities

The outcome of this analysis has identified that a number of product cost estimation techniques can be enhanced/adapted to ascertain appropriate approaches for estimating the cost of a service. The future research for the authors is to identify how these findings can be tailored to a service environment. To ensure this goal is attained the authors have commenced a case-study with a service provider for manufacturing machine availability. The in-service data from the case-study company for example; machine breakdown, labour, spare parts etc. will be used to create a framework which will utilise the findings of this analysis to identify the appropriate product cost estimating technique to be enhanced/adapted to estimate the service cost. It will also be used to identify which elements of a service cannot be modelled using the PCE techniques.

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Table 1 Intuitive cost estimation methods used on products (adapted from Niazi et al., 2006).

Product Cost Estimation (PCE) Methods			**Main Advantages**	**Main Disadvantages**
Intuitive Cost Estimation Method	Case-Based Systems		- Design approach tends to be more creative	- Mainly rely on past data and previous experience
	Decision Support Systems	Rule-based systems	- Capable of providing optimised results	- It is often time-consuming
		Fuzzy logic systems	- Considering uncertainty to produce a reliable estimate	- Cost estimate complex features is often time-consuming
		Expert systems	- Able to estimate costs more efficiently, reliable and accurately	- It involves complicated programming

Table 2 Intuitive cost estimation techniques used on services.

Product Cost Estimation (PCE) Techniques			**Service**			
			Apply PCE technique to services	**Likely advantages in applying PCE techniques to services**	**Likely challenges in applying PCE techniques to services**	**Future Work to overcome challenges**
Intuitive Cost Estimation Technique	Case-Based Systems		- Possible	- Save time and money for cost estimation	- Requires a great deal of historical service data - The intangibility characteristic has no physical attributes to make the comparison - Service delivery is usually a dynamic and flexible process, which makes more complex and time-consuming to build up the knowledge data base	- Identify and estimate according to differences and similarities between new services and past ones
	Decision Support Systems	Rule-based Systems	- Possible	- Capable of generating optimised service solutions	- Time-consuming - High initial research costs	- Requires to develop a rule-based algorithm/ standard for the service delivery by taking uncertainty and risk into account

		Fuzzy logic systems	- Not possible as it is designed for using in design and production	- Not applicable	- Not applicable	- Develop a fuzzy logic to handle uncertainty in service
		Expert systems	- Possible	- Provide quick, more accurate and consistent estimation	- Complex programming required	- Investigate how to mimic the human expert thought process to estimate in-service cost

Table 3 Analogical cost estimation methods used on products (adapted from Niazi et al. 2006).

Product Cost Estimation (PCE) Methods		**Main Advantages**	**Main Disadvantages**
Analogical Cost Estimation Techniques	Regression Analysis Model	- The method is relatively easier to use	- Incapable of solving non-linear cases
	Back Propagation neural network model	- Capable of dealing with uncertain - Possible to solve non-linear situations	- It fully depends on data to set up the model - It tends to be more expensive to set up the model

Table 4 Analogical cost estimation techniques used on service.

Product Cost Estimation (PCE) Techniques		**Service**			
		Apply PCE techniq ue to services	**Likely advantages in applying PCE techniques to servics**	**Likely challenges in applying PCE techniques to services**	**Future Work to overcome challenges**
Analogical Cost	Regression Analysis Model	- Might be possible but requires further work	- Saving time for cost estimation from scratch - Capable of producing a reliable result	- Limited to resolve linearity issues	- Ascertain if there is any linear relationship between historical service costs and certain

					variables so that the relationship could be used to forecast the future service costs
	Back Propagation neural network model	- Not possible at present but might be possible in future if further work can be done	- Not applicable	- Not applicable	- Create a model that can infer costs to new scenarios based on the relationship between service cost and past service-related attributes.

Table 5 Parametric cost estimation methods used on products (adapted from Niazi et al., 2006).

Product Cost Estimation (PCE) Methods	**Main Advantages**	**Main disadvantages**
Parametric Cost Estimation Techniques	- Cost drivers could be taken a more important role in cost estimation - Capable of producing results with high level accuracy	- Heavily reply on cost drivers - Difficult to cost estimate accurately without knowing cost drivers clearly

Table 6 Parametric cost estimation techniques used on service.

Product Cost Estimation (PCE) Techniques	**Service**			
	Apply PCE technique to service	**Likely advantages in applying PCE techniques to service**	**Likely challenges in applying PCE techniques to service**	**Future Work to overcome challenges**
Parametric Cost Estimation Techniques	- Not possible at present; Might be possible in the future if further work can be carried out	- Not applicable	- Not applicable	-Research how to identify and establish the CERs for service businesses -Study how to transfer the intangibility characteristics into some forms of tangible formula or common rules

Table 7 Analytical cost estimation methods used on products (adapted from Niazi et al., 2006).

Product Cost Estimation (PCE) Methods		**Main Advantages**	**Main Disadvantages**
Analytical Cost Estimation Techniques	Operation-based cost models	- Optimised cost estimation can be obtained through different process plans	- Estimation process is often time-consuming - Heavily depend on cost data related to detailed design and process planning
	Break-down cost models	- Has a broad costing scope - Easier estimation process without further training in computing or other software programs	- Heavily depend on cost data related to resources consumed
	Cost tolerance models	- Capable of cost estimation effectively by applying design tolerances	- Heavily depend on cost data related detailed design
	Feature-based cost models	- Easier to design and manufacture parts within the budget	- Difficult to cost estimate small and complex parts

		- Costs related to standard parts can be re-used for new products	
	Activity-based cost models	- Better profitability measures - Better decision and control - Better information for controlling capacity cost	- Not all costs have a clear activity can be allocated with - Might neglect some of the product costs during the product's lifecycle - Require high initial costs and management or accounting experience to set up and control this ABC system

Table 8 Analytical Cost Estimation Techniques used on Services.

Product Cost Estimation (PCE)Techniques		**Service**			
		Apply PCE technique to services	**Likely advantages in applying PCE techniques to services**	**Likely challenges in applying PCE techniques to services**	**Future Work to overcome challenges**
Analytical Cost Estimation Techniques	Operation-based cost models	- Not applicable as this technique is designed to estimate manufacturing costs related to machine operation	- Not applicable	- Not applicable	- Not applicable
	Break-down cost models	- Possible for adapting its concept	- Not applicable	- Not applicable	- Research how to estimate the total service costs by summing all the costs incurred during in-

					service
	Cost tolerance models	- Highly unlikely because this method is used to estimate costs by considering design tolerances of a product	- Not applicable	- Not applicable	- Not applicable
	Feature-based cost models	- Possible for adapting the concept because services also have cost-related features	- Be able to obtain a detail estimated result based on service features	- Might be difficult to tangiblised intangible service features	- Identifying service cost-related features - Find relationships between service factors and associated costs
	Activity-based cost models	- It has been applied in SCE, such as the blueprint technique.	- Capable of designing a optimise service within the target cost - Maximise any spare capacity	- Might neglect some of the service costs which hard to allocate or not include in the service activities	- Considering all the activities under different conditions through lifecycle of a service is challenging and required further work

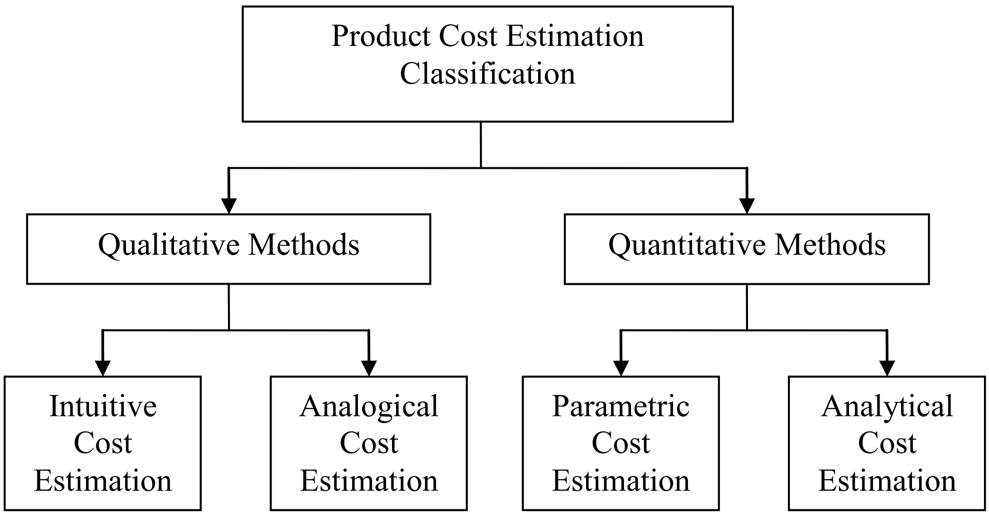

Figure 1 The classification of PCE techniques (adapted from

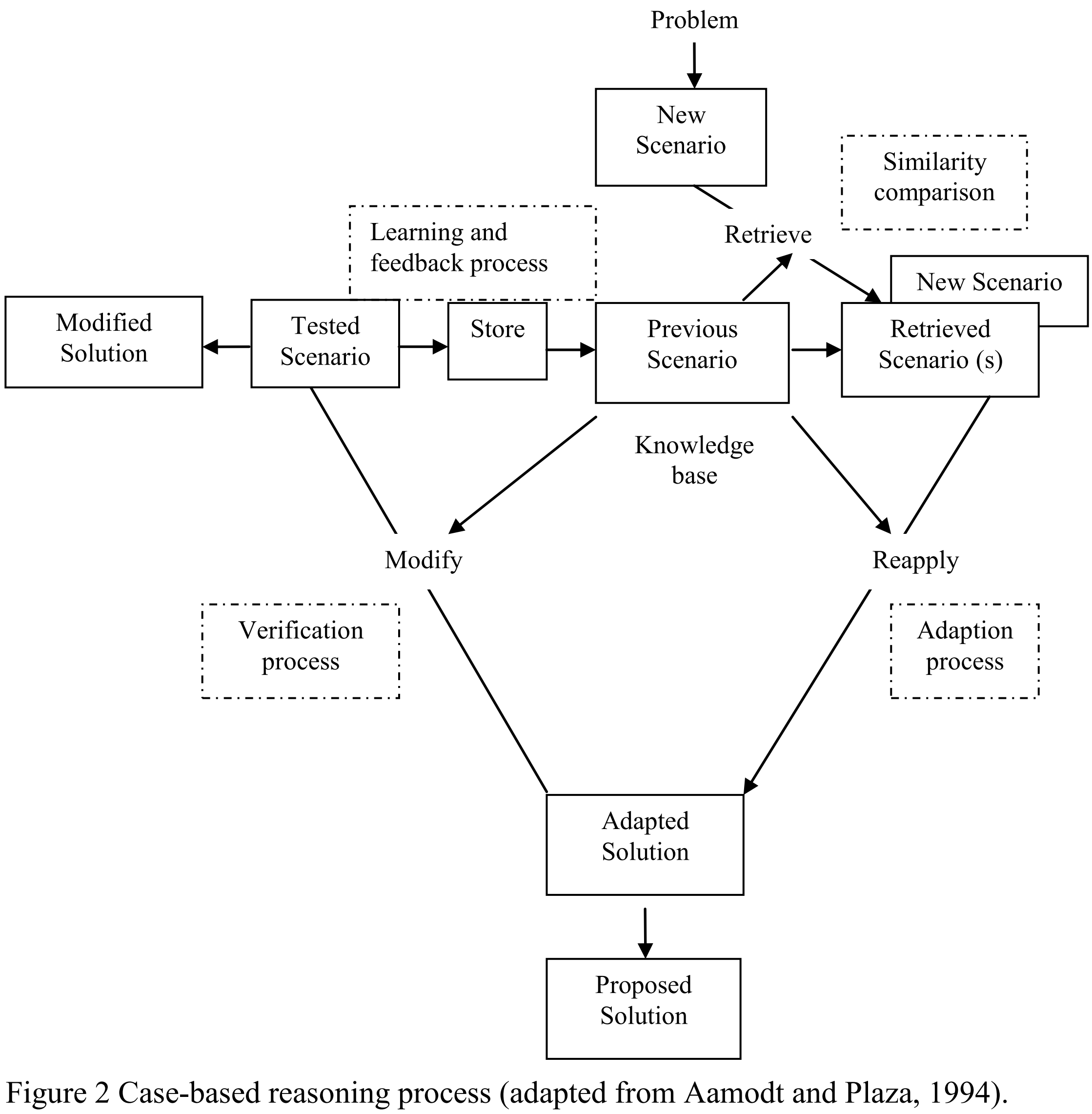

Figure 2 Case-based reasoning process (adapted from Aamodt and Plaza, 1994).

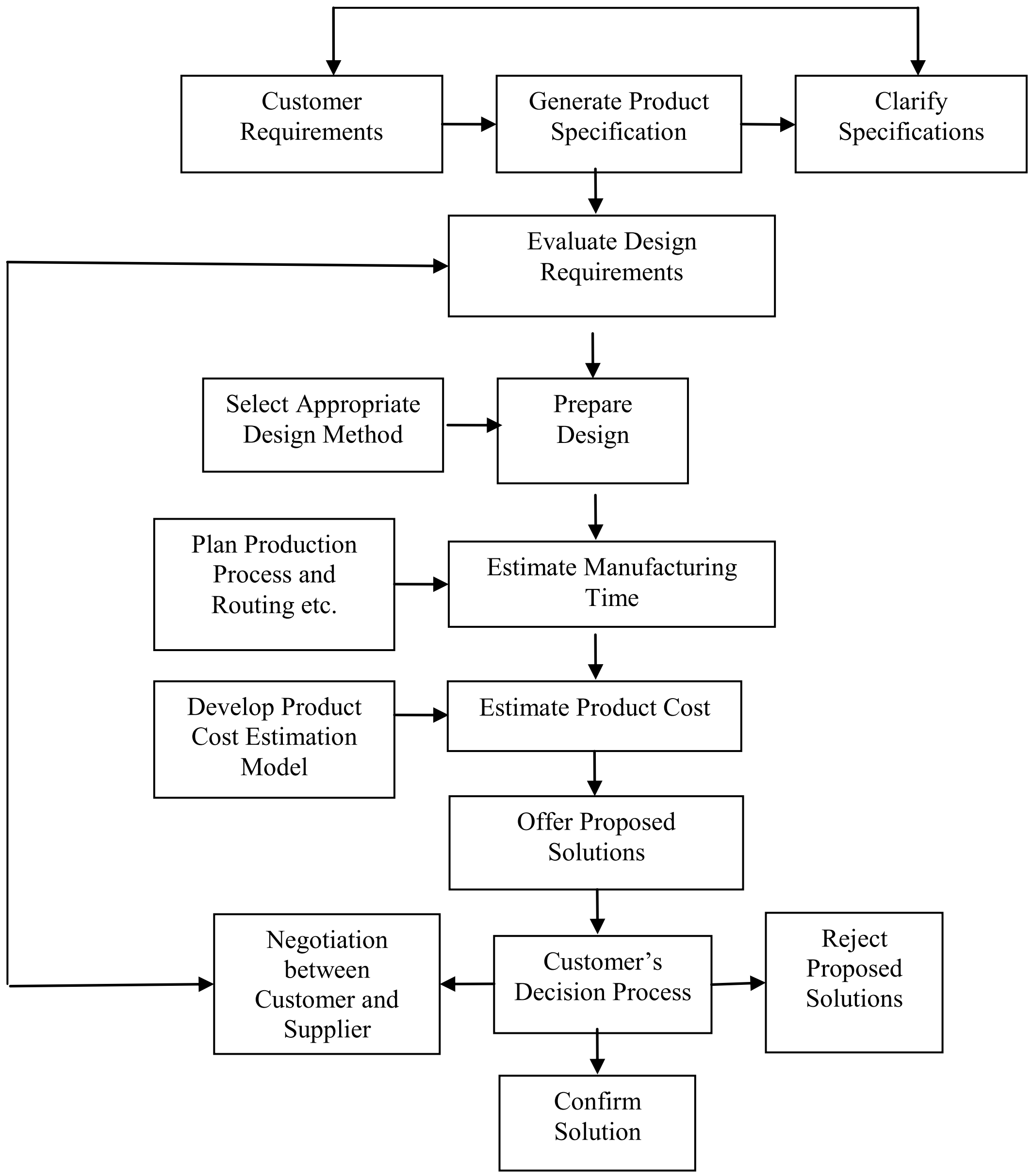

Figure 3 Decision support system approach to cost estimation (adapted from Niazi et al., 2006).