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LIFE CYCLE COSTS OF PRODUCTS

Vladimir MĂRĂSCU KLEIN
Transilvania University of Brasov, Romania

Abstract. The life cycle costing process includes identification of different types of items or methods. The structure of cost items will always depend on the nature of the product and should always facilitate life cycle cost analysis. The present paper is focused on determining the main items that influence the cycle cost and their importance.

Keywords: life cycle cost, management cost, quality

1. Introduction

The life cycle costing process includes identification of items to be monitored, identification of the cost structure, definition of links to estimate costs and establishing a method for formulating life cycle costs [1].

The cost items monitored include all costs incurred in relation to manufacturing of a product until its disposal at the end of its life cycle. The items should be structured so as to allow for identification of potential links between various items with a view to establishing optimal life cycle costs. The structure of cost items will always depend on the nature of the product and it should always facilitate life cycle cost analysis. The purpose of estimating cost links is to express cost items as a function of one or more independent variables. The final stage of the calculation process is determination of a method for formulating life cycle costs.

2. Manufacturing costs

In traditional cost accounting, the total manufacturing expenses include cost of goods sold, operating and non-operating expenses and income taxes. The cost of goods sold consists of factory cost, depreciation and inventory cost. The factory cost has three components: direct material, direct labour and overhead. The overhead account includes utility and other indirect expenses and is usually expressed as a percentage of the direct labour cost. The inventory cost includes both work-in-process and finished goods. The operating expenses are normally broken down to show expenses incurred in selling the products and administering a company. Accounting practices often disclose interest as a separate item. High quality, reliable delivery, short lead times, customer service, flexible capacity and efficient capital deployment, rather than cost reduction, are the most important advantages in today's competitive manufacturing environment. However, these aspects of manufacturing are neither reflected in traditional cost-accounting methods nor explicitly considered in investment analysis [2, 3].

In the next sections, we will address some of these measurement issues related to quality and flexibility.

Quality Cost Measurement

Product quality is increasingly considered a key factor in improving market share and profit margins. Quality-related measurement would document the reduction in total manufacturing cost resulting from increasing quality and decreasing defects. However, if manufacturing costs do decrease as quality increases, then the justification for new capital equipment should include not only the anticipated labour savings but also the savings in manufacturing cost as defects decrease. The costs associated with quality of conformance generally can be classified into four types: prevention costs, appraisal costs, internal failure costs and external failure costs.

Prevention costs are associated with designing, implementing and maintaining the quality system.

Appraisal costs are incurred to ensure that materials and products meet quality standards, including inspection of row materials, laboratory tests, quality audits and field testing.

Internal failure costs are incurred when materials and products fail to meet quality standards and result in manufacturing losses. They include the cost of scrap, repair and rework of defective products identified before shipment to consumers.

External failure costs are incurred when inferior quality products are shipped to consumers. They include the costs of handling complaints, warranty replacement, repairs of returned products and so forth. Once the quality costs are collected from the accounting system or estimated from available data, they need to be classified into prevention cost, appraisal cost, internal failure cost and external failure cost.

Flexibility Measurement

Flexibility, as measured by rapid response to customer demand, is a major concern in industrial sectors. The key to providing this response is the ability of the production facility to adapt to changes in the volume and mixture of products.

Many variations exist in defining manufacturing flexibility, but we view flexibility as a degree of manufacturing performance that indicates a system's adaptability to changes in the manufacturing environment. Four different types of flexibility measures are considered in this paper: equipment, product, process and demand.

Equipment flexibility is represented by the capacity of equipment to accommodate new products and variants of existing products. Equipment flexibility is measured in terms of idle cost. Idle cost is the cost in opportunity resulting from underuse of equipment. If the equipment has excess capacity, the idle time is inevitable. Equipment flexibility also represents the equipment's opportunity to add value to raw materials.

Product flexibility measures the opportunity to increase the value of products due to the changes in product mix. These changes normally result in shorter individual life cycles and smaller lot sizes as variety increases. Smaller lot sizes also mean higher setup costs. Machine setup costs may include both the labour cost of setup during parts changeover and the opportunity cost of lost production. In advanced manufacturing, reducing setup times will permit shorter productions runs and shorter machine idle times, thereby providing benefits of reduced time loss in production.

Process flexibility is the adaptability to changes in part processing, such as those caused by machine setup, equipment and tool breakdowns, random access of product mix and changes in process schedule. Because process flexibility provides an opportunity to add value to materials processed, waiting cost is another opportunity cost.

Demand flexibility measures the adaptability to changes in demand rate. The two types of demand considered are customer demand for finished products and internal demand for raw materials. Demand flexibility can be measured in terms of inventory cost of finished products and raw materials. Inventory costs consist of carrying cost and shortage cost. Whit demand predicted accurately, inventory costs disappear. Therefore, demand flexibility measures this opportunity of adding value to products according to improved job scheduling and demand forecasting.

Proposed cost classification

While reclassification or new definition of accounting costs cannot play the key role in initiating or implementing technological innovations, the accounting system should provide incentives for improving manufacturing performance and measurements to evaluate progress toward this goal. For this purpose, we propose that the total cost be divided into two categories: production cost and non-production cost. Production cost consists of manufacturing, depreciation and inventory. Non-production cost includes operating expenses and financing costs. We combine direct and indirect labour to define labour cost. Direct and indirect materials are also combined to define material cost. We break down overhead to setup, machine, tool and floor space costs. Computer software costs are associated with any level of factory automation. In particular, we expand our cost definition to include the non-traditional cost items such as prevention, failure, waiting and idle costs.

3. Materials costs

The material process must satisfy the product's life-cycle requirements imposed by design engineering, marketing, manufacturing, reliability, aesthetics, and quality. Consequently, the selection problem is a multi-attribute decision making (MADM) problem where each attribute corresponds to one of the product profile requirements. The design of a product and its fabrication processes must be simultaneously pursued in the competitive markets of today. Some of the most important decision, those with the greatest effect on overall cost, is made during engineering design. It is indicated that upwards of 70% of a product's cost is determined during the design stages. An important aspect of concurrent engineering is the early consideration of manufacturing in the product development process to achieve a reduction in product development time, production costs and quality defects. This is called design for manufacturing (DFM) and is typically conducted with a particular manufacturing process in mind. A potentially important decision-making activity precedes DFM and this is the selection of materials process [4].

The material process selection decisions are difficult due to several reasons. First, the selection must be made during preliminary engineering design, which is characterized by qualitative descriptions of requirements, imprecise data, and unknown or complex relationship. Of the multiple factors that influence material process selection, many can only be estimated, such as production volume. Second, the problem is exacerbated since the multiple criteria are of unequal importance. Third, there exist over 100 000 material alternatives to evaluate and new materials are continuously being developed. It is impossible for designers to have knowledge of all the possible candidate materials.

4. Life cycle costs

Life cycle effects, which for many applications will dominate manufacturing costs, **include all other activities associated with the product**. Life cycle effects are more difficult to quantify into costs than manufacturing activities [5]. The following life cycle activities are among those that product will influence.

Design costs. If designers require specialized training, or new CAD and/or other specialized design tools to successfully perform product design, then the costs of these activities must be considered. One must also consider costs associated with effort and tools for design verification and functional test development. Extra design costs may also include libraries of models for product from symbol libraries to high-performance models for use in simulation. The inclusion of product may also affect the degree to which a design can be reused and upgraded (re-design costs). Also included in the design costs are prototyping costs i.e. are product applications going to require additional prototype boards.

Non-recurring costs. Equipment is not the only non-recurring cost that may be associated with product. There will be additional tooling (artwork) for layer pair production, potentially additional chemistry to be managed in the board fabrication process, and finally licensing fees and royalties may have to be paid for the use of technology, material, and/or processes.

Time-to-Market. Does the design, verification, and prototyping of product require more calendar time than that for conventional systems? Delays in time-to-market for a new product of weeks or months can cost substantial money and in some cases mean missing the market for the product completely.

Performance value. Product may result in size or performance improvements in systems that enable increases in market share for the manufacturer. It may be the case that for some quantifiable increase in system cost, a manufacturer can differentiate itself from its competition by providing a product that is lighter, smaller, faster, and more reliable or with greater functionality than its competition, and the customer is willing to pay extra for one or more of these improvements.

Qualification and certification. The introduction of new materials and processes into product fabrication requires material providers and product fabricators to assess and possibly update safety certifications.

While the cost of this type of certification is not directly borne by the users of product, it will be reflected in the product costs. On the other hand, there will be a reduction in the costs associated with qualifying other product manufactures.

Liability. New product, or any new technology, material, or process may carry with it unforeseen financial liabilities. The liabilities may be in the form of causing injury to customers, employees of the manufacturer, or the environment. Long-term studies of the effects of the materials and the processes used to incorporate them into product may be necessary to prove or disprove liability claims.

Sustainment is a collection of many activities all of which have an economic impact. In general, sustainment is all the activities necessary to:

- keep an existing system operational (able to successfully complete the purpose it is intended for),
- continue to manufacture and field versions of the system that satisfy the original requirements,
- manufacture and field new versions of the system that satisfy evolving requirements.

Conventional wisdom is one system reliability will improve because of the reduction in the number of solder joints, however, this will only be realized if the reliability does not commensurately decrease due to other product specific effects. Reliability questions arise from two origins: first, are the specific products reliable or more reliable than the rest of the components and packaging? Secondly, are there product specific processing conditions that remove life from other conventional product? Changes in system reliability appear either as warranty costs (replacement) or as maintenance costs (repair).

For systems that are subject to repair product may change the ease with which problems in the system can be diagnosed, physically repaired and retested. In turn, if the faulty product is to simply be replaced, its reliability affects the number of "spare" product that must be manufactured to fulfil expected replacement commitments.

Sustainment, however, goes further than reliability driven replacement and repair. Sustainment also means that the system should remain manufacturable through the end of its support life (to fulfil additional requirements for new product and spare replenishment). This is not generally difficult for manufacturers of laptop computers and other short-life consumer products, but is a huge concern (and cost issue) for long-life products such as avionics for aircraft.

The biggest component related problem that long field life systems see is obsolescence (particularly electronic part obsolescence). Most electronic parts have short lifetimes (from an availability perspective) relative to even the design cycle of an aircraft, let alone an aircraft's support life. For systems like aircraft, qualification and certification requirements may make simple substitution for obsolete parts with newer parts prohibitively expensive.

Product will mitigate some obsolescence problems by replacing discrete parts that would become obsolete. On the other hand, if the materials used to manufacture the product within the board become obsolete, i.e. replaced by newer materials, the overall obsolescence problem may well become much worse.

Environmental and end of life. The fabrication of product obviously increases the volume of waste produced during the product fabrication process. Disposal of product fabrication waste is a significant contributor to the price of boards. If any of the product specific contributions to the waste steam are considered hazardous then the waste disposal costs could increase. Waste disposal is also a factor at the other end of the life cycle, i.e. at the end-of-Life. Depending on the type of product within and the location in the world where the product is being sold, the manufacturer may bare some or all of the cost of disposing of the product when the consumer has finished with it.

Financial. Several costs associated with creating and holding inventory (handling, storage, procurement) associated discrete passives are potentially avoided; this includes the cost of money that is invested in stored passives as opposed to invested elsewhere.

4. Conclusion

There are three major drivers behind the costs of a product life cycle [5, 6] from its initiation until its termination: business costs, user costs and social costs. The objective of the life cycle concept is to maximise the value of the product while keeping the manufacturer, user and social costs. Manufacturer costs include those related to various corporate activities, for example during planning, design, development, manufacturing, assembly, distribution and servicing of products. These are all costs incurred from the moment when a demand for delivery arises until dispatching the product to the customer. User costs are those related to activities carried out by the user. They cover the period from product delivery to its disposal where the ownership of the product ends. These costs may also include recycling and disposal at the expense of the user. Social costs are those that burden the society when the product is being used and, in particular, those related to its safe recycling or disposal.

References

1. Woodward, D.G.: *Life Cycle Costing – Theory, Information Acquisition and Application*. International Journal of Project Management, Vol. 15, No 6, December 1997, p.335 – 344, ISSN 0263-7863, Elsevier
2. Mărăscu-Klein, V.: *Aspects of cost analysis in materials selection*. Acta Universitas Cibiniensis, Vol. LII, Technical series, December 2005, p.61 – 64, ISSN 1583-7149 Sibiu, Romania
3. Park, C.S., Son, Y.K.: *An economic Evaluation Model for Advanced Manufacturing Systems*. The Engineering Economist, Vol. 34, No.1, 1988, p. 1-26 , ISSN 0013-791X, Taylor & Francis, London, UK
4. Mărăscu-Klein, V.: *Utilisation of relational data base for material selection*. Proceeding of International Conference “Mechanics and Machine Elements”, p. 289 – 294, Sofia, 4 – 6 November 2005, Sofia, Bulgaria
5. Sandborn, A.P., Etienne, B., Herrmann, W. J., Cincholkar, M.M.: *Cost and production analysis for substrates with embedded passives*. Journal Circuit World, Vol. 30, No.1, 2004, p.25-30, ISSN 0305-6120, London, UK
6. Labuschange, C.: *Sustainable Project Life Cycle Management: the need to integrate life cycles in the manufacturing sector*. International Journal of Project Management, Vol. 23, Issue 2, February 2005, p. 159-168, ISSN 0263-7863, Elsevier