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Management of product costs in research and development
- Exploring the frontiers of target costing

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Abstract

Although prior decisions constrain the freedom of further choices and commit the organization to subsequent incurrence of costs, they do not discard the need for continuous cost management. Our main proposition is that product cost management should start before the well-structured product development in order to ensure built-in cost capability of a product. This report is based on the findings of a two-year research project. Professionals from ten companies or divisions of a company cooperated with the researchers. The researchers used a literature research, interviews, and interventionist approach in gathering data.

Streamlining the product development process transfers important cost-inflicting decisions from this process to the earlier development stages. The uncertainty related to these early stages makes the direct application of target costing difficult. For example, modular product structures support the target costing process because the design process can be separated into somewhat independent tasks. However, concepts based on new technologies may be created to challenge the prevailing product architecture, which complicates the process of calculating the product-level target cost to the component level. Modular designs, part commonality, and product platforms reflect design policies which individual product development teams must follow. Since design policies contain implicit assumptions of cost effectiveness, those who create these policies must be aware of cost behavior. Cost management should focus especially in those costs that are influenced by the decisions at hand.

The underlying ideas of target costing can be adjusted to the earlier development stages. The studied organizations use versatile methods to manage costs. In the early stages, the methods are not purely cost management methods but innovation is managed as a whole. Building and maintaining cost databases for the various R&D purposes requires significant effort by management accounting and technology experts. The virtual price table tool is an example of such a database. Potential suppliers are asked to make quotes on specified cost drivers and to show a trajectory of future price developments for specifications, which reflect the future components. The tool is based on a detailed model of cost drivers, a database of old price quotations, and constant updating. Another approach is introduced to evaluate offerings of different suppliers concerning technologically challenging products. Because of technological challenges, there are gaps that can not be eliminated without extra development effort by the supplier. The approach seeks for a competitive price given to a supplier that can eliminate the gaps.

In information-intensive products, the unit-level cost of a product becomes less significant compared to the costs incurred in product-sustaining and product-founding activities. The change in the life-cycle cost structure means that managing product costs requires more attention to the trade-offs between development effort and functionality. Equally, the target costing equation should be adjusted. Radical changes in a product may also mean changes in the value chain and in business models; thus, demanding a broader perspective of costs. Seeing the costs from customers' perspective is important for the product's success. The decisions made in development also affect the customer's costs of using the product.

Keywords: cost management, cost estimation, target costing, product costing

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1. Introduction

Jouko Karjalainen

Competitive industries are characterized by their products' increasing performance at a relatively stable or even decreasing price (price erosion). The demand-based view of technology evolution espoused by Adner and Levinthal (2001) offers a generic explanation for this phenomenon. When the rate of technological change outpaces the demand for such improvement, customers' marginal utility derived from performance plays a crucial role in shaping pricing and developmental decisions. Early in a technology's development, innovation is guided by a drive to meet market requirements. In the later stages of development, innovation is driven by competition among suppliers faced with "technologically satisfied" customers. In the demand-maturity stage, product development becomes a way of maintaining product price rather than satisfying the needs of new customers.

Combined with short product lives, performance improvement and price erosion require that profitability must be designed into products. There is little opportunity for trial and error. It is commonly stated that a significant percentage of costs are locked-in during design. Many decisions could undoubtedly be reversed, but it would be too risky or expensive to redesign the product. To be able to introduce a continuous flow of new products to please the customer, diverse product versions are based on a common platform. In this instance, the choices made during platform development constrain the attainable cost-level. Eventually, platforms are substituted but, once again, impulsive deviations contain risk and could lead to an increase in total cost. The central message of this report is that product costs should be managed throughout the product life cycle, commencing ultimately at the pre-development stages.

1.1. The domain of product cost management

The ultimate purpose of a business is to create sustainable wealth for shareholders. But it is only possible with satisfied and loyal customers. Management of product costs is subordinate to the following primary objectives: value creation and customer satisfaction. A common misunderstanding is to confuse *cost management* with *cost reduction*. Shortsighted actions may sometimes be taken to cut costs; or there may be a conflict of interest concerning the actions between different stakeholder groups. Frequent occurrence of these kinds of incidents causes a negative interpretation to the phrase *cost reduction*. Cost reduction should be seen as a necessary part of cost management. Cost reduction comprises actions that are taken to achieve the justified cost targets that are based on the primary objectives. 'One-eyed' cost cutting without justified targets is not *cost management*; it is poor management.

Companies should manage product costs in all the phases of a product's life cycle. Accordingly, one can identify various key areas of cost management. However, this report focuses on product cost management during research and development (R&D). R&D professionals also manage R&D costs; and occasionally there is a trade-off: specifically, whether to increase the development budget in order to reduce the final product cost. In many cases, it is assumed that the cost targets can be accomplished without exceeding the budget. Research and development (R&D) activities can be classified in three broad areas: basic and applied research, advanced engineering, and

development (Dodgson 2000). Basic research and applied research belong to the investigative-exploratory domain. The output of these projects ranges from research papers to patents. Advanced engineering (experimental development) aims at demonstrating technical viability, eliminating technical uncertainty, and selecting technologies and materials. The output of advanced engineering projects usually becomes a core concept for a specific product or process development project, or provides a foundation for multiple projects. Finally, developmental projects (design engineering) translate the known and demonstrated principles into new products and models. By ‘pre-development’, we refer to the phases prior to the well-structured new product development (NPD) project.

Target costing (discussed in chapter 2) is usually the method advocated for managing product costs within the NPD project. Davila and Wouters (2004) have recognized alternative practices used to manage product costs during NPD but around the development team. Some companies manage costs by creating boundaries for design decisions, within which individual product development must comply. Modular designs, part and process commonality, and product-platform development articulate design policies to which individual product development teams must adhere. Since it is difficult to model the cost behavior of shared resources, the development teams are not supposed to make trade-offs based on cost estimates. However, Davila and Wouters (*ibid*) do not describe how costs are considered when these design policies are established or when product platforms are developed.

It seems that streamlining the NPD process in order to ensure short time-to-market transfers the cost-inflicting decisions from NPD projects to pre-development. The closer to the research domain one goes the more difficult it becomes to manage product costs. This is for the simple reason that products may not be defined in the research domain. During technology development, the image of the product may still be vague, but it should be possible to define potential application areas with a targeted customer segment. The application area helps identify customer preferences and a likely market price level, against which product costs can be managed. The focus at this point is in analyzing business models based on the new technology but, in principle, it is possible to start applying techniques intended for managing the product cost.

In generic terms, a product is a deliberate package of characteristics or attributes offered to customers (Bromwich 1990). A product is based on several compatible technologies. Invariably these include both product and manufacturing technologies, but one can usually identify a limited number of technologies that truly characterize the product. In this report technology refers to the underlying set of technologies characterizing the product. The word *product* can be used in different abstraction levels, and companies use different terms to identify the level: for example platform, product type, model, version, generation, variant, and product item. Furthermore, a core product can be enhanced with different accessories or add-ins. The connotation of product life cycle depends on the connotation of the phrase *product*.

Products may consist of material objects, services or information. The importance of the production costs compared to the development and marketing costs differs. This should be reflected in the cost management practices. The production of some services cannot be specified *a priori* like the production of material objectives, but

there are services that should be engineered to guarantee profitability. Resources needed to produce one unit of a solely information-based product are minimal when compared to the product's unit price. This makes the management of production costs less important. Despite these differences, the key principles of product cost management should be applicable to all types of products and services.

Recognizing that prior decisions often commit the organization to subsequent incurrence of costs is important in cost management, and requires understanding of the product's life cycle. The central aspect in product cost management is the producing organization, i.e. a single firm or several intensively cooperating firms. Therefore, product life cycle is viewed from the producer's perspective; and considered from the point of initial product idea until the end of the producer's financial responsibilities. Similarly, product costs refer to the (measurable) costs incurred by the producing organization. A customer observes the total cost of ownership, yet the product may cause costs by other stakeholders. But these elements of the product's total life-cycle costs are not interpreted as product costs (input). Instead, they are included in the dimensions of product performance that eventually invoke customer satisfaction (output).

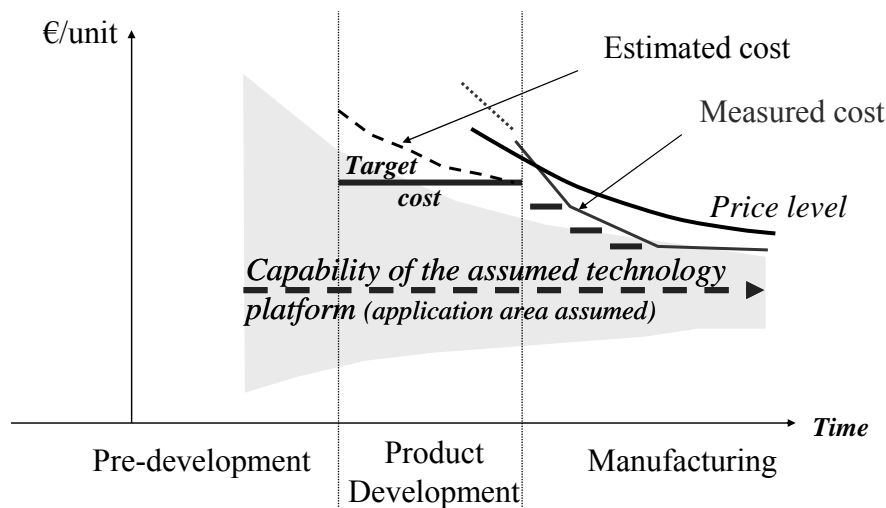


Figure 1-1. The challenge of product cost management

Figure 1-1 summarizes the challenge of managing product costs in R&D. The main proposition is that **product cost management should start before the well-structured product development in order to ensure built-in cost capability of a product**. This proposition leads to the following problem: **what kind of cost management should be applied during the pre-development stages**. Cost capability refers to the potential of a technology, i.e. the foreseen attainable minimum cost level. With cost capability, one can also characterize the organization's ability to achieve justified cost targets during the product's entire life cycle. The attribute "justified" emphasizes that correct cost targets are set.

1.2. The origins and structure of the report

This report is based on the findings of a two-year research project (INCA, Increased Cost Awareness) carried out by BIT Research Centre at the Helsinki University of

Technology. The project was funded by three Finnish companies and Tekes (Finnish Funding Agency for Technology and Innovation). Altogether, professionals from ten companies or divisions of a company cooperated with the researchers. The researchers used a literature research, interviews, and interventionist approach in gathering data. Several research papers have been published separately and they are referred to in this report. The report is intended as a summary of the entire project.

The main problem under investigation is stated at the close of section 1.1, and can be further divided into the following research questions:

1. Could target costing be adapted to the pre-development stages?
2. What kind of structured cost management practices do companies use now?
3. What kind of modifications to these practices would make cost management during pre-development more efficient?
4. What are the key characteristics that make the modified or present practices effective?

The remainder of this report is organized as follows. Chapter 2 addresses the first research question. Chapter 3 continues to analyze the issues related to cost estimation. Chapter 4 provides an outlook of applied practices, thus answering the second research question. Chapters 5 to 8 answer the third and fourth research questions. The more novel and innovative practices and ideas are described in chapters 5 to 8. Conclusions are drawn in chapter 9.

2. Adjusting target costing for pre-development

Jouko Karjalainen

Target costing is a well-known cost management method intended to be used during product development. It was originally invented by Toyota in the 1960s. A review of target costing studies (Karjalainen 2006) indicates that it has been widely applied in many Japanese industries; whereas companies in other countries have been less active in adopting it. The operative definition of target costing varies across studies and companies, but certain characteristics are generally connected to the method. Target costing was first applied for the design stage of product development, but it has been implemented upstream of the product development (Tani et al. 1994). However, its application becomes more difficult as the product's degree of innovation increases (Cooper and Slagmulder 1997).

2.1. The essence of target costing

The primary objective of target costing is to ensure that each product, over its life, contributes its planned share of profit to the firm's long-term financial objectives. The target costing process can be divided into three major sections: market-driven costing, product-level target costing, and component-level target costing. The market-driven costing identifies the product's future allowable cost, i.e. the manufacturing cost that generates the required profit margin when the product is sold at its target price. The process of product-level target costing acknowledges the difference between current cost and allowable cost and, thereafter, sets the actual target cost, given the capabilities of the firm and its suppliers. The component-level target costing allocates the product-level target to the components by means of the product's major functions. (Cooper and Slagmulder 1997)

The target costing process draws on the firm's long-term sales and profit objectives. Once a firm has established its product-line structure, consumer analysis is used to determine the required functionality and quality of each product. The target price for a product is defined in line with functionality and quality. This competitive positioning of the product limits any further trade-offs that might be made to achieve the target cost. The sales volumes and selling prices of historical products are typically used as predictors of new models, if the new product is designed to replace the previous year's product. Conversely, setting a target price is particularly difficult when a firm launches a product that has no immediate predecessor.

The essence of product-level target costing lies in setting a challenging but attainable target, and in the disciplined effort to reach the target. According to the 'cardinal rule', the target cost must never be exceeded but, in practice, many Japanese companies sometimes exceed the target cost at product launch (Tani et al. 1994). This contradiction reflects the view that target costs are set at a level that requires substantial effort. Monitoring the progress towards reaching the target cost requires reliable cost estimates at different stages of the product development. Japanese firms use extensive cost databases (cost tables) for this purpose. Initially, the current cost of the new product is determined by summing the current manufacturing cost of each major function of the new model. Some firms define an 'as-if' cost, which reflects cost-reduction opportunities identified when the previous generation of the product

was being designed or manufactured. Engineering techniques, such as quality function deployment (QFD), value engineering (VE), or design for manufacture and assembly (DFMA), can help product designers find ways to reduce the product cost. Although these techniques are often connected to target costing, companies can also use them independently.

Component-level TC deconstructs the product-level target to the component-level using the product's major functions. Target costs for components can only be set when the product design has reached the stage at which specific components can be identified. One of the critical decisions in component-level target costing is the sourcing of components. Suppliers are selected based on their bids, reputation and innovativeness. The bids are taken as early as possible in the target costing process and are incorporated by an iterative process into the component-level target costs. In its basic form, target costing does not actively involve the supplier in the buyer's cost management program. The buyer's target costing process merely identifies the purchase price of the outsourced item. However, the method becomes more effective when applied in the context of long-term supplier relations that are co-operative in nature. The forms of inter-organizational cost management emphasize the active involvement of both the buyer's and supplier's design teams in cost management (Cooper and Slagmulder 2004a).

2.2. Target costing in concept development

Many of the costing techniques designed for a well-structured new product development may not directly apply to the preceding stages of the innovation process because, for example, the nature and availability of information is different. It is normally considered that the target costing system is of less value as the degree of innovation increases and the new product relies less on existing designs (Cooper and Slagmulder 1997). Nevertheless, some properties of target costing may be adjusted to the earlier stages. *Concept development* is an interesting area since it can be seen as a link between the advanced engineering domain and development domain in R&D. A product concept is a concise description of the technology, working principles, and form of the product (Ulrich and Eppinger 1995). Concept development is often depicted as the first phase of the generic development process, during which time the needs of the target market are identified, alternative product concepts are generated and evaluated, and a single concept is ultimately selected for further development. The following analysis is presented in more detail in Karjalainen and Ojapalo (2006).

At the early stages of concept development, critical problems concerning the attainable product performance mitigate the importance of particular cost management practices. For example, there may be technical problems concerning the alternative concepts. If these problems are not solved, the product with the planned performance would be impossible to manufacture or the cost of making marketable products would certainly be too high. Therefore, the fundamental technological uncertainties must be resolved before any detailed cost target becomes meaningful. Generally, criteria related to the product performance may outweigh product costs and make the target costing process less attractive in the early development stages.

The activities of concept development match well the content of market-driven costing. The first stages of concept development, i.e. identifying customer needs and

analyzing competitive products, provide information that is needed in setting the target-selling price. However, if the value proposition related to the product is novel, the value created to the customer by the new product is difficult to estimate and the target-selling price is complex to establish. The refined product specifications, i.e. the precise description of what the product has to do, are developed at the end of the concept development process by assessing the technological constraints and the expected production costs (Ulrich and Eppinger 1995). During the refinement of product specifications, the development team makes significant trade-offs amongst cost, functionality, and quality. On the other hand, concept development and the consequential phases of product development should not be separated by the concept freeze in a turbulent, uncertain environment (Iansiti 1995). In these cases, it is more difficult to set a clear target price early in the development.

There are case-specific factors that may help or even complicate the process of determining the target price. In consumer-products, the uncertainty and instability of customer preferences is a problem. For suppliers with industrial customers, the situation is more straightforward if concept development is synchronized with the customer's concept development and the customer delivers specifications with cost targets. In contrast, many suppliers want to develop proprietary concepts that could be offered to multiple customers. This means that concept development becomes uncoupled from customers' concept development, although there would be information exchange concerning forthcoming products and related technologies. The precise description of product requirements will not be determined until a new concept is applied in a customer's product program. Knowing customers' product costs is valuable for those suppliers that offer technologies enabling component integration. A new integrated concept must provide at least the same performance with a cost that is less than the cost of components needed without integration. This, in fact, could be the first estimate of the target cost.

Ambiguity in the target selling price is reflected in other parts of target costing. For example, if the precise functionality of a product concept is not locked, it is difficult to set a strict target cost and discipline it. Although the cost target could be considered challenging and achievable, the "cardinal rule" can not be applied. Then again, well-justified exceptions from this rule are allowed even in Japanese target costing practices. If the cost target describes more a *target level* than an exact and stringent figure, then it becomes less important to distinguish allowable cost and actual target cost. As the degree of innovation increases, historical cost information regarding earlier products has less value. This is especially the case for products that rely on completely new technologies. Problems in cost estimation make it harder to assess how realistic the market-driven allowable cost is. Uncertainty related to cost estimates also complicates the calculation of current cost and monitoring the progress of achieving the target cost. An outcome of developing a new concept could be the knowledge of the cost drivers and cost structure. This knowledge could be utilized in evaluating the further products based on the concept. Radical changes in the product may also mean changes in the value chain and in companies' business models; thus, demanding a broader perspective of costs.

Modular product structures support the target costing process since subassemblies provide major functions and the design process can be broken into multiple, somewhat independent tasks. However, new concepts may be created to challenge the

prevailing product architecture in order to create competitive advantage. However, this complicates the process of composing the product-level target cost to the component level. Furthermore, alternative concepts considered during the concept development may lead to different product structures, and making early component-level cost targets useless. Changes in the concept can remove or integrate components, for example. New materials are often protected by intellectual property rights, and the owner of these rights may have large financial expectations. The manufacturer may not always have enough relational power to set target costs to material suppliers. In the worst case, the typical break-down of the product-level target cost to the component-level can sustain the current product architecture. Cost models may reflect the prevailing architecture and the current processes, instead of new technological opportunities emerging in fast-moving environments.

2.3. Modifications to market-driven costing

The underlying ideas included in target costing can be adjusted to the pre-development phases. It should be easy to accept that the proxy for the target price should be market-driven and include consideration of competition. Furthermore, specific goals increase motivation better than non-specific ones, and the level of challenge should be optimized because both too easy and too difficult goals tend to reduce motivation (Simons 1995). So disciplined target setting and achievement certainly has its merits. Alternatively, it may not be effective to persist in the original goal if changes in the environment require revision of the plans; which is likely to happen when the planning horizon gets longer. Product cost management in the pre-development stages probably resembles target-costing philosophy in many ways, but the practices are less formal than the actual target costing practices. Techniques should be modified to the uncertainty and the nature of available information concerning the decision-making situations.

A product's survival zone (Cooper and Slagmulder 1997:76) refers to the challenge of balancing product's functionality, quality and price. Some companies can fine-tune the product just prior to the launch by deciding on standard and optional product features; whereas other companies may base their analysis on a single distinctive product feature. A thorough market analysis is the basis of market-driven costing and quality function deployment (QFD) because it should provide information that helps decision-makers to set subjective weights to different product characteristics. Thus, the target price is derived from product attributes, and the product-level target cost is allocated to components using a similar weighting system (Hoque et al. 2000). However, at the pre-development stage, there is not necessarily enough market intelligence to establish weights for product attributes. Generally, for a product to survive, it must yield at least the same amount of each characteristic as its competitors, unless it generates sufficient extra of other characteristics to offset the equality (Bromwich 1990). This means that the product is not undisputedly dominated by some other product. One can sometimes identify a primary attribute but cannot always exclude all the other attributes and so determine their order of importance, not to mention numerical weighting. At some point, technology is able to provide more than what customers require, which changes the rank-ordering of the criteria by which customers choose one product over another (Christensen 1997). This aspect cannot be ignored in turbulent environments or with long planning horizons.

Decision-makers can limit the set of competitive alternatives by simultaneously comparing alternatives across critical attributes, including price or estimated cost. The comparison could be completed with partially qualitative data and rough estimates if it were based on a purely ordinal scales and the logical definition of dominance. Likewise, the outcome of the analysis would be merely suggestive. Data envelope analysis (DEA) is a more sophisticated technique that could be applied to comparing alternative concepts and reckoning the competitive level of products' price or cost. DEA can be an efficient method in ruling out poor alternatives if the number of characteristics does not exceed one third of the number of alternatives (Vitner et al. 2006). The method was introduced by Charnes et al. (1978) and it originates from the generic problem of estimating performance efficiency as a ratio of the weighted average of results to the weighted average of expenses and investments needed to achieve the results. DEA does not need ex-ante determined subjective weights although the linear programming procedure produces weights in order to rule out the unanimously inefficient solutions. However, the weights determined for a potentially efficient alternative indicate something of the landscape where this alternative could be the best one. A 'what-if' analysis could be conducted for an inefficient alternative in order to determine, for example, which unit cost would move the alternative among the potentially efficient ones. These issues are considered in more detail by Karjalainen (2007).

Komatsu's method in setting target costs for components resembles the idea of DEA, but it is based on accumulated internal experience. The information of all similar components (for example a radiator) used by the firm is applied. First, each known solution is plotted with respect to its primary functionality (cooling capacity) and the primary physical determinant of functionality (surface area). Then, a line is drawn so that it passes through the best of existing solutions (providing maximum cooling capacity with minimum surface area). This minimum line and the required functionality are used to identify the target value for the primary determinant. Finally, the target cost is determined by plotting the cost against the primary determinant for all similar components used by the firm. The minimum line is used to derive the target cost from the target physical characteristic. The appropriate information concerning costs and physical characteristics is maintained in cost tables. (Cooper and Slagmulder 1997)

The alternative solutions analyzed with DEA, or some other method, should also include all the known competing solutions. Different variants of the same basic alternative may also be included. Naturally, the quality of the analysis depends on the quality of input data. Estimating the future capability of the competitors' solutions is not an easy task. Chapter four identifies techniques that may help achieve these estimates. Another problem when applying DEA is in providing a price estimate for the alternatives. Price is available only for those solutions that are already in the market. While the selling price of products can be disconnected from costs temporarily, if the firm is to remain profitable in the long run then costs must be brought into line with selling prices (Cooper and Slagmulder 1997:31). In the pre-development, the purpose is to assess how competitive the solution can be in the long run. Therefore, unit cost could be used as a characteristic instead of price. This, of course, creates the problem of how to estimate the potential future cost of a new solution. This problem is considered in chapter 3.

3. Estimating product costs in the case of new technologies

Jouko Karjalainen and Maija Koskela

Cost estimates can be used for several purposes. For choosing among otherwise equal alternatives, the estimates must order the alternative by cost. It is more about *reliable comparison* than about the exact numeric estimate. In platform development, the numeric estimate of an attainable cost level is necessary, but the accuracy may be poor because several forthcoming decisions still affect the product cost. More accurate cost estimates are needed while monitoring the progress towards the target cost. The purpose of the estimate determines its relevant features. Thereafter, one can consider which estimation technique matches the problem. A cost estimate can be extended to cover the costs that the product generates for customers once used. Chapter 8 considers life-cycle costing with customers' costs included.

3.1. Generic properties of cost estimates

A cost estimate is based on an explicit or implicit cost model that includes perceptions of how costs behave. Cost behavior is articulated through cost drivers, i.e. parameters of the model. In order to make numerical estimates, one needs to define quantifiable cost drivers. However, a cost driver can refer to a loosely defined qualitative indicator that merely helps us understand cost behavior. For example, design rules embrace qualitative cost drivers, and decision-makers may apply their knowledge of cost drivers in addition to formal estimates. A systematic analysis of cost drivers should precede the construction of a cost estimation model. Such analysis starts from the descriptive level that provides a comprehensive picture of cost behavior and proceeds towards selecting the significant quantifiable cost drivers. The use of cost drivers in the case of new technologies is addressed by Karjalainen and Tuomi (2005).

In the context of R&D, estimates try to predict a product cost that will become measurable in the future. The time horizon can vary across different estimates concerning the same product, which complicates the comparison of estimates. Typically, the estimates used in the target costing process predict the product cost at launch or after a short ramp-up period. Because product costs need to be managed throughout a product's life and through product generations, it is also useful to estimate the achievable cost closer to the end of a product's life. Cooper and Slagmulder (1997) suggest that lean enterprises should always benchmark themselves against a waste-free standard and not just against the best competitor. The lean enterprise's ultimate goal should be the perfect waste-free cost, which assumes that no non-value-adding activities are performed and that all value-adding activities are performed as efficiently as possible. The waste-free cost is not the immediate target cost but reflects the strategic cost-reduction challenge. The definition of the waste-free cost implies that the activities of the production process are known and the long-term task is to streamline the process by ultimately eliminating waste.

Fundamentally, cost projections made by experts during pre-development can also reflect a waste-free level. However, these projections may be solely rough estimates based on a preliminary understanding of the process. Further development may reveal that not all the necessary activities were considered and, therefore, the projection was far too optimistic. Another problem of rough estimates is that they do not necessarily

specify which cost elements have been included in the estimate. In analytical cost estimates, costs should be clearly classified in terms of the considered resources and parts of the value chain, although the scope and the level of detail can vary in estimates made for different purposes. The nature of various estimates is illustrated in Figure 3-1.

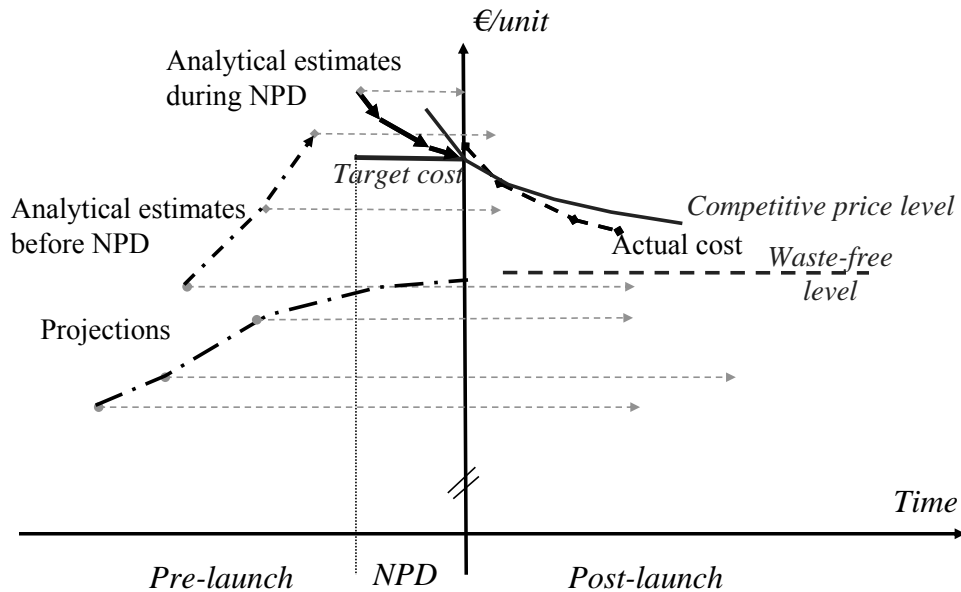


Figure 3-1. Projections and analytical estimates

Estimation techniques are based on history, but the future cannot be extrapolated from the past. Therefore, estimates include the estimator's assumptions concerning the future. During the NPD, prototyping and pilot production can provide measured data that help predict the cost at launch. However, estimators need to make assumptions of learning-curve effects during the further development, in order to identify an indicative estimate. For example, the yield in trial manufacturing may be low but past experience has shown that most of the yield problems can be fixed in process design. The location and operating system also affect the cost level. During the pre-development, e.g. in technology selection, these issues are not decided, however. In some cases, technology may restrict the potential choices of the manufacturing location, but not generally. The way that the production is organized can make a difference in overhead costs. Lean companies tend to have lower overhead per unit of sales than bureaucratic or niche companies (Blaxill and Hout 1991).

The estimation model should focus especially on those costs that are influenced by the decisions at hand. Many target costing systems use cost estimates that are close to full cost (Tani 1994), which is the appropriate approach in long-run decisions. However, the treatment of indirect costs must not distort the estimate. For example, new production technologies have decreased the influence of direct labor in several industries, but the total cost savings of automation are exaggerated if indirect costs are allocated in proportion of direct labor. Novel materials tend to be more expensive but have improved properties that may lead to reduced material consumption and conversion costs because of integration of parts. Although the direct material cost is high, material-related overhead costs can be closer to a normal level. At least these costs do not increase in proportion to volume. On the contrary, increasing volumes

can lead to price discounts and improvements in the in-bound logistics of the new material.

Although, activity-based costing (ABC) offers better ways of estimating overheads, the rules of assigning an overhead in regular product costing systems tend to reflect the current resource-mix and product architecture. To avoid systematic errors induced by product costing systems, overhead should not be assigned to a new product in proportion of its characteristics. Instead, it would be advantageous to use the absolute overhead cost of a comparable old product. When solutions based on old and new technologies are compared, the treatment of overhead is neutral. When it is known which specific production-supporting activities and corresponding resource requirements are transformed by a new technology, one should estimate the cost of these changes explicitly.

3.2. Cost estimation methods

There are several cost estimation approaches in the literature. Typically, cost estimation models are classified as analogous models, parametric models, and detailed models (Asiedu and Gu 1998). Detailed cost models can be constructed when all the main elements of the production process and of the product's material structure are defined. Many important choices may already have been made at this point, however. Cost accounting methods, including activity-based costing, are based on rather detailed product data. Detailed cost models can follow the industrial engineering method or the account analysis method (Horngren et al. 1999). The industrial engineering method estimates cost functions by analyzing the relationship between inputs and outputs in physical terms. Standards and budgets transform physical measures into cost. Accounting methods examine current accounting data from the manufacturing facility and tries to assign these costs across all of the products.

In parametric models, the cost is expressed as a function of a set of variables characterizing the product. Parametric models can be based on different product features (performance, morphological characteristics) and, therefore, they are useful in the early phases of product development. Parametric models may contain several cost drivers and non-linear cost relationships, but they can also be based on few variables and linear models. Clark et al. (1997) warn about using overly simplified rules based on multiplicative factors or two-dimensional cost-performance plots. These methods have limited predictive capabilities because they do not identify the underlying process. Because the cost function is verified using historical data and statistical methods, parametric models are mediocre for estimating the cost of products that utilize new technologies. Neural networks have also been applied for cost estimation but they require historical data as training data. While the use of a parametric model requires an explicit specification of the cost function, this is not necessary with a neural network. The models described in literature are somewhat promising compared to the regression models (Cavalieri et al. 2004, Zhang et al. 1996, De la Garza and Rouhana 1995). However, the studies do not consider how well neural networks can be adjusted for new products and technologies.

Analogy-based techniques draw on similarity between the new product and a well-known reference product. These techniques are used in the first phases of the development process but they require expert knowledge and judgment. Nevertheless,

efficient use of analogies can facilitate the estimation process. A more detailed cost analysis may focus only in the essential differences of the new product and the reference product. Analogies can be used on different levels: from identifying similar modules or chains of activities to estimating cost driver values of the new product.

Technical cost modeling (TCM) can be used with new processes that have no history upon which to base cost estimates. It was developed at MIT in the late 1970s. According to Maine et al. (2005), TCM has emerged as an accepted metric for material and process comparison in automotive industry. The method requires that the different cost elements for each processing step are estimated separately based on engineering principles, the manufacturing process, and specified economic and accounting assumptions. The main advantages lie in the fact that TCM is predictive and allows one to investigate the sensitivity of the outcome to changes in the input parameters. The sensitivity analysis enables the product designer to look at the effects of unknown or uncertain model parameters, e.g. price of a new material or process cycle time. TCM enables a cost comparison between functionally similar systems made with competing materials and processing methods. (Clark et al. 1997)

TCM resembles the industrial engineering method, because it focuses on estimating the resource consumption or process cycle times. Conversely, it could be used to estimate cost-related technical parameter values in parametric models, as well. To manage the workload, TCM could be conducted only on the crucial elements of the new product. Increasing the level of detail and number of cost drivers in selected points assists in understanding the uncertainties through sensitivity analysis. However, one should assess the sensitivity of the cost to production volumes. The effect of the batch-size is important when comparing manufacturing technologies because they may rank differently according to speed and flexibility. The more novel the technology applied, the more difficult it becomes to attain reliable data for estimates. Being able to pinpoint the most crucial parameters, once again, could reduce the time and total effort needed for a decent estimate.

Cost tables are an element of Japanese cost management. They form an integrated cost estimation database. Approximate-cost tables are used in new product development; whereas detailed cost tables are used for purchasing negotiations and for production cost management. Approximate-cost tables are constructed by deciding on a small number of key cost drivers. Detailed cost tables include an accumulation of costs for each production activity using a comprehensive set of cost drivers yielding complex, multi-dimensional tables. The focus of cost tables can be in production activities and parts, or in the functions of products. Function-oriented cost tables help assessing the cost implications of modifying, dropping, or adding functions in the product. Cost tables can also be prepared based on external information of methods that are not currently being used by the company or its subcontractors. Thereby, cost tables may include “information from the forefront of technology”. (Yoshikawa et al. 1990) The literature on cost tables does not emphasize the estimation method but the availability of cost estimates for various purposes. Cost tables represent an easily accessible source of information, but their creation and maintenance requires significant effort by management accounting and technology experts.

4. Management of early innovation phases using cost management tools

Frank Bescherer

It has been claimed that it takes approximately 3000 raw ideas in the initial stage to achieve one commercially successful product. In a self-screening process, R&D employees pick ideas – interesting and potentially feasible in their eyes – to do some simple experiments or discuss them with management. Through that process, the amount is reduced to 300 followed-up ideas. Less than half of these then lead to small projects that might result in a patent. Subsequently, only nine of these lead to larger projects, and only half of that become major development efforts. Subsequently, only 1.7 of original ideas is commercially launched, and on average only 59% of the launched ideas turn out to be successful (Stevens and Burley 1997). This leads to product development ‘funnels’ like the ones shown in Figure 4-1.

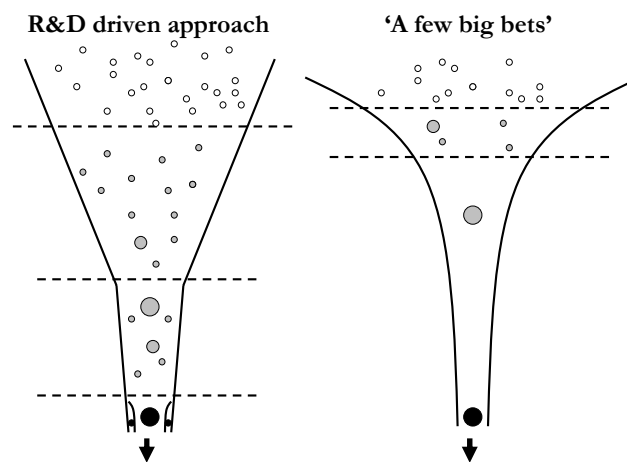


Figure 4-1. Two extreme models of the development funnel found in industry

Wheelwright and Clark (1992) found company practices for innovation idea screening, which could be illustrated by the two extreme funnels (shown in Figure 4-1). In their view, the correct screening is seen as essential for efficiency in this phase of innovation. Similarly, Kim and Wilemon (2002) suggest that it is vital to adopt the correct screening methods – not too soft and not too ridged. The first will lead to few projects being killed and resources wasted; the latter will lead to too many ideas being rejected. The screening criteria often have to be varied from case to case. Additionally, different variations of an idea should be considered. These should then compete until the best product concept crystallizes.

4.1. Generic consideration of challenges in early innovation phases

According to Zhang and Doll (2001), development teams have to manage the uncertainty associated with the demand, technology, and competition, in order to develop new products successfully. They state that for a robust product conception and definition, information and feedback from many sources in and outside of the developing company is needed. This information typically consists of data that comes from engineering, R&D, marketing and manufacturing. Kim and Wilemon (2002) claim that it is also important to provide information systems and build databases that

allow R&D personnel to promptly check data on technologies, markets, other development projects and competitors.

It is claimed in literature that most lock-ins happen during innovation. For example, although only about 5% of total cost of a car is spent on the design activity itself, it determines about 70% of the total product cost (Boothroyd 1988). Similarly, the success of an innovation depends partly on good concept development, as the following quote shows (Iansiti, 1998:4): *“Once an organization has committed to a future product’s concept, most of the potential for change and improvement is gone from the project. If the concept is a bad one, if the product is difficult to manufacture or inappropriate for the desired user application, the project will run into problems – no matter how well integrated the team or how powerful the project leader”*.

The early phases of innovation allow one of the greatest opportunities to improve the overall innovation effectiveness, as ideas can be turned into high-quality proposals and designs. However, the flip side is that uncertainties are higher during these early stages. According to Schneider and Miccolis (1998), risk management is very important to senior managers these days. They see the job of senior management as business risk managers. Business is often a trade-off between some kind of risk and a possible return. “In a sense, the uncertainty and possibility of harm is the price we pay for a reward” (Schneider and Miccolis, 1998:10). Shareholder value is created when the return exceeds the cost of risk and the higher the achieved return per taken risk the more an investment is worth. This translates to higher stock prices of stock listed companies, as investors will pay a premium for a company that manages uncertainty more effectively than others (Schneider and Miccolis, 1998).

4.2. Tools identified in the benchmarking study

Compared to research on costs in the new product development process and its later stages, e.g. manufacturing costs, the costing in early innovation phases has received little attention in the accounting literature. Similarly, in the new product development literature, analyses of costs are reduced to feasibility studies, which are usually lacking the preciseness that cost management techniques offer. Seven international companies were benchmarked to identify how they deal with cost information in early innovation phases. This chapter focuses on several cost management related tools.

4.2.1. Roadmapping

Extensive technology roadmapping in early innovation stages can be seen as one of the better practices found to manage different kinds of portfolios. This is used for planning purposes and to identify areas requiring further elaboration or accelerated development. Of the studied companies, the most sophisticated one, from a cost management point of view, is carrying out trend analysis to understand the dynamic development of the performance and cost of different technologies for its roadmapping.

If additional development of an important technology is uncertain, research projects to explore new technological possibilities are initiated. As developments might take several years until market launch, it is important to know how the costs connected to

certain technologies will develop over that time. In this case, the expertise and experience of senior employees is used to estimate the dynamic cost behavior of technologies over time.

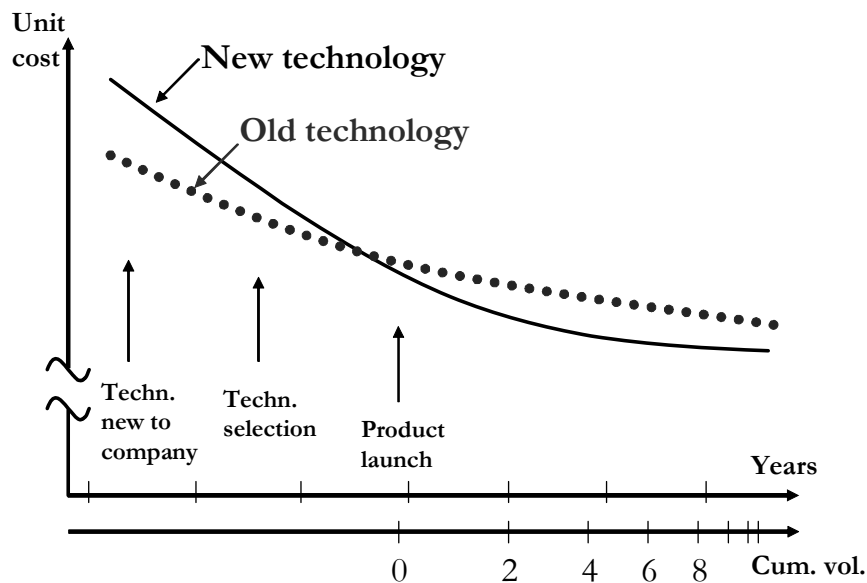


Figure 4-2. Technology choice on the example of dynamic unit costs

For example, a situation similar to the one shown in Figure 4-2 would be possible. In that case, there are two competing technologies that could be employed in the new product development. The managers of the company would try to estimate the cost potential of both technologies for several years ahead using expert judgment. In case the costs of both new technologies under discussion are estimated to be too high to fit into the target cost for that product part, the company has to find another solution. Thus, the company is performing a target costing process that includes figures that are blurry in the beginning, but are to be refined during the R&D process. As a senior new technology purchasing managers explains:

“If you’re pitching a technology towards the [...] release in three years’ time, then you can say that roughly speaking it needs to come at this [cost] level. So it is still using target costing [...] and it’s more fuzzy, so not so sharp. The closer you get to the product launch, the more certain you can be about the target costing. But you still use some [estimates] for target costing in the early stages as well. You’re using a rough guess, you’re saying the price erosion [...] will be roughly [...]X] % per year.[...] You can do [...] a rough cut, then you have to structure your architecture and component choices such that it will meet that kind of very rigorous target. So I think there is this form of target costing as well before [...development], but done with a more general understanding.”

In case this is completed intensively, the gained insight is regularly updated. The cost development over time is compared to a feasible market price, a paradigm known from target costing, to estimate the feasibility and the development of it over time. If the cost estimate and the feasible market price are ultimately too far apart, development is stopped. However, even if both estimates are apart, but the company evaluates the market launch as possible, research efforts are launched to bring the technology costs down to a feasible level.

4.2.2. Cost modeling, estimations and calculations in early stages

From the several cost estimation approaches, the benchmarked companies often use parametric cost estimations in the early phases of radical innovations. In case of incremental innovations, the full set of different cost estimation approaches is used. Especially the engineering cost estimation method can well be used if the bill of materials of a new development idea is similar to the one of an existing product.

One of the benchmarked companies is already formulating its first cost models at the front-end of innovation. This cost modeling uses the information gathered during the basic research and later R&D activities. Through this early modeling, the benefits and disadvantages of different design solutions can be quantified during the very early innovation phases. The company that was identified as having the earliest cost modeling regarded its effort as cost scenario modeling, mapping out possible cost settings and developments. Cost modeling in early stages could be further enriched by also including other costs from the total cost of ownership perspective, e.g. logistic costs. If the new development idea is not particularly radical, this kind of information should be easily available inside an organization. Whether early cost modeling is worth the effort might depend on the targeted market. As seen in one benchmarked company, the decision as to whether calculations are made or not depends on whether the targeted customers are sensitive to prices or not.

Whenever possible, one case company tries to quantify the benefits and disadvantages of different design solutions as accurately as possible. The company performs cost modeling at the front-end of innovation. This cost modeling uses the information gathered during the basic research and later R&D activities.

Development engineers have to understand different parameters for the technology selection process. The first parameter is what kind of alternative technologies are available, the second is the performance levels that can be achieved, and the third one is the cost structure connected to a certain technology. In the early phases of innovations, cost modeling is seen as preparation for the correct basic technology choices. One company is carrying out basic cost modeling prior to the technology selection. Due to the uncertainties attached to it, it might be more of a cost scenario modeling, mapping out possible cost settings and developments.

In another case company, the first cost calculations are made at the second stage after idea generation. However, rough estimations are previously made before that point. The cost calculations were described as simple, usually based on the bill of materials. Additionally, logistic costs are included and the investment costs are estimated using analogical cost estimations from experience. The further the new idea development proceeds, the more accurate the cost estimations. In cases of rather incremental developments that are launched to previously served markets and potential customers, projects can be evaluated very fast with the help of investment appraisal methods, such as the net present value and return of capital calculations.

A third case company uses cost driver analysis to investigate the cost structure and actual costs of their products and purchased components. This has revealed some counterintuitive pieces of cost information. Subsequently, the company redefined cost drivers that were more accurate. This 'realizing' of what the known cost drivers are,

radiated into their early innovation analysis. Thus it is important that costing and cost estimations are done correctly already in early stages of innovations.

4.2.3. Cost capability estimations and target costing

Generally, the benchmarked companies recognize target costs as an important factor that has to be evaluated relatively to the potential market price of the innovation. The benchmarked companies are using qualitative estimates to evaluate the cost capability of new technologies. For these early phases of innovation, the cost capability of a new technology is playing a significant role in the dynamic development of the target costing. As the cost capability estimation is a difficult task, it should be completed by experts in this field. This restricts the earliest possible use if there are many different new development ideas to be evaluated. Thus the cost capability estimation has to be made in early stages and during the time that different design choices have to be evaluated.

One interesting practice found and that can be associated with target costing family is a cost/functionality trade-off analysis. One company is analyzing what kind of cost level per functionality can be achieved with a specific technology or technology generation for planning and decision making. This information can then be transferred to different kinds of roadmaps of a company. However, these methods can be seen as rather laborious and time consuming. If a company is operating in a volatile environment, it might be too difficult to set up target prices, and different approaches might yield a better cost management result.

One case company uses cost capability estimation, based on qualitative estimates, in early innovation phases. This is carried out by employees analyzing and evaluating the value of a new idea to the potential customers. This is principally conducted by the marketing function. This analysis and evaluation also includes forecasts of volume.

Another case company is target price estimating in the early innovation stages. Actual target costing that starts with a target price might be too difficult to establish, as the company is a price adjuster in a market that experiences high price fluctuations, and the prices for their products and services are continually dynamic; as the interviewed director in charge of the concept development states:

“You must have some kind of estimation how much customers would be willing to pay for something, and then how big amount of customers we could get and other possible alternatives, but on the other hand, with existing products, there are all the time price changes depending on the market situation, so you never know for sure how much customers actually will pay for a product after some years.”

In a third case company, the cost capability estimations are completed mostly during the early stages of innovation. Cost capability estimates are conducted during development. Once the production is initiated, the design is locked and the company is not interested in changing them, as a change would mean that a part has to be redesigned or that the development would be delayed. Thus, the cost capability estimation has to be made at the early stages and during the time that different design choices have to be evaluated.

In a fourth case company, a similar approach was found. The senior manager for new technology development has initiated a product cost calculation that could be labeled 'perfect waste-free'. He has made calculations on the theoretical minimum costs to fulfill a function. The difference is that in the literature the perfect waste-free cost level is used to evaluate the efficiency of the installed production equipment and process (Cooper and Slagmulder 1997). However, he is using it to evaluate different new, potential production technologies before any equipment is purchased and installed.

4.3. Summary

There are several challenges that companies are facing in the early innovation stages. One challenge is 'lock-ins' resulting out of uncertainties that are usually imminent to the early innovation phases. A response to these challenges is to proceed more efficiently at the very early stages of innovation. This can be done by dealing with uncertainties in a professional manner. Furthermore, information gathered with the help of effective cost management methods can lead to a reversal of lock-in effects into good developments and designs, as managerial decision making is made less problematic.

The tools described in this chapter are not standalone methods, but have to be used as a set of tools bringing additional information to the mosaic of the early innovation. As developments take several years until market launch, it is important to know how the costs connected to certain technologies will develop over time. Additionally first cost models can be developed at the front-end of innovation. This cost modeling uses the information gathered during the basic research and later R&D activities. Finally, cost capability estimation of new technologies together with 'perfect waste-free' product cost calculations could be used to analyze the theoretical minimum costs to fulfill a function.

The lineage of the different tools can be seen at different levels. It leads from (cost) data capture, over presentation and processing, finally to the decision-making preparation at the early innovation phase. Cost management can effectively assist this process during the early phases of innovation and significantly contribute to the success of a new development.

5. The virtual price table tool

Frank Bescherer

In times of saturated markets, the cost aspect becomes more important, as products have to be sold cheaper in order to reach new markets, which could economically not meet the expenses of the products to-date. One answer to these cost pressures is to make sourcing more cost efficient. This gives the sourcing function strategic value in a company. Another answer is to design new products cost efficiently. This chapter looks at a tool that can be used for both of these opportunities, and analyses a virtual price competition tool called virtual price table (VPT).

5.1. Deliberation regarding sourcing

In order to operate economically, it can be seen as essential for a company to minimize transaction cost of purchased supplies and limit the risks connected with the collaboration with its suppliers. Transaction costs can be defined as the costs of supplier and client location, price negotiations, ensuring that the agreed terms are fulfilled and other aspects of cross-organizational exchange (Parkin 1996). The lower these costs, the higher the profit of a product (at same selling prices) or the lower a still profitable price can become. Furthermore, as organizations are open systems, depending on continuous supply of raw materials, they have to manage the purchasing to be cost efficient and risk efficient. After the supplier selection, a client takes a decision and makes investments, which are tailored to the chosen supplier. This buyer commitment can be seen as a lock-in, as the client would experience costs when changing the supplier. This is especially true if the product development is in cooperation with the selected supplier. There is a trend to change from an arm's length relationship with suppliers to a closer, more cooperative relationship by reducing the supplier base and working as allies with the remaining suppliers (Swift 1995).

The root of the research on supplier selection is the work of Dickson (1966), where he examined the supplier selection methods used in the US. Since then, supplier selection has been studied in several other articles. An overview of these articles until 1990 is given in Weber et al. (1991).

5.2. Background of the virtual price table tool development

The studied tool is used in a specific area of a large company in the telecommunication industry. The analyzed department is operating in a business-to-business environment without direct contact with the end-customer. The products the department is producing are platform-based and thus to some extent standardized. The supplied parts purchased with the analyzed tool can be seen as standardized but are custom-built after a design given by the client.

The VPT tool was developed along with a change in tactic of the analyzed company. Before the application of the tool, the business unit was sourcing their components through several suppliers, with the intention of scattering orders and maintaining several suppliers, which were then competing. The change in tactic was to reduce the

supplier base in order to operate more effectively, but only under the condition of not losing buying power or contact with the supply market. Furthermore, the analyzed business unit experienced supplier-switching costs with its components, once the development started with a particular supplier. At the point of commitment to a supplier, any change would have meant costly re-engineering to design the component and replace it with the one of another supplier; as the component under discussion was always single-supplied in order to avoid costs and benefit from economies of scale.

The dilemma was that the supplier was working with the engineers of the buying organization up to the final design, with only a one-price quotation, which was not detailed sufficiently to derive a comprehensive cost understanding. The quoted price from the supplier was merely a value without background information of how it is derived and what the cost/price drivers are. Nevertheless, as the design specifications were changing during the development process, the initial quoted price could not be used as the design often changed. Thus, the client had to ask for another final price quotation. Moreover, as the supplier switching costs were already serious, this left a possibility of opportunism to the supplier, which could spoil the trust of the buying company and harm the financial aspect of the designed product. This effect was encountered by asking frequently for price quotation updates before the VPT was used. However, these frequent re-checks also meant more work and higher cost.

The VPT is not a standalone tool. It is one of a set that addresses the demands of continuous changes caused by innovation. It helps in the endeavor of the technology-sourcing department to fulfill its tasks for the company as effectively as possible. The department has the general aim to reduce uncertainty – which is naturally connected to innovation – as fast as possible in order to reduce risks and unnecessary spending. The VPT is one part of a set that can provide realistic figures in the innovation process. Based on that information, feasibility studies can be made and economic and technological assistance can be given for the development of roadmaps and products.

With the help of the VPT a price model is developed that incorporates information on prices and their drivers. This makes it more visible for the buyer on how the quoted price is derived. The quoted price can be broken down into individual items and use the position of those prices in the supply market, rather than only considering the end figure. This allows information to be more factual and allows ranking the suppliers in a more detailed manner.

5.3. Purchasing criteria and buying center

Certain boundary conditions in the form of performance requests are attached to a requested quote from the VPT tool. Generally, there are several different possibilities on how to choose a supplier. In the analyzed case the supplier selection is usually done in two steps. The first step is an early vendor assessment (audit); the second step will be the selection according to the process of the VPT tool (described above). In the audit, several criteria are considered, from quality, delivery reliability up to financial health of the supplier. These criteria are *hygiene factors*, which have to reach a prescribed level, so that the supplier is not excluded before requesting a quote. This rating will provide an indication of which suppliers are better than their competition and show if there are problematic circumstances, where the supplier should be

excluded from the quotations (breach of hygiene factors). The supplier selection is completed with the help of score-points for each supplier. Nevertheless, the weighting of these different criteria is problematic. There will always be some degree of subjectivity when deciding the weighting of the different analyzed purchasing criteria. It is worth mentioning that the actual supplier selection is based on the quoted price, not the actual total cost of ownership (TOC).

In general business practices, the communication between suppliers and the client is usually multilayered. Different persons of the client company will try to attain information from their network / contacts at suppliers. However, this puts the sourcing department in a weaker bargaining position, as R&D managers might insist on the selection of a special supplier that they selected based on disclosed information, relevant only for them. The VPT avoids this kind of weakening of power for sourcing, because (a) it has a cost overview, which it can communicate to R&D already at the early stages and (b) the supplier was in an open position when supplying its first quotes. This means that they cannot increase the price in negotiations based on the knowledge that they are likely to be chosen, even if the quote is higher than competitors are.

This method greater practical application over the time that the knowledge was gained through early vendor assessments, as the results of the VPT is centered on few suppliers and persons. It is then shared on need to know basis with the other actors of the buying center. The buying center of the studied organization changes from case to case. It is usually cross-functional, containing representatives from technology sourcing, global sourcing, technology management and responsible program managers from the business unit. In the optimal case, technology sourcing prepares the information related to supplier rating, and quotes and aligns it with the program manager. Usually it is the program manager, who makes the final decision, while the other parts of the buying center are giving consulting advice.

5.4. Price and cost estimations

The information that the technology-sourcing department is collecting through the VPT is multilayered. On one hand, pricing relevant cost information about suppliers is accumulated. On the other hand, details about the production processes related to the purchased components and its best manufacturing are also collected.

With the time the responsible managers from the sourcing department identified price drivers of the production processes under study that could equally be cost drivers. It is possible to formulate price estimations based on several parameters with the data gathered with the VPT. The calculation is based on values of the price drivers that are entered into the model according to the component under study.

An interesting aspect that the studied buying company discovered was, that the production cost is independent of the ordered volume, as there was no additional grade changing cost related to the order size. The volumes only had an impact on the capacity utilization of the production line of the suppliers. Correspondingly, the difference for the total cost of delivery was not large and the price difference asked was exaggerated by the suppliers, which gave large discounts for high volume orders. Before the analysis through the VPT, the suppliers built in a 'price cushion' and then

offered a discount for high-volume orders. Yet seen retrospectively, this is perceived as not adequate, but no one from the buying organization questioned it at that time prior to the VPT analysis.

5.5. Benefits and challenges of the virtual price table

One significant positive aspect of the VPT is that if it is used correctly it saves time in the new product development process because of a pre-selection of suppliers. Most of the quotation work is conducted prior to a special new product development project on a non-critical time path. It has been reported that the use of the VPT saves from three to six months in the new product development process. However, it depends on the technology maturity of the process for which the data is requested. If it were a mature technology it would not reduce much time, as the traditional request would not take very long. Nevertheless, especially for the new technology or in case of new vendors, it is an important feature for a faster time to market. As already described above, the VPT decreases the asymmetric information situation between buyer and supplier. The quoted price will stay constant even so design changes arise during the product development process. So the discussions about how these changes affected the price are easier. Furthermore, very detailed component cost information is available through the VPT. This information can be used to analyze different designs and find the optimum solution from a cost point of view. Another main benefit is that the buying company can maintain supply market conditions for single-supplied components.

However, during implementation and execution of the VPT, challenges were discovered. The greatest experienced difficulty was that some suppliers were not willing to share the requested information. That was leading to power-showdowns with the supplier. Excluding any unwilling suppliers could lead to situations where opportunities are left unused. However, that depends how strictly the buyer pressures the suppliers to provide the information. Sometimes the buyer has to be satisfied with less-than-complete information, and may have to focus more on the functionality issues. Similarly, negotiations can be held-up due to lengthy discussions with the supplier. Furthermore, there is always the possibility for misinterpretation of the requested information on the supplier side. However, this is usually identified during the data analysis activity of the VPT, and can then be solved.

Nevertheless, also internally the VPT has challenges. The analyzed company has experienced organizational problems caused by non-acceptance of the model within its own organization. In this case other departments were getting quotes and overruling the VPT structure. In addition to organizational problems, it is also important to understand correctly the tool and its use. This can be difficult due to the large amount of details in the tool. Because of that, and especially if the tool is set-up for new components, expertise knowledge about the production process of the components under study is needed. The efficient use of this tool requires several years of industry experience in the specific technology area in order grasp and model the cost-structures and processes. Additionally there might be (soft) factors not analyzed within the VPT, that turn out to be critical at later stages. These factors can be incorporated later when the tool is refined.

5.6. Contingency factors of the development

In the view of the author, the development of the VPT has been facilitated through several aspects (contingency factors) that made the application of the tool easier than in other fields. The most important was that the production processes of the analyzed components are standardized and thus comparable. Furthermore, the components were only manufactured by a limited number of companies (7-10). This allowed the buying organization to develop a deep knowledge in the supplier's manufacturing process. The components under study were very often subject to design changes during the NPD process. Thus, a tool to address the above-described possibility for supplier opportunism had to be developed. Furthermore, the components were usually single-sourced and produced by one supplier over the complete life cycle of the product. This led to the perception that there is a strategic need for the development of this kind of tool. Another contingency factor is that there were economies of scale in the information gathering and usage. The purchased component must have a significant value (A-class product) for the buyer, when rating it from the purchased turnover, so that the cost of information gathering is economically efficient. A-class products are the most important purchased products, as they are crucial to the product and/or a major cost factor. In the studied case the buying company has many components that are made with the same production process. Thus, they could use the existing cost driver information on several purchased components, independent of the exact specifications, and thereby only discussing the variable mixture of the price driving parameters. Hence, the company had fixed cost to establish the cost information database, but little cost for the actual application of the model. Furthermore the development of the VPT benefited from senior management backup. There were situations in the past, where suppliers tried to undermine the VPT tool by trying to surpass the executing manager. In this case, the senior management insisted on proceeding *via* the VPT tool. Only if both organizations follow the procedure of the VPT, will any unnecessary blockage or delays be reduced. In addition, the VPT tool was first used with suppliers which the client had an existing business relation. Therefore, trust and respect between the familiar managers from the client and supplier-side might have eased the introduction of the tool. Last, but not least, the recognized company name of the buyer helped to acquire quotations, as it is a large company with a recognized brand, purchasing components from numerous sources.

5.7. Summary

In a summary, one can argue that the VPT can shorten time-to-market in new product development projects, keep fair component prices even when design changes occur or parts are single sourced, and can increase the use of cost information throughout the innovation process. It is called 'virtual' because it is sometimes carried out without a direct product development project to assist in researching the supply market. The analyzed tool uses a detailed model of price/cost drivers and a database of old price quotations for deriving price estimates of purchased components. The database is constantly updated by requesting virtual quotes in an auction technique from several suppliers. The basis for the detailed cost driver model was made through modeling the production process of the purchased component and thereby recognizing the variable parameters affecting the production cost. Nevertheless, the analyzed organization uses the tool only for hardware components, even though the tool could also be used for services. However the tool is not without challenges. The biggest difficulty is arising

through the unwillingness of suppliers to share detailed information of internal processes that are important for the development of a precise and detailed price driver model.

6. The assessment of vendor's product performance

Ville Hinkka and Frank Bescherer

The aim of this chapter is to present a model that could be used for evaluating different quotes of technically challenging tasks or products. The special focus is on comparing situations in the early phases of innovations in a high-technology environment. The challenge is that the purchaser wants to get an as high-quality product as possible for a competitive price. There are usually only a few potential suppliers in a given situation, but the selection may be difficult as each of the potential possibilities may have some advantages in some of the several criteria encompassed in the quote. As the required technology is usually experimental and does not exist yet, the quotes are based on the promises that suppliers provide. So there are possibly gaps between the purchaser's requirements and suppliers promises. The model is constructed to help the purchaser evaluate these gaps, compare them, and make the final decision based on the gap valuations and price differences.

The idea of the Theory of Constraint (TOC) philosophy was the starting point for model development. The TOC prefers to optimize the whole operation system by considering each local area and trying to improve them. Therefore, it is important to distinguish between "the Bottleneck Resource" and "the Non-bottleneck Resource" (Hsu and Sun 2005).

The TOC approach is centred on a five step process:

1. Identify the primary constraint of the system.
2. Develop a method for exploiting the system's primary constraint.
3. Subordinate all other actions to the decisions made in step two.
4. Determine whether to elevate the constraint.
5. If the constraint has been broken in step four, return to step 1.

So the guiding research question is: *How could performance be evaluated with an approach similar to the theory of constraints?*

6.1. Overview of scorecards

A scorecard is a summary of different important parameters that are analyzed together to give a coherent 'big picture' for decision-making. The best-known scorecard is the Balanced Scorecard (Kaplan and Norton, 1992). It has four main perspectives that give a holistic view of the business of a company and its development, and can be adopted as a starting point for performance and productivity improvement efforts.

Academics have criticized traditional accounting, and strongly advocated knowledge-based approaches to book-keeping. To value intangibles, a financial valuation method of the intangible scoreboard is developed. It is a top-down approach based on reviewing the past and the future. The purpose of the method is to come to an estimation of the financial value of the intangible capital of a firm based on publicly available data and then, later, to analyze the economic consequences of investment in intangible assets. For measuring intangibles, the value chain scoreboard is developed.

It is a bottom-up approach divided into three phases of the value chain. It is aimed at both internal and external decision-making (Andriessen, 2004).

6.2. Background on the developed model

The authors have developed a method to solve the challenge of optimal supplier component selection. The overview of the method is presented in Figure 6-1.

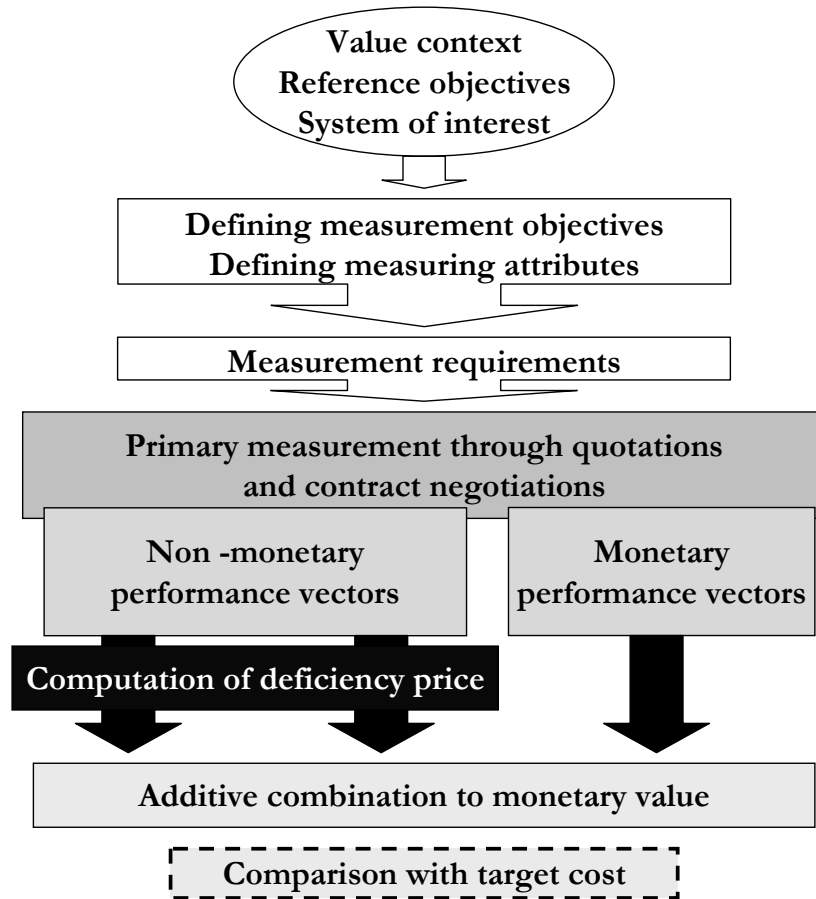


Figure 6-1. Overall outline of the proposed valuation model

The approach commences by defining the task and the system of interest under study. Different managers will have different value standpoints. Next, the company is required to define the attributes to be evaluated in the different options. It is better to include more here than less. Afterwards the following steps are taken to compute the deficiency price: 1. Get quotations, 2. Identify critical parameters, 3. Arrange parameters from most to least critical, 4. Identify target levels, 5. Pinpoint constraints and relationships, and 6. Valuation of deficiency and deeper inspection of critical parameters.

Initially, the company needs to receive the quotes for the required product or service choice. The second step is to identify the critical parameters from the quotes. The third step is to arrange these parameters in an order, from most to least critical. The vendor's price is always the last parameter. The fourth step is to identify the target level of the each critical parameter. The fifth step is to find out constraints, i.e. which

of the parameters in the quote do not reach the target. Highlighting the constraint parameters helps to estimate their possible relationships. Delivery time, for example, is usually defined as a parameter, meaning that late arrival becomes a constraint. Little delay may be possible to catch up with overtime work, but together with other closely linked constraints (e.g. difficult testing), running out of time may be reality and in that way cause multifold problems than the mere late arrival.

The sixth step is evaluating the margin between the target and offered level. There are two different values possible to calculate. First, in the improving approach, it is possible to calculate the cost that is needed to increase the parameter to the target level. The quickest way is to ask the vendor or some other's price for improvement. Sometimes the breaking down process is a way for identifying price drivers. If there are, for example, capacity problems it is possible to highlight all the other applications that use the same resource. Instead of decreasing the size of the coming application, it may be possible to decrease the amount that other applications use the resource and estimate the cost for that. The second way is the customer approach. It is possible to estimate the sales reduction caused by the fact that company provides lower than target level of quality. This approach has at least two different ways for price calculation. The breaking down process offers ways to exclude some less important application for making space for the new feature. Then it is possible to estimate the value of missing application. An alternative might be considering the life cycle costing of the exceeded target from the customer's perspective. The price used is usually the minimum of calculated values. Sometimes the targets may have been exceeded and the surpassing can be taken into consideration as a benefit.

When comparing the quotes, it is possible to draw a valuation chart to measure the value of the margin between target and offered level. They are drawn in a way that if the target and offered performance are the same, there is no effect on price. If the offered level is below the target, the price increases. Exceeding targets may have positive, negative or no effect on price depending of the situation. If there is a connection between two parameters, the first (and more critical) parameter is evaluated without considering the connection. However, when pricing the latter parameter, the effect of the first parameter is now taken into a consideration in evaluation. The effect of the connection may be negative, as in late arrival and difficult testing.

When price differences are calculated, the next step is to sum all the prices of the different parameters. If there are exceeded targets, these values are reduced from the calculated prices. We finally conclude with the price that is titled 'deficiency price'. That value shows the price. This comprises a mix of cost for improving the product to reach the targets and the estimation of the price that a customer suffers from the defects in the offering. The greater the deficiency price is, the more insufficient the offering. The last step is to sum the prices that the vendor asks and the deficiency price together to calculate the total price for each of the compared quotes.

6.3. Example demonstration

The company needs a software program. It has received four different quotes presented in Figure 6-2. The selection does not seem to be simple, so our method is used. The critical parameters are identified and prearranged in the following way: 1.

Usage of memory, 2. availability date, 3. level of programming, 4. easiness of test, and 5. easiness of maintenance.

Program 1:

5000 lines of code
 100 programming man-hrs
 Uses 100kB of the memory
 Easiness of maintenance rated 2
 High level programming – easy to transfer to product platforms but slow on hardware
 Cost: 120/man-hr
 Availability: After two months
 Easiness of test on hardware rated 3

Program 3:

4500 lines of code
 110 programming man-hrs
 Uses 90kB of the memory
 Easiness of maintenance rated 3
 Low level programming – difficult to transfer to product platforms but fast on hardware
 Cost: 130/man-hr
 Availability: After four months
 Easiness of test on hardware rated 1

Program 2:

4000 lines of code
 120 programming man-hrs
 Uses 80kB of the memory
 Easiness of maintenance rated 4
 Low level programming – difficult to transfer to product platforms but fast on hardware
 Cost: 100/man-hr
 Availability: After three months
 Easiness of test on hardware rated 3

Program 4:

4300 lines of code
 170 programming man-hrs
 Uses 70kB of the memory
 Easiness of maintenance rated 5
 Medium level programming – ok to transfer to product platforms but ok on hardware
 Cost: 165/man-hr
 Availability: After one month
 Easiness of test on hardware rated 1

Figure 6-2. Four different example alternatives

The next step is to identify the target level for each parameter. There are set target levels and the performance of each program is shown in Table 6-1. The following step is to find out which of the parameters do not meet the targets and to clarify the connections.

Table 6-1. Targets and performances of compared programs.

Parameters	Program 1	Program 2	Program 3	Program 4	Target level
Usage of memory	100 kB	80 kB	90 kB	70 kB	80 kB
Availability date	2 months	3 months	4 months	1 month	After one month
Level of programming	High	Low	Low	Medium	Medium
Easiness of test	3	3	1	1	1
Easiness of maintenance	2	4	3	5	1

The next step is to evaluate the margin between the targets and level offered. The most critical parameter was the memory use. It is impossible to decrease the size of the new programs. Therefore, larger than 80 kB size of the program requires rearrangement of other applications. Breaking down the process is presented in Figure 6-3. Next, it is evaluated to identify the applications that could be removed or cut. The final cost assessment gives a cost estimate of 500 /kB that is over the target level. The allowance of 200 /kB was calculated for exceeding the target.

The second critical parameter was the availability date. The market launching schedule of the end product is tight. However, through some priority changes, which cause extra cost in the product development department, the delivery time could be reduced by one month. The department gave the following cost estimates:

accelerating by 1 month for the target would cost 4000, by 2 months would cost 10000, and by 3 months 20000.

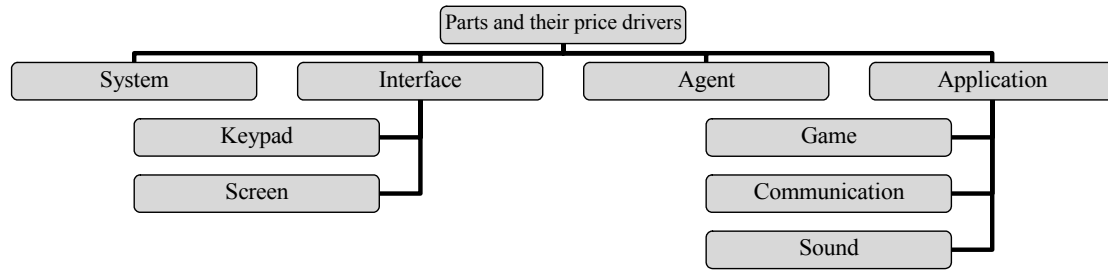


Figure 6-3. Breaking down the parts of the bottleneck process

The third critical parameter was the level of programming. It is a trade-off between the ease to transfer and the speed on the hardware. So the medium level programming is the target. Low-level programming has a cost of 6000 and high level has a cost of 2000.

The fourth critical parameter was the ease of testing. The ease is evaluated with the scale of 1 to 5, where 1 means easy and 5 very difficult. Every integer over 1 increases the cost by 5000. This parameter and delivery time has a connection. Extra cost of 1000 for every integer over the target level is set, if the program comes one month late for the target, and 3000 for every integer over the target level, if the program comes two months late, and if the program comes three months late, the ease of testing has to be in the target level.

The last critical parameter was the ease of maintenance. It has the same scale as ease of testing. Every integer over the target increases the cost exponentially.

Table 6-2. Calculating the total prices of different programs by adding marginal costs of deficiencies

	Program 1	Program 2	Program 3	Program 4
Parameters				
Usage of memory	10 000	0	5 000	-2 000
Availability date	4 000	10 000	20 000	0
Level of programming	2 000	6 000	6 000	0
Easiness of test	12 000	16 000	0	0
Easiness of maintenance	2 000	8 000	4 000	16 000
Total deficiency price	30 000	40 000	35 000	14 000
Vendor's asking price	12 000	12 000	14 300	28 050
Total price	42 000	52 000	49 300	42 050

Table 6-2 shows the total deficiency prices, vendor's asking prices and the total prices. The programs are arranged according to the vendor's price quote from the cheapest to the most expensive. The total deficiency price should behave vice versa. But in the case of program 2 and 3, the total deficiency price is higher than in the program 1. Therefore, if the prices are evaluated correctly, programs 2 and 3 can be dropped. The total price for program 1 and 4 are almost the same, even if the vendor's asking price for the program 1 is 57 % cheaper. Hence, the selection depends on the

following questions: Are the deficiencies evaluated correctly? (Program 4 has only one constraint, but none of the parameters in the program 1 are in the target level.) Would it be possible to fix the only constraint that program 4 has with cheaper cost? Is the allowance of the 'saved' memory in the program 4 possible to obtain?

The proposed method was also employed for a case with data provided from a case company. The method proved to be capable of doing the comparison. The case was presented in a conference paper by Hinkka and Bescherer (2007).

6.4. Discussion and limitations

The presented model can be used for comparison of options in technically challenging settings. The model is especially suitable for comparison of quotes at the early phases of innovation in a complex technology environment, where suppliers are promising something they do not have yet, but they (stipulate) are able to deliver in the future.

Although managers do realize that there are more factors than the price in purchasing, the vendor's price still plays a highly significant role in decision-making. On the other hand, company engineers may strive for the best possible technology without thinking about costs. The purpose of the proposed model is to demonstrate the *real cost* of other usually qualitatively measured factors and to offer a tool to select the most favorable option.

A limitation of the method is the valuation of the different parameters. Even if we presented several valuation approaches, applying the proposed method still requires time for the valuation of different options. However, the discussions and comparisons will be eased by using the proposed method, as different concerns can be expressed in numerical values.

Furthermore, the selection of a supplier may lead to the longer-term relationship, because switching cost may rise relatively high. This lock-in situation may provide for supplier to price the improvements and updates freely. So this lock-in situation should be taken into a consideration, when choosing the supplier. The method can be seen as part of a set with a virtual quotation system that would prohibit sole-supplier opportunism.

7. The impact of product-specific investments on target costs

Jouko Karjalainen

The primary planning objectives in target costing have been direct material and conversion costs. This is because the ratio of these costs to a producer's full life-cycle cost has been high. In knowledge-intensive products, the conversion cost tends to be lower compared to the *a priori* product-specific investment, e.g. development effort. Managing a product's life cycle cost requires more attention of the trade-offs between development effort and functionality. The following section presents a modification of the regular target costing equation. Next, we consider how this equation can be applied in setting cost targets. The final section of the chapter gives some practical advice for applying the equations. A more detailed analysis of these issues is presented by Karjalainen (2007).

7.1. The modified target costing equation

The traditional target costing method ignores the time value of money in the process of planning and controlling the recovery of the initial product-specific investment. Since the current business environment is characterized in terms of shortened product life cycle and larger initial cash outflow followed by periods of cash inflow, Suematsu (2000) has suggested an approach based on cash flows generated by the product. Equation 7-1 is derived from his approach. The basic idea is that the net present value of all the cash inflows and cash outflows caused by the product should recover the initial investment and contribute to the enterprise value. A product is considered as a project and it is assessed using a method that is consistent with the method used in investment appraisal and in free-cash-flow based valuation.

$$V = \sum_{t=1}^T \left[(q(p-u)g_t b_t - f) \frac{1}{(1+r)^t} \right] - I \quad (7-1)$$

V = product's value contribution

t = index of the period (year)

q = periodic volume

p = price per unit at launch

u = long-run unit cost at launch

I = product-specific investment

T = product life cycle (years)

g_t = growth factor

b_t = price erosion factor

f = fixed periodic cost

r = discount rate

To highlight the basic idea, tax effects and working capital employed are omitted in equation 7-1. The following form of the target costing equation can now be written using the first equation.

$$p - \frac{V}{qA^*} = u + f \frac{A}{qA^*} + \frac{I}{qA^*} \quad (7-2)$$

The expected market price, less the targeted value contribution, gives the target cost, which is further divided into three elements (unit-cost, fixed-cost and investment). Target selling price is set by taking into account the product's functionality and

market conditions expected when the product is launched. The mere annuity factor is denoted by A , and A^* is A adjusted with growth and price-erosion factors. With constant volume and price, A^* equals A . Equation 7-2 assumes that continuous improvement reduces unit costs at the same rate as price erosion reduces unit price. If this assumption is not valid, u should be multiplied by A^{**}/A^* where A^{**} is the annuity factor adjusted with the growth factor and a separate cost-reduction factor.

7.2. Setting a target cost for uncertain volume

In Equation 7-2, the targets for the fixed cost (f) and the product-specific investment (I) depend on the product's life cycle volume and its dispersion over the life cycle. In the reported target costing practices (Cooper 1995: 139,142), the previous product's sales volumes and selling prices were considered as good proxies; or target cost was established only for the highest volume variant. In highly competitive markets, we should consider the use of expected volumes instead of a conservative volume estimate. Basically, we could also use a volume that will be reached at a preset probability, e.g. $P(\text{volume} > X) = 60\%$. For this, we should be able to formulate the probability distribution. Alternatively, we could simulate different volume patterns with spreadsheet software and make a discretionary choice.

The following example illustrates how we can deduce cost targets by describing the critical elements of volume uncertainty. We assume a fully intangible product that has an expected life-cycle of three years. By fully intangible, we mean that there is an up-front investment, e.g. software development effort, but thereafter we can replicate as many copies of the product as needed with no additional cost. The estimated market price at launch (p) is €1.00. The annual rate of price erosion is 10%, e.g. the price is only €0.90 in the end of the first year. The target costing equation in the case has the form of equation 7-3. A target value should be set to the product-specific investment (I).

$$p - \frac{V}{qA^*} = \frac{I}{qA^*} \quad (7-3)$$

To continue, we must make some assumptions of the sales volumes. One of the fundamental assumptions is that the volume follows a stochastic process in the beginning of the life-cycle. The volume of the first month (q) is 1000 units but thereafter, the volume can increase every month during the first year according to the coefficient up or decrease according to $1/up$. The movements up or down have equal probability. After a start-up period of 12 months the volume will settle approximately at the attained level. The starting volume and the drift (articulated by up) describe the possible range of outcomes. For example, if $up=1.4$ the average monthly volume would be over 40000 units after the first year. To avoid unrealistic volumes, we can set a maximum level for the volume. A minimum level describes the risk of a flop. If the volume reaches the minimum level, the product will be terminated immediately. The life-cycle is not exactly 3 years but $2\frac{1}{2}$ - $3\frac{1}{2}$ years (the sunset phase). The factor p ($=0.81$) indicates the probability that the product life continues the next 6 months. These assumptions are illustrated in Figure 7-1.

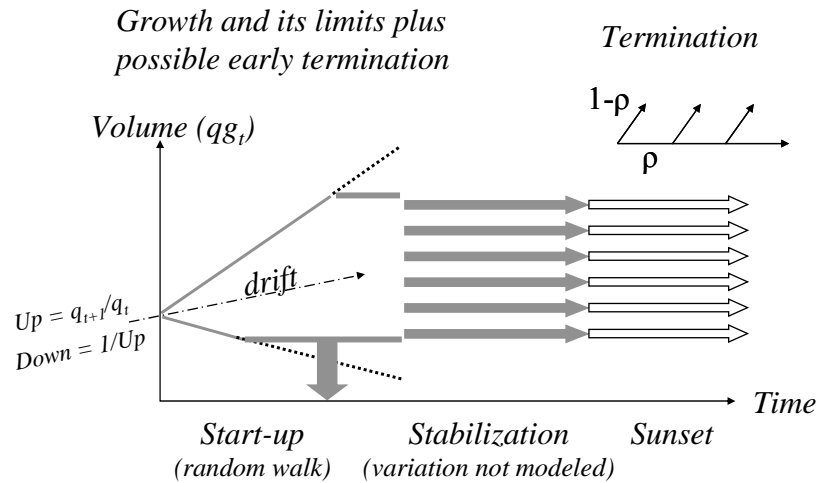


Figure 7-1. Modeled uncertainties concerning the sales volume

We do not need to calculate explicitly the probabilities of different outcomes. Instead, we can apply the same back-propagation method that is applied in dynamic programming and in decision-tree analyses. If we prefer a conservative estimate for the expected value, then we stipulate that the investment must attain positive net present value with the volumes of two years, for example. We can model the case with regular spreadsheet software and use the goal-seek property to find the cost target for the development effort (I). Table 7-1 summarizes the results of different scenarios. In the preceding calculations, the value contribution was set to zero and discount rate was 10 %.

Table 7-1. Maximum product-specific investment (expected net present value = 0)

	base	up=1	up=1,1	up=1,2	up=1,3	up=1,4	
Volume uncertainty							
A	Mean monthly quantity, t=1 year	1000	1000	1055	1206	1442	1760
B	Random walk max in 11 steps	1000	1000	2853	7430	17922	40496
C	Earliest month to reach 8000	NA	NA	NA	>12	9	8
D	Earliest possible termination month	NA	NA	11	7	5	4
Simple estimates							
E	Annual average, mean values	29 842	24 424	25 729	29 393	35 340	43 795
F	Semi-annual average, certain lifetime	30 454	25 733	26 956	30 354	35 778	43 306
G	Semi-annual average, uncertain lifetime	30 287	25 493	26 702	30 064	35 431	42 883
Lattice estimates							
H	Base: no quantity limits	30 631	26 831	27 913	31 028	36 315	44 274
I	Quantity limits: max 8000, no min			27 913	31 028	35 856	41 238
J	Quantity limits: no max, min 400			27 907	30 592	34 457	40 369
K	Quantity limits: max 8000, min 400			27 907	30 592	33 998	37 334
L	Quantity limits: max 4000, min 400			27 907	30 387	31 728	31 383
	Row H / Row G	101 %	105 %	105 %	103 %	102 %	103 %
	Row K / Row G			105 %	102 %	96 %	87 %
	Row L / Row H			100 %	99 %	94 %	84 %

The rows A-D in the table analyze the six different volume scenarios arranged in columns. The two left-most scenarios (base and up=1) are trivial since they assume a constant monthly quantity. Base scenario has no price erosion. They were used to check the spreadsheet model and to illustrate the deviation of results created by modeling assumptions. We can solve the problem with simple models that use annual (E) or semi-annual mean (F) volumes and even consider the uncertainty concerning the lifetime (G). The deviation of these estimates is round 5 %. Presuming that the

modeling assumptions are valid, the most detailed estimate (G) would be the most accurate. Row H refers to the base model describing the start-up uncertainty and its consequences during stabilization. The difference from the best simple estimate (G) is small in all scenarios. Slightly larger investment is allowed because the distribution of outcomes in the stochastic process is skewed towards the large volumes. Adding quantity limits changes the picture with higher drift values (up is 1.3 or 1.4). Quantity limits do not really restrain the opportunity window with lower up-values. The threat of early termination (row J) reduces the allowed investment more than cutting the growth to the level that corresponds the case with up-value of 1.2 (row I). Assumptions of the growth pattern have a significant impact on the allowed investment.

Significant volume uncertainty should be considered explicitly when setting the cost target for product-specific investment in case of intangible products. It is therefore easier for decision-makers to articulate different scenarios and base the decision on the analysis of these scenarios. If we return to the more general situation (equations 7-1 and 7-2), the modeling effort is not always worthwhile. In case of a tangible product, there is a significant unit cost, which mitigates the possible modeling deviation compared to simpler techniques. Conversely, the fixed periodic costs may encourage the use of more sophisticated models.

7.3. Further application of the modified target costing equation

Application of the equations requires a consistent break-down of costs. Different firms may classify the same cost elements in a different way. Product costs are divided in unit-level, batch-level, and product-sustaining costs in activity-based cost systems (Kaplan and Cooper 1998). The long-run unit cost at launch (u) refers to unit-level and batch-level activities and corresponding costs. It contains both variable and fixed costs, e.g. as well direct material as the cost of using non-dedicating equipment. Although the actual batch size will be determined later, some technological choices may lead to large batches whereas others offer more flexibility in this respect. Activity-based costing identifies product-sustaining activities, e.g. maintaining product specifications, special testing, tooling and technical support for individual products. The fixed period cost (f) refers to the related costs. As with product-sustaining activities, the product-specific investment (I) represents resources sacrificed to enable the production of individual products to occur. The difference is that product-sustaining activities tend to recur during the product's life; but product-specific investment takes place once before the product launch. Separating these elements is important in analyzing product concepts that integrate information, service and artifacts. The costs related to both types of efforts do not depend on the production or sales volume, but the profitability of the product is contingent on volume.

Setting target value for the product's value contribution (V) is an equivalent task to setting the target profit margin. It is up to strategic discretion, and even a negative contribution may be allowed in some cases. For example, it has been reported in financial news that several game consoles are sold at prices that do not cover the manufacturing cost. The pure value contribution should be inflated to cover the future joint costs that were excluded from the product costs. Sunk costs should be excluded, however. Alternatively, these joint costs could be allocated to products. Firms must

consider the same issue in conventional target costing, as well, in order to ensure the consistency of the practical definitions of profit and cost.

The approach used for assessing the target for product-specific investment could be amended for other situations. For a product that has all the cost elements (u , f and I), one should first identify the most critical element concerning life-cycle profitability. That would probably be the element with the largest life-cycle cost. The target value would be searched for this element by following the previous approach. One could also consider trade-offs between the cost elements, e.g. increasing the product-specific investment in order to decrease the fixed cost. Likewise, a firm might think of setting a more aggressive unit-level cost target, which would require extra development effort.

Prior decisions lead to subsequent incurrence of costs, but products can still be redesigned after the market launch. There is evidence that it is done for products with very short lifespans in a company that applies target costing (Cooper and Slagmulder 2004b). The approach of section 7.2 can be extended with a decision-tree analysis to deal with such redesign options. Generally, redesign can refer to new tooling or even to the change of manufacturing location. Figure 7-2 illustrates an outcome of such an exercise. In the scenario, the product can barely create positive net present value when redesign is carried out immediately. However, a redesign clearly increases value if it is carried out only after some of the volume uncertainty has been resolved.

NPV with redesign

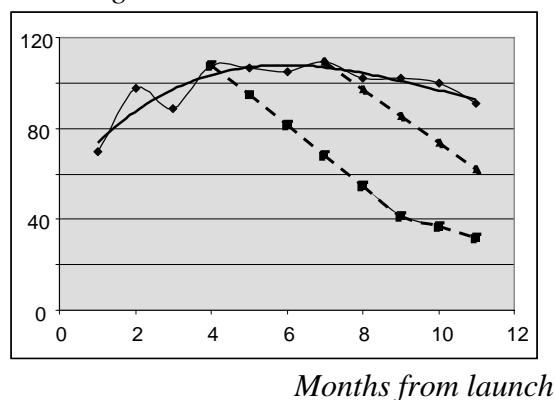


Figure 7-2. Value of a redesign

The waved curve in Figure 7-2 describes the effect of a redesign realized at different points after the launch. The curve is waved because the model uses discrete time steps. The smoothed curve shows that the optimal timing of the redesign seems to have a minor effect. Closer to the end of the life-cycle the curve would clearly turn downward. The two downward lines starting from the waved curve express what would happen if the redesign took longer than planned. A delay would clearly erode the benefits of the redesign. Naturally, the shape of the figures alters according to the setup values of the case. However, it can be demonstrated that redesign may be a cost-efficient option for products with short life cycles. This requires that redesign efforts are planned and well-managed. In practice, the available time can be more crucial than the immediate cost effects. Firms need tested and demonstrated solutions with known performance and cost structure in order to carry out fast redesigns.

8. Life cycle trade-offs in product design

Frank Bescherer

In times of saturated markets, production costs become even more important, as products have to be sold cheaper in order to reach new markets. In order to minimize the total life-cycle ownership cost, selection of product designs should be based on the optimum trade-off between spending on design and manufacturing cost with the price of lost energy. A power supply case shows that it is advantageous to use power supplies with higher efficiencies, even when the initial development and manufacturing costs are higher (Bescherer and Sippola 2006). It is critical to make the correct decision at an early stage of design. In this chapter the important trade-off between purchasing cost and operating efficiency is analyzed in two case studies on power supplies for mobile telecommunications.

8.1. Generic properties of life-cycle ownership cost

R&D professionals can affect costs in two important ways. First, there is the manner in which their activities influence the cost of innovation – the R&D cost view. The second way is related to the effect of innovation decisions on subsequent product life-cycle costs – the cost of ownership view (Shields and Young 1994). This chapter is concerned with the latter of both possibilities.

Life-cycle costs are the expenditure for development and production or acquisition, operation, maintenance, and disposal of one specific exemplar of a product. According to literature, life-cycle costing deals with finding the cost-wise best solution for an investment over the whole life span of a product or asset (e.g. Woodward 1997). Usually there will be a trade-off between costs occurring at different times of this life span (e.g. higher development costs can save costs during operation). Life-cycle costing is a tool for finding the lowest life-cycle costs, by analyzing these trade-offs. Life-cycle costing, as a technique, is over fifty-years old; and became popular in the 1960s when the concept was taken up by U.S. government agencies as an instrument to improve the cost effectiveness of equipment procurement (Riggs 1982).

Several ways to conduct a life-cycle costing study have been identified in the literature. Some authors investigate the environmental cost of products using internal and external effects (e.g. Durairaj et al. 2002); while others focus on cash flow generating costs (e.g. Woodward 1997). This article addresses the second type of costs, specifically: cash flow. However, it is acknowledged that environmental aspects should play a significant role in business decisions. Such a position would translate in a claim that products with high efficiency, and thus less energy losses, should be chosen in order to minimize environmental impact e.g. green house gas emission.

8.2. Choosing a life cycle cost optimal efficiency level – case study A

In a power supply case, life-cycle costing was used to analyze whether electronic products are designed optimally (Bescherer and Sippola 2006). In the literature, many life-cycle costing studies analyze the trade-off between, on the one hand, purchasing

cost or development and manufacturing cost and, on the other hand, maintenance cost. In contrast, this case study supports analysis of the trade-off between purchasing costs and costs of energy losses associated with the operating efficiency of power electronics for two power converter types.

Internally established cost factors, e.g. the current engineering and manufacturing estimates, were used to find the cost of the different elements. The parametric cost method uses parameters and variables to build-up cost estimating relations. These relationships are usually equations where, for example, person hours are transformed to costs.

8.2.1. Calculating the life-cycle cost efficiency

The analyzed products have a negligible maintenance need and cost. The important element of the life-cycle costs are the energy losses through inefficiencies. Thus the analyzed life-cycle costs incorporate the main categories of the purchasing price and costs incurred through energy losses, as shown in (8-1):

$$Life\ cycle\ Costs = Cost_{Purchasing} + Cost_{Energy\ losses} \quad (8-1)$$

The purchasing price was chosen as it reflects the trade-off in the most precise way. The purchasing price includes pre-development, development and manufacturing costs and also overhead and profit contribution of the supplier. In other words, the price used for the analysis includes all unit level cost as a profit contribution to cover batch-, product- and facility-level cost. Furthermore, it includes a targeted return of capital employed for the analyzed supplier. The analyzed trade-off is graphically presented in Figure 8-1.

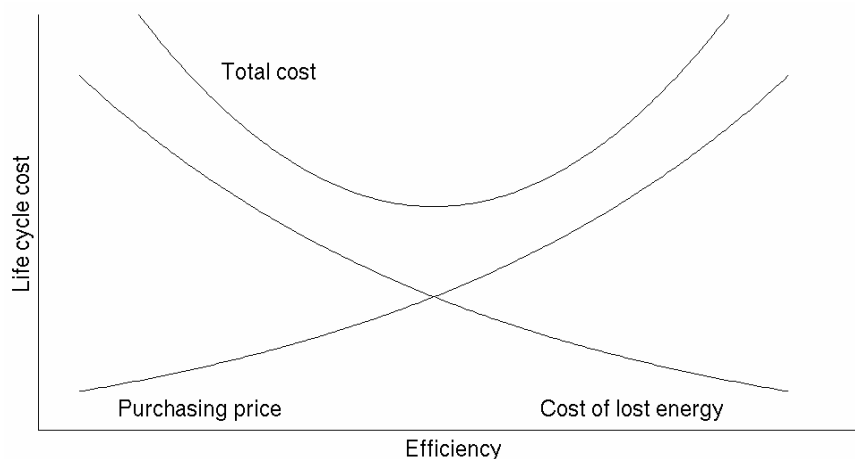


Figure 8-1. The analyzed trade-off (Amended from Woodward 1997:339)

8.2.2. Cost settings

Two different power supply types were analyzed. In order to show the trade-off between high development and manufacturing cost and running cost of energy-losses, three different configurations with different efficiencies (called alternatives) were

analyzed. The analyzed power supplies show a cost per unit curve according to their efficiency. This cost curve is shown in Figure 8-2. The continuous curve shows that the cost for more efficient power supplies is higher than for ones with a lower efficiency.

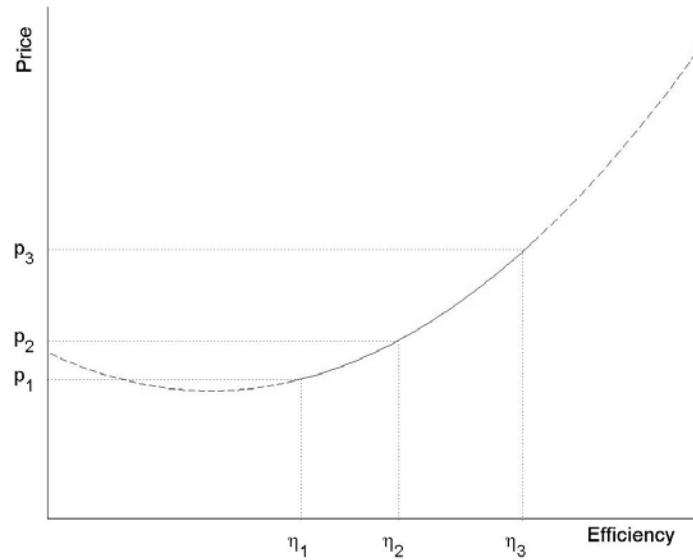


Figure 8-2. Cost distribution for power supply variations with different efficiencies

The costs for the lost energy per year are calculated with (8-2) and discounted:

$$Cost_{E\ 1\ year\ t} = \left(\frac{1}{\eta} - 1\right) \cdot P_{max} \cdot UL_{avg} \cdot t_{op} \cdot c_{el} \quad (8-2)$$

where: η is the efficiency of the analyzed power supply; P_{max} is the maximum output of the power supply [kW]; UL_{avg} is the average usage level; t_{op} is the operating time per year [h]; c_{el} is the price for electricity [€/kWh].

8.2.3. Analyzed power electronics

The two types of power supplies analyzed are shown in Figure 8-3. Power supply A has a higher outlet power than power supply B. However, the efficiency levels of A tend to be higher than that of B.

	Power supply A		Power supply B	
	Mode 1	Mode 2	Mode 1	Mode 2
η_1	89%	79%	80%	70%
η_2	91%	81%	84%	74%
η_3	93%	83%	91%	81%

Figure 8-3. Efficiencies of the different power supplies

The power consumption depends on the utilization of the end appliance. The power supply is not always working at maximum capacity. Dependent upon the end customer for the products under study, the power consumption varies between operation modes. With this variation of the load, the efficiency of the studied power supplies varies. During operation mode 1 (at 70% load) the power supply operates at maximum efficiency. During operation mode 2 the operating load will tend to be lower. Thus, during operation mode 2 (at 40% load) the efficiency is reduced by 10%.

8.2.4. Cost trade-off

As previously described above, equipment often has a trade-off between costs occurring at differing times of the life span. In the analyzed case, these costs are higher for development and manufacturing cost, and for the running cost of energy losses. In order to find the cost-wise best solution, this trade-off was analyzed. The results for the two different power supplies and their alternatives are shown in Figure 3 and Figure 4. The bars in the Figures reflect the different efficiency levels for a realistic combination of mode 1 and mode 2 during a usual operation day.

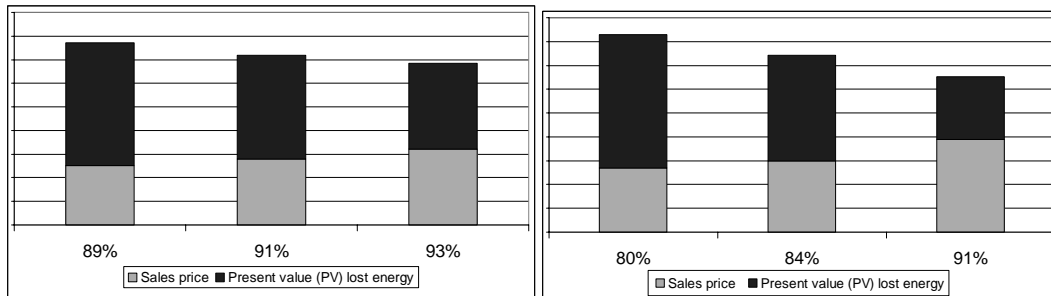


Figure 8-4. Cost behavior of the alternatives for power supply A (left) and B (right)

Figure 8-4 shows the estimated sales price and the net present value (NPV) of the running cost of energy losses on a stacked column. The costs due to energy losses are decreasing the higher the efficiency for both power supply types (A and B). The interesting aspect of these phenomena is that the total sum of costs decreases. The total variation between the alternatives is larger as the efficiency span for power supply B is larger than for A. Due to this the decrease in the sum of the cost is greater.

8.3. Choosing a life cycle cost optimal design – case study B

In another case study (Sippola and Bescherer 2006) a reel-to-reel assembly process and winding layout technique for leadless surface mounted Z-folded planar transformers was analyzed from a technical and life cycle cost perspective. The electrical performances of different transformer geometries were compared. Prior to the life cycle cost analysis, design equations for candidate transformer geometries were developed and refined using Finite Element Method (FEM) analysis and prototype measurements. Prototype transformers were manufactured and measured to demonstrate and validate the proposed component technology and analysis.

In order to understand better the trade-off between losses and manufacturing cost, a life cycle cost analysis was conducted for the two most promising, but different

transformer geometries. Life cycle costs of Z-folded transformers are the sum of all cost which occurred during its life-span starting with its development, manufacturing and operation till scrapping or redeployment. Even so, some life cycle costs might not occur at the customer site, e.g. development costs, they are still included in the price the customer is paying to the manufacturer. For this paper the life cycle cost is estimated with a parametric cost method, as recommended by the IEC standard 60300-3-3:2004. As the name already states, the parametric cost method uses parameters and variables to build up cost estimating relations. These relations are usually equations where, for example, person hours are transformed to costs.

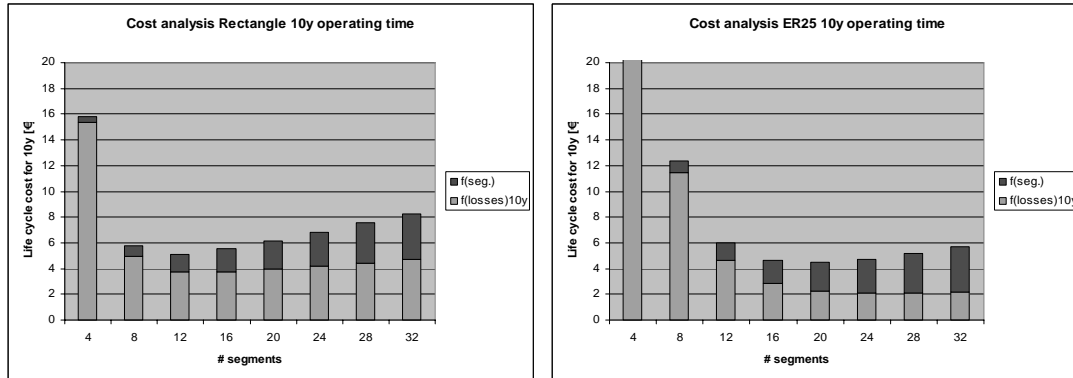


Figure 8-5. Life cycle costs over 10 years for several types and technical specifications

The elements of a life cycle costing study vary according the research question to be answered. For the analysis in this paper the manufacturing costs – costs incurred inside the factory associated with transforming raw materials into a finished product – are constant for the different core geometries and only dependent on the amount of segments. Thus, the amount of segments is the first variable. The second variable is the total loss computed above. This leads to the following life cycle cost function:

$$Z = f(x_1, x_2) = f(x_1) + f(x_2) \quad (8-3)$$

Where Z = life cycle cost; $f(x_1)$ = cost function for amount of segments; $f(x_2)$ = cost function for total (power) losses.

The cost function for amount of segments is the unit costs multiplied by the amount of units. The unit costs include costs for the core, the used copper, the flexible printed circuit board, and other component costs. The batch and product level costs (e.g. the etching) are not taken into consideration, as they are independent of the core geometry, and thus irrelevant for the answer to which geometry should be favored. The cost function for total losses is influenced by the industrial electricity costs [€/kWh], the operating time [h] and the average load level for the transformer.

The total life cycle costs for a Z-folded planar power transformer with the rectangular shaped 2 pole core and the ER25 1 pole core are shown in Figure 8-5 for an operating time of 10 years. In this analyzed example the ER25 1 pole core with 20 segments should be chosen.

8.4. Summary

On the one hand, there are trade-offs between initial investment cost in development and manufacturing stages and the running cost of energy losses. Thus the optimum between spending on design plus manufacturing cost, and the cost of lost energy should be identified at an early design stage in order to minimize the total life-cycle ownership cost. On the other hand, product design in early innovation phases offers a multitude of alternatives. It is important to make the right decisions at an early stage of design. High cost awareness can assist in making cost efficient decisions regarding technology management during new product development processes. Also at later stages, if power supplies are custom-tailored for a specific client, there is a clear lock-in effect when the client freezes the specifications. Before this occurs, the discussion between supplier and client would clearly benefit by modeling life-cycle cost for the possible alternatives.

9. Conclusions

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Firms must be able to manage product costs in all phases of a product's life cycle. The approach to cost management depends on the decisions to be made at the specific phase. Although prior decisions constrain the freedom of further choices and commit the organization to subsequent incurrence of costs, they do not discard the need for continuous cost management. It appears that streamlining the NPD process in order to ensure short time-to-market, transfers important cost-inflicting decisions from NPD projects to the earlier development stages, i.e. pre-development. Modular designs, part commonality, and product platforms reflect design policies which individual product development teams must follow. Since design policies contain implicit assumptions of cost effectiveness, those who create these policies must be aware of cost behavior. Our main proposition is that product cost management should start before the well-structured product development in order to ensure built-in cost capability of a product. Target costing is usually the method suggested for managing product costs within the NPD project. The focus of this report is in the methods that could be used during pre-development.

The uncertainty related to the pre-development phase makes the direct application of target costing difficult. Market-driven costing identifies a product's allowable cost, i.e. the manufacturing cost that generates the required profit margin when the product is sold at its target price. Since the target price is based on product functionality, setting a target price can be difficult during pre-development, when the essential functionality of the product is not frozen. Ambiguity in the target price is reflected in other parts of target costing. If the target price and, thereby, the cost target describe more a target level than an exact and stringent figure, it becomes less important to distinguish allowable cost and actual target cost in product-level target costing. Historical cost information about earlier products has less value, especially in the case of products that rely on new technologies. Problems in cost estimation make it harder to assess how realistic the market-driven allowable cost is. Consequently, the discipline of the conventional target costing is inappropriate. Modular product structures support the target costing process because the design process can be separated into multiple, somewhat independent tasks. However, concepts based on new technologies may be created to challenge the prevailing product architecture, which complicates the process of calculating the product-level target cost to the component level.

A cost estimate is based on an explicit or implicit cost model that includes perceptions of how costs behave. Cost estimation techniques typically use historical information to establish the estimate. There is a risk that cost models reflect the current processes and the prevailing architecture. To avoid this, a systematic analysis of cost drivers should precede the construction of a cost estimation model. The estimation model should focus especially in those costs that are influenced by the decisions at hand. Early cost estimates cannot include all the forthcoming decisions that still affect the product cost. Comparison of product concepts should focus on the elements that truly lead to different architectures and processes. The purpose of the estimate determines its relevant features. Therefore, different people prepare cost estimates differently and use them for different purposes even in the same organization, which complicates the

comparison of estimates. Radical changes in the product also mean changes in the value chain and in companies' business models; thus, demanding a more comprehensive, inter-organizational perspective of costs. A consistent classification of costs helps in accumulating cost information related to new products. The elementary meaning of consistent terminology is demonstrated in the demarcation of cost and profit margin. Product profitability can be measured using different levels of profit, and the target profit is meaningful only if it is defined in alignment with the definition of product costs. Building and maintaining a cost database for the various R&D purposes requires significant effort by management accounting and technology experts.

An interview was carried out to find out the cost management practices used during the early stages of new product development. Targeted companies had relatively high R&D expenditures because such companies have more R&D activities and, thereby, the likelihood of finding good practices increases. The organizations used versatile methods to manage costs. In the early stages, the methods are not purely cost management methods but innovation is managed as a whole. The generic methods often include a cost management angle, however. All the companies had business intelligence and roadmapping practices. These activities gather knowledge of new technologies and market opportunities, which is necessary for cost management. Few companies constructed specific cost roadmaps, though. Every firm had some kind of a stage-gate system including financial evaluation of the project. Some companies used multi-dimensional scorecards to evaluate initiatives. The disciplined use of target costing was not typical but the use of cost estimates and cost databases was more frequent.

Involving suppliers earlier in the product development can lead to larger cost savings through inter-organizational cooperation. Long-term relations have their merits but single sourcing includes risks. It can deteriorate the buyer's information of supply markets, and the supplier can gain excess negotiation power in form of high switching costs. Chapter 5 described a practice that was developed to tackle these problems. It is based on virtual quotes asked from suppliers. During the process, suppliers are openly told that they are quoting on virtual components and design specifications and the information is used for strategic selection of preferred suppliers. With this information, the actual supplier selection is accelerated once the development project is to be started. The practice of virtual quotes is based on a detailed model of cost drivers, a database of old price quotations, and constant updating of data. The detailed cost driver model ties together the understanding of the production process of the component and thus recognizes the component and process parameters that are likely to affect the supplier's production cost and quotation price. To achieve comparability, the virtual quotes are requested on standardized templates. In spite of some similarities, it is not an ordinary open-book data sheet. The potential supplier is asked to make quotes on specified cost drivers and to show a trajectory of future price developments for several specifications, which reflect the specifications of real components. Several reference components and scenarios of purchase volumes are used to obtain a price range for cost drivers.

Chapter 6 introduced an approach to evaluate offerings of different suppliers concerning technologically challenging products. In target costing, ex-ante specified product functionality is not compromised and creative solutions are sought to achieve

the target cost without extra development cost. In the reported approach, the starting point is also product functionality defined by the customer. However, the customer is prepared for a situation where none of the suppliers can meet all the requirements. Because of technological challenges, there are gaps that can not be eliminated without extra development effort by the supplier. The approach seeks for a competitive price given to a supplier that can eliminate the gaps.

The primary planning objectives in target costing have been direct material and conversion costs, as the ratio of these costs to producer's full life-cycle cost has been high. The life-cycle cost structure of knowledge- and information-intensive products may be different. The unit-level cost of a product becomes less significant compared to the costs incurred in product-sustaining and product-founding activities. Activity-based costing systems identify product-sustaining activities, e.g. maintaining product specifications, special testing, tooling and technical support for individual products. As well as these recurrent activities, diverse product-founding activities, such as design engineering or product-specific marketing efforts, should also be considered. The costs related to both types of activities do not depend on the production volume but the profitability of the product is contingent on volume. Separating these elements is important in analyzing product concepts that integrate information, service and artifacts. When the proportion of manufacturing costs becomes small in the life-cycle cost structure, managing a product's life cycle cost requires more attention to the trade-offs between development effort and functionality. Chapter 7 suggested a modified target costing equation and a corresponding modeling approach to cope with these challenges.

Chapter 8 expanded the scope of product cost management by including the customer's costs of using the product. The decisions made in development affect these costs as well as manufacturing costs. Life-cycle costs should be considered when alternative product architectures or designs are compared. It can be highly beneficial for a supplier to be able to estimate the costs of using the product; otherwise, the purchase price may be the dominant criterion in the supplier selection process. From the buyer's perspective, it is vital to optimize the total cost of owning and using the product, not just the direct cost of acquisition. However, a product's life-cycle costs are not always reflected directly in the customer's purchasing decision, although these costs could be reliably estimated. However, seeing the costs from the customer's perspective is important for the product's success. The cases describe the trade-offs between purchasing or manufacturing cost and the cost of energy losses, but the basic ideas apply generally.

All cost management methods should include three types of routines. Target routines align the cost target with the intended value offering and required profitability of the organization. The costing routines identify, quantify, and communicate the consumption of resources in financial terms. The implementation routines support the creation and realization of cost reduction ideas in order to achieve the cost target. The boundaries of cost management methods and other management methods are not explicitly clear. Implementation routines are intertwined with the methods used in managing different operations. In the other extreme, strategy processes are connected to the target routines of cost management. Versatile information of markets, technologies and organizations is needed for effective cost management. Cost management literature identifies several methods. Many of them have been developed

by practitioners in firms and thereafter articulated by scholars. Furthermore, other firms apply and modify the methods. Understanding the diversity of the toolkit is more important than inventing a plethora of new methods.

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