

ACTIVITY-BASED COSTING AND PRODUCT PROFITABILITY

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ABSTRACT

In a typical manufacturing company the profitability of products varies greatly. According to the literature, the most profitable 20 % of products can generate about 300 % of profits and the remaining 80 % lose 200 % of profits.

The aim of this study was to find out how much the profitability of a product varies. The underlying hypothesis was that all products are not profitable. Furthermore, it was assumed that activity-based costing would indicate greater differences in the profitability of products than the previously used marginal costing system.

The case study was conducted in a Finnish metal industry company which manufactures and assembles industrial goods. Firstly, the activity chains were modeled and the activity-based costs were calculated according to the resources consumed by different activities. The activities modeled were manufacturing, purchasing, sales, documentation, and engineering. Secondly, the activity-based cost of the final products was calculated. The costs of products were compared with the selling prices to determine out the relative profitability. Furthermore, the sales volume per product was taken into account in calculating the absolute profitability of a product.

The results of the study show that the profitability varies significantly. The most profitable 20 % of the products generate more than 150 % of the profits and 50 % of the turnover. Moreover, characteristics of the most profitable products are indicated and the reasons for the profitability are discussed.

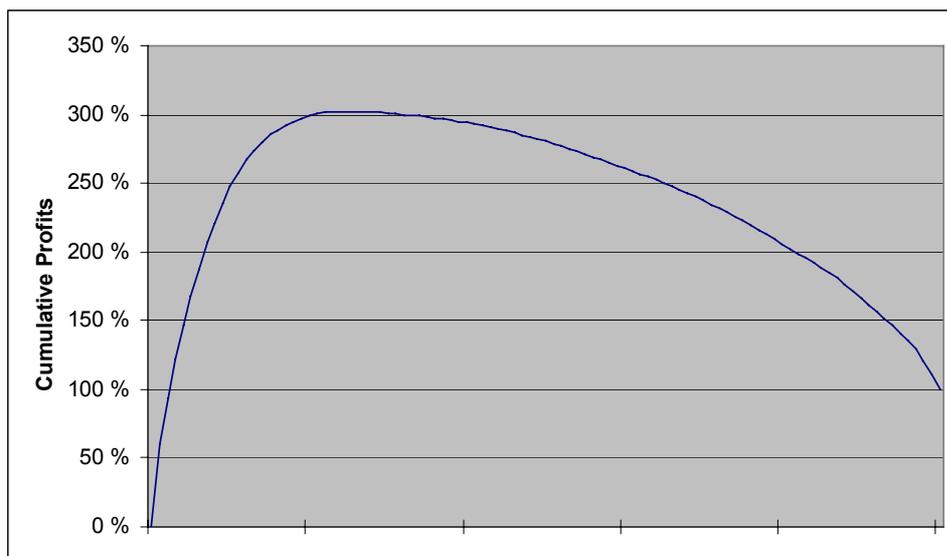
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INTRODUCTION

Information on product costs and product profitability is a prerequisite for cost-conscious management. Only if there is cost information available, is management basically able to make various decisions that take the cost perspective into account. Cost information can be utilized for instance in decisions that concern: product variety, product volumes, profitability developments, or marketing efforts. Therefore, to understand causes and effects of product costs is vital in terms of a company's short and long-term planning.

The so-called whale curve or Kanthal curve (Figure 1.) demonstrates the effect of plotting a company's cumulative profits as a function of products ranked by their profitability (Kaplan and Atkinson, 1998, p. 150-151, Kaplan and Cooper, 1998, p. 162-163, Cooper and Kaplan, 1991, p. 533). It is said that companies encounter a whale curve of cumulative product and customer profitability especially in activity-based cost systems constructed for companies or business units that meet two main conditions: expenses in indirect and support resources are great and there is a great diversity in products, customers, and processes (Kaplan and Atkinson, 1998). Kaplan has described the "Kanthal effect" in his Harvard Business School case where the original purpose was to demonstrate the significance of measuring individual customer profitability (Cooper and Kaplan, 1991). The analysis of customer profitability revealed that only 40 percent of a company's customers were profitable and these generated some 250 percent of total profits. The least profitable 10 percent of customers caused a loss of 120 percent of the profits. The original Kanthal plot (whale curve) has later been altered to describe not only customer but also product profitability. Typically, both the most profitable products and the least profitable products are among the best performers in sales volume. If the whale curve is used as a management tool, Kaplan suggests that several different actions can be taken to reshape the curve and to increase the profitability of product lines: reprice products, substitute products, redesign products, improve production processes, or eliminate products (Kaplan and Cooper, 1998).

Figure 1. Whale curve of cumulative profitability



Product cost is the cost of producing and bringing a product to the marketplace. It refers to an idea of activity-based costing that product costs can be determined by assigning the costs of

activities to a product that employs those activities. In the ABC framework, activity is a task that is undertaken to make or deliver a product. Product profitability is the relation of a product's selling price and its cost. The higher the price or the lower the cost, the better is the product's profitability. Absolute profitability refers to the absolute difference between the price and the cost, whilst relative profitability is the absolute profitability in relation to something. Typically, a relevant reference value is the selling price of the product. When the costs are assigned to products, one has to decide what is a correct cost driver in a particular situation. Cost driver is a factor that causes or drives an activity's costs. Kaplan and Cooper have suggested that costs are driven by activities that occur at different levels (Kaplan and Cooper, 1998): for example, unit, batch, product-sustaining, order, or facility.

Unit costs are related to activities that are performed in proportion to volume produced. Batch activities are not related to production volume but to the number of batches in production or in support functions. Product-sustaining activities are those that enable the production of individual products to occur, including product specification updates and maintenance. Order-related activities are specific to a particular order but independent of the volume or content of the order. Facility-sustaining activities provide general production or sales capabilities that cannot be directly assigned to a product or to a customer.

An interesting issue related to the product profitability whale curve and product-related costs is the question of product variety. How broad a product line is preferable from the profitability point of view? Several studies agree that broadening the product line increases a company's power to compete in the market. It leads to a higher market share and performance. (See e.g. Yeh and Chu, 1991, Kekre and Srinivasan, 1990, Tang and Yam, 1996) However, a company may lose its cost advantage at the same time (Yeh and Chu, 1991). This might be somewhat contradictory to the observation of Kekre et al. that broadening the product line also increases the profitability (Kekre and Srinivasan, 1990).¹

The aim of the paper is to analyze the phenomenon of product profitability and to investigate the causes behind the differences in product profitabilities. The question is if there are systematic reasons that explain the phenomenon demonstrated by a whale curve. A case study has been conducted to explore the cost structure of products that can be described as investment goods. Most of the manufacturing process is assembly work where the material costs are significant. In this study, pricing strategy or the prices as such are not studied but they are considered as given. Furthermore, delivery costs and after-sales costs are not included in the study.

THE CASE STUDY

The case study was conducted in a company which manufactures and assembles capital goods for industrial customers. The subject of the study was the company's production volume in 1999. The company manufactured in 1999 approximately 2 700 end products. About 10 % of products were customized for a special environment and thus products had some extra requirements. Moreover, the company manufactured main components for the end products. The main components were also sold to other end product manufacturers. The production volume of main components was about 10 000 pieces per year.

¹ (Regarding the product variety and profitability discussion see also Swenson, 1998, Mughal and Osborne, 1995)

The main component production was mainly mechanical machining. At the time of the study there were three different main components and 17 different models in production. Of these models 15 were sold to other manufacturers and two models were made only for the producing company's own end product line. The products differed in design and the models typically in size. However, the production of all products was quite similar and differences were typically in work cycle time and in batch size.

The end product manufacturing was mostly assembly work. The main component was the heart of the end product and, moreover, it was the most expensive component. At the time of the study there were five assembly lines, and 16 different products and 78 models were in production. Differences between the products were in the frame structure of the product and in the main component. The models differed from each other typically in output power, cooling system, or operating environment. Within a model there were minor differences, like operating voltage. However, minor changes had no effect at all on the production processes.

The preceding three years the turnover and the production volume of the company had been increasing. During the same time period, the company's profit had been 5 to 10 % of turnover. In 1999 the turnover of the company was about € 30 million. Moreover, the turnover of the production units was about € 22 million. The company had been profitable, but within the company there was no exact knowledge regarding which of the products were profitable. However, it was believed that main component production was profitable and it even subsidized the end products' production by underpriced transfer prices. Moreover, there was a hypothesis that almost all the products were profitable. Some customized products were known to be time and activity consuming, but the higher profit margin was expected to make them profitable. After-sales was known to be profitable, but this was left out of the study.

THE ACTIVITY-BASED COSTING MODEL

A marginal costing system was used in the company. It was not well updated and the overheads were not accurately allocated. It was assumed that activity-based costing (ABC) would allocate overheads more accurately. In 1999 the company decided to start using ABC as a costing tool for products. The ABC model was created during the years 1999 and 2000. The activities modeled were manufacturing, purchasing, sales, documentation, and engineering. The activities which were left out were general management, research, and after-sales. While creating the ABC model, almost all white-collar workers and altogether 52 persons were interviewed.

The ABC model includes 85 % of the company's costs and 97 % of these costs were assigned to the product by an ABC cost driver. 15 % of the company's costs were caused by facility-sustaining activities, like general management. These costs were allocated to the product by a profit margin. The activities were classified in four groups and the classification is shown in Table 1. Total costs of activities vary between € 500 and € 740 000. Moreover, there were eleven activities, the total costs of which exceeded € 200 000, and ten of these were production activities.

Table 1. Activities and costs of the ABC model

Type of activity	Number	On allocation level	Share of the costs
Unit	79	62	20 %
Batch	7	4	1 %
Product-sustaining	18	18	7 %
Facility-sustaining	9	2	15 %
Total activities	113	86	43 %
Material costs			57 %
Total			100 %

The activity costs were assigned to the product based on interviews and company production time follow-ups. The ABC model was triangulated by comparing the model's total working hours with the company's recorded yearly working hours. Moreover, the costs of the model were compared with the income statement. There was some inaccuracy found and corrections were made based on interviews. After readjusting, the ABC model's accuracy was 98 %.

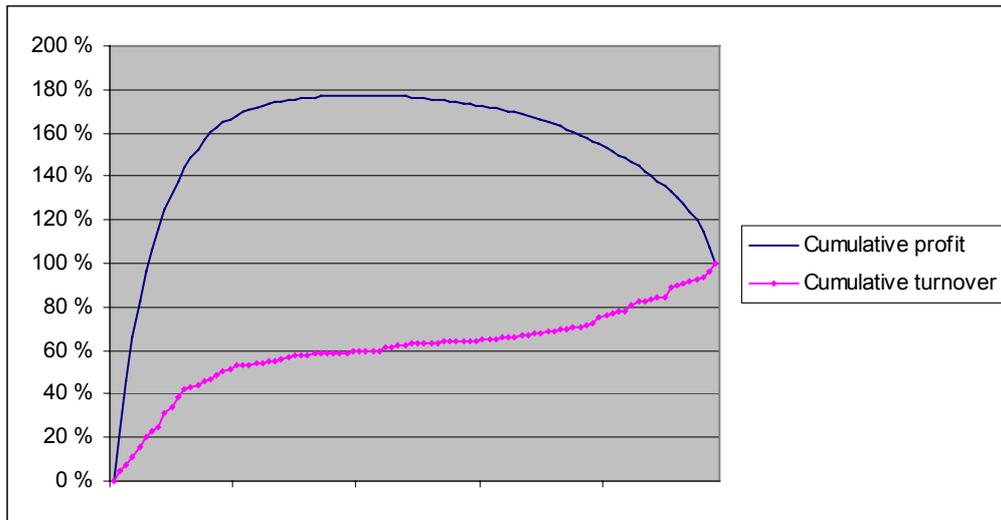
To determine the profitability of the product, the sales prices were checked in sales documents and by interviews. Average prices were used. Comparing the turnover based on the ABC model (volume times prices) with the turnover of the income statements, an accuracy of 103 % was achieved.

RESULTS

TOTAL PRODUCTION

According to the results calculated with the ABC model, the products' profitability varied greatly. A whale curve showing cumulative profits is presented in Figure 2. The company's profit was at its maximum after 38 product variations. At that stage the profit was 177 % of total profits. The most profitable 20 % (19 models) of the products generated 168 % and the most unprofitable 20 % caused a loss of 55 % of total profits. The six most profitable models generated over 100 % of the total profit. Moreover, the share of the most profitable 20 % of the turnover was 53 % and the share of the most unprofitable 20 % was 24 %. Furthermore, within the most unprofitable models there were three models which generated 11 % of the turnover.

Figure 2. Cumulative profit and turnover



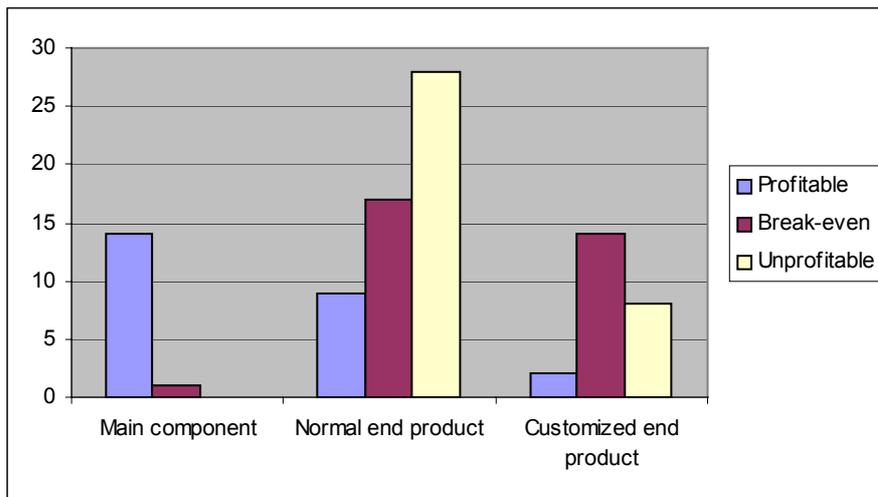
The models were classified in three different groups based on total profitability, relative profitability, production life cycle phase, and type of product. The classification is shown in Table 2.

Table 2. The classification of the models

Total profitability Share of total profit	Type of product	Production life cycle phase	Relative profitability Profit margin
1. $\geq 0.5\%$, profitable (n=25)	Main component (n=15)	New, production started in 1999 (n=19)	I $\geq 10\%$ (n=27)
2. $0.5\% > x >$ -0.5% , break-even (n=32)	Normal end product (n=55)	Stable (n=55)	II $10\% > x > -10\%$ (n=25)
3. $\leq -0.5\%$, unprofitable (n=36)	Customized end product, special operating environment (n=24)	Closing, production ended in 1999 (n=19)	III $\leq -10\%$ (n=41)

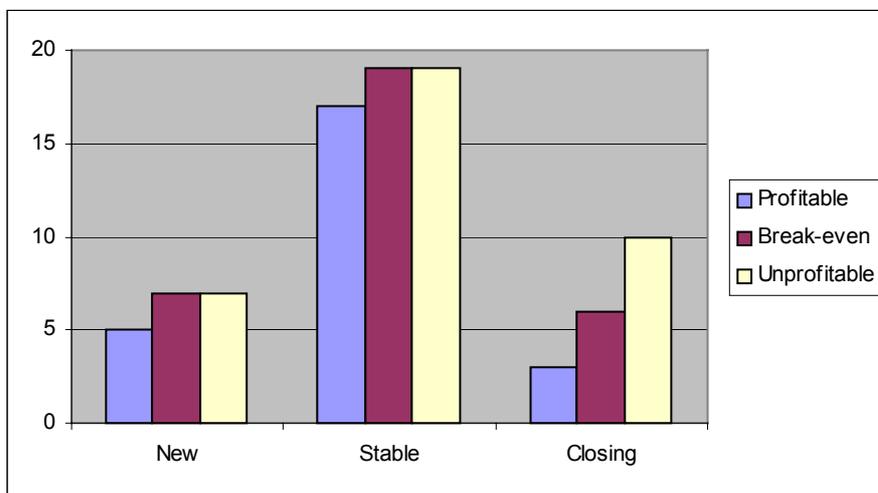
Figure 3 shows how different types of products are grouped according to the total profitability. The main components were very profitable, with 14 out of 15 belonging to the profitable group. For normal end products the unprofitable group was biggest. The customized products were mainly break-even models and thus they had only a minor effect on the total profit. This was mostly because their production volumes were low.

Figure 3. Total profitability and type of product



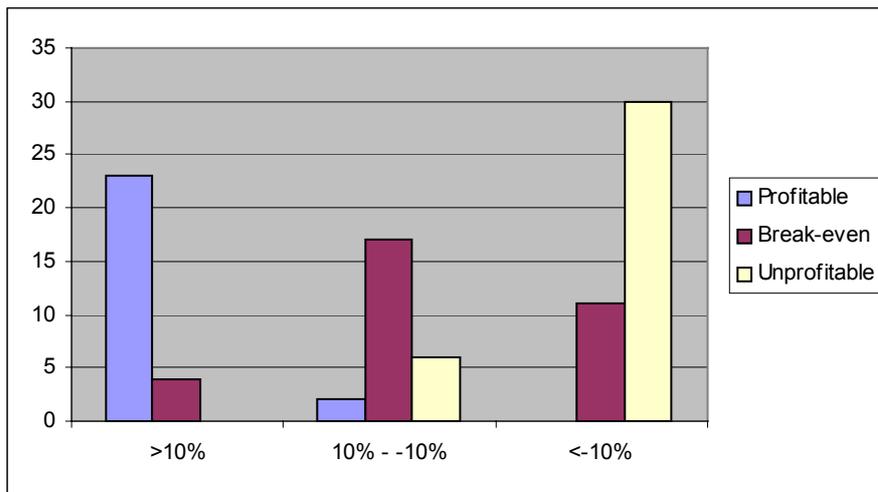
In Figure 4 there is the same classification based on the production life cycle phase of models. The shape of the distribution was the same for new and stable models. However, within new models there were more distribution within one class. Three out of four of the most unprofitable models were new ones. Moreover, some of the most profitable models were new ones. Models which were in the closing production life cycle phase were most unprofitable. Ten out of nineteen were in the unprofitable class.

Figure 4. Total profitability and production life cycle phase



Total profitability was compared with the relative profitability. Within break-even models there were big differences in relative profitability. The four most unprofitable models were in the break-even class. The profit margin of these models varied between -68 % and -91 %. However, the volumes of the models were low (between 2 to 6), explaining the minor effect on the total profit. Moreover, there is one product within the break-even class which has a profit margin of 38 %.

Figure 5. Total profitability vs. relative profitability



END PRODUCTS

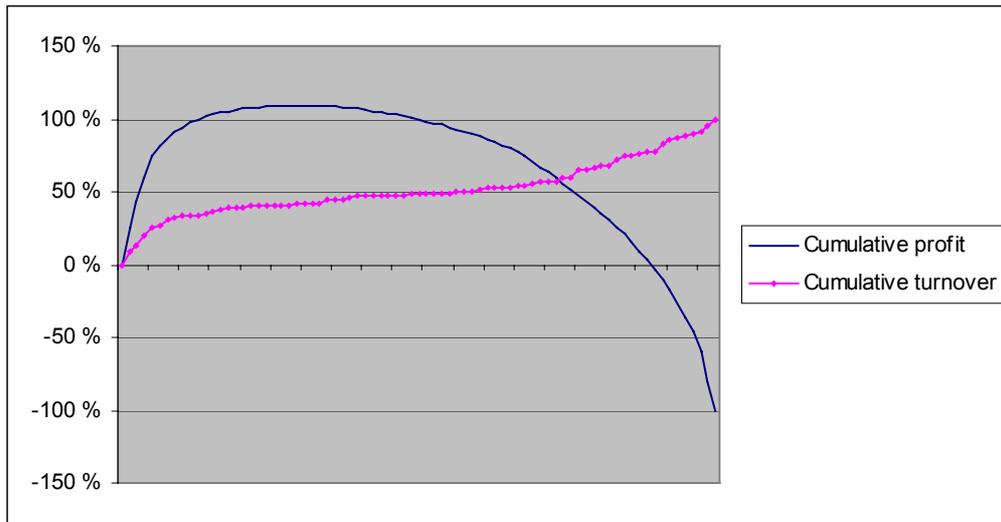
There was a major difference in profitability between main components and end products. Further on the study concentrates on the end products. Normal and customized models were compared in Table 3. In both groups the share of unprofitable products was about the same (30 %). Moreover, normal end products are slightly more profitable but the difference is not statistically significant. Due to this, the end products are considered as one class.

Table 3. Normal and customized end products

Type of product	Profitable	Unprofitable	Profit margin	Volume (average)
Normal (n=54)	16	38	- 4 %	46
Customized (n=24)	7	17	- 8 %	10

A whale curve of the end products' profit is shown in Figure 6. The total profitability is negative and the curve ends at -100% . The most profitable 20 % contributed 107 % of the profit and 40 % of the turnover. Furthermore, the most unprofitable 20% caused a loss of 135 % of the profit and generated 32 % of the turnover. The profit was at its highest level after 23 models, i.e. 109 %. As in the previous whale curve, the largest turnover was with the most profitable and unprofitable models.

Figure 6. Whale curve of end products



End products which were in their closing production life cycle phase were the most unprofitable group, with a profit margin of -19 %. Moreover, only one model among them was profitable. The difference in profitability between new and stable models was minor. However, the production volume of new products was higher than others. This was mostly because of the relative low share of customized products, four out of eighteen, and the high production volume of four models (≥ 100).

Table 4. The profitability depending on a production life cycle phase of end products

Production life cycle phase	Profitable	Unprofitable	Profit margin	Volume (average)
New (n=18)	7	11	-3 %	52
Stable (n=44)	15	29	-2 %	33
Closing (n=16)	1	15	-19 %	25
Total	23	55	-4 %	35

End products were classified in five different groups based on the size of the product (Table 5). The most profitable size was large (L), in which there was only one product with 14 models. The most unprofitable size was extra large (XL). There were six different products and 18 models of that size, meaning that there were on average only three models per product in production. Furthermore, the production volume of XL products was lower than the average. That was mostly because XL products were typically somehow customized. In size S there were two products, a new one and a closing one. At the time of study there were two production lines kept going to make these models. This increased product-sustaining costs for both products and partly explains the poor profitability.

Table 5. The size of end products

Size	Different Products	Models	Production life cycle phase			Volume (average)	Share of turnover	Profit margin
			New	Stable	Closing			
XS	6	13	1	3	2	74	15 %	-8 %
S	2	14	1		1	54	18 %	-17 %
M	2	19		1	1	36	30 %	5 %
L	1	14		1		17	20 %	8 %
XL	6	18		5	1	5	16 %	-18 %

The cost structure of the products was studied more closely. Material costs were the highest with a share of 59 %, as typical in assembly production. Unit costs were the second-biggest group. Most of the unit costs are due to from direct assembly work. Facility-sustaining costs (15 %) were mostly assigned to product by profit margin and because of that they were about the same for all models. Within product-sustaining costs there were significant differences. The profitable group differed statistically significantly from the other two (t-test $p < 0.01$). Batch-related costs were always below 1 % and as such not important.

Table 6. The cost structure based on total profitability

Total profitability		Material	Unit	Batch	Product-sustaining	Facility-sustaining	Volume (Average)
Share of total profit							
1. ≥ 0.5 %, profitable (n=11)	Average	64 %	15 %	0 %	4 %	16 %	56
	Variance	0.7 %	0.4 %	0.0 %	0.0 %	0.0 %	
2. $0.5 \% > x > -0.5$ %, break-even (n=31)	Average	58 %	18 %	0 %	8 %	15 %	8
	Variance	0.8 %	0.1 %	0.0 %	0.4 %	0.0 %	
3. ≤ -0.5 %, unprofitable (n=36)	Average	58 %	18 %	0 %	8 %	16 %	52
	Variance	0.8 %	0.2 %	0.0 %	0.3 %	0.0 %	
Total	Average	59 %	18 %	0 %	7 %	16 %	35

The cost structure based on relative profitability was studied closely in Table 7. There were significant differences in product-sustaining costs between the most unprofitable group (III) and the others. The product-sustaining costs were about double compared with others. Moreover, unit costs differed statistically significantly between groups II and III. Other differences were not significant.

Table 7. The cost structure based on relative profitability

Relative profitability		Material	Unit	Batch	Product-sustaining	Facility-sustaining	Volume (Average)
Profit margin							
I ≥ 10 % (n=12)	Average	64 %	16 %	0 %	4 %	16 %	41
	Variance	0.7 %	0.5 %	0.0 %	0.0 %	0.0 %	
II $10 \% > x > -10$ % (n=25)	Average	63 %	16 %	0 %	5 %	16 %	45
	Variance	0.2 %	0.1 %	0.0 %	0.0 %	0.0 %	
III ≤ -10 % (n=41)	Average	55 %	19 %	0 %	10 %	16 %	27
	Variance	0.9 %	0.1 %	0.0 %	0.5 %	0.0 %	

Cost structure based on the production life cycle phase of models is shown in Table 8. Models in closing phase had significantly higher product-sustaining and unit costs than others. Unit costs were higher mostly because the design of the models was old and manufacturing and assembly had not had high priority when designed. Furthermore, the high product-sustaining costs were due to the company's having to keep up production line,

maintenance, product update, and technical support while at the same time the production volumes had declined. This had increased product-sustaining costs per unit even though the total costs had even declined a little. New products' unit costs were on an average level but after the study they have been declining because of process improvements and a learning curve effect. Moreover, new products had lower material costs than the ones they were replacing. Thus, new products' total costs were lower than old products' total costs.

Table 8. The cost structure based on production life cycle phase

Production life cycle phase		Material	Unit	Batch	Product-sustaining	Facility-sustaining	Volume (Average)
New (n=19)	Average	62 %	16 %	0 %	6 %	16 %	52
	Variance	0.5 %	0.4 %	0.0 %	0.0 %	0.0 %	
Stable (n=53)	Average	61 %	17 %	0 %	6 %	16 %	32
	Variance	0.4 %	0.1 %	0.0 %	0.1 %	0.0 %	
Closing (n=19)	Average	48 %	21 %	0 %	14 %	16 %	25
	Variance	0.9 %	0.2 %	0.0 %	0.7 %	0.0 %	

CONCLUSIONS

It is said that companies encounter a whale curve of cumulative product profitability especially in activity-based cost systems constructed for companies or business units that meet two main conditions: expenses in indirect and support resources are large and there is a great diversity in products, customers, and processes. In this case direct material expenses were 57 % and most unit costs were due to direct labor. Furthermore, the number of different types of products was low, even though the number of models was high. Differences in processes were mostly between main component production and end product assembly. Based on this material nothing can be said about customer diversity. However, the cumulative product profitability curve follows a whale curve shape, even though the maximum profit is only 177 %. Most of the products affect the total profitability only slightly, mostly because of low production volumes. However, the most unprofitable 20 % cause a loss of 55 % of company total profit.

The main component production is profitable. In many cases, the company cannot add value to the main component by making an end product out of it. The total profitability of end product production is negative. Within the end product production normal and customized products do not differ significantly in terms of profitability. Furthermore, end products' cumulative profit follows the whale curve shape, only ending in negative value.

The relative profitability differs greatly and the profit margin of the end product is typically between -30 % and 33 %. Furthermore, there are few models that have a profit margin as low as -92 %. However the production volumes of these models are low and the effect on total profitability is minor. Relatively most unprofitable products are in their production life cycle in new or closing phase. However, there are some new models whose profit margins are among the highest.

Within the models in their stable life cycle phase the profitability differs depending on the size of a product. The most profitable products are in sizes M and L. Sizes in which there are many products, which might even compete with each other, are the most unprofitable. Moreover, for XS products typical product- and facility-sustaining costs are high and make

them unprofitable. Furthermore, in XS products the large number of products divide the production volume into too many products and the company cannot achieve the economy of scale which is needed. For XL products the sales in 1999 were quite low, causing inefficiency in production and thus increasing expenses.

The cost structures of profitable and unprofitable new products are close to each other, and thus no conclusions can be drawn based on the cost structure. In this case it looks as if the profitability is strongly related to the competitive situation within the market. The most profitable models are the ones that can offer savings for customers in operation expenses. Moreover, these products are not so price sensitive (Hill, 1995). The most unprofitable products are those which are trying to enter a market where there is already tight price competition. Furthermore, the company has not achieved the competitive edge required with a new product.

Products in the closing production life cycle phase are the most unprofitable in both terms, absolutely and relatively. Unnecessary extension of life cycle keeps total product-sustaining costs almost on the same level as in stable stage. Like in this case, there are still assembly lines and tooling ready for products in their closing phase. Furthermore, resources like material handling, supervision, and engineering are still needed. Moreover, assembly times of these products are high, partly because of old design and partly because of low production volumes.

On the basis of this study, it looks like it is profitable to increase product variety by making more models out of one product. However, increasing variety by making a similar product in the same size is unprofitable. The most profitable size L has only one product and 14 models. Furthermore, the unprofitable ones XS have 2.2 models per product and XL sizes have 3 models per product. Similar products increase product-sustaining costs and sales volume does not increase enough to make them profitable. Moreover, size S is unprofitable, but at the time of study the production of a new product generation had just started. That is why it cannot be compared with the others. However, it can be said that change of generation can make a product unprofitable in the short run.

Before the ABC project the company knew its direct labor costs and material costs quite accurately. The advantages gained were in the field of fixed costs. Especially within product-sustaining costs there are major differences between products. At least with some products high product-sustaining costs make them unprofitable. On the basis of this evidence it can be said that marginal costing does not work well in an environment where there are major differences in product-sustaining costs.

Product-sustaining costs are assigned to products mostly based on interviews and documents. For assigning R&D and engineering activities some estimations have been made. This might cause some inaccuracy in product-sustaining costs. However, the estimations have been made in mutual understanding and it can be said that the possible inaccuracy is minor, most likely less than 20 % of product-sustaining costs. Furthermore, facility-sustaining costs are allocated by profit margin ratio. Most likely there is some inaccuracy within this 15 %, but facility-sustaining costs are typically difficult to assign directly to a product. In this case, it can be said that the end products require more facility-sustaining activities than the main components. This would make the end products even more unprofitable, but there is no proof of that.

MANAGERIAL IMPLICATIONS

Having product, customer, and supplier cost information is very relevant for top management. The actual weakness of the situation here is a well-known fact. Several times when we presenting a whale curve we have heard the following:

- How to use information in practice?
- What to do with unprofitable products?
- How to tell the customer that we are not going to deliver unprofitable products any more?
- Our customer demands also those unprofitable products. Otherwise he will not buy the profitable ones.

It is clear that even from the cost management perspective the problem of unprofitable products cannot be solved just by eliminating those products. In that case part of the costs, nonincremental costs, would be either cost of free capacity or increase the costs of other products. It is important to understand that costs can and should be controlled and managed: costs are not just the incidental result of other important decisions.

One of the main messages of the whale curve is that different products and customers have different profitability. It is difficult to say whether equal profitability of all the products is the ideal. However, it is practically impossible in a multi-product environment. Treatment of an unprofitable customer or product depends on the options available. If an alternative action has a positive influence on profit, it is worth carrying out. In that sense it is impossible to set an absolute lower profitability limit for individual customers or products. Mostly those limits are targets. The situation is the same with upper limits (super profitable product or customer).

In practice, the whale curve typically describes the profitability of a one-year time period and an absolute way to measure profit is used. There are no limiting principles that demand a one-year period and absolute profit. However, it is also important to measure the lifetime profitability. One reason for this is the after-sales. The after-sales is an interesting and economically significant business area in many industries today. It is often even claimed that it is the most profitable function of a corporation. The service period is typically much longer than the production period. In the production phase a product may be unprofitable but it is possible that it will be profitable in the after-sales phase. The length of this service period depends on the type of product.

Return on investment (ROI) is a typical ratio for business-level profitability measurement. ROI is attractive because it proportions the price not only for the operating costs but also for the capital investment required. In cost management, decisions are made not only at corporate level but also at the level of activities, products, suppliers, and customers. Activity-based costing makes it possible to use ROI at customer and product level. Considerable differences may exist among products in their demands for resources. It is possible that ROI and the absolute way to measure profit give opposite picture of product profitability.

Strategic thinking emphasizes core competencies. The whale curve helps companies to identify these hidden competencies. Profit is one way to measure whether a competence really is a core one. If companies are unable to measure product, customer, and supplier profitability, there is full reason to doubt their ability to define core competencies too.

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