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Activity Based Costing as a method for assessing the economics of modularization – a case study and beyond

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Abstract:

The paper accounts for an Activity Based Costing (ABC) analysis supporting decision-making concerning product modularity. The ABC analysis carried out is communicated to decision-makers by telling how much higher the variable cost of the multi-purpose module can be compared to the average variable cost for the product-unique modules that it substitutes to break even in total cost. The analysis provides the platform for stating three general rules of cost efficiency of modularization, which in combination identify the highest profit potential of product modularisation. Finally the analysis points to problems of using ABC in costing modularity, i.e. handling of R&D costs and identification of product-profitability upon an enhanced modularization.

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1. Introduction

In order to maintain competitiveness manufacturing companies in general aim to offer a wide selection of products to meet customers' increased demands for variety. However, even though empirical results are not consistent (Anderson, 1995:364), it is generally accepted that increased variety, or more correctly increased heterogeneity in the product mix, impacts negatively on costs and operational performance (e.g. Miller & Vollman, 1985; Banker *et al.*, 1995; Kaplan & Cooper, 1998). The company will have to source, produce and sell in smaller batches and support functions will have to be expanded to accommodate increased internal demand for activities such as planning, setups, documentation, etc. To mitigate the negative effects from increased variety, manufacturing firms may pursue process based and/or product based strategies (Fisher *et al.*, 1999). Product based strategies, which is the topic of this paper, focus on product designs that allow for high product variety at reasonable cost. One such strategy is that of modularization (e.g. Heikkilä *et al.*, 2002). When individual modules can be used in different end products, the manufacturing firm can offer variety at lower levels of component heterogeneity by combining modules and at the same time preserve some of the benefits of mass production (Perera *et al*. 1999).

A review of the literature on the concept and multiple effects of modularity, and paradigmatic approaches to manage modularity (Jørgensen, 2004) reveals that the concept of modularity has many faces (Hansen *et al.*, 2003) and that a number of the economic benefits of modularization are taken for granted although the methods applied in identifying and assessing these consequences have something to be wished for.

The task of the paper is twofold. The first task is to investigate the merits of the Activity Based Costing (ABC) as a method for assessing the cost consequences of modularization. This is done through a case study followed by reflections on how ABC (might) need to be developed to be able to serve as the relevant costing tool. The second task is to infer some general rules on the cost efficiency of modularisation from the case study. In this way our contribution is of a more pragmatic character than, for example, Nepal *et al*. (2005), who develop a fuzzy logic model to handle cost information at the early stages of the product development process.

The paper proceeds as follows: section 2 searches the literature on management accounting and costing to identify those parts of the (internal) value chain where cost effects of modularization are likely to occur. Section 3 provides a brief introduction to ABC, and section 4 accounts for the ABC case study and points out some general characteristics of situations where modularisation is cost effective. Section 5 reflects on problems of the ABC method in analysing the consequences of modularisation beyond the specific case context. Section 6 concludes the article.

2. Revenue and/or cost consequences of modularization

In order to assess the economic consequences of modularization it is essential to distinguish between modularization efforts where only cost effects are necessary to analyse and efforts where it is also necessary to account for differential revenues. Generally speaking, the consequences of modularization can be confined to costs, when the number of end products and their features – in the eyes of the customer – are the same whether produced with or without the use (or increased use) of modules. In that respect Fisher *et al.* (1999) suggest that components should be categorized according to their influence on quality in its widest sense, i.e. including the customers' perceptions of the product. Fisher *et al.* argue that components having high impact on customer-quality perceptions should have a minimum of sharing across products whereas components with low quality-perception impact can be – and ought to be – shared across products. In the words of Robertson & Ulrich (1998) this can be explained by an inherent trade-off between "commonality" and "distinctiveness": the higher the level of commonality the less distinctive the products will be. As the manufacturer increases commonality to mitigate the negative effects of increased variety, the risk of products cannibalizing each other is also increased. Therefore, whether the commonality is visible to the customer or not – Labro (2004) suggests the terminology "internal commonality" (not visible) and "external commonality" (visible) – becomes an essential input to the process of financially evaluating and deciding on the appropriate level of commonality.

2.1 Cost effects of modularization

The basic rationale for introducing modular products is to obtain cost reduction (and reduced time-to-market) within an unchanged product variety. But as we shall see, one cannot unconditionally infer that the net effect is a cost reduction. In the following paragraphs three categories effecting costs are discussed: “economies of scale”, “inventory carrying cost” and “cost of support activities” in terms of their behaviour in a modularity regime.

2.1.1 Economies of scale

There is an inherent trade-off between the level of variety offered by a firm and the achieved economies of scale (Starr, 1965). Modular products are perceived as a way to mitigate the poor scale economies resulting from high variety as modules or common components can be used in several products, thus increasing volume. Only in the rarest of cases, however, will the variable cost per unit of the common module be less than the variable cost per unit of each of the otherwise product-specific modules that it substitutes. Actually, it is more likely that it will be costlier than even the costliest of the product-specific modules that it substitutes. This is due to the necessary over-specification that allows for the same module to be used in different products (Zhou & Grubbström, 2005). For the total variable cost to decrease, the effect of over-specification has to be outweighed by purchase discounts, lower setup costs (if these are handled as variable costs) or learning curve effects.

2.1.2 Inventory carrying cost

Concerning inventory cost it is argued that introducing modularity will decrease holding costs as fewer parts need to be inventoried (e.g. Fisher *et al.*, 1999). This is typically explained by reduced safety stock from the increased commonality (Collier, 1982), or delayed product differentiation (Lee & Tang, 1997). In an assemble-to-order production regime fewer components need to be inventoried to accommodate a specified service level (a certain lead-time), if products are based on modules, as the same number of modules may be combined into different products (Mirchandri & Mishra, 2001). This is the well-known risk-pooling phenomenon (Eynan & Rosenblatt, 1996; Weng, 1999; Thoneman & Brandeau, 2000). However, although the number of units inventoried can be reduced, the cost of these units will normally be higher and, therefore, the net effect can only be determined in relation to a specific situation (Labro, 2004).

2.1.3 Cost of support activities

The third category – support activities and associated costs – is a complex category. It may comprise the following subcategories from every part of the value chain:

- Design costs

- Procurement overhead costs
- Production overhead costs
- Quality costs
- After-sales service costs

In the literature it has been argued that each of these – and more – cost categories have been influenced by modularization. For example, design costs will decrease as the volume of designs are reduced when shifting from a number of unique components to one common component (Krishnan & Gupta, 2001), and production overhead costs will decrease as fewer material handlings and setups are required (Kaplan & Cooper, 1998). The latter is an example of the more general argument that a reduction in the number of transactions (Miller & Vollman, 1985) and complexities of operations (Johnson & Kaplan, 1987) will reduce overhead costs. Finally, Fisher *et al.* (1999:299) argue that quality costs will decrease due to learning and quality improvements associated with increased volume.

Again, while it may very well be true that increased commonality will decrease the number of times activities in the support functions are called upon, it may be equally true that the duration and complexity of performing these support activities are more costly to perform (Labro, 2004). Thus, the benefits from burdening support functions less frequently may to some extent be off-set by the increased costs of each support function burdening incidence.

It appears from the above discussion that in order to evaluate the economics of modularization, we need to adopt a total cost perspective, i.e. to take the cost consequences along the entire (internal) value chain into account.

3. Activity Based Costing (ABC)

The origin of ABC dates back to 1983-1984 (Kaplan, 1983, 1984a,b, 1985a,b, 1986) although the term “Activity-Based Costing” was not coined yet. The origin grew out of dissatisfaction with the dominating costing procedures at the time, variable costing and traditional full costing, which were argued to be obsolete in modern manufacturing environments. During 1987-1992 Robin Cooper and Robert S. Kaplan ventured into a series of “innovative action research cycles” (Kaplan, 1998) in which ABC was developed. While Cooper and Kaplan initially searched for an improved full-cost product-cost calculation, the model grew into a more fullfledged costing system for hierarchies of activities and cost objects. The current state-of-the-art of ABC is reflected in Kaplan's and Cooper's book "Cost and Effect" (1998) and supplemented with Time-Driven ABC in Kaplan & Anderson (2004).

3.1 Basic feature: the ABC hierarchy

A number of basic features of ABC should be noted. Basically it is a two-stage procedure in which cost of resources in the first stage are allocated to activities to form Activity Cost Pools, which in the second stage are allocated to cost objects based on these objects' use of the different activities. Cost object is the generic term of ABC for products, services and customers. In order to differentiate between the different allocations at the two stages, the first-stage allocation bases are termed "resource cost drivers" and the second-stage bases "activity cost drivers". Activities and cost objects are placed in a hierarchy to avoid arbitrary allocations of costs. A typical hierarchy in the product dimension is shown in figure 1.

The conception is that each level contains different activities and that these activities in essence are decoupled, i.e. the consumption in any higher-level activity is unaffected by, i.e. do not vary with, activities at the lower levels. In other words, the higher-level costs are always common to all activities at lower levels, and therefore should not be allocated to these lower levels. Especially the allocation of all costs to the unit-level will create misinterpretations because "when batch and product level costs are divided by the number of units produced, the mistaken impression is that the costs vary with the number of units" (Cooper and Kaplan, 1991b:132).

FIGURE 1 INSERTED HERE

Except for the most aggregate level in figure 1 all levels can also be thought of as forming a hierarchy of products, and consequently common cost belonging to higher levels, e.g. product sustaining cost of product x, should not be allocated to lower levels, e.g. units of product x.

3.2 Basic feature: Different types of activity cost drivers

In the allocation of costs from activities to cost objects, the activity cost drivers can be defined at three levels of accuracy using either "transaction", "duration" or "intensity/direct charge" cost drivers (Cooper & Kaplan, 1991a:279; Kaplan & Cooper, 1998:95-97). To illustrate with batch cost using a transaction cost driver means allocation of these costs based on the "number of batches", e.g. setups, assuming implicitly that all setups are equally resource demanding. If this is unrealistic, then duration of setup might give a better estimate of setup cost per product provided that the cost of each setup hour is approximately the same. If not, it may in certain situations be necessary to measure resource consumption for each individual setup, which is the most accurate driver type, but also the costliest to measure.

3.3 Basic feature: Avoidability and the treatment of unused capacity

Two additional characteristics should be noted. In order to avoid arbitrary allocation of costs of unused capacity to cost objects, only the corresponding cost of the used part of the resources supplied are allocated to cost objects. The distinction between used and unused requires an estimate of the practical capacity in an activity, or, alternatively, the capacity of a resource (Kaplan & Cooper, 1998:111-130). The benefit of this procedure is – in principle – that the calculated cost of serving any cost object is independent of the capacity utilization of the current period. Finally one should be aware that ABC allocates overhead costs to cost objects even when the resources are shared by the cost objects, and whether or not these costs are avoidable in the event the cost object were removed/given up. The consequence of these two characteristics is that the ABC information cannot directly serve as decision-making information in terms of bottom-line financial consequences of removing/expanding parts of or whole arrays of products or customers (see also Homburg 2005). However, it will serve as attention directing.

In strategic activity based management ABC has been used for a variety of purposes, e.g. assessment of product-line and customer mix, supplier and customer relationships, market segmentation and distribution channel configuration. To some extent it has also been used in product design documented in Harvard Business School cases (Cooper & Turney, 1988a,b; Kaplan, 1992, 1995) and in a few articles, e.g. Ness & Cucuzza (1995) and Ben-Arieh & Qian (2003), and in a related area, total cost of ownership, Ittner & Carr (1992). However, in this paper we look for an alternative way of communicating the outcome of ABC calculations, and to identify prerequisites for these calculations to be valid.

4. Case: The ABC trial at Martin Group A/S

The company has three product lines: intelligent lighting, smoke, and sound. The intelligent lighting business is relatively young, and the case company has been an important player in the creation and development of the market since its start in 1989. With a variety of products within each product line, the company serves three market segments, namely DJ & Club, Stage & Studio, and Architectural (internal and external). Its major geographical markets are countries in Europe and North America. The company has experienced a high growth since its start with a turnover today around DKK 900 million. Growth is expected to continue and every year about 30% of future revenues are expected to come from new products.

4.1 The product context of the case study

The products are mechatronic products, i.e. a mixture of electronics, software and mechanical technologies. Future products need more sophisticated integration of these technologies and a shorter time-to-market. Technologies such as LC-displays and other forms of digital displaying technologies, wireless communication, and enhanced integration of electronics into complete multi-functional units (chips etc.) are all important examples. Likewise, optical technology will become even more important in the development of leading-edge products as the core of the product purpose is “giving light”.

A product family is created through configuration of assembly modules. An assembly module is defined as a sub-assembly that is used in the final assembly process. Thus the assembly modules can be assembled by external producers as well as the internal module assembly groups. This is a purely physical understanding of the modules and essentially following the conceptions of production modules of Pahl & Beitz (1996) and assembly modules of Otto & Wood (2001). The product family analyzed in this case is depicted in figure 2. The ABC analysis is focused on the pan assembly module.

FIGURE 2 INSERTED HERE

The ABC trial was part of a project contemplating the technical feasibility and the financial viability of reducing the number of modules in two related product lines. The current structure and the contemplated new family structure with a higher degree of commonality are shown in figure 3 which depicts the differences in the use of modules across the end products (external variants, 11) in the current structure (marked with □) and the contemplated structure (marked with ◊).

FIGURE 3 INSERTED HERE

It shows, for example, that the product family (11 product variants in all) originally used 6 (totally) end-product-unique modules and only two totally common modules, which were contemplated to be changed to only one unique module and 6 totally common modules within a total structure of modules reduced from 45 to 24. The contemplated changes are of an internal character (Labro, 2004) and therefore not visible to the customer. Thus, there is no risk of cannibalization and therefore no revenue effect to account for.

4.2 The cost analysis performed

As a starting point a cost structure suitable for an ABC product-hierarchy analysis was outlined. In addition to the traditional ABC categories inventory cost was added, whereas facility sustaining cost – not affected by the commonality assessments – was left out. In principle this gave the following five cost categories:

- Direct materials costs
- Volume/unit related activity costs
- Batch related activity costs
- Product sustaining activity costs, which are costs that are neither unit nor batch related but on the other hand still related to the specific component, module, variant or family
- Inventory costs, i.e. costs associated with having an inventory (holding costs, space, heating etc). These are not included in any of the above activities

All five categories are affected by the degree of commonality/variety. Figure 4 is an illustration of the structure of the ABC model for costing modules at Martin. In the ABC literature direct cost is a subcategory of unit-level cost (cf. figure 1). In this application, however, it was decided to separate direct material cost from the activity cost at the unit level due to the conceptually different behaviour in terms of divisibility and avoidability of these cost categories. Furthermore, it is also indicated in figure 4 which categories were expected to yield the highest contribution to the cost differences, and termed primary and secondary areas respectively.

FIGURE 4 INSERTED HERE

In the specific example, a pan module can potentially be reduced from six unique modules to one common module, termed “multi-module”. The new multi-module is an alternative design - thus no historical data is obtainable. In this situation, two approaches to the total cost comparison can be identified:

- One is to estimate the material and assembly costs (operation time) of the new multi-module and then execute the calculation with these estimates. This approach needs, as a minimum, a conceptual outline of the replacing multi-module, which would normally involve input from the product development department and often external component suppliers too. If the cost comparison is going to include internal and external scale and learning curve effects, this approach is necessary.
- Another approach is to exclude an explicit calculation of the materials and assembly costs of the new multi-module and alternatively calculate how much these cost items are allowed to increase to break even with the average cost of the same items for the six modules being substituted. Consequently, the outcome is an estimation of a yearly cost reduction from the changed inventory profile and activities at the batch and sustaining levels. The approach has the advantage of not needing the product development department to articulate a new multi-module design concept as an input to the calculation. The estimate can subsequently be used in product development as the maximum allowed cost increase to cover a potential over-specification of the multi-module resulting in increased materials cost and/or increased assembly costs. This approach is believed preferable in the early stages of scanning the product portfolio for cost reduction potentials through modularization.

In this case, the latter approach is chosen. The cost analysis structure provided in figure 5 illustrates the calculation principle used.

FIGURE 5 INSERTED HERE

The sum of the differences between the cost items from Batch to Inventory in the Unique Modules and Common module columns, respectively, constitutes the Savings potential in the Common module project regarding those cost items, and at the same time the maximum allowable increase in unit level cost (in this case direct material cost and volume related activity cost, i.e. assembly) to off-set potential costs of over-specification.

Figure 6 depicts a departmental-named materials flow at Martin and indicates a number of support departments, e.g. planning, production technique, etc. The departments written in bolded letters are those included in the activity cost analysis.

FIGURE 6 INSERTED HERE

The figure illustrates that the different support departments provide services for all primary function of which the ABC-analysis only deals with the Module Assembly.

The details of the ABC study are as follows:

4.2.1 From resources to activities

In the allocation of resource costs to activities, two situations were separated: the allocation of salaries and other costs related to salaried employees (white-collar workers in the support departments), and the allocation of costs related to production and assembly departments (wages of blue-collar workers and machine costs).

4.2.1.1 Allocation of resources for staff functions (salaried employees)

For the departments using salaried employees the basic assumption is that there is no significant increase in accuracy using the employees' individual salaries as opposed to the average salary in the departments involved. The modest variation of salaries and the homogeneous nature of the working conditions for salaried employees make this simplification acceptable in this specific analysis. Thus the resource cost driver "number of salaried employees" is used in allocating salaries to each department. Most of the other resource costs connected to these departments, e.g. equipment (PC's), rent and training costs (cf. figure 7), are allocated using the same resource cost driver, "number of salaried employees". However, travel costs are traced directly to departments inasmuch as it is already reflected in the chart of accounts of the company.

In the delimitation of activity centres, departments, to include in the analysis the point of origin was the company's organization chart. The activity centres included, focusing on assembly, are "production technique and support", "quality", "planning", "purchasing", and "service", which are all departments normally incorporated in "overhead departments" to assembly and production departments. Other departments are also – in principal – influenced by the degree of commonality, but in this study not considered significant.

The allocation of cost from activity centres to activities within these centres is based on interviews that captured the percentages of time devoted to each activity, and costs are allocated proportionally. Activity names are not shown in figure 7, but appear in figure 9.

FIGURE 7 INSERTED HERE

4.2.1.2 Allocation of resources directly engaged in production and assembly

In the production and assembly resource-costs have to be allocated to the specific activities performed. The initial identification of activity centres within the production and assembly departments (from print production to assembly) are based on the already existing structure within the organization.
As an example of the resource cost allocation, the assembly activity centre is illustrated in Figure 8.

FIGURE 8 INSERTED HERE

The identification of the activities within each of these activity centres has to be sufficiently detailed. The activity catalogue has to capture a number of activity differences:

- It should capture the distinction between product and customer-related activities since some departments have both. Thus it is necessary to identify customer related activities in the design of the ABC analysis in order to avoid having these costs allocated to products.

- The other product segments and assembly departments: Practically all activity centres were addressing two product segments – “low” and “high” complex products – during the period of analysis. Awareness of these differences is important inasmuch as it affects the centres differently. For example, the resources per MRP order within the two segments are the same, whereas the quality department is differentiating the amount of resources dedicated to each, which has to be taken into account in the resource allocation.
- The hierarchy of activities, i.e. unit, batch and sustaining activities.

Thus, the outcome of the first step is the allocation of cost of resources to the individual activity centres and activities within these centres.

4.2.2 From activities to cost objects

Having identified the cost of resources and the related activities, the next step is to allocate the activity costs to the cost objects using activity cost drivers, where each activity is given a separate driver in order to allocate the activity costs to cost objects. These drivers can, as mentioned previously, be either a transaction, duration or a direct charge driver providing different degrees of accuracy. Since this ABC study was the first in the company, it was deemed important to have simple, readily understandable and readily retrievable activity cost drivers. Thus standard production information was used. For example, the unit-related drivers are mainly based on “operation time” (i.e. number of minutes), a duration driver, and the batch-drivers are based on “number of MRP orders”, a transaction driver, as both are available and generally accepted to capture the differences in resource consumption. Concerning the sustaining activities, adequate cost drivers that will reflect the causality from the cost object are more complex to identify and difficult to obtain. For example, there is presently no systematized information or data accumulation during ramp-up and introduction of new modules or end products. One possible activity cost driver was “number of product changes” (a transaction driver) identified by the production technicians during ramp-up, in which case the company actually has a formal document. However, usage of these formal documents varies among the technicians and is generally not believed to be a reliable source for the resources devoted during ramp-up. In the analysis “number of item numbers” (a transaction driver) is chosen as a proxy to assess the product sustaining costs.

Another issue common to all activity centres, and a general ABC consideration, is the question of excess or unused capacity. However, in the Module Assembly department of the company the work processes are very labour intensive with limited investment in equipment and consequently left out in the cost of excess capacity calculation.

4.3 Outcome: Total cost differences between design alternatives

In the following subsections the numerical result of the cost analysis is provided, and the limitations of the calculation discussed. This gives rise to identification of three dimensions in a search strategy for identifying a potentially cost efficient modularization programme beyond the case company. Finally we discuss the prerequisites for cost savings to materialize into bottom-line increases.

4.3.1 Activity costs and the Bill of Activities (BOA)

The documentation of the ABC analysis can be done in terms of a cost sheet that describes the cost of the Bill of Activities, BOA. For each cost object it is possible to document the analysis in a simple and readily understandable form via the BOA of the specific cost object. In the analysis the result is formalized in a BOA for the assembly module. In the following evaluation of the total cost, the cost data of each of the assembly modules are based on the same BOA. As an example of a BOA, figure 9 provides one for pan 1, which is one of the six product-unique components, possibly to be substituted by one common module, multi-module. From such an overview, the information is directly accessible, and thus subject of discussion and general evaluation of quality and validity.

FIGURE 9 INSERTED HERE

Total costing using ABC is obtained by costing each relevant object via the BOA. As such the costing process is repeated for each assembly module that is included in the design evaluation.

4.3.2 Inventory costs

One of the assumptions is that variety reduction reduces inventory costs. However, inventory level interacts with the order policy (the lot-size model applied) and the safety stock level wanted.

In a scenario including parts economics, e.g. a lot-size model with economic order quantity (EOQ), the effect of commonality improvements on inventory level can be determined via the changed conditions of setup and holding costs, and thus obtaining a new optimal inventory level. However, a limitation of the EOQ model is that the model is intended for a single product context and not a group of products. The model is neglecting that setup cost might depend on the sequencing of products. Having a group of nearly similar assembly modules such as the six unique assembly modules would presumably constitute a limited changeover compared to a changeover between different types of assembly module.

The order policy in the case company is lot-for-lot (LFL) - thus no parts economics are included. How do we then assess the influence from increased commonalty on the level of inventory? In the calculation the number of orders for the multi-module is set to the same as the highest volume of the currently unique six modules, which in this case is pan #5 with 39 orders per year.

The safety stock level constitutes the other part of the inventory discussion. Safety stock level and commonality is directly related. Collier (1982) has shown that safety stock for the common module (S_{Multi}) equals the total sum of the safety stock level of each unique module ($\sum S_{Unique}$) divided by the square root of a commonality index factor (C), i.e. $S_{Multi} = \sum(S_{Unique}) / \sqrt{C}$. This commonality factor is exemplified in Figure 10.

FIGURE 10 INSERTED HERE

In the calculation, the interest rate is set at 15%, and a one-week safety stock. Thus the inventory cost is estimated as: (yearly demand/52/$\sqrt{C}$ + yearly demand/number of orders/2) * (material costs + direct assembly costs) * 15%. As mentioned above we are ultimately looking for the maximum allowable increase in unit-level cost (in this case comprised of direct materials and volume/units cost items) for the new multi-module to break even with the current module structure (through savings in batch, sustaining and inventory cost). Therefore, interest on inventory for the new multi-module should actually be found through an iterative procedure. To avoid the iteration and to make the calculation simpler, the materials and direct assembly cost of the costliest of the six unique modules are used as input in the formula above.

4.3.3 Total cost scheme

Thus the total range of activity and inventory costs has been established. The outcome can be depicted as shown in figure 11.

FIGURE 11 INSERTED HERE

The savings potential is found to be DKK 15/unit. This means that costs of direct material and assembly activities may be DKK 15 higher for the multi-module compared to the average cost of those cost items of the unique modules. In other words, this is the amount allowable for a potential over-specification of the assembly module as a necessary means of reducing variety.

As can be seen in the figure a zero-difference is added to the analyses in the volume/units row. *This is a purely case-specific result* which is explained by the fact that there is practically no variation in assembly time between the six current unique modules, and therefore the volume/units related cost is believed to be a good estimate for the new multi-module too. All allowable cost increases are consequently ascribed to materials cost. Thus, in the example, direct material cost of the common module can be increased by DKK 15 per unit above the average direct materials cost of the product-unique modules without jeopardizing the total cost efficiency.

A number of features of the cost calculation should be noted:

- The analysis yields (at least) two insights:
    - Volume is paramount to multi-module profitability. 91% of the allocated costs are volume-driven.
    - About 2/3 (DKK 60,000) of the reduction in activity costs stems from the sustaining area and a little less than 1/3 (DKK 34,000) from the reduction in number of batches. Only a minor part of the cost reduction flows from inventory costs (DKK 8,000). Below, we will comment on the likelihood of these cost savings materializing into savings in spending.
- The calculation has not taken into account the cost of developing the new multi-module, only the yearly “sustaining part” is included. Incorporating the development cost will at first glance reduce the amount that the materials costs are allowed to rise, but on the other hand, these development costs are of an investment character and are to be “written off” over the

lifespan of the module, say 3-5 years, which at least reduces its annual value of influence to 33% to 20% with yearly volume unchanged. Furthermore, we have not taken into account the development cost of the six unique modules to be substituted for the simple reason that these costs are sunk. On the other hand in the more general case, where neither the six product-unique modules, nor the common multi-module have been developed, R&D cost of the "common" should be weighed against the sum of R&D costs for all the unique modules.

- It should also be noted that no learning curve effects have been incorporated. It follows from the calculation procedure where the process times, as mentioned above, are based on the current time used in the most time consuming of the unique modules. In case all six product-specific modules had the same yearly volume, the potential learning curve effect would be six times as fast per calendar period with a common module. However, in the actual case these effects are deemed small and insignificant.
- No learning curve effects in production up-stream and down-stream from the Module Assembly (i.e. Components; Metals & Electronics and Final Assembly, respectively, cf. figure 6) are included either. The reason is again that these effects are deemed negligible in the particular case. On the other hand, the reduced batch and sustaining costs both up-stream and down-stream ought to be taken into account in a more elaborate calculation of the total cost effects.
- Finally, the calculation assumes the cost of updating the multi-module – as expressed in the sustaining costs of the multi-module – is the same as for each of the unique modules. This is implicit in using a transaction driver to calculate "product sustaining costs", because each transaction (update) is costed equally. This is probably not realistic, because the multi-module update most likely is more complex (more costly per update), but also because one might expect a higher frequency of updates, i.e. lower than the sum of updates of the unique modules, but higher than the individual product-unique module updates.

In the specific case the material costs of the common module are allowed to increase by DKK 15 which amounts to only 3 percent of present materials cost. This is truly a limited cost change, not least considering that the most costly of the unique modules has a direct material cost of DKK 450. Thus, the outlined modularization plan is not viable. Even though it looked promising from a technical point of view – cf. figure 3 – the project is deemed unprofitable.

4.3.4 General characteristics of cost efficient modularity

Three general characteristics of cost efficiency of (internal) modularization can be deduced from the example:

- The more types of product-unique modules the common module substitutes (in the example there are six) the more likely it is that it will be profitable to implement the use of the common module. It follows from the fact that the more product-unique modules substituted, the more savings we potentially have at the sustaining and batch levels and to some extend also at the level of inventory costs (unless the increase in cost of stocked units offsets the decrease in the amount of stocked units which, however, will have to be curtailed by volume discounts on direct materials and unit level costs due to learning curve effects).
- The less the total number of units the common module will substitute the higher the unit-level costs of the common module can be in comparison to the average unit-level cost of all the product-unique modules being substituted. The reason is that the cost of sustaining, setting up and safety stocking the unique module in this situation is higher expressed per unit.
- The bigger the difference of unit-level cost among the product-unique modules, the less likely it is that the least costly of the product-unique modules will be part of the group of modules to be substituted. Alternatively, the costliest of the products in the group (in terms of unit level costs) must be discarded from the group. This is a consequence of our assumption that the unit level cost of the common module will be at least as costly as the costliest of the product-unique modules that it substitutes. The reason is that in this situation, it follows logically that the increase in total variable costs of the least costly unique module will outweigh the cost savings (obtainable at this module's sustaining, batch and inventory level) sooner, the bigger the difference in unit-level cost of the otherwise unique modules is. This effect will occur more often, the larger the volume of the product-unique module is. This in turn means that the higher the variance in unit-level cost among the types of product-unique modules the less likely – ceteris paribus – is the overall profitability of the modularization strategy.

Combining these general characteristics, a cube can be drawn to illustrate the segment of a portfolio that may show the highest, or the lowest potential for profitable modularization efforts, cf. figure 12:

FIGURE 12 INSERTED HERE

The cube highlights that the highest (lowest) profit potential of product modularisation is where (i) commonality between otherwise product-unique modules are high (low), and where (ii) volume and (iii) difference between unit-level cost of otherwise unique modules are low (high).

4.3.5 Avoidability and divisibility of resources

When we take the calculations at face value, and allow the materials costs of the multi-module to be up to DKK 15 higher than the average materials costs of using the specific modules, this rests on either of two conditions: (i) that the difference in costs at the sustaining, batch and inventory levels in the two modular structures will materialize into the same amount of savings in spending, since it is the latter that brings about the bottom-line effect on the income statement. Or (ii) that the resources freed up can be redeployed in other profitable activities.

The situation referred to by condition (i) demands that the resources are avoidable and for that to be met, the divisibility of the resources must be at a level, where separable resource units are at least the size of (as small as) that part of the resource one wants to dispose. In addition we have to assume that management are willing to actually let go of these resources, mainly manpower. Especially the divisibility assumption is rarely fulfilled, when only minor changes to the modular structure are contemplated, since this often entails only fractions of resource units. Low degrees of avoidability and divisibility are characterizing the very situation in the case calculated. Thus, the case company needs a wider modularization programme to meet condition (i). On the other hand, as pointed out above, this lowers the chance of the whole modular strategy to be cost efficient due to the increased likelihood of higher variance in unit-level costs. -But it also pulls towards higher potential if more unique modules are substituted.

In order to meet condition (ii) the company must be facing an increasing demand for its products, or alternatively be able to utilize capacity in other ways (e.g. insourcing activities, R&D activities, subcontracting, etc.). As long as this is the case, the degree of avoidability and divisibility of resources does not enter the picture. This is the situation in the case company, where resources freed up can relative easily be deployed in other activities.

5. Problems with ABC beyond the case application

This section points out two potential problems using ABC in the cost assessment of modularity which is not addressed in the case. The first addresses the handling of R&D cost within the ABC model, and the second discusses the added complexity of product-profitability descriptions, when the degree of modularization is extended.

5.1 Placement of R&D cost in ABC

The ABC model includes all costs with the exception of cost of unused resources (already discussed in section 3.3 and 4.2.2), and cost of R&D for completely new products (Cooper and Kaplan, 1988b:101-102; Kaplan, 1988:65). However, the idea is still to include R&D costs used on *existing* products and product lines. This brings about two questions: (i) how is the discretely different R&D costs separated in the context of modularization; and (ii) if not included in ABC, how can they be taken into account in the decision of whether or not to pursue modularization?

Question (i) is not straightforward to handle with the "simple" criterion given in ABC. Modularization in essence defines a wider scope of product development activities than simple one-off projects, and also in some instances cuts across product lines/families (e.g. a common chassis across VW, Audi etc.). Thus it seems to become contingent on the specific situation whether or not R&D costs used in modularizations projects are included in the ABC analysis.

Whether or not the R&D costs are included in ABC, management has to take the R&D costs into account when deciding on the direction and level of modularization. This relates to question (ii). Figure 13 in principle illustrates that both short term cost consequences (operational level) and long term cost consequences (investment level) of modularization may potentially be contributing to either a decrease or an increase in total costs. In principle it is all weighted together in a capital budgeting exercise, where one compares the cost of a modular versus a non-modular product structure within the planning horizon. This is, of course, much easier said than done.

FIGURE 13 INSERTED HERE

Garud & Kumaraswamy (1993, 1995) in their framing and discussion of the concept of "economies of substitution" point to a number of effects to take into account. According to these authors "economies of substitution exist when the cost of designing a higher performance system through the partial retention of existing components is lower than the cost of designing the system afresh" (Garud & Kumaraswamy, 1993:362), and argue that modularization is essential for realization of these economies. The main benefit from modularization is that "modularization minimizes performance problems via limiting the incorporation costs from incompatibility to only those issues that were not anticipated while designing the standard interfaces" (Garud & Kumaraswamy, 1995:96). On the other hand, modularization efforts are not free, and especially three groups of activity costs will normally increase: (i) initial design cost, which might be up three to ten times higher compared to designing an object for one-time use only (Garud & Kumaraswamy, 1995, citing Balda & Gustafson, 1990, and, Kain 1994), (ii) testing costs, which are typically higher for reusable modules compared to one-off components, and (iii) increased search costs caused by the increased difficulty for designers to locate reusable modules. Also, one should be aware of "strategic" cost types that may be associated with modularity, e.g. path dependant innovation (Henderson & Clark, 1990), or lower rate of innovation (Hauser, 2001).

5.2 Description of product profitability with products of modular structure

Following the idea of the ABC hierarchy, the analysis of product profitability also becomes hierarchical. This means refraining from allocating costs which are common to a number of cost objects (modules or products) among these objects. Any allocation method (based on revenue, number of units, direct labor hours etc.) is bound to be arbitrary insofar as there is no cause and effect relation between the costs and the objects. Instead one should summate the contributions from all the relevant products and deduct the common cost as an aggregate figure. Figure 14 illustrates the two opposite procedures.

FIGURE 14 INSERTED HERE

The arbitrary allocation in figure 14 occurs when higher-level costs are allocated to lower levels, for example, when batch costs are divided by the number of units in the batch, and then added to the unit level costs. The same can be done at all levels, but this will all be arbitrary.

The margin analysis starts from the unit level. The approach is first to subtract from the revenue of each product unit, the corresponding unit level costs and then aggregate the resulting margins across all products in the batch. Secondly, the batch level expenses are subtracted from the aggregate unit level margin, and so on. The outcome is that each product unit/product batch/product/product group (family), and the whole plant has a related margin.

Addressing the profitability hierarchy presented with a modular structure in mind, it can be seen that the batch cost and sustaining cost of modules can be placed only at the product- or product-family level which contains *all* products using the module. Therefore, when we have an extended modular structure, most of the batch and sustaining cost are placed at very aggregate levels in the profitability analysis. With a normal cost structure this means that most of the individual products in the product line will show a positive margin which, however, does not prevent the total product-line to run with a deficit. At first glance this seems strange, but is actually a correct signal. The decision of management becomes more a matter of keeping or skipping the whole product-line and not the individual product in the line. Dropping one or more of these (with positive margins at the product level), which one would be inclined to do, if we had allocated the cost (due to negative “profits” after arbitrary allocations), will actually deteriorate total profitability.

6. Conclusion and the need for further research

The paper accounts for an Activity Based Cost (ABC) experiment in a case company – Martin Group A/S – to support decision-making concerning product modularity. The cost analysis pursued makes use of ABC’s activity and cost object hierarchies, but the outcome of ABC-analysis is communicated as “unit-level” information in terms of the maximum allowable increase in cost of materials for the over-specified potential common module compared to the average materials cost for the substituted product-unique modules. This information is instrumental in providing quick and easy-to-understand insights to designers, and can easily be expanded to encompass all unit-level costs. However, providers of this information should be aware of the prerequisites for these data to be relevant, i.e. that freed-up resources can be either taken out of the organization or redeployed in other profitable activities. The fulfilment of these prerequisites should be weighed by top management, before use of the calculations procedure is released for decentralised use in the organization to avoid distorted calculations.

If the prerequisites are satisfied, and if in addition it is assumed that an over-specified common module is at least as costly as the costliest of modules that it will be able to substitute, the paper identifies that the most profitable modularisation efforts can be put where commonality between otherwise product-unique modules are high, and where volume and difference between unit-level cost of otherwise unique modules are low.

The paper also points to two areas where caution should be exercised in using ABC in assessing the economics of modularisation. R&D cost of developing the initial common module is a common cost to all units and all periods in which the module is put to use. Thus, these costs are of an investment character and will in a "calendar-based" system as ABC be difficult to incorporated without arbitrary allocations to periods and/or products. In addition, it is argued that the product-profitability hierarchies resulting from extended modular structures are more complex than described in literature. This is mainly because sustaining costs of more common modules will only appear at very aggregate levels, i.e. above the level of the individual products, in non-arbitrary cost assignments; and this placement is essential to avoid distorted information.

In the specific case the materials costs of the common module were only allowed to increase by 3 percent of present materials cost. In the specific company this was deemed infeasible. This result provides tentative support to the existence of a *modularity paradox* suggested by Jørgensen (2004) as a parallel to Skinner's (1986) *productivity paradox*, which relates to the process-based strategy to mitigate the negative effect from increased variety (Fisher *et al.*, 1999). We suspect that the same type of phenomenon is apparent in the product-based strategy of modularization. More research is needed in this area.

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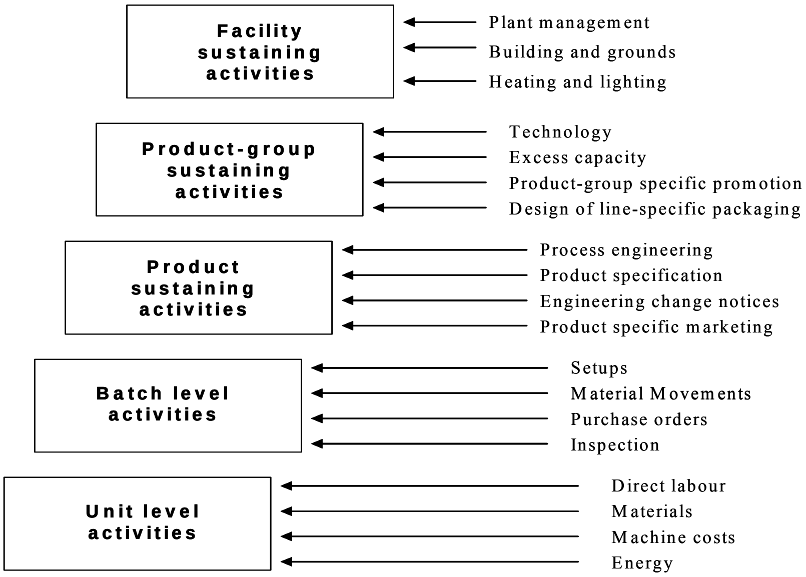

Figure 1: The hierarchy of activities and expenses, which outlines the elements of the non-volume activities into four levels. Combined and adapted from Cooper & Kaplan (1991a) and Kaplan in Robinson (1990).

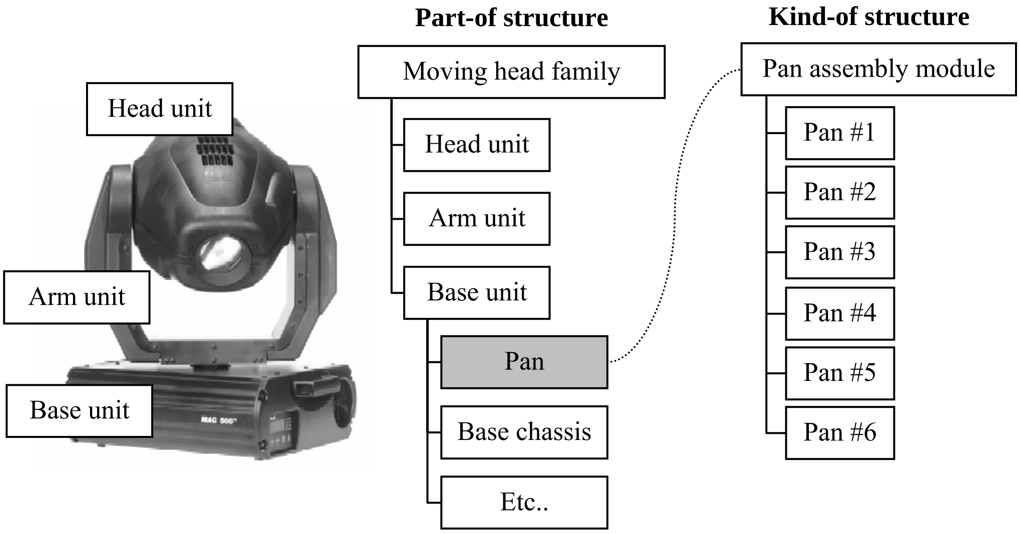

Figure 2: The product family analyzed in the case is a so-called "moving head". The base unit consists of several assembly modules. The product family has six different variants of the pan assembly module.

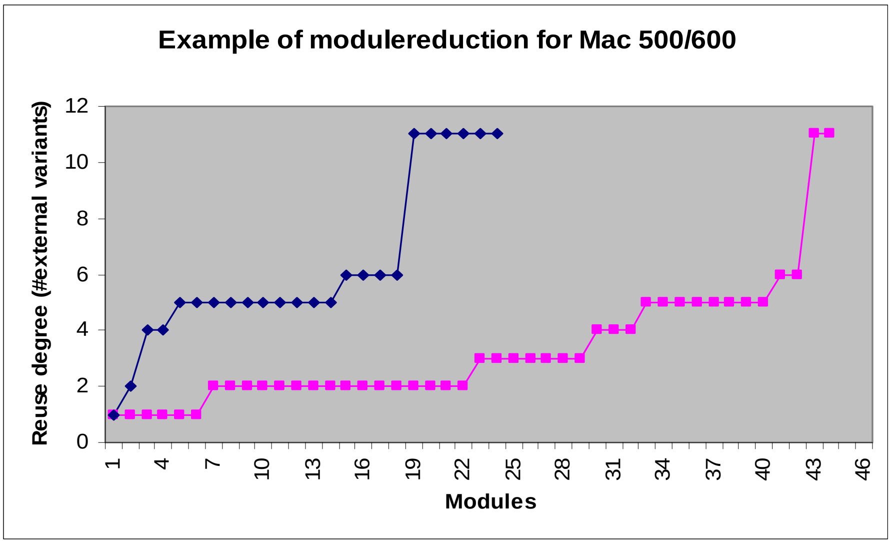

Figure 3: An overview of the commonality degree of the assembly modules. The two lines illustrate the present situation and a scenario with an improved commonality.

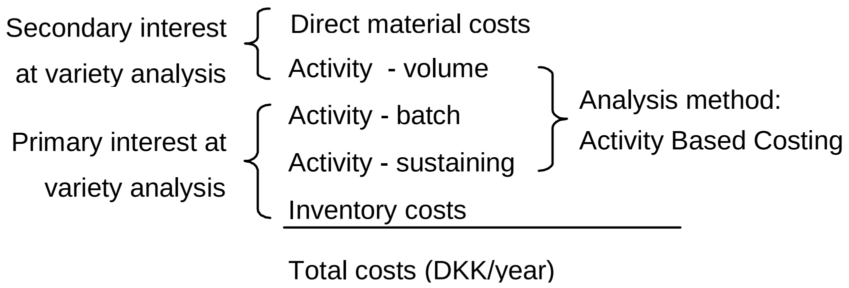

Figure 4: The cost structure applied in the Martin case.

Costs	**Module 1**	**Module 2**	**Module ...**	**Module n**	**Total, unique modules**	**Common module**	**Difference**
Direct material							
Volume/units							
Batch							
Sustaining							
Inventory							
Total cost							
Savings potential							

Figure 5: Illustration of the comparison of estimated total costs of two design alternatives, one based on "n" unique modules, and the other based on an over-specified common alternative.

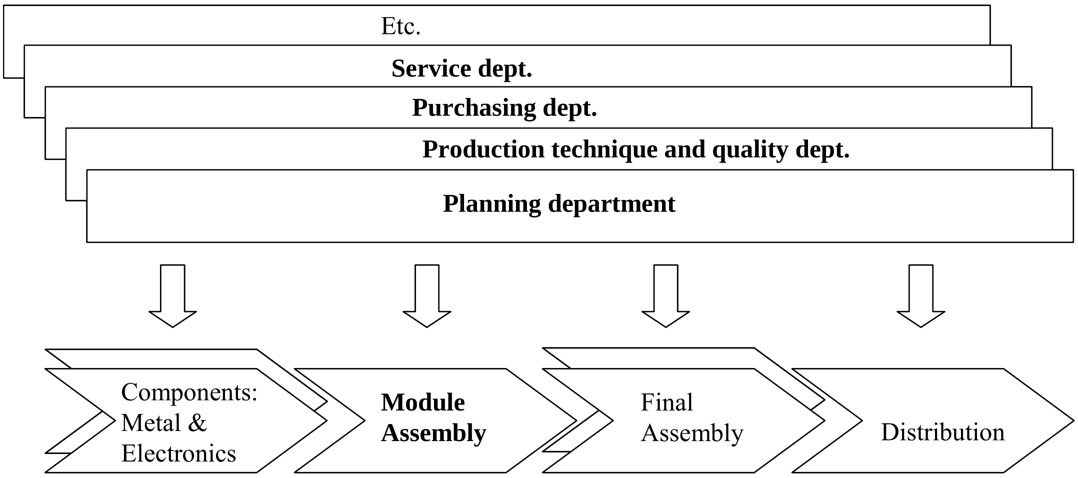

Figure 6: The material flow and support departments at Martin Group. The departments written in bolded letters are included in the reported ABC study.

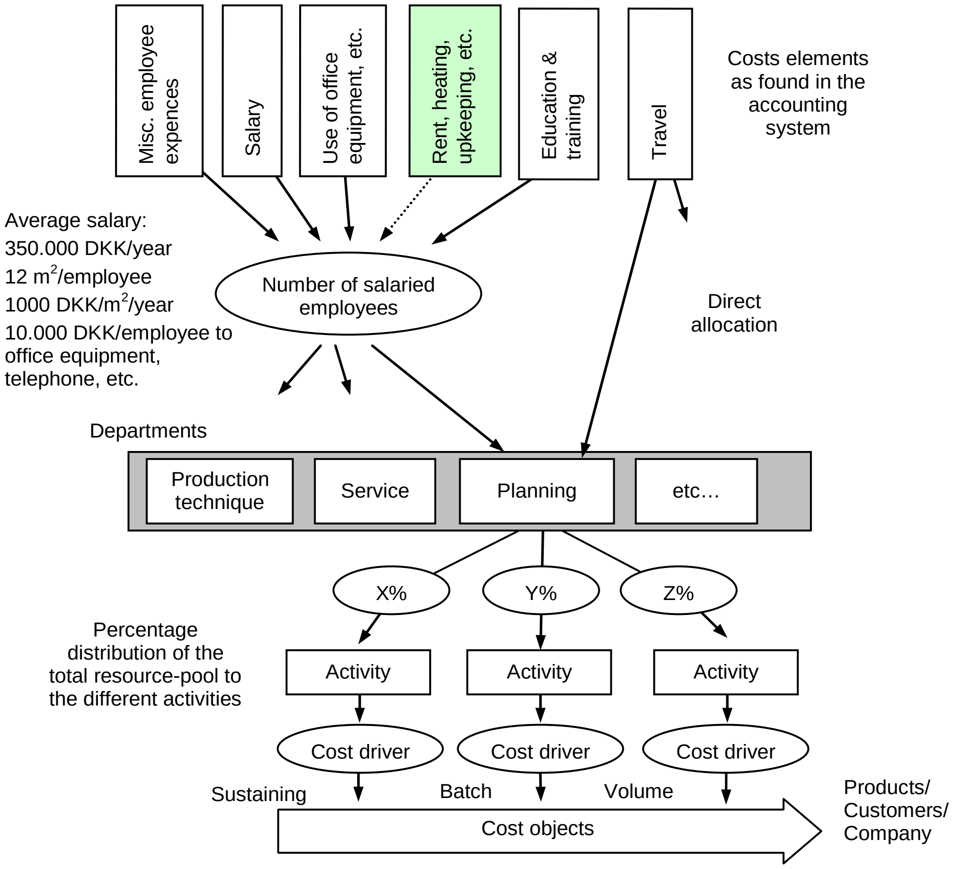

Figure 7: The allocation of resource costs in staff functions

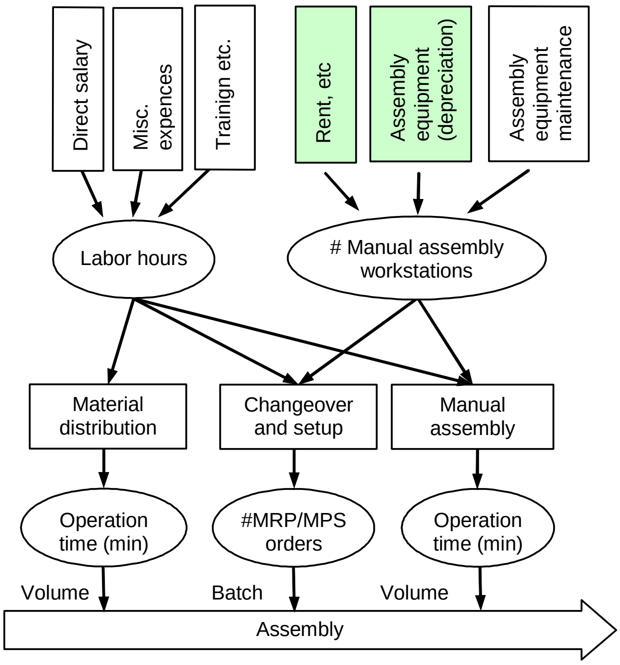

Figure 8: The resource distribution for manual assembly.

Item: Pan1	**Item#:**	**5521xxxx**					
Activity centre	Activity	Activity type	Cost driver	Driver rate (DKK/unit)	#driver rates	Total (DKK/year)	%
Production technique and quality	Support and problem solving, MOST analysis	Sustaining	Number of items	9,350	1	9,350	7%
Service (Aarhus)	Documentation, website and manuals	Sustaining	Number of items	482	1	482	0,4%
Planning	Planning and scheduling	Batch	Number of orders	25	34	850	1%
Foremen	Support from foremen	Sustaining	Number of items	1,950	1	1,950	2%
Assembly	Direct assembly	Volume/units	Operation time (minutes)	3.08	32,528	100,186	78%
	Material distribution	Volume/units	Operation time (minutes)	0.16	32,528	5,204	4%
	Setup/ changeover	Batch	Number of orders	299	34	10,166	8%
					Total	128,188	100%

Figure 9: Example of the cost of BOA, Pan 1. The outcome of the ABC analysis as depicted in figure 7 for the salaried employees and figure 8 for the assembly are merged. The salaried employees constitute the first four activity centres of the BOA.

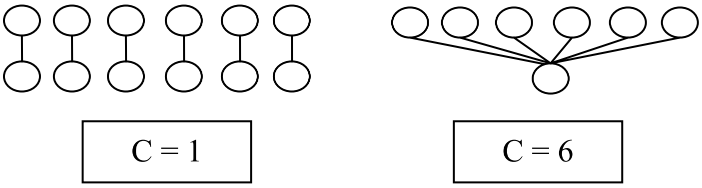

Figure 10: The commonality index factor as defined by Collier (1982). In the given example of having six assembly modules with no reuse an index C=1 is obtained. Having the maximum commonality an index of C=6 in the example is obtained.

	Module 1	**Module 2**	**Module 3**	**Module 4**	**Module 5**	**Module 6**	**Total, unique modules**	**Common module**	**Difference**
Direct material									
Volume/units	106 (79)	14 (45)	29 (60)	4 (19)	154 (83)	36 (61)	343 (72)	343 (91)	0
Batch	11 (8)	4 (13)	5 (11)	4 (20)	13 (7)	10 (16)	47 (10)	13 (3)	34
Sustaining	12 (9)	12 (38)	12 (24)	12 (60)	12 (6)	12 (20)	72 (15)	12 (3)	60
Inventory	5 (4)	1 (4)	2 (5)	0,3 (2)	7 (4)	2 (3)	18 (4)	10 (3)	8
Total cost	134 (100)	31 (100)	48 (100)	20 (100)	186 (100)	60 (100)	478 (100)	378 (100)	100
Savings potential per unit	(478,000-378,000)/6,600 = DKK 15/unit								15

Figure 11: Comparison of estimated cost of the two design alternatives and calculation of potential savings excluding direct materials costs. Yearly volume is estimated to 6,600 units.

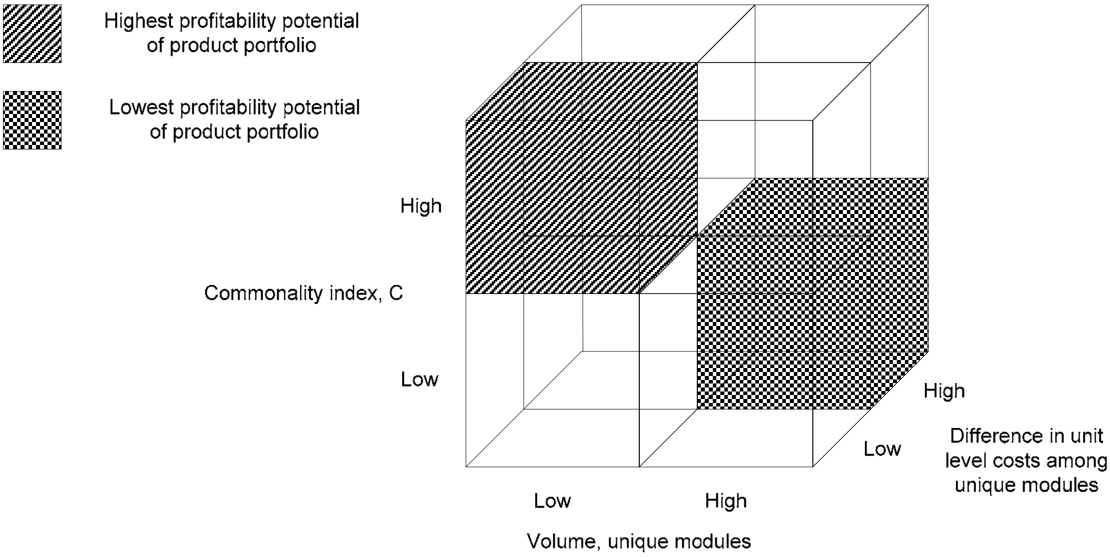

Figure 12: Segmenting product portfolio in terms of identifying profitable modularization potential.

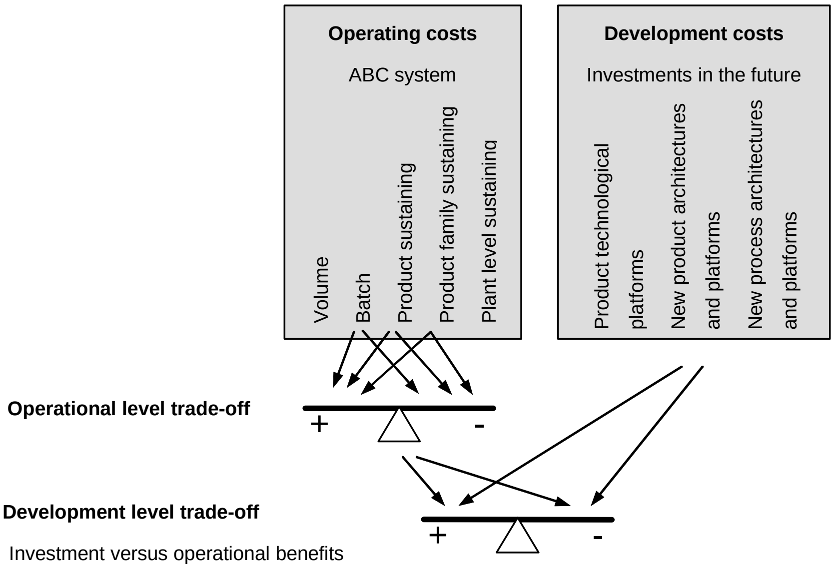

Figure 13: A conceptual framing of the levels of trade-offs involved in the evaluation of total cost impacts of commonality changes.

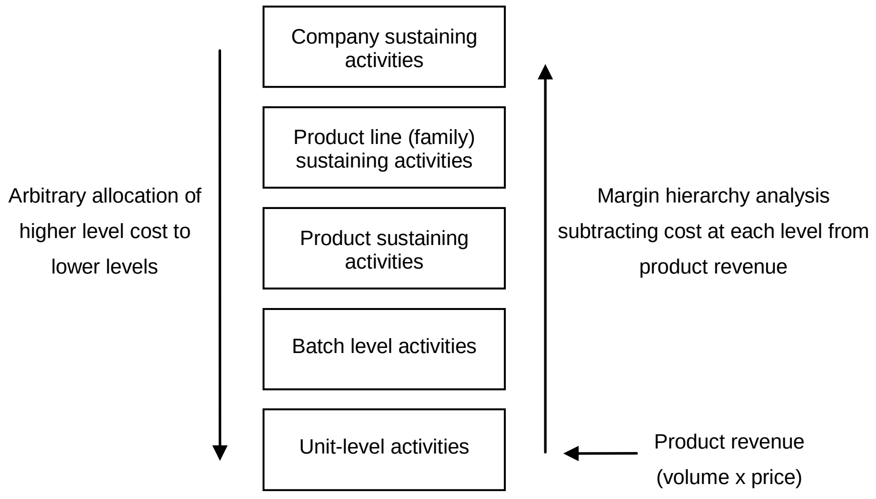

Figure 14: Illustration of arbitrary allocation versus hierarchical contribution margin analysis in situations with hierarchies of activities.

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