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MODULARIZATION - NOT ONLY A PRODUCT ISSUE

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Abstract

The purpose of this paper is to identify important modularization areas and issues, for which there is a need of further research. These are areas that are of crucial importance in accomplishing and implementing modularization in manufacturing companies. The empirical data for this paper comes from two in-depth case studies, at two vehicle-manufacturing companies, and an interview based survey with eight additional companies. In the first case it was found that product service demands when the product was modularized. In the second case it could be concluded that even if a module is designed in a cross-functional team, the cross-functional work must be continued during the products whole lifecycle; otherwise the benefits with modules can be eroded. The final finding is that companies that have modularized its products seldom have change their product development process so it support the modular product. In the paper it is concluded that modularization is an issue that concerns more than just the product, also the organization as well as the product development process are of great importance. The company's organization and product development process also have to be adapted to better suite modularization, and the development of modularized products.

Keywords: modularization, organization, product development process

1 Introduction

A constantly increasing product variety forces companies to deal with complexity. A complexity that is further increased due to, for example, reduced product life-cycles ([1], [2]) variety the more complexity (and thereby also increased costs) is added to a company's operations, e.g. to the product development and the production process. Companies have adopted the concepts of platform development and modularization in order to deal with this complexity. These concepts partly aim to develop variants in a leaner way. Even though these concepts have been tested and discussed during several years, both in practice and in academia, most companies and literature focus solely on the product [3].

1.1 Background

There is a clear product focus in the many different modularization methods [4], [5], [6], [7]. The focus in these methods lies in decomposing an existing product and then integrating the components into modules. Even though demands from different parts of an organization are sometimes included in this modularization, the focus clearly lies in engineering design aspects. The product focus in these modularization methods becomes even more evident in comparison to product development process literature (cf. [8], [9], [10], [11]).

Literature in the area of product development processes also include, in addition to product related activities, other activities that are necessary in order to have products that are proper for marketing design, manufacturing design, operations network design etc. This literature most often considers the product as a black box, which erases the engineering design aspects. The same pattern can be identified in the multiple product development process for modular products. Only a few attempts have been made to describe this multiple product development process. The findings in these studies can be divided into two categories; one focusing on strategic issues [12], [13] and another focusing on engineering details [14], [15]. It is also hard to further develop modularization without having a supporting product development process [16].

Despite the efforts to find activities for modular product development, there is still a lack of literature describing activities that aim to make use of the output from strategic activities and putting them into specifications for each product [3], [15], [17]. According to Hansen et al. [18] and Sundgren [13] the lack of product architecture management activities is one reason why many companies fail to manage the product architecture in a proper way. In addition, the product development organization would be affected by a platform and modularization strategy. The relationship between technology (e.g. products) and organization in general have been addressed and included in several organizational models (cf. [19]). Sanchez and Mahoney [20] use this in their modularization research. They argue that organizations ostensibly design products, but also that products design organizations, because the coordination tasks implicit in specific product designs largely determine the feasible organization design for developing and producing those particular products. The organizational dimension is seldom considered in the literature addressing management of modularization. Concurrently, many companies seem to fail in their modularization efforts partly because they underestimate the effects, for example the wide effects that modularization has on different organizational functions (c.f. [18], [21]).

1.2 Purpose

The present literature gives only a fragmented image of how modularization actually should be managed in manufacturing companies. Ulrich [22] argues, in his often-cited article, that modularization is a topic that rests on knowledge from different research communities. Detailed case descriptions about how companies actually work with modularization is seldom found in the literature.

The purpose of this paper is to identify important modularization areas and issues, for which there is a need of further research. These are areas that are crucial in accomplishing and implementing modularization in manufacturing companies.

2 Method

We have spent the last five years doing research in the area of modularization. During this time, in-depth case studies were carried out at two vehicle-manufacturing companies (see [21], [23]). Both firms implemented platform and modularization strategies a few years back before these studies and thereby the organizations have gained substantial experience. In addition to these results, we have done an interview-based survey with eight companies. This survey includes manufacturing companies having at least a development site in Sweden, and the companies also list modularization as an important part of their corporate strategy. These eight companies will in the following be named Company A-H. These interviews were semistructured, and focused on capturing their own experience of implementing and using modularization in the company.

In this paper we are not aiming to present quantitative data. Instead, more qualitative findings from case studies will be presented. The choice of the case study approach, and focus on more qualitative data, is appropriate since our interest concern “how” and “why” questions [24]. The purpose of this paper is explorative in its nature, and hence a case study approach is suitable.

3 Case Findings

In our research, we have found that, in addition to the product, the product development process and organizational aspects are equally important to take into account when modularizing. To illustrate these findings, we will present some cases in this chapter.

3.1 Organization

This section regards two different cases that are from the in-depth case study done at Volvo Car Corporation (VCC). The first case describes a service organizational trade-off, and the second one is describing a module change. Both of these cases illustrate organizational differences, differences that are important to be aware of when modularizing.

3.1.1 A Service Organizational Trade-off

In Figure 1, the structure of a modularized product is visualized. Here a module consists of two different sub-modules, and each sub-module contains a number of components in the product that have been grouped for certain reasons. Therefore, sub-modules can be considered smaller modules on a lower level of product aggregation.

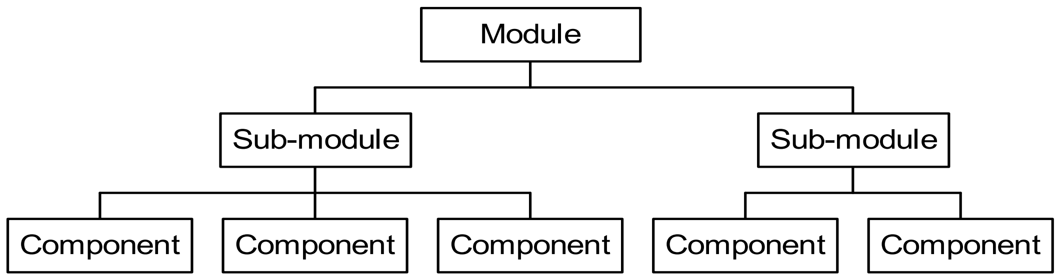

Figure 1: The structure of a modularized product

In the in-depth case study at VCC (see [21], [25]) it was found that a number of components that had been integrated very successfully for the Production function but it was not so good from a Service function perspective. In order to fulfill the service requirements of easy overhaul and repair, one of the components in the module had to be excluded from that module and placed somewhere else in the product. To illustrate, one of the components in the left sub-module in Figure 1 would be moved to the sub-module on the right hand side. This product change had not been accomplished if not the Service function had participated already in the early stages of the product development process.

At the case company VCC a number of product modules were studied, and the service costs for them were calculated. In the analysis of these cases the total service cost (summing the different service-related costs) was plotted as a function of the overhaul and repair frequency (see Figure 2). The exact figures of total cost and frequency had to be left out here for company-confidential reasons.

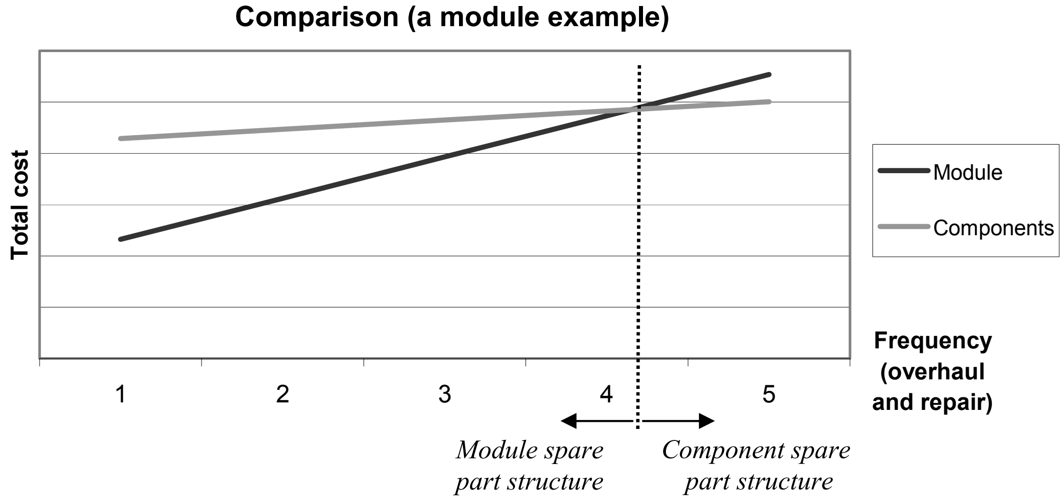

Figure 2: The total service cost for one of the modules

The results from these case studies are exemplified with Figure 2, a figure representing one of the modules at VCC for which the service (overhaul and repair) costs were calculated. For certain reasons the company decided that some components should be integrated into a module; these were components that had not previously formed a module. These components also became a module in the production process, meaning that they were pre-assembled and delivered as complete units to the final assembly line.

In figure 2 it can be noticed that a module spare-part structure should be chosen if the overhaul and repair frequency is under 4, but if it is higher than 4 a component spare-part structure would, from a service perspective, be the most profitable choice. However, when the Service department made this calculation they found that there were components in the module that needed to be repaired or replaced quite often; the overhaul and repair frequency was high. It scored higher than 4 in Figure 2, and hence a component spare-part structure would be most profitable from a service perspective. Therefore, they would like to exclude the components having the highest frequency of overhaul and repair from the module.

The main major finding in this case study concerns the fact that service requirements must be taken into account when modularizing, because there are effects on service-related costs from a modularization. A problem is that modularization can affect the Service function, and its requirements, negatively. In other words, modularization may be beneficial from an R&D and Production perspective, but at the same time effect the Service function negatively. The case description shows that there are effects of modularization on service-related costs. One must be aware of this when doing the modularization; otherwise sub-optimization can occur!

Further, it was concluded that, for the Service function, there is a trade-off that needs to be managed: between few spare parts (with limited accessibility in the product) and many spare parts (with high costs for handling them all). It is a challenge to find the most profitable spare-part structure. The more spare parts, the higher costs for handling them; but if too few spare parts are chosen, i.e. modules with a lot of content, the accessibility of single components is limited. With only a few spare parts it is possible to decrease the costs for developing service documentation, and to train the mechanics to do the work; however, if the overhaul and repair frequency is rather high for a single component in one of the modules, it will be very expensive for the company as well as for the customer to replace the complete module when only a single component is broken.

Legislation was the reason why these components were integrated in one module, and hence the components were necessary to become a service (spare-part) module. But, this had large negative effects on the Service organizational function. Hence, one need to be aware that a module that is appropriate for the R&D function can cause large negative effects on other organizational functions, negative effects that are larger than one might expect.

In this case service demands were not included when modularizing the product, and therefore disadvantages occurred. The lack of inclusion of service demands can be partly explained by the lack of communication between different organizational units, since the existing modularization process did not facilitate this type of communication.

3.1.2 A module change

During the in-depth case study at Volvo Car Corporation (VCC) a study was made about one of their existing modules, a module that was in on-going production. This case shows that there are cross-functional effects when the module is changed or re-designed in some way. The case shows that the module changes was intended to give performance improvements for the purchasing and the R&D organizational functions at VCC. However, the results from this case study show that the effects were large; larger than was estimated before the change was made. The changes also had effects outside the purchasing and R&D functions that had initiated the changes; negative effects also appeared in the Production function of the company. This change is an ‘opposite’ modularization, meaning that a good existing module was made more integrated, and less modular. However, the findings in this particular case study are still interesting as a lesson that modularization will affect different organizational functions in a company; modularization is not only a product issue, it is also an organizational issue.

The object of this study is a change of a part of a car that formerly was a complete module. This module was formerly assembled as a complete module at a pre-assembly station before it was assembled to the car body. For cost saving reasons some components were separated from the main module. The separated components were instead assembled into the car body after the main module had been attached to the car body. This module change is has also been described by Moestam and Persson [26] and by Moestam [27].

The change process

During the spring 2000 there were a number of on-projects rationalization going at VCC. They mainly aimed at decreasing the purchasing and assembly cost. One of these rationalizations regarded decreasing the purchasing cost for the some components belonging to the analyzed module. By changing the design of these components there could be a large decrease of the purchasing cost.

A cross-functional development team, a module team, made the original design of the module. This team consisted of representatives from the Purchasing, R&D, Production, and Service departments. The purpose with the cross-functional development was to have a module that was based on requirements from all the company’s main functions (design, production, purchasing and service) not only on design requirements. The investigation that resulted in the design change however, was not made by a cross-functional team. Instead, that investigation was initiated and performed by the R&D department. It could also be noted that there were no processes for handling module changes. The same pattern could be seen regarding the responsibility for the module. There was no one in the organization that had the responsibility to monitor the module in the steady state phase.

In the following the result of the change will be presented, according to quality, assembly time and lead-time, fragmentation, ergonomics, and cost respectively. In the study of the change of the module both positive and negative effects have been identified and analyzed. The results of this change are visualized in Figure 3.

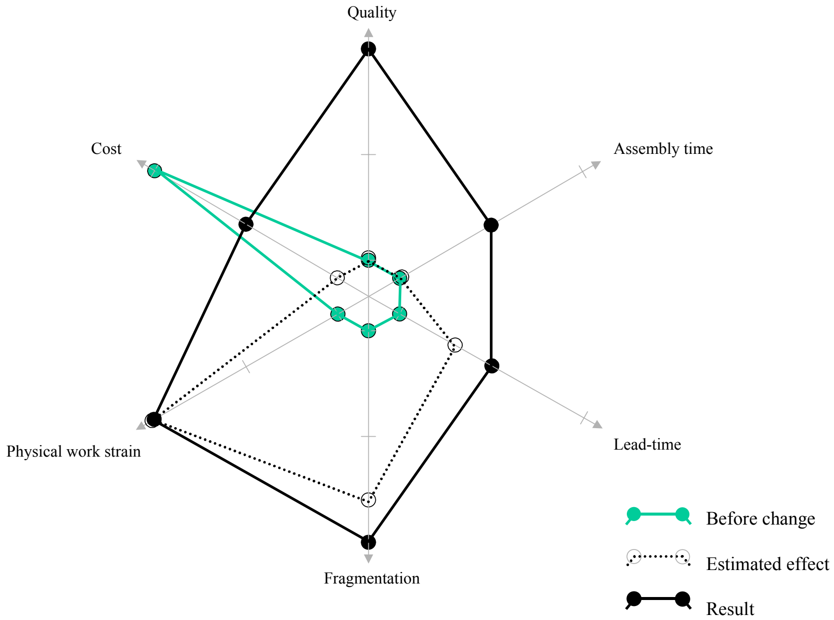

Figure 3: The levels of the parameters

This figure includes the situation before the change, the estimated effects of the change; and finally the actual result that was measured when the change had been accomplished. The largest differences between estimated effects and the actual result are for quality, physical work strain and cost. Hence, these three 'performance objective' will be further explained in the following.

Figure 4 illustrates the general principle that is used in the following figures related to each parameter. The level of each parameter is expressed on a scale ranging from low to high. The levels of the parameter are pointed out by dots before the change, the estimated level due to the change and the actual result after the change.

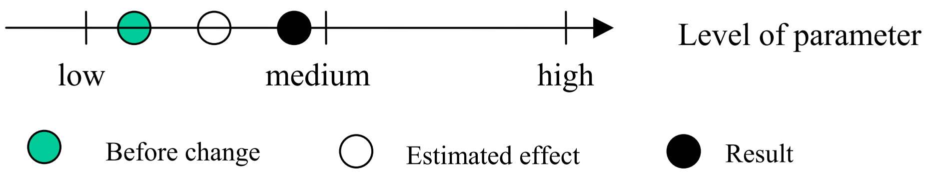

Figure 4: Illustration of principle for the following figures

The level of each parameter is relative and the aim is to show the degree of improvement or deterioration caused by the change. The judgments of the different parameters are also relative to each other considering seriousness of problem or importance of positive aspects. These judgments are based on the results from interviews done at VCC.

- Quality

Figure 5 illustrates the level of quality problems before the change, the estimated effects of the change and the results of the change. Before the change the quality level regarding the analyzed module were not considered to be a problem. The level of quality problems before the change can therefore be considered to have been *low*. In the estimations of the effects of the change the number of quality problems *was not expected to increase.* The actual quality result after the change was *much poorer* than what was expected and today it is a problem.

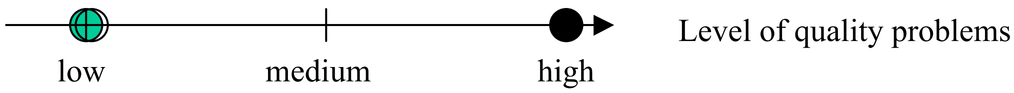

Figure 5: Change of quality problems

- Physical work strain

Figure 6 illustrates the level of physical work strain related to the assembly of the analyzed module that was changed. The figure shows the physical work strain before the change, the estimated effects of the change and the result of the change. Before the change the assembly at the pre-assembly was considered to be non-problematic. It can therefore be considered to signify a rather *low* level of physical work strain. The Ergonomist's statement clearly points out the *drastic deterioration* of physical work strain that the change would indicate. The result is just *as bad* as the Ergonomist estimated that it would be.

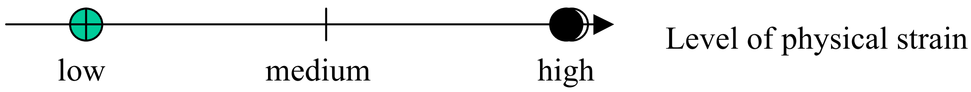

Figure 6: Change of physical work strain

- Costs

Figure 7 illustrates the level of total costs related to the assembly of the components in the module. The figure shows the cost before the change, the estimated effects of the change and the result of the change. Before the change the purchasing costs for these components can be considered to have been *high*. The estimations done before the change pointed at a big saving, meaning *low* costs. The actual result is *not as positive as expected*, due to unexpected costs for quality problems, ergonomic issues and increased assembly time.

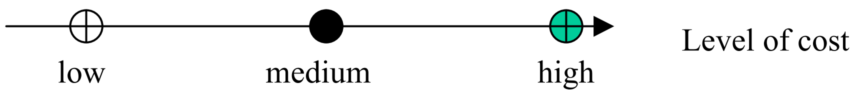

Figure 7: Change of cost

The estimates of the change showed considerable potential savings due to decreased purchasing costs. The costs related to quality would increase somewhat, but not considerably in relation to the savings. The assembly time was not estimated to increase and the increase of lead-time was not considered to become a problem. The working situation in the assembly shop would become worse due to a higher level of physical strain and fragmentation of work tasks. But, neither the physical work strain nor the fragmentation was regarded to be sources of more quality problems or increased costs.

This case description shows that there were large differences between some of the estimated effects and the actual effects. Even if this case represents an 'opposite' modularization (a part of the product that used to be very modular was made less modular) learning from modularization can still be made. This case indicates that it is important to make holistic evaluations of possible design changes before changes are carried out in order to reach efficiency in the production system. This study clearly shows the risks of making product changes without making a thorough analysis of the consequences. As this study shows, a measurement such as cost is too limited to estimate the effects of a product change.

This case shows that is was proper to re-design this module interface from a Purchasing and an R&D perspective. But, the chosen module interfaces implicated large negative effects on the Production organizational function. The product development of the product had been a highly cross-functional process, supported by a cross-functional development organization. But, when the product was in the steady state, no process or activities to secure the long-term modularity existed. The only link between the different organizational functions was the product.

Negative effects occurred that were lager than one might have expected before the change of the module interface. A module interface change that actually was to make a modular part (or chunk) of the product more integrated, and less modular. The designers that made the changes had no decision support considering total cost for the company. Therefore, the change decision was made even though it increased the total cost for the company.

3.2 Product development process

Another area where several companies have had problems regards how to support modularization in the product development process. In the following, different aspects of identified company problems are described.

3.2.1 Stand alone modularization project

In our survey company A, B, C, and D reported significant effects of their modularization. All of the companies had run their modularization as stand alone projects. But, they found it hard to obtain a beneficial modularization, since their product development process was not modified to support the modular product development. Each new product development project has to rely on product modularity existing only in the specific project. The lack of support from the product development process can be compensated with information and decision support systems, but in general such systems are poorly adopted for development of modular products.

3.2.2 Need for balancing the product modularity

Companies E, F and G in our survey had based their modularization efforts on the need for improving the industrial system. The industrial system performance was improved by exploiting the existing 'natural' product modularity. Companies E and F found it necessary to further analyze and develop their product development processes. Both companies E and F found it necessary to balance the demands from the industrial system by harmonizing them with demands from other stakeholders.

Company G, having their industrial system as the main modularization driver, chose to share modules only when it was possible to share them among all of their three different product families; and even more important, the modules should be of industrial standard. By this is meant that it was possible to purchase the modules from several suppliers, or in larger volumes. Company G is a low-volume manufacturer, and the increased volume gave them a good benefit from an increased economy of scale. The products from this company include only a few components, quite few variants of end products and they are quite modular from the beginning; hence the modularization was not very complicated. Therefore, the company only had to sit down and communicate the rules of what modules should be shared between the products, and for what reasons. No further changes of the product development process were needed.

3.2.3 Comprehensive approach

Company H in our survey also had a more or less modular product from the beginning. However, due to their product variety and the number of variants they found it necessary to totally change the entire product development process. They argued that, without changing the product development process, they would not be able to keep the modular structure and share modules between different products over time.

3.3 The importance of decision support

More or less all companies included in our survey emphasized their lack of decision support. Three different perspectives concerning the need of decision support were identified. Companies that had worked with modularization only for a relative short period of time needed decision support for convincing the potential benefits for the company. The companies that had worked with modularization for a little longer period of time found it more important to be able to calculate and estimate effects of changed interfaces, or deviation in the product architecture. The latter group of companies also identified the lack of product and industrial system information as a problem. The documentation of interfaces and relations between elements in the product architecture were mentioned as two areas for further improvement.

4 Concluding Discussion

It has previously been found that some companies tend to fail in their modularization efforts. Therefore, a part of the purpose for this paper has been to identify reasons and explanations to why these failures have occurred. A problem in the modularization process that has been highlighted in this paper is that different organizational functions (Market, R&D, Production, Service etc.) favor different modularizations, allocating components into modules, differently. One example is the ‘Service organizational trade-off’ case (from Volvo Car Corporation) presented earlier in the paper. The R&D and the Production functions wanted to group a number of components into a module, but Service wanted to exclude some of these components from the module – otherwise the overhaul and repair of that module would have become too expensive. This case shows the importance of considering aspects from different organizational functions when modularizing; not only from the R&D function.

The data underlying this paper shows that companies have difficulties in *supporting* modularization. One of the identified problems is that the modularization was accomplished as a stand-alone project. Another problem is the need for a structured way of synchronizing the different demands. Modularization must, as all product development, consider the demands from a lot of different stakeholders. If this is not done, there is an impending risk that the modularization can be a sub-optimization. The product development operations for example, are improved but at the same time the production activities in the company are affected in a negative way. A product development process suitable for the development of modularized products demands synchronization of activities. Hence, when modularizing there is a need for making changes to the existing product development process, in order to make it better suited for modularizing products, but also in order to support the development of new modularized products. These findings are in line with Gershenson et al. [17] that conclude that the research questions stated by Ulrich and Tung [28] are still relevant. One of the relevant questions is "What is the impact of product modularity on product development management?"

The ambition for many companies is to apply modularization, and they believe in its positive effects; this even though there is a lack of tools and methods for supporting modularization. Not being able to calculate the final costs of modularization in order to convince colleagues is one of the shortages. There is also a lack of support systems in order to identify all the consequences of a design for products that share resources, both concerning the product and the industrial system.

The main conclusion that can be made from the findings presented in this paper is that modularization concerns more than the product. Also, the organization and the product development process are of great importance. Hence, when modularizing, making changes to the product only is not enough. The existing organization and the product development process also have to be adapted to better suite the modularization and to be suitable for the development of modularized products.

5 Further research

Much literature has been published with the aim of acting as useful support in companies when they are about to modularizing. However, when it comes to considering modularization from a holistic point-of-view, the present literature is rather limited. By holistic is meant that, in addition to the product, also organizational aspects and the product development process are of great importance. Based on the knowledge gained from the long-term case studies we have carried out, this paper also aims to point out further research directions in the area of managing modularization. These are research directions that have been identified as being important to strengthen companies' operations; improving their product development, production etc. It has been showed in this paper that modularization is a task that includes product issues, organizational issues as well product development process issues. Hence, an important question for further research is to investigate the interplay between the three; the product, the organization and the product development process. An interesting question is also to try to quantify different modularization effects. As there can be large effects on different organizational functions when modularizing, it would be valuable if these effects could be estimated beforehand. This could then be used as a foundation for a more comprehensive decision support.

Another topic for further research is to investigate which is the most appropriate product development process to support the development of modularized products? Support in the way that positive modularization effects are achieved when the new products are developed. Examples of positive effects are component commonality, decreased product development time etc. An additional important aspect is that the product development process gives a continuously support. Modularization is not a one-time event, it is a continuous process!

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