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# Achieving Long-Term Modularization Benefits: An SME Study

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**Abstract:** Long-term commonalities and experiences with modularization in comparable small and medium-sized enterprises (SMEs) have been identified as a research gap. This paper contributes by describing a unique collection of experiences from companies that received a similar introduction to the same core modularization topics through a series of introductory initiatives. This shared introduction makes the projects and processes of the companies comparable. The study reveals three main aspects of achieving significant long-term benefits from modularization initiatives: The company must (1) aim big and be willing to change its foundation accordingly, (2) draw on the right positional strength and have broad organizational inputs, and (3) properly coordinate work and then actively seek to preserve the focus and results over a long period of time. Interviews were conducted with representatives from 12 of these companies. Qualitative and quantitative data obtained from the interviews were used to draw parallels between the definition, execution, and impact of modularization. The stated results and project circumstances show commonalities for the successful implementation of modularization. They indicate which actions lead to the desired changes and secure the results persistently. The participants have achieved various results, such as strategic changes, new architectures, fewer variants, higher product earnings, and new development processes. Some have also introduced maintenance plans to secure the results, such as establishing configurators, performing weekly analyses, and recruiting dedicated personnel etc. The interviews revealed several influencing factors, such as management support, internal communication, organizational drive, proper facilitation, and prioritized project management. They also indicated that significantly more improvement can be achieved with proper goal setting and commitment to specific goals. These are the factors that can help future SMEs in the proper incorporation of modularization and in maximizing their exploitation of modularization theory.

**Keywords:** Modularization, Product Development, Product Family, Product Architecture, Small and Medium-sized Enterprises, SME, Long Term, Review

# Introduction

Modularization, or the division of modules, is a broad concept that has been used across development and operational tasks in hardware, software, service, management, and strategic planning. According to Meyer and Lehnerd, “A product platform is a set of common components, modules, or parts from which a stream of derivative products can be efficiently created and launched” (Meyer and Lehnerd, 1997, p. 7). It is applicable and proven to be beneficial in many areas, which are only expanding further.

The literature review conducted in this study, revealed a large and steadily expanding application area of modularization. With this expansion, there is scope for more diverse terminologies and methodologies as well as much uncertainty of possible consequences of modularization for companies (Simpson, 2003; Figueiredo Facin et al., 2016; Mortensen et al., 2016). Scholars have primarily been researching specific methods of applying modularization or estimating the benefits and most often have relied on studies of single cases. This literature review observed lack of research regarding experiences of modularization implementation in small and medium-sized enterprises (SMEs). It also exposed an absence of long-term surveys about the impacts and potentials of modularization initiatives. Fixson (2006) conducted an extensive literature review on modularization and its impacts and recognized a need for research into its long-term implementation. Several other researchers also recognized this need and proposed further research topics regarding modularization implementation (Gershenson et al., 2003; Ulrich, 1995).

Modularization has been associated with companies with extensive product lines, mass production, and large-scale manufacturing. It has been successfully implemented in large-scale industries throughout the years, e.g., automobile, aircraft, and industrial equipment industries, such as Ford, Airbus, ABB, and Danfoss (Otto et al., 2016). There have also been records of successful use within SMEs (Stewart and Yan, 2008; Myrodiá et al., 2017).

A series of Danish initiatives aimed to enable strategies for SMEs by sharing generally applicable tools with company representatives and hosting workshops on modular development. The participants were introduced to general methods and project-focused tools through seminars and workshops conducted by both academic and industry experts. The knowledge was expected to precipitate within the organizations as concrete modularization actions, but this has yet to be documented. The authors of this paper revisited some of these participants to investigate how they have implemented modularity and whether they have succeeded in doing so. Based on their accounts, factors for positive modularization results are investigated and broader guidelines for achieving long-term impacts from modularization are sought. The initiative originated from the following four focus areas (RFvD Proof of Concept, 2013):

1. Providing techniques and models to address the company’s current situation through the analyses of market, product, and production as well as economic performance and key process visualization tools.
2. Evaluating the findings from the initial analyses to define the goals and boundaries by ascertaining the business area the company should operate within and what it should do.
3. Developing a product family architecture with the boundary defined in step two.
4. Realizing changes and considerations for obtaining the desired results.

## Problem Definition and Research Questions

Companies’ developmental stages and their intentions are known during the initial progress of the project. However, changes in major development strategies or complicated product portfolios may take longer than the introduction period. Up until this point, information regarding the actual progress attained by the

SMEs or the issues they encountered has not been gathered. It is important to understand whether the companies implemented modularization, to what extent it was implemented, and what factors influenced the success or failure of the implementation. Therefore, to investigate these aspects further, this study aims to answer the following research questions:

- RQ.1 How were the modularization projects defined within the SMEs?  
It is important to know how modularization was initially understood and what was expected of the undertaken task.
- RQ.2 How were the modularization projects executed within the SMEs?  
Understanding how they engaged and controlled the process while managing the transition is important in relation to how they exploited modularization.
- RQ.3 What were the commonalities for achieving a significant long-term impact from these modularization projects?  
The aim is to clarify how significant results are achieved based on the definitions, expectations, processes, controls, and management strategies revealed in the former research questions.

The authors have been working under the assumption that there are several SME-specific prerequisites for handling the transition to modular development:

- SMEs have less resources available for modularity-dedicated allocation.
- SMEs often find it difficult to balance day-to-day operations with development activities.
- SMEs do not suffer from a large organizational bureaucracy, making them more agile to change.
- SMEs often have a flat hierarchical structure, making internal suggestions and opinions more prominent.

These have not affected the study but were observed during the conducted interviews. On that basis, the authors anticipated these to be evident throughout the results and conclusions.

## Methodology

Information on the implementation of modularization in companies, specifically SMEs, has been partly acquired from the literature. The experiences of the process and achievements of modularization were primarily obtained from interviews conducted with the representatives of the companies that were involved in the mentioned initiatives.

### Literature Study Process

The literature search was initiated from a categorized list of relevant keywords. It was continuously updated as discovered literature led to new keywords. Combinations of the keywords formed search matrices, which were submitted as strings to multi-disciplinary scientific databases: Scopus, owned by Elsevier; Web of Science, owned by Thomas Reuters, and Google Scholar. These databases contain citation- and reference-tracing features; thus, the encountered literature contributed to even more findings. The literature studies were divided into two sub-studies. The first consisted of semi-structured searches with numerous keywords and search strings. The searches aimed broadly at papers related to knowledge gained on modularization and experiences with its implementation. More than 50,000 papers (including duplicates) were listed, from which a total of 76 papers were selected. A sub-selection has been used for the literature review in this paper.

The second sub-study was based on two highly comprehensive search strings (stated below). The searches were focused on SMEs and empirical studies in the field of modularization. All papers found from these searches were screened by title and the relevant ones were identified. The assessment of abstracts further narrowed the selection, and the full text of the remaining papers was read.

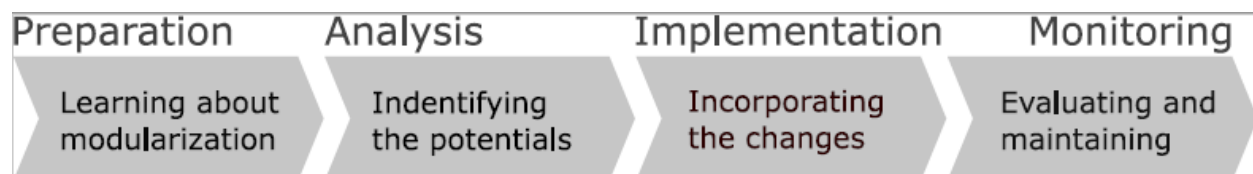
1. product AND (architecture OR platform OR modul\*) AND (survey OR experience OR review OR evaluation) AND (SME or SMEs or “small and medium enterprise”)
2. (“platform architecture” OR “platform design” OR “modular design” OR “modular product design” OR MPD OR modularization) AND (review\* OR experience\* OR evaluation\*) AND (compan\* OR enterprise\* OR business\*) AND (survey\* OR questionnaire\* OR interview\* OR dialogue\*)

The first string found 169 papers (including duplicates). Title and abstract screening reduced the selection to 25 and further to eight papers. From these, only one paper had a scope relevant to the research regarding modularization in SMEs. The second search string found 39 papers (including duplicates). Titles and abstract screening decreased this to eight and further to six papers; of these two were highly relevant.

### Data Acquisition Based on Interviews

The conducted interviews were semi-structured with both categorizations and questions for open debate. The former helped in the quantitative comparison and the latter helped in understanding the company-specific case (Bryman, 2008). Interviews are flexible and can be customized for a specific case. This is preferable for understanding the situation, progress, and results of an individual company. The interviewed representatives were preferably those who had the most responsibility and participation in the modularity project. In five cases, the interviews were conducted with the CEO or other representatives from the top management. Similarly, in five cases, section management, such as Head of R&D, Head of Innovation, or Head of Development, was interviewed.

At the beginning of each interview, an initial discussion outlined the project and fit the different parts in four phases, namely, Preparation, Analysis, Implementation, and Monitoring (see Figure 1). These phases and the questions within each are inspired by general knowledge on modularization and findings from the conducted literature review. This was to create a common understanding of the project boundaries and indicate the four question topics the interview would cover. Audio was recorded during the one-hour long interviews, and comprehensive notes were taken simultaneously by the two interviewers. Extensive summaries were written directly after each interview, based on notes and recordings.



**Figure 1: The four phases of the projects which formed the foundation for the discussions.**

For each interview summary, statements were individually created that described opinions or experiences by that specific company. Hence the interview summaries were condensed to generalized statements. Having done this for all the interviews, similarities were identified across them. Statements that were alike were rephrased to fit the meaning of both. The identified statements and the number of agreements with that statement comprise the results.

## **Company Sample Selection**

Twelve Danish SMEs were selected to participate in this study. For some of the companies, the modularization activities were done in smaller business groups or company divisions. In such situations, each specific group was treated as an isolated instance. These instances or the entire companies qualified for the definition as SMEs. A SME is defined by a staff headcount of less than 250 people and with a yearly turnover of €50 million or less (European Commission). Amongst them are Engineer to Order, Configure to Order, Manufacture to Order, and Manufacture to Stock. The markets in which they operate ranged from Nordic countries and European regions to worldwide segments. The companies and their projects greatly differ in type, scope, and time frame. One factor common to the participants is that they all attended similar seminars or workshops and thereafter sought to use the knowledge internally. The fact that the companies were introduced to the same core principles and theory makes them comparable. Other identified studies are based either on fewer companies or on a larger pool of companies with non-similar entry to the topic. The larger company selection, of 12 SMEs with a similar introduction to modularity, supports this selection and increases the relevance of this paper.

## **Literature Study**

This literature study focuses on the topic of modularization in case studies and surveys, with an emphasis on SME involvement. The aim is to uncover existing literature and knowledge contributions to this topic. The first part describes modularization in regard to implementation. The second part identifies relevant conducted studies. Finally, the research gap is described based on the literature findings.

## **Implementation of Modularization**

Modularization has been applied successfully in large industries and scopes throughout the years (Meyer and Lehnerd, 1997; Simpson, 2003; Otto et al., 2016). Although many of the tools were developed through large companies, records exist of successful use of modularization within SMEs (Sundgren, 1999; Stewart and Yan, 2008; Myrodia et al., 2017). The definition of modularization is very diverse in the literature. Approaches vary between cases while terminologies and application areas expand. This adds increasing uncertainty to the topic, and the uncertainty extends to the expected benefits and value (Meyer and Lehnerd, 1997; Andreassen et al., 2004; Gershenson et al., 2003; Simpson, 2003; Figueiredo Facin et al., 2016; Otto et al., 2016). It is challenging to estimate the potential impact for individual companies, as the range of possible consequences from modularity varies, making the estimation of the exact value difficult (Hvam et al., 2013; Hansen and Sun, 2010; Hansen and Sun, 2011; Mortensen et al., 2016; Løkkegaard and Mortensen, 2017). Many scholars agree that modularization is as much a management concern as it is an R&D concern. It is strategic, organizational, and technical and should be rooted deeply within the strategy of the organization to fully exploit its potential. Modularity will create new product dependencies and a need for new development processes, developer roles, and management. This requires coordination across the organization and combining competences, knowledge, and strategies for concurrent R&D (Mufatto, 1999; Cusumano and Gawer, 2002; Sanchez, 2005; Baldwin and Clark, 1997; Robertson and Ulrich, 1998; Fiil-Nielsen and Mortensen, 2006; De Weerd-Nederhof et al., 2007). Studies of modularized product configurators and the business performance of manufacturers have identified several important influencing factors. They include the following: support from top management and an open environment for innovation should be facilitated; benefits should be clearly and

continuously explained to key decision makers to keep them backing up the project; a larger body of the organization should be involved and trained; and open communication and employee involvement should be maintained (Ariano and Dagnino, 1995; Huang et al, 2010).

## **Relevant Studies**

This section identifies similar conducted studies, grouped by the extent to which they describe SMEs, followed by an outline of the most relevant studies and their relation to the focus of this paper.

The identified papers focus on different aspects of modularization and its implementation. Among the case study- or empirical-study-based research, some studies included only large companies (Nobeoka and Cusumano, 1997; Feitzinger and Lee, 1997; Mufatto, 1999; Meyer and Dalal, 2001; Appelqvist and Gubi, 2004; Wouters and Kerssens-van Drongelen, 2004; Stewart and Yan, 2008; Pasche, 2011; De Avila and Borsato, 2014; Løkkegaard and Mortensen, 2017; Piran et al., 2017). The rest included both large companies and SMEs or focused solely on the latter (Sundgren, 1999; Dadfar et al., 2013; Fagerstrom and Jackson, 2003; Antonio et al., 2007; Stewart and Yan, 2008; Hansen and Sun, 2011; Huang et al, 2010; Haug et al., 2012; Hvam et al., 2013; Engel et al., 2016; Saliba et al, 2017). Among these, only a handful drew upon multiple company experiences to communicate common factors for success or failure. The individual presentations of these companies along with their respective scopes and imparted knowledge, within the areas in which this paper aims to contribute, are described below.

Sundgren (1999) provided two long-term case studies from Swedish manufacturing SMEs. The study focused on the development of new product architectures considering interface management. The long-term evaluation therefore concerns only this topic.

Fagerstrom and Jackson (2003) presented multiple case studies regarding modularization; they sought to unveil how an architecture is defined, incorporated, and maintained and examined other aspects of medium-sized enterprises. The four companies that were interviewed achieved a sub-optimal state by integrating only about half of their modularization goals. The R&D, marketing, and production departments had different opinions on what an architecture is. Thus, coherent development was hindered, and a full-blown strategic decision was not achieved. The reasons for its improper implementation were presented in their work; however, it does not address actual experiences from company representatives, e.g., individual problems of understanding or goal-setting issues.

A comprehensive empirical study conducted by Antonio et al. (2007) effectively collected 251 useful questionnaires from both large and very small firms (less than 50 employees to more than 5000 employees) in China (mostly Hong Kong). The study targeted competitive capabilities and performance. It is highly comprehensive in terms of the number of participants, but there is a lack of long-term beneficial factors.

The problem of the complexity in managing modularity was addressed by Hansen and Sun (2011), which studied 40 projects in 22 companies. The authors proposed two methods to support management efforts, the Benefit Matrix and Platform Template. These tools are intended to help managers assess benefits and improve ways of communicating the same, by establishing a shared vocabulary. However, the article does not include overall considerations of successful implementation or address modularization as a concern throughout a company.

Dadfar et al. (2013) presented a research and interview study of innovation and platform development in eight small and medium-sized medical production companies in Iran. The following general terms defining beneficial development were discovered: proper focus on the strategy, organizational structure,

and processes. The conclusion presented useful results regarding management considerations but lacked long-term evaluations. Furthermore, the paper states that further evaluation research on the modularization benefits in the industry is required.

Hvam et al. (2013) conducted four case studies of companies, of which only one is classified as an SME, having 100 employees. The article presents the benefits of applying product configuration systems. General results on the beneficial tendencies of modularization projects in SMEs are sparse because of the small sample size of SMEs and the specific focus on mass customization tools.

A recent empirical study by Saliba et al. (2017) concerning reconfigurable manufacturing systems presented the results gathered from 70 different companies using a structured questionnaire. Special care was taken to include small, medium-sized, and large firms. However, the study focused on considerations in manufacturing automation, separating itself from the scope of this paper.

## Research Gap

Modularization has been proven beneficial in both larger and smaller studies. Evidentially, some companies can successfully implement modularization, with various strategies. Most of the identified studies focused on short-term development changes and improvements. They often dealt with cases of a single business, product, or development cycle. In such studies, there is a general lack of information on the experiences with modularity implementation and the concerns related to this process.

In addition, there is a shortage of studies with larger selections of comparable SMEs that focus on the long-term commonalities. Specifically, there is no clarity on what actions, approaches, and precautions are adopted to support its significant impact on the company. An investigation is needed on how SMEs incorporate modularization, how it impacts them, and how they can affect this impact.

## Results

Common answers and shared perspectives amongst all 12 interviews are divided and presented in four tables. The first three (Tables 1, 2, and 3) primarily concern RQ.1, RQ.2, and RQ.3, respectively. They share the same structure, with a generalized statement followed by indications of which interviews supported this. The second column is a summation of these indications. Finally, Table 4 also concerns RQ.3, but with a focus on categorizing the project impacts and the company maintenance plans. A distinction is made between the short- and long-term significance of the impacts. Some of the achieved benefits are reminiscent of normal or large product development projects. Others are more deeply rooted in the companies and their approach to developing products; hence, the changes are likely to affect subsequent development cycles and projects.

Generally, the interviews indicated that the projects ran consecutively but often with a very vague transition between the project phases (as classified in Table 4). There was no specific preparation before participating in the initiative; it was rather an immediate entry from one day to another. Another general notion with the participants was that Analyses and Implementation often merged together, as key decisions of implementation were made during analysis meetings.

The representation of authority and project prioritization was discussed considerably in the interviews. The participants noted that the layers of the organization were involved differently throughout the project phases. This representation is illustrated in Figure 2a and Figure 2b for the companies with short- and long-term impacts, respectively. The numbers indicate the number of the companies in which the specific management layer was represented.



**Table 1. Interview findings related to RQ.1 (primarily)**

Statements	$\Sigma$	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Found top management support important	11	1	-	1	1	1	1	1	1	1	1	1	1
Had to change/adjust goals during the project	8	1	1	-	-	1	-	-	1	1	1	1	1
Had no real expectations on how modularization was going to be applied	7	-	-	1	1	-	1	1	-	-	1	1	1
Are positive about new modularization projects or are already planning such projects	7	1	1	1	-	-	-	1	1	-	-	1	1
Found it difficult to explain the process, benefits, value or the organizational changes and thereby convince key decision makers	7	-	1	1	-	1	1	1	-	1	-	1	-
Found that the mindset of modularization was the most important contribution from the initial phases and limited their use of specific tools	5	-	1	-	1	1	-	-	-	-	-	1	1
Found the early representation of top management important	4	-	-	-	1	1	-	-	1	-	-	1	-
Found inspiration from others important	3	1	-	-	-	-	-	-	-	-	-	1	1
Had consultants follow up on their process	3	-	-	-	1	-	-	1	-	-	-	1	-
Found financial support crucial for participation	3	-	-	-	-	-	-	1	1	-	-	1	-
Found it very beneficial with external facilitation and guidance	2	-	-	-	-	-	1	-	-	-	-	1	-
Found that clear achievements or prospects convinced top management	2	-	-	1	1	-	-	-	-	-	-	-	-

**Table 2. Interview findings related to RQ.2 (primarily)**

[illegible]

**Table 3. Interview findings related to RQ.3 (primarily)**

	$\Sigma$	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Were satisfied with both the process and results	11	1	1	1	1	1	1	1	1	1	-	1	1
Found it important that the introduction came from the position it did, with the accompanying responsibility and connections	11	1	1	1	1	1	1	1	1	1	-	1	1
Found it unlikely that the project would have evolved if the introduction had come further down the company hierarchy	11	-	1	1	1	1	1	1	1	1	1	1	1
Concretely used modularization or the obtained results	10	1	1	1	1	1	-	1	1	1	-	1	1
Had it introduced by top- or section management	10	1	1	1	1	1	-	1	1	1	1	1	-
Found it important to prioritize the project in relation to normal routines	9	-	1	1	1	-	1	1	1	1	1	1	-
Found dedicated personnel/time/workspace important	6	-	1	1	-	1	-	1	-	1	1	-	-
Found it important to have good communication between layers /departments, preferably from a flat organizational hierarchy and/or short communication routes	5	-	-	1	-	-	-	1	-	1	1	-	1
Found it important to make a strategic decision that includes fundamental or organizational changes	5	-	-	-	1	-	-	-	1	1	1	1	-
Had a task force with broad company representation (all relevant sections/ stakeholders)	5	-	1	1	-	-	1	1	-	-	-	1	-

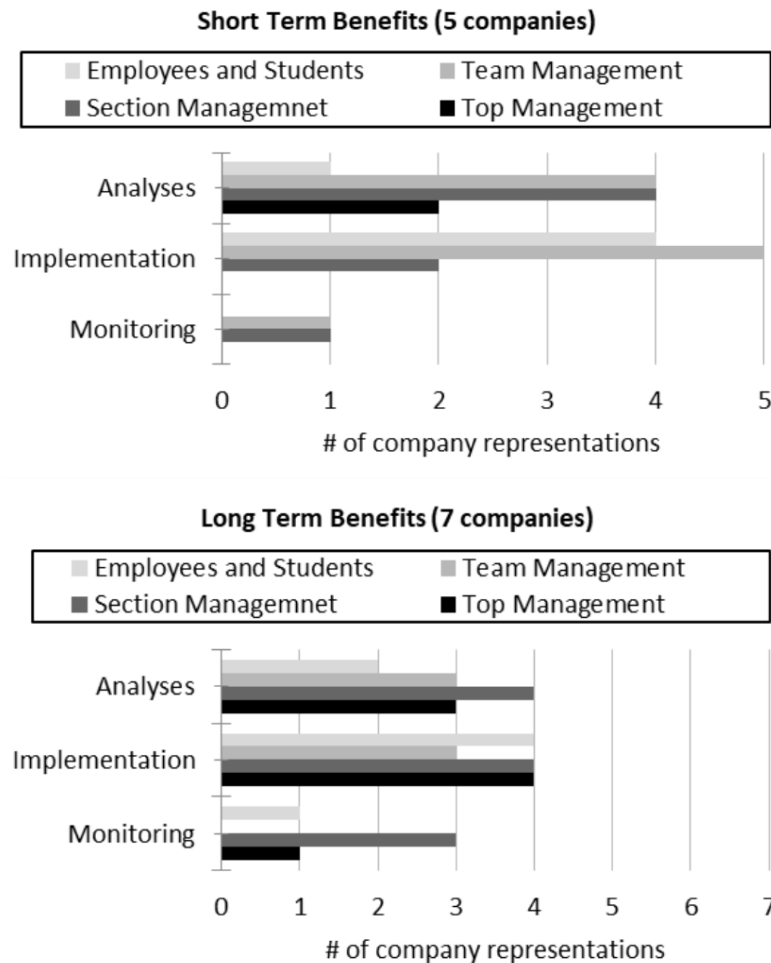
Acknowledged a need for internally maintaining modularization know-how	4	-	-	1	-	1	-	-	1	-	-	1	-
Found it important to have a clear owner or monitor of the project	3	-	-	-	-	1	-	-	-	1	1	-	-
Found it difficult to balance the new initiative with legacy development	3	-	-	-	-	-	1	-	-	-	1	1	-
Did an instant switch from old to new	2	-	-	-	-	-	-	1	-	-	-	-	1

**Table 4. Interview findings related to RQ.3 (primarily). Scopes are labeled P (Portfolio) or S (Single). Impact significance is labeled S (Short) or L (Long).**

**(\*) Proceeded by a pilot project with a single-product scope**

	$\Sigma$	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
<b>Scope</b>		P	S	P*	P	P	S	S	S	P	S	S	P
<b>Impact</b>													
Strategic change	4	1	-	1	-	1	-	-	-	-	-	-	1
New architecture	4	-	-	-	-	-	-	1	-	1	-	1	1
Fewer variants	4	-	1	-	-	1	-	-	1	-	-	1	-
Fewer parts	4	-	-	1	1	-	-	-	-	-	1	1	-
Clear development- and product plan	2	-	-	-	1	-	-	-	-	-	-	-	1
New production routines	2	-	-	-	1	1	-	-	-	-	-	-	-
Postponed variance creation	2	-	-	-	-	-	1	-	-	-	-	-	1
Better internal communication and/or coordination	2	-	-	-	-	-	-	1	-	1	-	-	-
New market segmentation	1	-	-	-	1	-	-	-	-	-	-	-	-

New configuration or documentation system	1	1	-	-	-	-	-	-	-	-	-	-	-
Shorter lead times	1	-	-	1	-	-	-	-	-	-	-	-	-
Cost cuts	1	-	-	-	-	-	-	-	-	-	1	-	-
Logistical cost cuts	1	-	-	-	-	-	-	-	-	-	-	-	1
<b>Maintenance</b>													
Digitalization / New software	5	1	-	1	1	1	-	-	-	-	-	1	-
Dedicated personnel	4	1	-	1	-	1	-	-	-	1	-	-	-
Internal education in modularization	2	-	-	-	-	-	-	-	-	1	-	1	-
New development roles	1	-	-	-	1	-	-	-	-	-	-	-	-
Weekly modularization-focused meetings	1	-	-	-	-	-	-	-	-	-	-	1	-
Routinely top management involvement	1	-	-	-	-	1	-	-	-	-	-	-	-
Re-investment in modularization	1	-	-	1	-	-	-	-	-	-	-	-	-
<b>Impact Significance</b>		L	S	L	L	L	S	L	S	L	S	S	L



**Figure 2. Involvement of management in the project phases described by the representation of company management levels. Top: Companies categorized with short term impacts. Bottom: Companies categorized with long term impacts.**

## Data Analysis and Discussion

The participating companies had driven their modularization projects from the introduction of the same core principles. Expanding from these core principles, they used the theory differently; nevertheless, many similarities are observed between them in the process of introducing the new development style, with both positive and negative influencing aspects. The key observations gathered with respect to the three research questions are described as follows.

### **How were the modularization projects defined within the SMEs?**

The interviews indicated participants' uncertainty about the modularization process, especially its outcomes. More than half of the participants (7/12) had no clear expectation of how modularization was going to be applied. Several (3/12) found significant inspiration in hearing what others had achieved with

modularization. Some (2/12) found the external facilitation and guidance useful for steering the process. Moreover, several (3/12) had to revisit consultants to follow up on the methods and theory. As the value is intangible, the participation of some (3/12) depended on financial support. This uncertainty of application and value was underlined by the majority of companies (8/12), who had to adjust their goals during the project. Uncertainty challenges the communication of value and potential. This makes it difficult to justify the project and convince key decision makers, as commented by multiple participants (7/12). Most participants (11/12) agreed that convincing top management is important, as their support is critical. Some (2/12) stated that tangible achievements convinced the top management. These findings suggest a need for involving the top management early in the process. In addition, several participants (4/12) acknowledged the importance of having key decision makers involved from the beginning. Finally, almost half (5/12) of the participants pointed to the mindset of modularization as the primarily tool that they brought into the company from the workshops.

In sum, the companies could not easily define modularization; thus, many entered the projects with an open mind, defined modularization as the projects progressed, and acquired more knowledge about themselves and how modularization fit within the companies. There are many opportunities with modularization, but there is also a lack of certainty. The vast application area and largely varied spectrum of consequences implies a lack of clarity of both the process and value. Modularization becomes difficult to explain and justify within companies. It is important to have prospects clearly presented for key decision makers or allow them to discover the value for themselves by being involved in the projects.

### **How were the modularization projects executed within the SMEs?**

The observed modularization projects can be categorized into two scenarios: portfolio (6/12) and single-product (6/12) projects. There was a good representation of both amongst the interviewed companies, and the results point to the satisfaction of most companies with both scenarios (11/12). Both project scenarios can achieve beneficial results, thus ultimately providing some value. The satisfied participants (11/12) also found the project to have improved the companies' position, and some (7/12) even planned new projects already. The use of modularity depends on several aspects and must be adapted to fit a company's unique situation. Some companies (4/12) highlighted the fit for their situation, while some (6/12) highlighted the fit for the project. The goals are set accordingly. However, goal setting and balancing of the application area versus the reach of modularization has proven difficult. More than half of the companies (7/12) acknowledged that they had to lower their goals during the implementation. Although ambitions are high and often adjusted down, several interviewed participants (5/12) agreed with scholars in that modularity became an important strategic decision for the significant improvement of the company. Likewise, a majority (9/12) found it important to prioritize the project in relation to normal routines. This could lead to changes in staff, as experienced by some companies (6/12), because of the new development roles.

In sum, there are two options for implementing modularization projects. One is a product-centered scope that can have potential value, which is the right choice for some companies. The other option is a more in-depth rationalization of the development roles and structure. If the company dares to plan for and pursue portfolio and organizational changes, despite the inherent uncertainty, there is greater potential value to be realized. However, many find it difficult to make this choice beforehand and must determine their match during the project.

## **What were the commonalities for achieving a significant long-term impact from these modularization projects?**

For most companies (10/12), it was either top or section management who introduced the initiative, and almost all (11/12) highlighted the importance of the introduction coming from the managerial level that it did. The same number (11/12) stated that the initiative would have met more resistance if it had been introduced from a lower managerial level. A fourth of the participants (3/12) found it important to have a definitive owner of the project.

Several participants (5/12) stated that the project conditions can be improved by having a broad representation of relevant stakeholders. An equal number of participants (5/12) highlighted the importance of proper communication between relevant parties in the company. A fourth of the participants (3/12) even stressed the importance of having clear communication among the entire organization regarding the project or having the organization engaged early on. The same fraction (3/12) stated that customers should also be represented or be heard. In any regard, the composition of stakeholders and organizational representatives in the project should be sorted out early in the process, as several participants stated (4/12).

Table 4 shows actions and outcomes from the projects. Some of the companies achieved similar results for regular or large product development cycles or processes. These results are not likely to significantly affect the company and its foundation of development. However, some achieved significant deep-rooted improvements in their organization and the ways in which they develop their portfolio. These improvements are respectively categorized as short- and long-term significant impacts. The following observations can be made from the table. All companies with the intention of organizational change had implemented maintenance measures to secure the achievements. They had all achieved significant long-term results. In addition, they are all amongst the companies (10/12) that use modularization, or the results from modularization, concretely in development. A third of the companies (4/12) acknowledged the need to maintain the modularization knowledge internally. Half of the companies (6/12) noted the importance of dedicating resources, such as personnel, time, or workspace. In contrast, almost all companies that focused on single products had no maintenance plans and achieved only short-term results (4/12).

As shown in Figure 2a, with the companies achieving short-term results, there appears to be a change in responsibility from the top and section management (representation declines) to team management and employees (involvement increases). The same figure also shows the lack of maintenance plans, as the representation here is almost non-existent. In contrast, Figure 2b shows that with the companies achieving long-term results, the top and section management is well represented throughout (also during monitoring). Likewise, employees and team management are steadily involved in the analyses and implementation. In addition, significantly more representations (thus more activity) are observed in monitoring because of the initiated maintenance plans.

In sum, there must be an ownership of the modularization development and allocation of responsibility. The representation of various company instances and the ownership of the modularization project are highlighted in both the literature and the conducted interviews. It is important to consider who has the primary responsibility, or more importantly, who it should be. Which position and attributed connections will most prominently maintain the momentum of the project? The answer depends on the organizational structure and the situation of the company; the reflection of ownership is important nonetheless. Apart from the allocation of responsibility, the representation of company organs throughout the project phases must also be considered. The initial team composition is crucial. Key decision makers should be included



to gain momentum and to convey prospects. Practitioners must also be included to ensure the proper attribution of the knowledge of tools and methodologies. The representation is then vertical, from top to bottom. However, it must also be horizontal, across sections and departments. Departments such as production, sales, and development should all have an early influence. Apart from creating the foundation for potential benefits, the support of actual achievements is important. Maintenance plans for securing achievements and the dedication of resources are very important for properly exploiting the potential of modularization. If the project accomplishments are not maintained, they risk being devoured by routines and legacy development. Maintenance can be done in various ways and are ultimately plans meant to secure the progress of the initiative. It could be investment in software to support modular development (Prasad et al., 2010), education of staff, concurrent development teams, changes to the design process (Prasad, 2001a) or proper team-based management (Prasad, 2001b). A potential maintenance plan involves dedicated personnel (new positions with focus on modularity), time (work hours allocated for the topic) or workspace (dedicated areas or locations for product rationalization). If resources are not dedicated or the company not equally committed, the initiative risks becoming sidelined and losing its momentum and impact.

## Research Limitations and Error Sources

Several considerations were made when extracting quantitative and qualitative data, particularly from the interviews. The following are considerations of the influencing factors.

Due to the number of participating companies, the findings are not statistically significant. The sample of quantitative results is not sufficiently large to draw general conclusions. However, compared to other similar surveys, more companies have been analyzed with a similar introduction to the topic. The participating companies differ in their size, type, organizational structure, product, customer base, and other aspects. Thus, it is complicated to make comparisons and locate definite parallels. However, they have all participated in the same overall program and acquired the same core knowledge of modularization.

The projects had continued for a considerably lengthy period of time. Therefore, in a study like this, it is impossible to avoid the everyday developments made in the companies. Over time, it becomes highly difficult to assess which actions lead to what specific improvements.

An interview guide was created for the interviewers to maintain a similar structure through all the interviews. They were structured chronologically and conducted as open debates, with notes and audio recordings to allow the reevaluation of interpretations in the case of doubts. As the companies vary, the conducted interview sessions also varied. These aspects of variation and interpretation impacted the results. However, significant effort was made to categorize the answers and assess the similarities between statements to properly collect the pool of results.

The interviews were conducted with the representatives of the companies who had been preferably most involved in the projects. Their answers could have been biased, as the project leader or CEO might have been compelled to impart the company and project more positively. To combat this, the interviews were anonymous. In addition, it was stressed that they were not meant to evaluate and score the companies but rather for gathering experiences to further help SMEs with modularization.

# Conclusion

The aim of this paper was to investigate how a selection of SME companies has implemented modularization, based on a similar introduction to modular development. Understanding how the companies dealt with the task was helpful to ensure that the introduced initiatives and knowledge persevered.

A literature review was conducted to reveal the most important aspects of incorporating modularization into existing companies. It was concluded that research regarding SMEs and long-term experiences with modularization projects is sparse. This study elaborates on some of the research gaps revealed through an interview-based survey. Twelve Danish SMEs that progressed with a specific modularization initiative were selected. Their accounts of the initiation, process, and concurrent considerations were analyzed to indicate the significant impact of modularization.

Both literature and the participants of the survey indicate that the understanding of modularization varies widely and determining one generally applicable definition and procedure is not possible. Each one is tailored for a specific use case. This finding indicates an equally varied spectrum of possible outcomes and consequences, making it difficult to predict and estimate the value of the project. Company representatives find it challenging to properly communicate the value to top management and get their support, which is crucial according to both the literature and interviews.

Two scenarios were observed: some companies engage in modularization as a regular product development cycle, and others adapt it as a new strategy and allow it to contribute to the foundation of the company. Both scenarios can create value, but the most significant benefits are acquired if the goals and subsequent scope are substantial enough. Top management must show serious commitment, and the entire organization must rally behind the initiative to fully exploit its benefits. Simply making technical changes is sub-optimal. Entirely new roles of management and development are needed. It is important to distinguish the initiative and its benefits from a normal large-scale product development process. Based on the interviews, the companies find it difficult to place themselves in either scenario beforehand, and the scope is often determined during the projects. The external facilitation of inspiration from peers is sometimes required to make this decision. This depends entirely on the company's situation. If conditions are right and commitment is visible, the companies should aim for substantial changes and incorporate the necessary organizational and fundamental transformations.

Based on the interview participants' diverse responses and their accounts of what helped them in the progress of modularization, three main aspects were identified. First, it is essential that a company is willing to change more than a single product or product series. It must be enthusiastic and prepared to evolve entire programs and the underlying organization as well. Only with such changes in the foundation of the company will significant improvements be created. Second, proper organs of the company must be represented throughout the different phases of the change incorporation. The involvement of top management and key practitioners must be prioritized initially to successfully acquire the organizational priority and engage the executional workforce. Sections and departments across the company must also be engaged. This will secure the project in all corners of the organizational span and secure a solid foundation for changes. Finally, the development must be sustained and maintained to properly secure the achievements and benefits. Actions must be taken to continuously prioritize modularity in relation to legacy development. Examples of measures that will help secure the accomplishments are the recruitment for dedicated positions and the allocation of dedicated time or workspace for modularity related tasks.

Only a few sources of knowledge were identified regarding long-term experiences with modularization in SMEs and the implications of both project processes and results. By investigating these sources, the study contributes by offering a unique collection of experiences from companies that have had the same introduction to the core topics. This makes the projects and processes of these companies comparable, although they are different. Collectively, they point to three main aspects of achieving significant long-term benefits from modularization initiatives: The SME must (1) aim big and be willing to change its foundation accordingly, (2) draw on the right positional strength and have broad organizational inputs, and (3) properly coordinate work and then actively seek to preserve the focus and results over time.

## Further Research

Although this paper initiated from questions about the implementation and use of modularization in SMEs, it has unveiled more compelling questions. Some important ones, which would be quite interesting to research further, are the following.

- How is the task of implementing modularity handled differently across companies of different sizes?
- Is it possible to estimate the return of investments by hiring or allocating a dedicated workforce to the architecture management?
- Is it possible to prepare a guide for modularization to aid companies with the implementation and maintenance?
- How can companies benefit from sharing experiences with each other, and is it possible without sacrificing intellectual properties?
- Which is better: pilot projects with a limited scope or full-blown organizational changes, or perhaps a combination of both?
- What is the proper team size in the different project phases?

In general, the authors believe that research on a concrete guide for SMEs, with practical steps on how to engage with modularization, would be quite compelling. It would be highly interesting to conduct this presented study across other industry segments, sizes, and geographic areas.

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