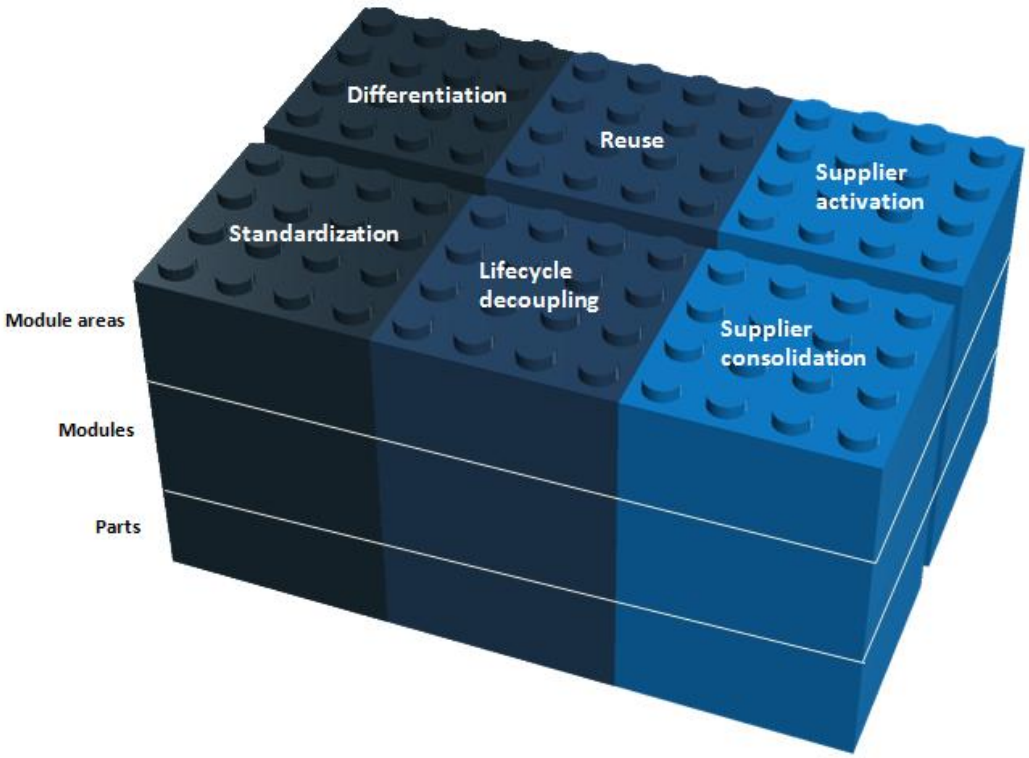
Kenneth Eskildsen
Aalborg University – Copenhagen
2011

Modularization



Kenneth Eskildsen

International Technology Management

Aalborg Universtity – Copenhagen

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Problem Formulation

As Modularization has gained increasing focus from companies outside its traditional industries of aircraft and automotive, more and more companies turn to it as strategy and product development tool. I intend to explain the importance aspects of modularization and how it should be initiated within a company.

After determining the theoretical steps of modularization success described in literature, I intend to conduct a multiple case study of companies who have implemented modularization in order to find how real world modularization was initiated and used to improve the company's competitiveness.

By combining theory and practical approach to modularization I will derive at convergence and divergence between theoretical implementation to modularization and real world implementation to modularization. This gives a valuable input for both implantations in companies as well as new aspects to be further investigated

Structure of report

In order to clarify the reading of the report I will determine how the structure of the report.

- The first part of the report determines my knowledge about modularization and what factors are important to consider when initiating a modularization project or strategy. At the end, this section will be summed up in a set of requirements for using modularization, based on my achieved knowledge.
- The second part of my report will determine the real worlds approach to modularization, from a multiple case study. This section will sum up a set of requirements for using modularization, based on empirical findings.
- The third part of the report will find divergence and convergence in the achieved knowledge and empirical findings of modularization. Then, the explanation of why the two derive at different and similar solutions will conclude the report.

Report dictionary

Mixing & Matching means the art of combining modules independently, i.e. the ability for a module to be combined with a number of different modules and to combine that module with a number of other modules

Methodology

In the following section I will describe the work process of this report.

Modularization introduction

In my initial brush with modularization with Electrolux North America, as a part of an internship, I learned that in order to achieve the best results from modularization, it was important to involve all functions of a company's operations. The reason for all functions to be a part of the modularization was due to the market service of the home appliance manufacturer and the company's product portfolio. Electrolux produce a series of home appliances serving a worldwide market, with high end product brands like Electrolux and regionally lower end brands to meet premium market segment. Because of the company structure, Electrolux had acquired a series of appliance manufacturers over the years and continued to produce products for the acquired brand's market segment. This left Electrolux with a dual business model which served a mid-premium market and a mass segment market, focusing on innovation and volume respectively. Electrolux have recently realized that in order to capitalize on their great production capacity worldwide, and their two main market segments they had to produce home appliances more flexibly. In order to utilize economics of scale and scope, the company turned to modularization as a means of accommodating these challenges. For Electrolux, the modularization stressed the need to identify modules which were necessary and static for all product variances, to drive scale, and which were differentiable, to meet market demand. In order to identify such modules a collaboration of functions, representing the challenges for the entire company, was needed in the modularization strategy.

Modularization literary discussion

An exploration in literature non-specific to a company has produced the following findings:
Modularization is not a new subject to the world of literature. Neither has it been new to the production industry where Scania A/S has been using this production strategy for more than 60 years[1]. It is widely known for its implementation in airline and automotive industry, where it has wreaked great recognition as a cost saving and production utilizing tool. But to find theory, or case examples about modularization is one thing, implementing them is an entirely different animal. Because modularization is so situation specific, it can only be vaguely described in processes and procedures. Few have effectively formed a work method to use modularization, for which they are now widely credited in the field of modularization. Therefore it is hard to formulate a theoretical discussion in the field of modularization. One can write about the evolution of modularization, but contradictions in literature are scarce. Even though this field has been known for a while there seem to be some gaps in the literature as how to approach modularization and identify the

[1] Appendix Scania Modular system

goals which are critical to fulfill a successful modularization strategy.

In the literary world Sanchez (2000)[2] has linked the organizational perspective with the act of modularizing, and refers to the decoupling in product design to be inherited in the organization. Sanchez also briefly touch the roles within the modularization project and refers to *architects* and *technology workers* but fail to specify a thorough analysis of the role within such a project, due to more strategic focus in his paper. However, since modularization, when implemented, is so situation specific and every project differs each time, the roles and the structure of the modularization project is very important to allow influence from all functions in a firm. The approach and adaptation of each function can be described in order to obtain maximum synergy effects of modularization at minimal costs in resources.

Mikkola (2003)[3] also describes modularization quite thoroughly in her aptly named article: Managing Modularity of Product Architectures: Toward an Integrated Theory. Mikkola derives at a very scientific and concise mathematical formula of how and to what extend to modularize, which is supported by two case studies. Even though Mikkola derive's through a mathematical function how to modularize, I find it difficult to believe the complexity of a product portfolio of a large company in any given industry can be calculated by any function with the such an absolute certainty that a company product strategy will follow its recommendation. However using a mathematical function to put findings into perspective, could be used tested for validity and used as guidance accordingly. I do not consider Mikkola's approach to 'manage modularity' but more than a propositional tool to open dialog with management or as validity enhancement to this reports interpretation of Managing Modularization.

Mass customization

As described in product formulation a derivative of modularization is mass customization where an interaction with the customer adapts the product specifically to each user. Such a tool is very powerful to accommodate specific customer needs where large variations in product requires great deal of customizing of the company. In mass customization there are more non-situation specific measures to be described, which is thoroughly described by Lars Hvam et. al. (2008)[4] where the setup of customer interfaces in a mass customization feature is set up, and how it affects the Product Variant Master or configuration system. Hvam et al. describe very thoroughly how different roles in a 'configuration' project are important. The 9 roles described, may be focused on developing a configuration system more than modularizing, but many of the aspects pointed out are transferable. Hvam et al. identifies the importance of approach in assigning a team the task of designing a configuration system in order to meet as many requirements as possible and

[2] Sanchez (2000)
[3] Mikkola (2003)
[4] Hvam et al. (2008)

not just focus on one. This is very much what is described in this report, where the different approaches create a synergy effect which enables a modularization project to redesign the scoped part or system to incorporate the requirements, and focus on key elements, from different functional approaches. In mass customization, with a configuration system, specification processes are incredibly important in order for a system to be designed with constraints and logical connectivity's. This very much applies to modularization, even though specification strictness is more essential in a configurational system. By defining specifications and determining interface points and its interaction, decoupling will be made easier thus enhancing the basis for modular product development.

Methods and frameworks of modularization

Since modularization is still a relatively new field, there is still a lot of methods and papers to come, but where this subject differs from others is the situation specifics from one project to another. Modularization is hard to pin down into one process or one method, because every product architecture in each company is different. When modularizing it is not only the architecture which differs. If the company serve a market which is very rigid there may not be as much reason to involve marketing departments than if the company were serving a very diverse and dynamic market.

One method has seemed to be adapted widely when it comes to modularizing, however. Gunnar Errixon's[5] Modular Function Deployment tool is often referred to and used as a step by step process of how to investigate which part of the architecture should be modularized and which should be standardized. As far as participation and execution of MFD, descriptions of roles and approach is narrowed to explain the employees involved should have a thorough understanding of the product. This does not constitute a very open minded modularization, in my opinion. If the participants of the MFD, which is used as a basis of the company modularization strategy, are all from the same department or of the same persuasion of how the product should perform, the modularization project may not include approaches from procurement which may have been able to save cost in standardization, or marketing which may have been able to determine future customer trends, or manufacturing which may have been able to use existing production knowledge the implementation process. In worst case scenario the modularization may fail to identify the real challenges rendering the proposition of product development strategy non effective.
Errixon et al. (1994)[6] further resonates that factory layout can benefit from modular product development in the same way as to decouple production and assembly in the same manner as modularly designed. I would hesitate to give a factory overhaul in order to produce modularly when outsourcing and offshoring is

[5] Erixon et al (1994)
[6] Erixon et al (1994)

as much a part of the world production industry as it is, and consider the possibilities in producing the parts of the product architecture, which does not create key differentiation, in LCC's. This way, the core competences are kept locally.

Methodology

As I investigated the literature in journal articles and projects of modularization stated above, I found no substantial evidence that provided an explanation of why this collaboration cross-functionally in a company was so important. Although the literature described similar benefits and achievements as the ones Electrolux had, the importance of cross functional presence in modularization was not acknowledged as one of the main challenges in order to implement a successful modularization.

As far as modularization theory goes, a framework is hard to describe because every modularization is situation specific and literature therefore rarely describes anything else than one practical example of modularization. The benefits in theory, can be tied to individual functions within a company (time-to-market benefit Marketing, economics of scale benefit Precurement, mix & matching benefit R&D, product reliability benefit Quality and flexible production benefit Manufacturing) and would suggest the involvement of functions across the company in modularization is key to meet the benefits tied to them. I have analyzed the present theory on modularization and discribed what aspects are important in order to conduct a successful modularization.

In order validate the theoretical approach of modularization, I have conducted a multiple case study to determine the successful modularization in real world cases. The empirical evidence, to prove cross function modularization is essential, is conducted by interviewing companies which have all used modularization in different degrees in order to improve their competitive position in their markets. In order to improve validity, I have constructed a questionaire from which I have conducted all interviews. This questionaire was phrased with open questions in order to allow the companies to explain how their modularization was conducted in their own words, eliminating subjective influence by the interviewing party. Afterwards I will conduct an analysis of the interviews that describe how the individual case company in question has conducted their modularization.

By conducting this empirical case study I intend to explain how theoretical approach to modularization fit into a real world analysis. By doing so, I am evaluating the theoretical framework of how functions affect the succes of a modularization by comparing it to actual modularization. This is done by analyzing how case companies differ from the theoretical approach of including all functions in modularization in order to achieve all benefits tied to modularization. This analysis will build explanations of why real world examples differ from the theoretical approach, and why such a differentiation occurs.

In order to conduct such a study it is important to speak with employees with managerial experience of modularization. To do so, you must achieve the attention of employees ranking high within a company. The cases studies represent a employees with direct managerial experience of modularization in danish companies. These companies operate in different industries of what is traditionally associated with modularization. Because these companies are in different industries, the analysis of cross-functional importance is used out of traditional context, and tested in industries that are not directly related to the practical examples from which theory has been derived.

Future research

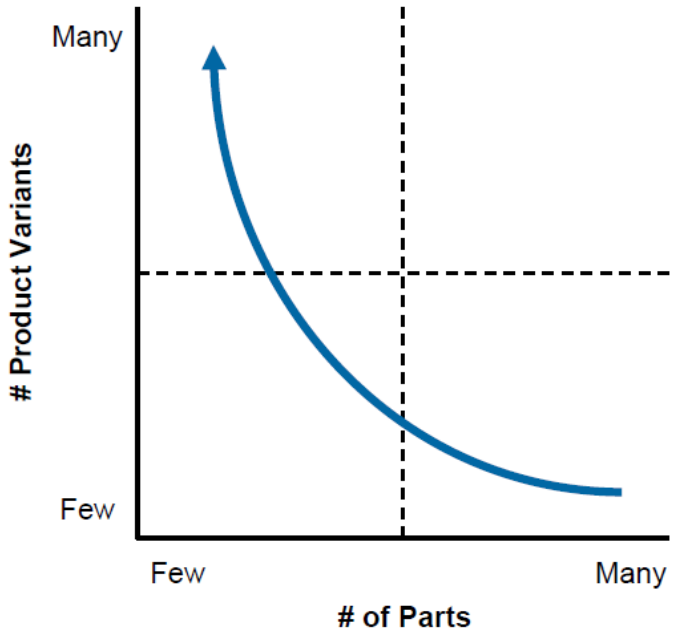
For future studies, interesting findings could be found by analyzing the coalition between the importance of cross-functional involvement and industry. This could be done by conducting a multiple case study of 5 companies within an industry, and replicating the study in a dozen industries. By doing so, study will determine how industry and market factors explain the importance of cross-functional modularization in each industry, and thereby also the benefits gained from modularization in each industry.

Theoretical Approach to modularization

In this section of the report I will write how modularization should be approach and what is important in a theoretical perspective. This includes what benefits to be reached, what is essential to reach them and how to use them.

Why a Modularization strategy will benefit a company.

In the following section I will describe how modularization can benefit a company and how benefits can be reached by using modularization. These benefits include Market Demand, Time To Market, Component Focus, Module Decoupling with Standard Interface and Mixing & Matching.



Figur 1 Variance vs Parts

Market Demand

Market demand is increasingly challenging to meet, and consumer awareness of value for money pressures companies to deliver high value solutions for low price increase. By using modularization, a company can identify consumer needs, and design products to efficiently reach these needs. And by using modularization to create needed consumer variants and keeping component complexity low.

In today's open and global market, competitiveness has never been fiercer. The focus on cost in worldwide industries have lead to an increasing need to squeeze every penny and earn every dime. Cost levels and performance levels are increasingly moving away from each other and companies have to better previous products at lower costs in order to maintain competitiveness.

Depending on the industry marketing demands vary, but common for most industries is visibly differentiable products with high quality and low cost. Additionally some industries, where product life cycle is short, frequency of products with above quality is important for the end user. The biggest challenges are faced in competitive technological industries such as the mobile phones industry, where consumers are well aware of their wants and needs and expect companies to provide these at low cost. Here marketing research along with innovative development is critical to generate products which suit the end users needs and expand their perception of product from previous generations. In an industry with low lifecycle as mobile phones, users have become very critical to specifications and have developed acute ideas of capabilities within phones. The technological improvements from year to year renders a phone outdated in a number of years. This makes the market competitive, but also evolves a sense of carelessness to the consumer, as a new and improved phone can be purchased in a short period of time for low expenses, i.e. short development time or high innovation frequence. Other industries serve products which calls for more careful consideration as which products to purchase, due to the cost and dependence of these products. An industry like the car industry is an example of one which have evolved to much more than four wheels and an engine. Here performance, quality, look and driver comfort are all different parameters which derive from the same basic functions of driving a four wheeled, fuel powered engine with a steering wheel. A realization of this and a thorough modularization understanding has lead the automotive to implement modularization throughout the industry in more or lesser extent. By doing so, commonalities from different product ranges are divided into modules thereby standardizing parts and reaching economies of scale. The automotive industry have in decades been led by North American and Western European (with the exception of Japanese Toyota) based companies, who have expanded central factories to meet huge volumes, and thereby increased the factory investment to the point where traditional offshoring was an unrealistic alternative. In order to still meet demands in an increasingly competitive market, modularization was implemented to cut cost and increase market responsiveness, thus reassuring automobiles were manufactured competitively near their respective markets, using assembly factories.

Additionally, search to improve time to market and response time challenges the offshoring trend. By sending an entire production to LCC's in hopes to save money can prove to compromise control, quality and time to market. In some industries, time to market is so valuable that the freight overseas to the company's home market alone forces them to lose competitive advantage. Modularization as a strategy offers a solution to the time to market constraint, as well as improve production lead time at large volume.

From a market point of view the quantity alone, and thereby economies of scale for the company, does not create much value at all. Instead having a varied product range with frequent new arrivals, targeting

different demographics, is the foundation of differentiation and essential for fulfilling consumer needs. Differentiating from other competitors comes with a price-tag. One which traditionally is hard to justify when lower costing products from competitors offer similar solutions, but with lower quality of design. When differentiating products to market by introducing new technological solutions, the market adaption of such technology is somewhat uncertain. Often, a company indulges a technological feature into its products, without having a documented sales expectation. This sometimes results in companies gambling on introducing technology that may not sell as anticipated. This can be a result of poor assumptions of the technology or purely bad timing of introduction. When such a scenario is present, a strategic decision to follow the technological solution can prove catastrophic for a company in terms of launching a large range of products which ultimately does not sell, and is therefore of no value along with the development of these products. When timing of product, or technology, launch is a factor, development time plays an important role in the quality of the end result. If such a time restraint is present, development quality may be of lesser importance than development time. Sometimes it may not be advantageous to gain first-mover advantage, but response to competition launch is crucial. This could be if a competitor launches a price competitive product, low cost product, and the company has to redesign current solutions, stripping features off existing products, in order to meet open price point determined by competitor. Brand value will deter for the length of period where competition have a product on the market without company representation.

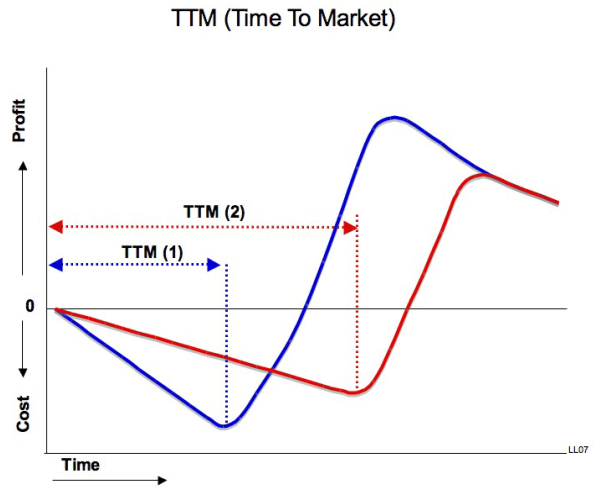
Modularization provides marketing opportunities to react faster to market trends, by building on base modules (or platforms) solutions to implement technologies without designing product from scratch. The awareness of future trends and solutions is critical in the initial modularization project stage, where these base modules are designed to accommodate upcoming strategic goals. These base modules also allow the company to target more market segments with module building blocks to reach market demographic. This allows the marketing process to identify the investment of a given product, and the rate of renewal or new generation of a given product. This being said, it is important not to overuse the ease of modularization to satiate the market with such a large number of varying products, leaving the customer confused with overwhelming options which can lead to hesitant buyers. The rate of most advantageous varying products is typically determined by the industry and the product. By rethinking the marketing process of introducing ‘upgrades’ or next generation of one product and launching a new one, allow the company to plan product launch more accurately with higher quality. The degree of variation between products is also important to maintain in order to distinguish product to product. No variation between products will ultimately

cannibalize market segmentation and leave consumers confused of price variance[7]. When modularizing, differentiation in important measures for the consumer is key. If the module does not distinguish in what is important to the consumer, rather than what is not, consumers will lose interest in the product. For example: When Scania is modularizing, a choice of engine size or cabin equipment is more essential than how the driveshaft is assembled in production. Even though improvements should be made to ease production, it should not be launched as a new generation or product, since it has low influence of the experience.

In some instances, demand can be scarce and customer specification high due to niche products or the like. In these cases a mass customization technique can allow the customer to supply the information which fit their specification, ultimately lowering time to offer[8].

Time to market

A well known fact in our day and age is the importance of time to market in industrial production. Especially industries with high technology have been victim in the race of launching products at a strategically important time. In these industries postponing a launch can prove catastrophic for the possibility of capitalizing on first mover advantages or even eliminating competitor advantage. The lifecycle, seen in figure 2, of a product is very much determined by the cost and time of development. If the development of a product is prolonged, the possibility of capturing market share decreases.

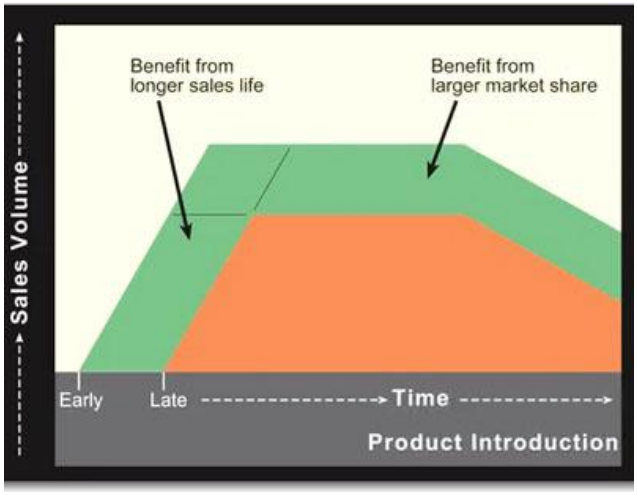


Figur 2 Time To Market

The realization of time to market importance is great and big firms try to diminish reasons for postponing projects. As a measure of the importance of meeting launch dates, stage gate models are widely introduced

[7] Businessweek November 1999
[8] Hvam et al (2008)

to structure development and set goals to be met in the development phase. Unfortunately the stage gate adaptation in some firms causes time spent on meetings, securing the development is on track, to rob valuable development on the actual project. This paradox of assuring launch dates and stage gates, which cuts into precious development, is a good indication of how important time to market has become. Therefore modularization principles contribute greatly to company's who must react quickly to gain market presence. By mixing and matching, i.e. reusing designs, companies with at modular product development strategy can respond quickly to competition product statements, and achieve faster time to market and gaining important market share. Not only does mixing and matching allow companies to reuse designs and lower development costs, they are capable of introducing large modifications to product architecture, because of decoupled product development, that normally would have vast implications in design and production. As vast product architecture changes, time to market and time to volume will increase[9] in traditional sequential product development, modularization principles will allow a company to utilize the decoupling points to mix and match parts or modules without such an drawback because modules can be reused.



Figur 3 Benefit from market introduction

As illustration figure 3 shows, early or late market launch can greatly influence the success of a product. Here, the graph indicates that late product introduction can be translated into direct loss in sales volume.

Component focus

An important part of modularization is to focus on components and the component architecture that builds a product. By focusing on the component architecture, the company breaks down product after product

[9] S Datar et al. (1997)

and analyses the composition in order to avoid unnecessary costs in terms of components. This is a difficult exercise for long term employees to do, because they may fail to see the limitations the current component composition inherits. If an employee has been working with a type of product long enough, it becomes harder to distance oneself from the problem at hand and attacking it from another angle, or thinking 'out of the box'. By introducing employees that are not directly related to the product or consultants, to open the thought process, it will be possible to pair the creative approach from non-associated employees and the comprehensive knowledge from expert employee simply by using chain of causality. In pair, these two approaches can form an in-depth interview which sheds light on why components, or solutions, are constructed as a means to an end, i.e. to make the product successful. By doing so, it may be possible to determine which components, or solutions, are serving the purpose better than others. This allows the staff to re-evaluate in the components, or solutions, with sub-par efficiency in order to improve the product architecture. Opportunities for improvements can be hard for the dedicated long-term employee to realize because his day to day activities with the product or technology has clouded his vision down making it harder to realize untraditional solutions. For a company with many products in the same product range, it can be of great value to have the in-depth interview with the person responsible for the other side of the decoupling. For example, when dealing with windshield wipers, the person designing how to clear the windshield of rain in the most sufficient way possible, can cooperate with the person designing the steering unit power controls. By doing so, they may realize that the interaction serves a beneficial purpose when it comes to the efficiency of designing the interface coupling. The employee responsible for the windshield wipers is aware of the different variations in his responsibility area, and can therefore determine standardized coupling for all his variations. The employee responsible for the steering unit and power controls, can design all his varying steering units to fit the specification interface of the varying windshield wipers. Regardless of what decisions or changes may occur before or after the interaction point, which is now specified, it will not conflict with the function of the wipers as long as the specification is sustained. This allows focusing component development within the wiper without risking costly redesign due to new architecture.

By designing with standardized interface specification, which in turn amplifies decoupling, it is possible to evaluate and determine component architecture in an effective and rational manner. A matter of trading one component out for another generates smaller complications than with sequential product development[10]. This forms a series of 'constraints' for product design which form as checkpoints or goals when developing parts for an end product. These constraints, or specifications, serve the purpose to standardize how interaction between parts is made in coupling points. When these are standardized, or

[10] Sanchez & Mahoney (1996)

constrained, it is possible to design parts independently of each other, as long as they fit the parameter of specification. This allows the company to manufacture parts which fit multiple product constellations which ultimately allows the company to vary end product portfolio at minimum cost and risk. Should a part for some reason not need any alteration from end product to end product, it becomes a static part in the architecture. The reason for not 'bundling the static parts' into one platform is the decline in quality and risk of production bottleneck. If a subset of the 'static platform' is flawed time spent finding error and repairing cost of platform will rise, opposed to modular approach where a subset of parts is accumulated into one product. In this instance, a defect is quickly to identify due to the decoupled product design, then the defective part is sent to rework and replaced with correct part. Additionally, static parts can be transferred into other product ranges, saving costs in economics of scale. This can be seen in our daily life if you are aware of it, for example have a closer look at VW's Passat and Skoda's Superb from 2001. This is a great example of transferring, or reusing, parts. Unfortunately for Volkswagen, the sharing of components and similarity started a speculation of how to justify the price difference between the two cars launched from the same parent company. It seemed, you could get the exact same car as the Volkswagen Passat, by paying less and settling for a Skoda badge on the front[11].

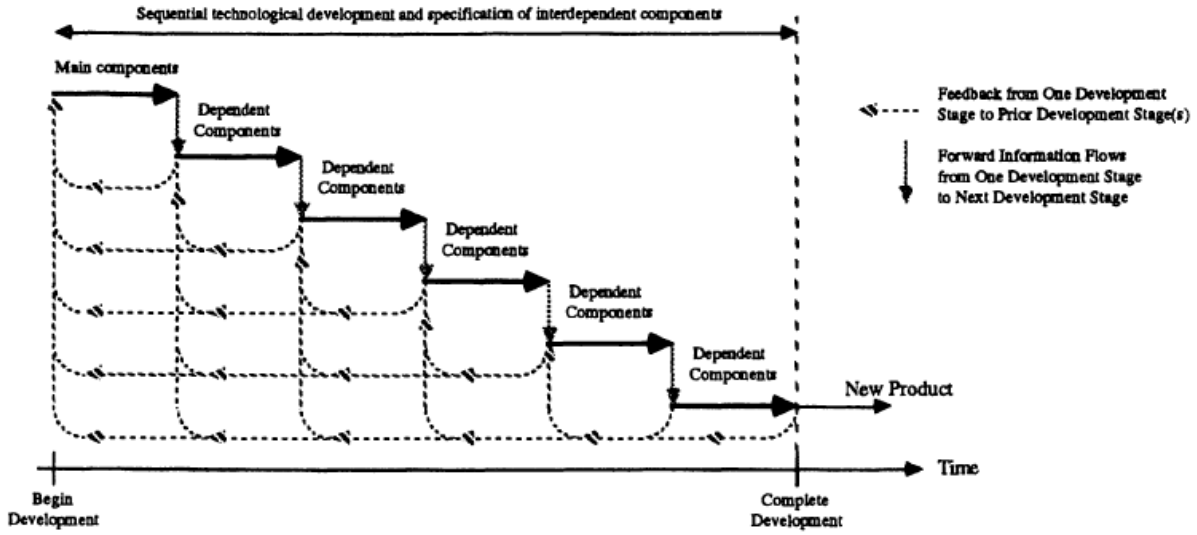


Figure 2(a): Sequential Organization of Product Development Processes

[12]

Figur 4 Sequential Product Development

In traditional product development, a change in a part can force an alteration in another part, causing a domino effect of redesign. This domino effect of redesign is dependent on the intertwined nature of the design. Due to the intertwined nature of the design, it is hard to place where the 'line in the sand' should

[11] Businessweek (1999)
[12] Sanchez & Mahoney (1996)

be drawn. This can force to costly redesigns further into the intertwined product architecture than necessary in order to improve the part, or prevent the proposed solution to see the light of day strictly because the implications assed were far too costly.

Component focus within modularization is possible because of the decoupled product design. The decoupling allows the company to focus on an enclosed design with a set of constraints that are unchangeable, and focus on the component architecture of this enclosed design. Components in the architecture that generate costumer value are systematically varied in the enclosed design to meet different customer requirements.

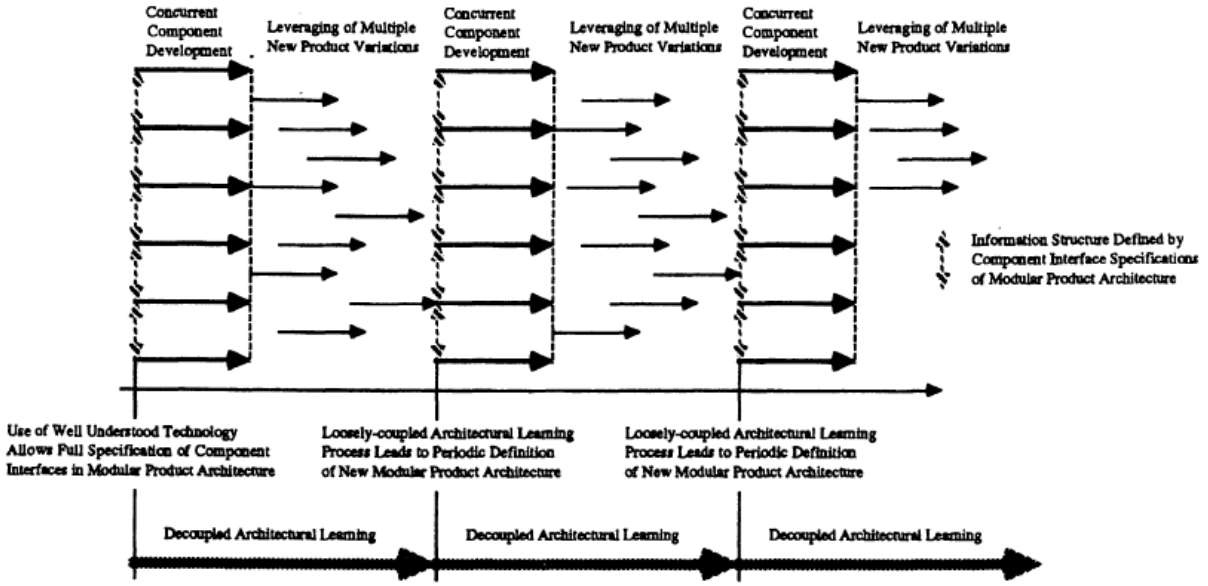


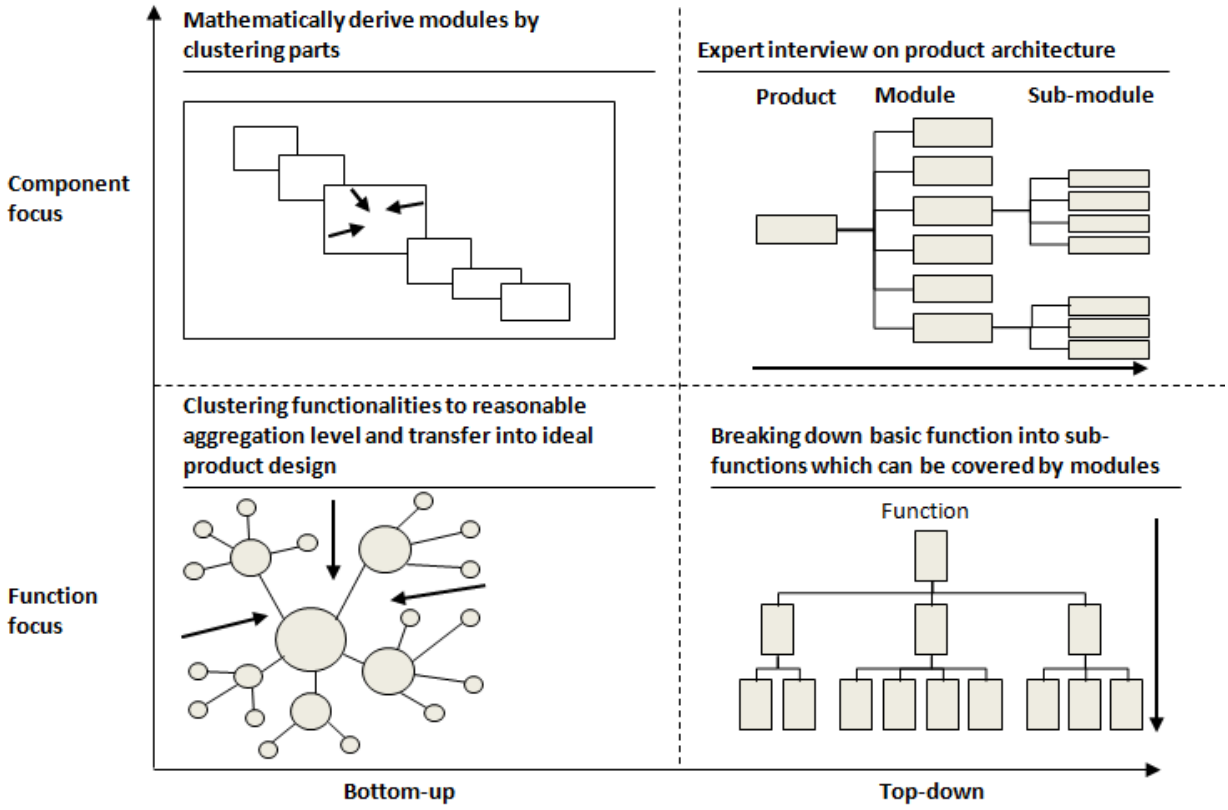
Figure 2(c): Modular Organization of Product Development Processes

[13]

Figur 5 Modular product development

Modularization can be expressed and initiated with four main focuses to use: Component bottom-up, component top-down, function bottom-up and function top-down. Each have different opportunities and benefits associated with the focus, but a main difference is the depth vs. sharing opportunity. By using a component focus, whether that be top-down or bottom-up, the modularization will be able to cost effectively rationalize every choice in the product architecture. This can be very beneficial for companies who may not have the most diverse product portfolio, and the 'cause and effect' sequential design is not overwhelming to unravel.

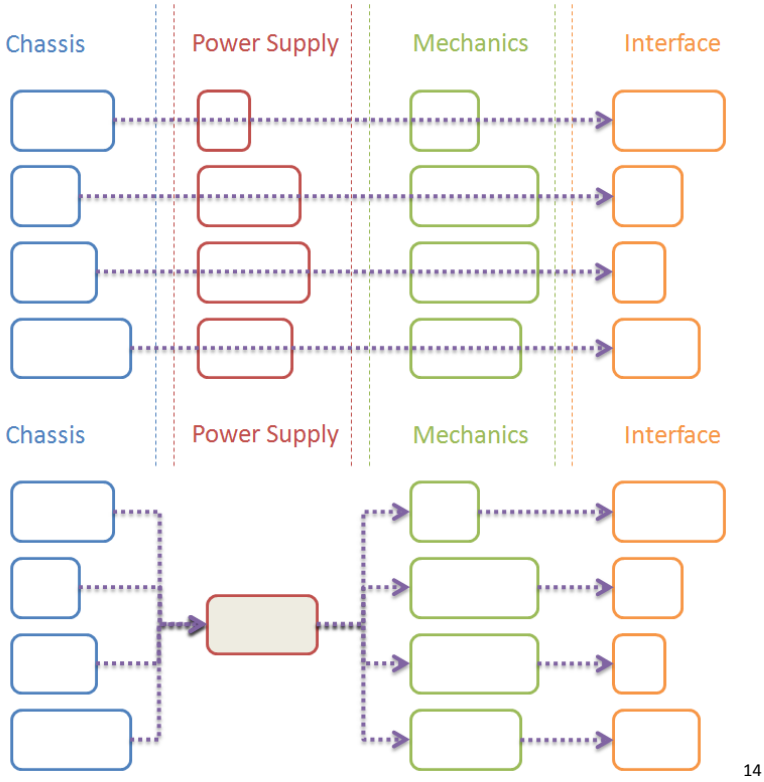
[13] Sanchez & Mahoney (1996)



Figur 6 Modularization approach

Companies with vast product portfolio's are more likely to take function focus modularization, as analyzing every product down to component level is a great deal of work. Instead these companies focus on the function, for example a gearbox, as driver for the modularization and work out how that function can accommodate as large a part of the product portfolio as possible. But by modularizing on function, they may be able to standardize components and reach economies of scale savings, which may be more difficult

for companies with smaller product portfolios.



[14]

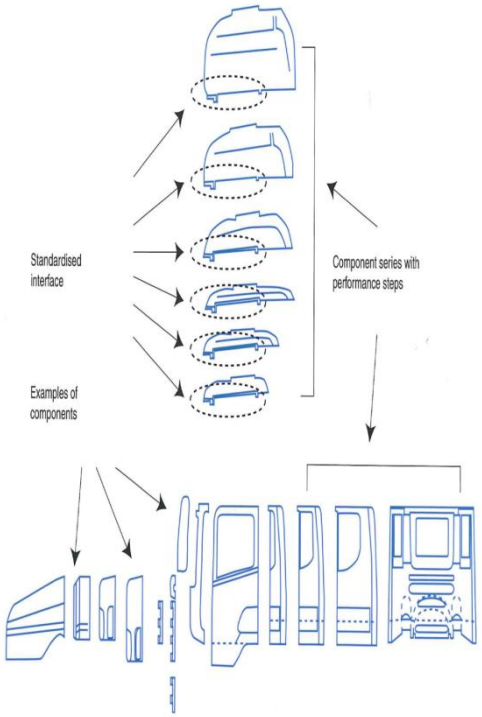
Figur 7 Modularization across product lines

By focusing on function, the company can affect all product ranges, by designing decoupled interfaces on each side of the function module. That way, they can analyze the next function across the portfolio further decoupling the product development strategy.

[14] Appendix Modularization Kenneth Eskildsen.ppt

Module Decoupling with Standard Interface

By focusing on decoupling modules by standardizing interfaces, a company ensures the ability to be modular. Module Decoupling with Standard Interface allows the company to focus on separate and enclosed modules, with a strict set of constraints known as interface specifications. These interface specifications breeds decoupling. By ensuring that a standard of input allows a module to perform in the desired fashion, regardless of the architecture of the input module is constructed, it will ensure next module functionality, as long as the interface specifications are kept. This allows a company to use different *modular architecture* in products that meet different market demands. Instead of having sequential integrated product development (traditional product development) a company can mix and match products without redesigning the entire product when launching new generations or new market entry products. Even though industries are not unaware of the benefits of designing a product and reusing existing designs from other products, more often than not, these existing designs need redesign to some degree in order to fit the new product. See *figure 8*



[15]

Figur 8 Scania Module Decoupling with Standard Interface of truck cabs

This 'rework' of existing designs or solutions is very costly and does not provide any value for the customer, when elimination of redesign is possible. In some cases, breaking from integrated sequential product

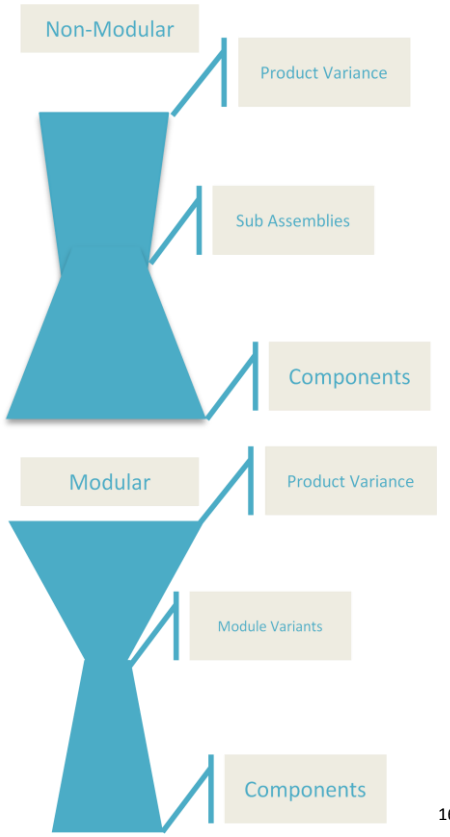
[15] Appendix Scania modularization.pdf

development and using modular product development can increase the cost for one particular solution or part, which will enhance skepticism to 'go modular'. But even though easily measurable costs may increase, many other parts of the company's operation is affected, which in turn will ultimately lower the cost for the company. This may seem unapparent for the company at first, but using a modularization project, with all functions included, identification of savings in other departments than the development BOM savings, will make it clear that modularization can provide a company with more savings of less measurable degree. These savings include time-to-market, manufacturing simplicity, process planning, increased reliability, etc. Implementing Module Decoupling with Standard Interface can be a large investment in terms of resources, and can seem overwhelming in large companies with decentralized production, as a result of acquisitions in past history. In such a case, every company acquired may in some way or another stick to their traditional product development or way of doing. This increases the integrated sequential design, and complicates the transparency of product development. But instead of implementing product development top down from the parent company, it can prove to be a great benefit to initiate a modularization project, whether the acquired company being a previous supplier or a competitor in the same field. By initiating modularization, the company can learn from both divisions and accommodate all implications that may arise to streamline the product portfolio, whether the goal being to adapt to parent design or keep different brands to reach more market segment.

Practical example - consider a bicycle producing company

Consider a bicycle company SBike that produces numerous city bikes for everyday use for the streetbike market. They acquire MBike, which produce numerous mountain bikes for everyday unpaved roads and competition mountain bikes. A series of components on a bike are vital for the operation, but are not differentiable for the customer such as pedals, mud flaps, chains, chain protectors, knots and bolts. Other parts are vital for the customer such as the frame, gears, wheels and steering. Instead of forcing the current solutions for SBike onto MBike's product portfolio, which will cause MBike's to alter their design, initiating a modularization project to determine the interface specifications, can allow SBike and MBike to reach economies of scale in parts, and launch products faster, and reach market segment in between the two company's profile by mixing vital parts for the customer with modules which are less important. In this case an acquisition spurred the modularization, because identifying decoupling points on a bicycle, and specifying them is a fairly simple task. But modularization could just as easily be spurred by a company producing a large volume of a complex product family. By standardizing interfaces and increasing decoupling in development, SBike can mix solutions thereby increasing the number of product variance, and at the same time minimizing parts or components and reaching economies of scale.

Just like SBike, who use two types of pedals for 14 variances of city bikes, a company can use two modules in a complex product family that contains 14 variances.



[16]

Figur 9 Non-Modular vs Modular

By standardizing interfaces, and decoupling product development, modularization also enables focus on component architecture within the module, where more focused analysis of component deliverable's to reach interface specification is done. By doing so, the company continue development on a closed system, but improving it, will not change the specification (even though upgrading specification to include more possibilities, or reevaluating the specification as technology improves may occur) and thereby not affect the module on the other side of the coupling. Needless to say Module Decoupling with Standard Interface is absolutely essential when doing a function focused modularization project.

Mixing & Matching

When modularization principles are introduced in product development, the company in question can draw great benefit from mixing and matching its decoupled solutions. As described in Module Decoupling with Standard Interface, limitation of designing solutions to fit specifically to one product is avoided, and the solutions developed are instead determined by an interface specification which will apply for majority of

[16] Modular Management AB

the product line. By doing so, these solutions can be reused in other applications or product, by connecting them at the interface point, thereby increasing the variety of the product line. This decreases the unique components intertwined and used for designated products, but still allows the company to increase variation in products, by reusing and switching between current solutions.

In case of the practical example of bicycles SBike can develop one frame complying with the predetermined interface specifications, but mix and match solutions to create a series of products from only one frame. As one might suspect, reusing support solutions, such as pedals, chains etc, will minimize the product development cost because the need for development of support solutions are minimized. By using modularization principles the company development of products will be focused on the modules that create differentiality at low cost. This not only creates opportunities to eliminate costly development and launch cheaper products, but it also creates and advantageous position for the company against its competitors who will have a hard time complying with the price point potential. The company will be able to ensure the quality and reliability of the customer valued parts of the product, and couple them with support solutions of less importance to the customer that live up to the criteria's of the product in question. Depending on market segmentation some of these support solutions may increase in importance for the customer. If such a market arises, and the company is able to reach economies of scale advantages on implementing a new support solution to fit the market segment, the company will have no increased development cost (once the initial support solution is designed) and still be able to use mix and matching to launch new products.

Even though mix and matching is a great tool to lower development time and cost, other aspects can also contribute from this, when developing products to meet customer demand. By determining customer trends and needs, the company can introduce new generations of parts or modules that are in tune with existing constraints of interface specifications, which will leave the rest of the product unaffected due to decoupling. This way the products keep up to date with trends and demands without developing dedicated prototypes which need manufacturing, assembly and design adjustment throughout the supply chain by making the product development more transparent. Product development transparency also allows the company to increase the effective planning of product launches keeping within the confines of strategic product launches.

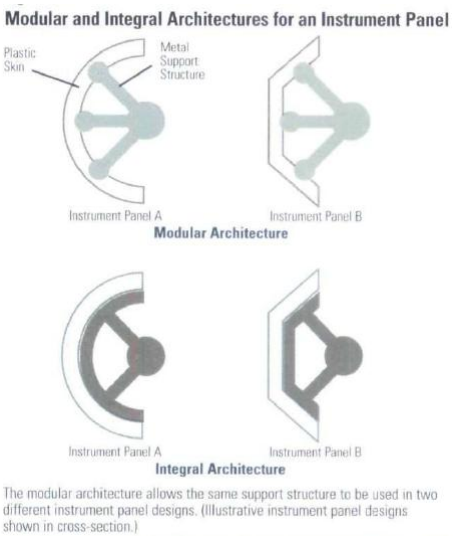
Why cross functional involvement is key to Modularization

Modularization is more than a tool or an exercise. It is a strategy which should treated as a full package solution that involves everything in the company operations, when implemented full scale. And only by implementing modularization full scale, can a company wreak the maximum benefits. Therefore, it is absolutely critical to insist on cross functional participation when implementing modularization. In this section, the majority of different functions' approach to modularization will be described, and how their role in modularization will lead to previous discussed benefits.

Marketing

Marketing has a key involvement in order to gain consumer insight and determine what creates value and what doesn't. In Modularization, a more focused understanding than traditionally of how a product creates value for the customer is needed. This understanding is done by thoroughly analyzing the product to identify the key performance indicators of each module. Instead of viewing the overall product, it is important for marketing to identify how each solution in the product creates value. This is used iteratively during the modularization project. As the more technical members of the modularization project will draw up solutions, which can accommodate their approach, marketing will have the ability to determine whether the costumer wishes a solution to be included in the product and pay for this solution. Throughout a product there are many technical decisions made in order to support the overall design which the consumer will most likely never see. These solutions do therefore not create value for the consumer, which will create the consensus among the modularization team of simplifying the solutions in question. This way marketing allows the technical solution to standardized and leveraged to lower total production cost, because the technical solution does not differentiate the product for the customer.
In other instances, solutions that will appear to- or involve the costumer are critical not to standardize in order to differentiate products from one to the other. Often these solutions are interactive or visible for the

costumer, such as surface interface's or indicators.



[17]

Figur 10 Modular and integral architectures for an instrument panel

From a marketing standpoint it is very important to distinguish the surface interface from product to product, and is often done so to meet different market demographics. The representation of products by differentiating surface interface is widely used in the consumer industry, but often increasing technical complexity by adding features, or changing look create large costs within companies who sequentially develop products (also known as tightly-coupled development).

The connectivity, however, of these surface interfaces, are not important to the costumer. Therefore a product launched with a low cost, average and high end finishes on surface interface, would in a modularization project be clustered as a separate module, in order to mix the surface interface without changing the architecture of the product (see example on right). This separate module of surface interface will then be perceived as decoupled, which allows for mixing of surface interface. A more complicated matter would be to standardize the surface interface in regards to standardizing button layout. In order to achieve scale of economics, Marketing will have to estimate and contribute of how the current layout should be for multiple demographics and product lines, and accommodate future trends (for example touch control). The modularization team might agree that a future standardization of button layout in surface interface should be a separate module and not be leveraged with current portfolio. But regardless of the integration of touch control, the interface specifications should remain static. The reason for this is to increase decoupling points, exactly for the reason of upgrading a module without affecting the remainder of the modules. So, if marketing determines that there would be touch control,

[17] Robertson & Ulrich (1998)

NearFieldCommunication or 3D representation in the foreseeable future, basic measures such as power supply and heat requirements should be considered when designing the current surface interface module. Is innovative solutions like above, not determined by marketing to be involved in the foreseeable future, it would be unwise to overcomplicate the modularization to accommodate this, and should therefore be left out. This is critical for the complexity of the module and the cost of design.

Even though it seems like a near impossible job to determine what functions and applications to include in the future, standardizing interface specification should allow a company to increase innovative speed and integrate new value adding modules to already existing products. With the right research, this accommodation for future implementation should be possible, and will prove to be a great benefit to the modularization project.

Example: when modularizing an oven cavity to reduce complexity of large oven cavity variance, it is not an important technical solution to the consumer whether or not the hinge, which supports the door of the cavity in the range, is specifically designed to withstand a unique size of cavity. However, it is an important technical solution to the consumer that it withstands the weight of whatever you put into the oven. Therefore a large oven cavity variance can be supported by 1-3 types of hinges, as opposed to a unique hinge for every cavity variance, thereby standardizing components and reaching scale of economics by leveraging suppliers for cavity hinges.

Purchasing

When modularizing, two key components are supplier consolidation and development of new suppliers. Even though the principle of supplier consolidation relies on component standardization, this cannot be done without the substantial knowledge about suppliers. A company with a large product portfolio can be difficult to analyze in terms of finding common components to introduce outside of product family. Only with the specific purchasing knowledge and interaction with suppliers will it be possible to find component standardization possibilities.

When modularizing the greatest task of purchasing is to consolidate suppliers. As mentioned, one of modularization's levers is to standardize parts and increase product variance at the same time[18]. By standardizing parts, scale of economics can be reached which lowers cost by consolidating suppliers. In order for purchasing to initiate supplier consolidation, however, a series of analysis and prerequisites are imperative for purchasing to know what to consolidate and who to consolidate. These analysis and prerequisites cannot be determined by one person or department, much like every other aspect of modularization. When product analysis is done, areas will be found where standardization is possible in order to lower cost of parts used.

At first, a method of identifying those parts more costly than others, a mapping of components and parts is done for every product in the modularization area. This method is easily translated into a visual indication of what parts to attack. Parts which have similarities, but a large variance, can be a great indicator for modularization. If these parts do not fulfill a need for the customer but vary from product to product, it is possible to analyze the function of the part and redesign it to fit more than one product, thus lowering the part variance.

Example: Company BedsRUs produce Beds for a variety of demographics. If a support hinge for a bed frame is made differently for every type of bed a company makes, a large amount of hinges will be made. In this instance BedsRUs have 20 different beds varying from comfort to strength. Since the hinge is of no importance for the customer, there is no need for having 20 different, uniquely designed, hinges for bed frames. Instead the company may want to standardize the hinge to have a variance of 5, each matching the requirements of 4 types of beds. Even though the fourth strongest bed does not need as strong a hinge as the strongest bed and in some respect is over-engineered for the fourth strongest bed, scale of economics can be reach and thereby cost can be lowered. This is done by reducing the variance of hinges, allowing the supplier to eliminate setup costs and allowing discounts for the vaster amount of hinges of one type. Depending on the volume and the saving by standardizing, consolidating suppliers, purchasing role in

[18] See figure 9, Non-modular vs Modular in Module Decoupling with Standard Interface

modularization, is often considered the complying the most savings to modularization. This is in many respects true, when looking at financial documents. Costs which normally are allocated are now lowered, which means the company makes more money. However, if the parts create differentiation, and create value for the customer they should not be standardized. These parts create another opportunity for the company to effectively keep the customer happy with distinguishable look and feel. If the parts are key to segmenting the products differently and reach multiple customers the company can standardize their interface specification, creating decoupled modules, and thereby switch between the differentiable parts without altering the rest of the product. This creates value for the company which may not be as visible as standardizing component and reduce cost directly.

Supplier consolidation is often the first cost saving opportunity in modularization, and sometimes considered as the 'lower hanging fruit' which are perceived as the easiest benefits to reek. This is a very important part of modularization, a undisputable the easiest measurable benefit, far greater achievements than 'just' standardizing is reached with modularization. One of these many other achievements is supplier activation, which heavily involve the purchasing department.

Supplier activation describes how ventures to other industries can allow for further innovative production opportunities. Often, companies settle for the industry suppliers and fail to achieve benefits from including other solutions or processes from outside the industry that can improve products or production. Supplier activation is a product of analyzing current processes and solutions with 'out of the box' thinking. Once the goal of a certain process is defined down to the very basic properties, it can be possible to find suppliers in industries which traditionally are not tied with the company doing modularization.
An example of this is Danish windmill producer, Vestas A/S, which found that the netting they needed for producing their wings were much similar to a northern Danish plastic company that were producing plastic netting for protection of liquor bottles. Vestas A/S activated the supplier to deliver larger quantities of netting which was used as a mesh for applying coat on windmill wings.
When modularizing, supplier activation is a natural repercussion for further cost cutting options. Along with current purchasing role, a never ending struggle to receive parts from suppliers for the cheapest price at sufficient quality, new suppliers from unforeseen businesses may be able to offer solutions to reach the output scale which standardizing components delivers.

Research & Development

One of the greater challenges in modularization is the ability to design modules of decoupled interfaces which can build on other modules, thereby mixing solutions to match market demands. The design, and thereby effectiveness, of these modules derives from Research & Developments ability to encounter all

aspects in the value adding process. Research & Development will not only be in charge of designing the platforms and interface specifications, but the problem solving knowledge embedded in Research & Development is key to identify what solutions are critical, and what solutions can be leveraged in order to create more value for the customer.

Research & Development is key to any company's innovative ability. But thinking Research & Development alone can implement modularity within a company will resolve in semi modularization, which will not wreak all the benefits possible. When the modularization team determines an opportunity it will afterwards be a task of redesigning the part or module to incorporate the opportunities identified, which is often reserved for R&D members. Having that said, R&D have important input to contribute whilst finding these opportunities, and the problem solving nature of the department will contribute greatly to any modularization. Once again team solving across functions will allow for solutions which service all division's goals.

The important information gathered from the cross functional team is often vast and incomprehensible, but nevertheless essential for developing modularization. In order to compensate for the very hard task of sorting out intertwined solutions, modularization introduces decoupling points. These decoupling points standardize the interface specifications and thereby giving each interface a set of deliverables to achieve, in other words commanding that 'interface between module A and module B is XX communication/connectivity'. By achieving these predetermined deliverables it is possible to initiate development on 'module B' before 'module A' is finished, because the deliverable measure for 'module A' is already known. This sort of predetermined 'blackbox engineering' is where the R&D department comes in handy. By using specification and goals, determined by the modularization team, the R&D department has a specific set of deliverables which has been derived by involving all functions. This allows them to redesign parts or modules to meet concrete constraints, which will either lower number of parts or increase number of variants. Modularization is typically not done on a blank canvas, meaning a company already has existing products and processes. This allows modularization to achieve great benefits once these existing products are streamlined, but it also involves a lot of work untangling the existing solutions into ones which can be redesigned to meet specification. The reason for this is the tightly coupled product architecture which has been the classical way of product development in industrial production. This dilemma of existing solutions will be discussed within the modularization team when finding optimizations, which is crucial for designing new part or module. R&D will play the role of seeing these improvements to actual development and design tangible solutions which fit the specification. This will normally be done by R&D in the aftermath of a modularization team gathering, as the decision come to light. R&D posses the

necessary competences and execution to implement the solutions of redesigned parts or modules, and will perform work which result in tangible solutions as well as strategic.

The strategic implementation for the R&D department is to spread word of new interface specifications and enforce their use in ongoing or future development projects. Being in the modularization team the participants from R&D are familiar with which products are affected. The task of informing personnel responsible for affected products will allow the responsible personnel to adapt the modularization principle to their daily activities. This can include extending existing R&D projects to take decoupling into account in development, or simply inform responsible personnel of a part change. There is, of course, a tradeoff of implementing modularization findings in ongoing projects, which should be evaluated from case to case. If delay of a project to include these findings will ruin market potential, a rolling change to include modularization findings in next product generation would be more beneficial. These rolling changes can be an easy way of introducing the modular design, if the product generation cycle is relatively short. But since modularization projects will continue in other areas, ultimately reaching already modularized areas, it is important that these changes are made with a frequency which allows production to adapt, and not implementing all changes at once. Having that said, if product portfolio is relatively small and architecture simple, a once-over implementation may be possible without greater repercussions.

Manufacturing

In Modularization the manufacturing department will participate with their knowledge of fabrication of the products or module areas of scope. Manufacturing can provide insight to how easy solutions can be implemented. Manufacturing have great experience in how to design tools in order to achieve easier assembly in production, knowledge which is imperative in order to utilize the responsiveness modularization can provide. Along with the expertise of determining tooling to adapt and implement the proposed solution from the modularization project, manufacturing will contribute greatly to the iterative decision making within the modularization team by sharing their knowledge of fabrication. This knowledge can provide great insight when determining standardization of parts and implementation of solution.
From a manufacturing standpoint, a company and its production have a set of capabilities in the form of personnel and equipment. Some solutions might be good on paper, but not suit the company's fabrication process, for which upgrades would have to be purchased in order to encounter these solutions. However, manufacturing can provide information of how this solution might be altered in order to minimize initial cost, and still reach the proposed result. When determining solutions, which can create cost savings, it is important to evaluate the company's current capabilities. If the proposed solution save $5.000.000 a year, and the manufacturing investment in order to adapt such a solution is $50.000.000, the modularization

team may want to think of different alternatives, since a payoff rate of 10 years usually is too long for industrial companies. In this instance, it may be possible to find a solution to use current capabilities to fabricate a solution, which may not be *as* effective, but still support the principle of modularization.

In a long term point of view, the manufacturing department will have great influence to how the company adapts modularization. In time, the production facility can be designed to support modularization by dividing facilities up into modular production plants. Sections within the production facility will utilize the decoupled designs to concentrate on a section of similar modules from the portfolio. This reduces setup times and allows a company to minimize bottlenecks even further than with traditional lean principles. By implementing a modular fabrication, manufacturing will gain great cost reductions throughout the production of the portfolio. This way it will be able to have a final assembly connecting the decoupled interface point, and switching between great variance in end product without starting final assembly from scratch but rather attaching a different module.

Quality

As industry trends force acknowledgements of competition from new evolving markets, one of the remaining edges is the production technologies are focusing on quality, which ensure a high quality of products. Due to consumer awareness, quality has developed into an important performance measure. This consumer focus and awareness of market adaptation importance have created worldwide standards companies must fulfill in order to sell their product. These standards are made to ensure a certain level of quality is maintained. In some countries and regions, standards differ which offer challenges in product design to abide sale in different markets. Such standards or regulations are chiefly set to ensure consumer safety and are principally the same, but differ in minor respect. However, these regulations are, until recently, not necessarily followed by Far East LCC production companies. As a natural consequence of this, products from the Far East LCC's cannot be sold on the western market, which have left a general belief of western products being safer and of better quality.

Modularization allows a company to enhance quality as an affect of loose decoupling. When producing modular decoupled products, it allows the company to assess the functionality or quality of each module as it finishes. By standardizing the interfaces, i.e. the decoupling points, it is easy to test each module after it is produced by introducing test rigs in production as a checkpoint. This can improve product quality greatly and is a great benefit for the company. A transparency of the product can be traced through the production ultimately ensuring quality of the finished product. Testing each module can be considered a costly expense in time, and often unnecessary expense depending on the module, but in industries with critical quality requirements be of essential importance. If all the modules are tested, bottlenecks on the final assembly

line should be close to zero, due to the ensured working modules. Regardless of industry, having decoupling interfaces simplifies the production of an end product which automatically will increase quality. When quality or the lack thereof, affects product assembly lines by creating bottlenecks whenever a module is mal-functional in productions, it is important to either service the module or part, or swap it with one that is without error. Having Quality influence in the modularization project, can highlight areas where service of a module or part can be increased in order to minimize cost of assembly line breakdown. But such an influence can also ensure that modules or parts with errors are systematically replaced with new ones, downtime on the actual assembly line is once again lowered. Even though this calls for an inventory, of size matching the frequency of error, it can prove to save critical expense of downtime on assembly line.

Another aspect of quality is the maintenance of products in the field. In many industries having a product serviced is done by having a mechanic inspect the product from one end to the other. This can prove to be a costly affair, and often result in loss of a product for a considerable period. When producing decoupled modular assembled products, it is possible to locate errors faster and more efficiently. If a module fails, or is compromised, the modular architecture allows for an easy substitution to a functioning module. Not only will this same time and money for the service mechanic, and thereby the company, but it will also enable customers to be charged with a lower fee than what it usually costs to have a repairman investigate products on site.
In order to save time, quality functions input in the modularization project can prove to have great after-sales value. If in fact a product fails, accessibility and disassembly can prove to be a costly variable in terms of resources and skill level of quality workers. If a quality input in the modularization project, i.e. the 'development phase' (even though this is in fact a redesign), can simplify the disassembly in order to service the malfunctioning component, personnel training to handle such a product service is lowered, which disables the need for highly educated technicians with greater salaries.
By improving service and accommodating the problem of the customer, regardless of fault, customer loyalty will increase (or in some cases, by using damage control, the aggravation from the customer will decrease). This will allow the company to minimize loss of popularity because of poor service.

Involvement of all departments

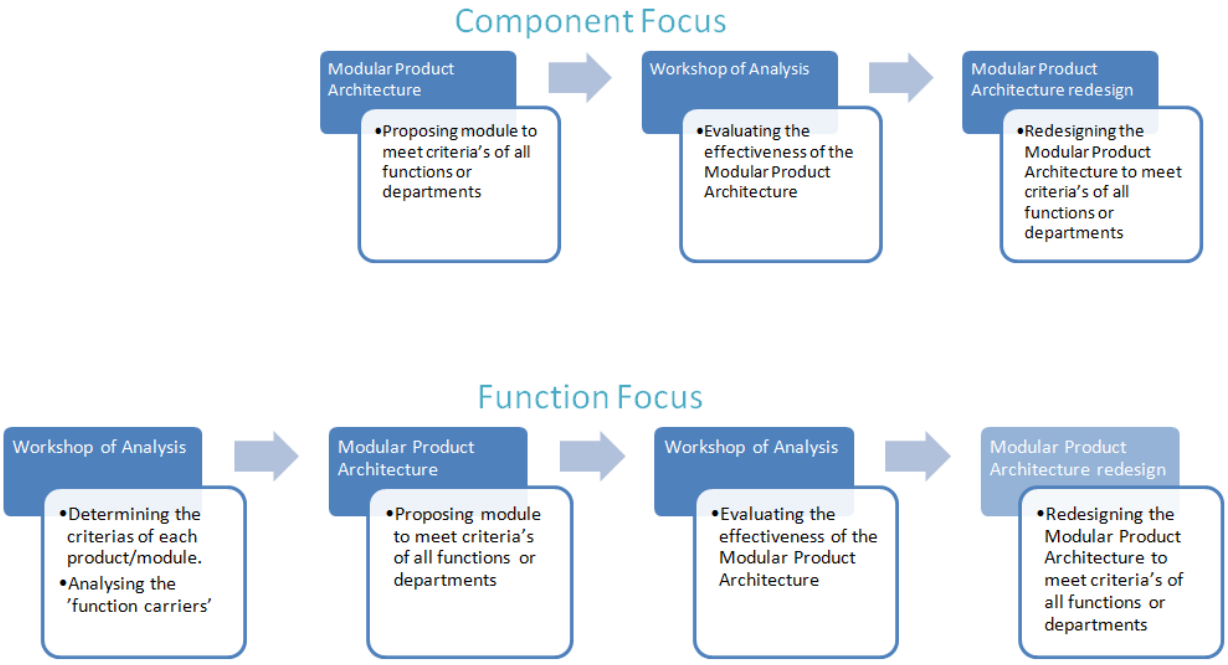
When modularizing, it is imperative that cross functional teams lead the modularization. Overall, when considering modularization, the involvement of all departments (Marketing, Purchasing, Manufacturing, R&D, Quality, etc.) ensures a company that every criterion from all functions of the organization in the product redesign has been heard, thus creating the synergy benefits of modularization.

Market variations may conclude that some departments are less critical for certain types of companies. In markets or industries where innovation rate is low, Marketing functions may not be proportional to the remainder of the company. This, however does not mean the inclusion of Marketing functions in modularization projects should be disregarded, as important insight to customer requirements and market trends are extremely valuable for accommodating future innovations. By taking these requirements and trends into account, the company can prolong the life cycle for a module, and reuse the same module in new generations of product.

How Modularization

In this section the process of reaching modularization will be described. There are many ways of reaching modularization and this is just a handful of them. Each path is beneficial in certain companies and industries. In order to implement a modularization strategy it is important to remain patient. No strategy is implemented all at once, and modularization is no exception. I will be discussing modularization 'projects' which will cover the initiation of modularizing, where a company isolates the module to analyze and redesigns the module to fit a modular strategy. Such an analysis and redesign may occur in various shapes and forms, but the most common being workshops of analysis, including all functions or departments of a company, and Black Box Engineering to determine product architecture. This can be implemented several times in order to completely modularize a product, and even more to modularize a product range or portfolio. Depending on the company's existing product complexity and variation, the 'projects' will vary in resources and time. In small companies with low portfolio complexity, a company may be able to cover several modules in one 'project' whereas large companies with great portfolio complexity will not be able to do so. Once the modularization 'project' is proposed, development of the tangible modular solution will begin (typically in R&D department), and the implementation into production will follow.

There are four main approaches to determine modularity. These can be described as results in a 2x2 matrix seen in figure 11 below. The matrix axes determine which end the perspective in architecture should be, and whether component or function is the driver of modularity. Once again the modular approach is situation specific and companies may choose different approaches to reach modularization. If the product architecture is complex, companies may tend to use functional approach, whereas product architectures less complexity may tend to use component approach. Depending on which approach a company chooses there commonly be different structures of the modularization project (illustrated below). When using a component focus, the proposition of modular product architecture will be followed by a workshop of analysis, to determine the effectiveness of the modular product architecture, followed by a redesign of product architecture.



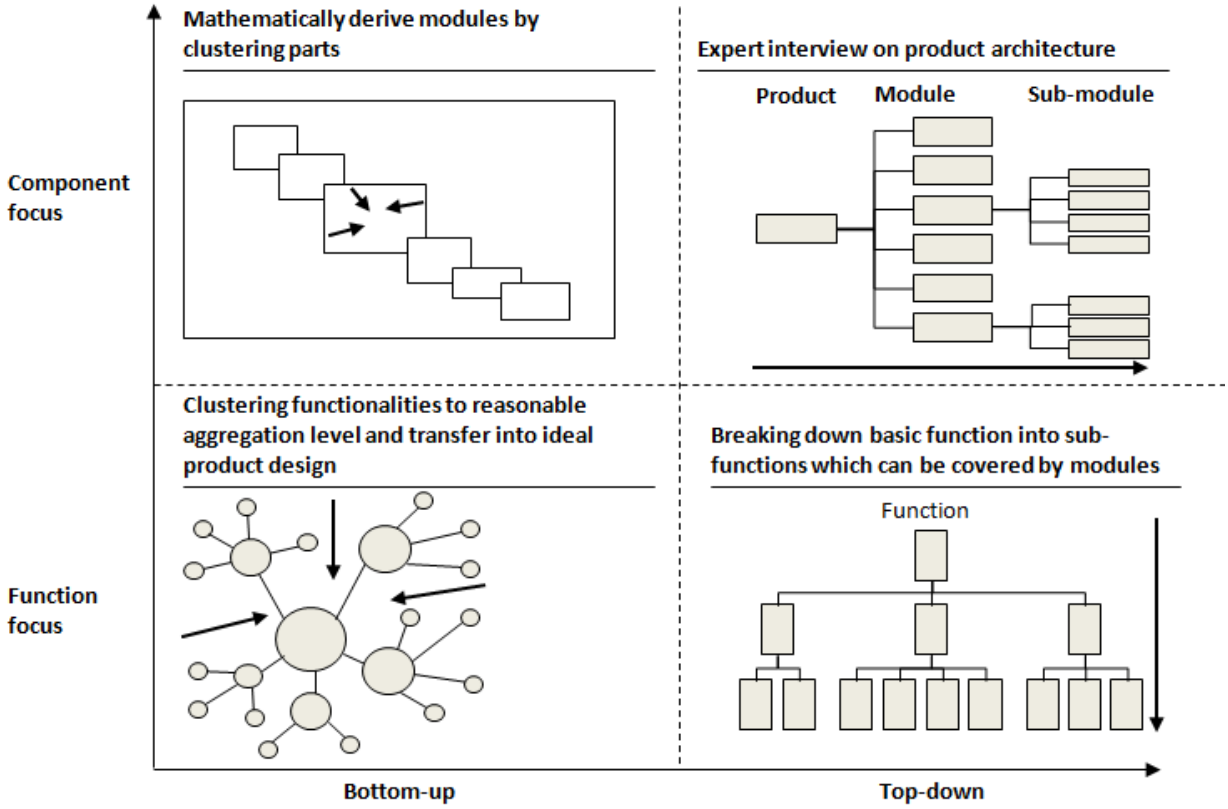
Figur 11 function or component project structure

Blackbox/workshop/blackbox/workshop

When using a component focus, the workshop of analysis to determine criteria's of functions will be followed by a proposition of modular product architecture, which once again be evaluated by a workshop of analysis to determine the effectiveness of the modular product architecture.

Modularization focus

As described above, a 2x2 matrix can generalize the 4 main approaches to modularization. One axis describing the component or function focus and one axis describing the top-down or bottom-up approach.



Figur 12 modularization approach

Component Bottom-up

A component bottom-up focus to modularization is beneficial for companies who typically are producing known architectural products. Such a company can be described as a company with clear market segmentation with little overall variation of product function. These types of companies are aware of their customers and their market, and have no immediate intention of straying from this product strategy. An important factor for using component bottom-up focus to modularization is the ability to grasp the product architecture without getting lost underway. If a component bottom-up focus for modularization is used for a car manufacturer, the complexity of including all components may very well be too large a task for effective modularization. By 'knowing' the product architecture a company can analyze the current product decomposition in hopes of deriving at a modular structure. One of the ways to do this is by clustering components into modules which are included in the majority of the product portfolio, and modularize those which are not immediately substituted from one product to the other. One way to do this is to

mathematically apply framework for determining what parts or components to cluster into modules[19]. By using a mathematical approach to component bottom-up modularization, the company will find how modular the product is, which in turn can be used to determine how to increase modularity. By analyzing the mathematics, the company can then determine what components in the architecture are best to cluster into modules, and where it is beneficial to increase decoupling in order to accommodate product variation in the portfolio. By analyzing the architecture mathematically, the company will derive at very tangible and scientific approach in order to determine the architecture of the product. This can then be used as a check list for designing the new, more modular, product architecture. As this mathematically derived framework is not situation specific the company should, as always have a certain degree of skepticism as to how accurate the mathematical function incorporates all considerations. Factors like foreseeing ones product in a larger scale composition can prove to be order winning factors. If the company chooses to follow mathematical tools to determining product architectures, which complicates or alters a large future customer's requirements, the company may fall short of winning that order.
This mathematical tool is also applicable internally in a product architecture where a function of a product, or module, can be analyzed by use of component bottom-up in order to increase modular performance of the overall product.

Another approach to component bottom-up modularization is to focus on key company components and build surrounding architecture to reach proposed solutions. This approach may be less attractive for established companies with existing market segmentation, and more of use for a company trying to apply knowledge of components to design products. If a electronic company in the semiconductor industry have a specific knowledge and design a microchip that fulfill specific solutions, but fail to apply the proposed functionality to existing market solutions, they can use bottom-up component focus to architectural design connectivity and communication for the component in order to achieve functionality. By using this focus, the company can modularly determine how interface specifications critical to the component should be incorporated to design products.

Component Top-down

By focusing on the component it is also possible to derive at modular solutions with a top-down approach. This approach can be useful when the existing product architecture is vast and complex, making it overwhelming to analyze the architecture from the bottom up. Many companies prefer the component approach to modularization, because it allows them to consider concrete existing solutions as a reference point and work towards an architecture that is more modular. By using component top-down approach to

[19] Mikkola, J.H. & Gassmann, O. (2003)

modularization, a company is able to derive at modular architecture within a faster timeframe than meticulous component analysis. This way, the company may reuse existing knowledge and expert experience to derive at modular structure with more intangible knowhow than other approaches. It can be argued that this approach has a higher fail rate of human error, than a structural scientific approach, but managerial confidence and employee ownership trade-off will result in quicker modularization. By using component top-down approach, intangible knowledge is used to determine what architecture is desirable for the modular structure in order to accommodate the future product design. When using component top-down approach to modularization, expert interviews to propose modularity are used for essential parts of the product. Depending on the existing architecture, numerous experts are introduced in collaboration to accommodate the component requirements. By doing so, the architecture is divided into responsibility areas to be analyzed in detail by the designated expert. After doing so, the responsibility areas are collaborated and used to determine interface specifications in architecture. With this approach it is imperative that the experts are in tune with the principles of modularization in order to incorporate the benefits associated with modular product development and production strategy. This alignment is to ensure that all experts in each separate responsibility area reach decision that benefits all aspects of the company's operation and the modularization proposed are effectively benefitting across all functions.

Function Bottom-up

Another approach to modularization is the function focus. The function focus can be considered more loosely coupled to the existing product architecture, since the approach is reevaluating the goals of functions, i.e. the way the product achieves its predetermined goals. By using functional approach to modularization, the participant's mindset is more out of the box and can derive at a product architecture that may prove to be different than what is currently used. The function focus approach to modularization can be more time consuming than the component focus approach, since there is no tangible components to reuse and evaluate. Only when the different goals are set for each function, the components and parts used to fulfill these goals are determined. It can be argued that function focus can be less true to the current product architecture, and therefore be harder to implement. Solutions found in function focus may prove to be so different than existing processes that costs may increase in training resources, production equipment and the like. However, the function focuses have its benefits as well. If a company is not happy with its current product architecture a redesign by function focus is a great implementation, because it allows the company to reevaluate the requirements for a function. For example, by reevaluating the requirements of input method for a computer, Apple introduced a Macbook with a circular iPod input method rather than a traditional keyboard. Also, company mergers can lead to product development alignment, where a function focus modularization can be a great way of accommodating this alignment by

including both parties. Function focus approach have great benefits when product portfolio similarities exist, and the company wishes to consolidate its portfolio architecture complexity.

By using function bottom-up focus, the company cluster functionalities to reach modules that deliver the proposed solution. To cluster functionalities there are different tools to use usually derived from other product analysis tools like Quality Function Deployment. A widely accepted method in modularization theory of clustering functionalities is Gunnar Erixon's MIM (Modular Indication Matrix)[20] where rating of connectivities by 'function driver' indicates what functionalities may be a good module. Erixon's widely acclaimed method of determining modularity can very well be used as a tool to determine modules by function bottom-up approach as described above. By determining these clustering's of functions in a well adapted general framework can propose functional composed modules which can be used to determine 'module architectures'. To determine these 'module architectures' the participants will use their respective experts to derive at component structure to fulfill the goals identified in the MIM. This once again highlights the importance of participant diversity in determining goals and the expert knowledge necessary to determine the means of meeting these goals.

The function bottom-up focus analyzes the functions within a product and derives at a clustering of components that serves functionality, as a proposition of modularization, which will be used to determine product architecture by expert development team. This has a great benefit in evaluating existing product architectures which serve same or similar functionality. By using function bottom-up approach to modularization, the existing components used in product architecture to serve as a functionality is evaluated and aggregated into an ideal design to meet functionality criteria. Depending on the complexity of the product portfolio, function bottom-up can be translated into portfolio-wide modules that can be implemented across product lines, like the Black & Decker motor[21].

Function Top-down

Much like the function bottom-up approach to modularization, the function top-down approach analyzes functionalities in a product portfolio in order to derive at modules. The main difference in the functional approach is how the clustering of existing functions in bottom-up is done, and how the function within a product is determined in top-down. When using top down, a very loose innovational mindset is used in order to conceptualize what a products function should be, and how sub functions support these functions. Much like the bottom-up approach, tools like MFD[22] can be used to determine how functional decomposition of products are used to determine what justifies a product and how the means of these

[20] Erixon et al (1996)
[21] Koen et. Al (2002)
[22] Erixon et al. (1996)

justifications. This is done in a decomposition to rationalize how and why products function in order to meet these functions and only nothing else. An important mind set in such an exercise is to filter out knowledge about how solutions are done specifically to support functions in current production, in order not to reach the same product. Of course commonality of will occur in such a problem solving, but the open mindedness of defining what functions do in the means of solving problems within the product or module will be key to determining the right modules.

Another application of function top-down approach is to define cross sectional modules across product lines. This can be done, by reevaluating functionalities in a product portfolio to meet similar goals that can be used cross functionally. Whether this goal being a communication module in the powerboard in a company producing a wide range of home appliances, or a gearbox that can be used in all types of busses and trucks.

Organizing Modularization

There are several organizational steps which need to be taken into account in order to implement modularization successfully. Firstly, the need for modularization has to be adapted by top management in order to generate leverage in using resources. Secondly, roles have to be assigned for designated modularization employees, whether this is a permanent or temporary role.

Anchoring Modularization

When implementing modularization as a strategic tool it is imperative that top management are committed and take ownership for the implementation. Not only is there a large investment tied to the implementation of modularization, there is an expenditure of resources when applying redesign to the designated modular areas, which will erode the effectiveness of current product development. The benefits reaped by a full modularization are not developed instantly, and top management will have to understand the implementation process and costs in order to guard them with the patience necessary. If modularization is not adapted top down, and management does not commit to modularization, the initiatives driven in order to achieve modularization will fall short of importance and not be considered top priority. Should this happen, redesigns to fit modular product development can become obsolete and the resources and time spent on initiating modularization will be lost.

Another paradox of optimizing a company with modularization is the risk of opportunistic behavior corrupting the success of the implementation. When modularizing product development and implementing modularization as a strategy, people will view modularization as a cost cutting exercise which may lead to the individual employee losing their jobs. For example, an employee involved in a modularization may see the product decoupling as a means of outsourcing his or her particular area of expertise, since the decoupling allows the module area to lift out of the product development. Even though there are possibilities of outsourcing particular modules tied with modularization the strategy and tool is first and foremost one which increases existing production ability by effecting product development and eliminating unnecessary components. An opportunistic behavior may cause the particular employee to use misinformation which can be costly and in worst case destroy the ability to modularize. In order to avoid opportunistic behavior, many companies implementing modularization promote certain employees to accommodate the practicality of dealing with modularization (workshops, analysis etc.) and only use salary staff to provide with data used for modularizing in the initial phase. By using hard core facts the company then present saving opportunities, which are impossible to dispute, it clarifies the opportunities rather than allowing the individual employee to doubt fear for their jobs. As companies who have implemented full scale modularization realize, ‘converting’ to modularization is as much a change process as any other.

Therefore creating 'the burning platform' or 'a sense of urgency' and 'dealing with Nono's[23]' can be done simply by estimating the current costs based on indisputable facts and acknowledging that the competition may view these as sunk costs.

Once the approach is selected for the specific company, a matter of organization can affect the implementation and adaption of modularity depending on company structure, product complexity, etc..

Defining Roles

When the prerequisites for modularization are in place, the practical roles need selection. It is important that the company assign the managing of modularization. The employee managing modularization does not have to be the most experienced one, nor does the employee need the most expert of insights into production development. The employee assigned to manage modularization needs leadership skills and the principles of modularization, along with the ability to delegate tasks. The Modularization manager's role is primarily to organize and plan the modularizational steps needed in the implementation and initiation phase. By delegating and evaluating on the conclusions of his appointed experts, the modularization manager, will along with the rest of the modularization team, conclude the analysis of products and determine modular architecture proposition. Once again, the importance of including all functions of the company in the modularization team is essential for modularization success. While the primary job of proposing product architecture to fit modularity is in tune with the black box engineering philosophy of an R&D department, obstacles and benefits reached in different departments by modular product development may not be foreseeable by even the best of engineers. If a company has a small marketing need, one might argue that the role of marketing in the modularization project should be left out, but gaining insight from that small marketing need, regardless of size, is essential for a modular strategy. When determining the scope of the modularization team, a rule of thumb is to ensure proportional fit of influence in modularization team as in company organization.

[23] Kotter (2006)

Figur 13 Modularization organization

When the analysis and proposed modular architecture have been successfully concluded, the implementation will be adapted to the company organ, and will once again become situation specific. One solution often implemented however, is a 'cook book' implementation guide, where planned steps to achieve modularization in the proposed area is described.

Designated Modularization team

When adapting a modularization strategy, companies will be initiating modularization projects throughout the product portfolio before they are finished. In fact, finishing modularization is not exactly a tale often told, as the adaption of modularization turns companies into religious pursuers of modular benefits. Scania, a modularization heavyweight, is approaching a decade of modularization strategy indicates that the adaption modularization rarely reaches an 'end goal', rather than the one of becoming a little better every time. Therefore a company may find it necessary to introduce a designated modularization team. Depending on the need for modularization and how frequent these projects occur, the roles and positions may be permanent or occasional. With planning, organizing and initiating the modularization manager may have a fulltime position, but members of a modularization project like experts in product architectural design or workshop analysis may not be considered a full time position. Also, including the same people time and time again may lead to undiscovered possibilities.

A recent trend in company organizational build is 'integrated product organization'. Integrated product

organization can be described as a team covering different parts of a company's operation to serve one product. In modularization organizing to accommodate products or modules are essential. As argued previously, modularization projects are in need of collaboration of all operations of a company to accommodate all the benefits possible tied to modularization. As products become increasingly decoupled into modules, the organization adapts into same decoupled ties. Such a decoupled organization is described within modularization theory and acknowledges the need for diversity to meet demands driven by modularization[24]. The need for flexible organizations when producing modular products is an increased factor as mixing and matching becomes a product development strategy[25].

Start up Modularity

Modularization in production industry has followed a series of investments in resources and time in order to meet modular production development principles. The reason for the amount of resources and time spent to redesign existing solutions and products is due to the fact of existing solutions and products. A history of sequential product development can lead further away from modularization principles and increase the necessary investment to adapt modular strategy. However if a company, starting from scratch, chooses to use modularization strategy, the time and resources spent to redesign existing processes and products are gone. The development may initially still take longer in order to develop modules that are sustainable for mix & matching, low setup costs in production, standardizing components, etc. but will reap the benefits much sooner since reinventing product development processes is not necessary. When implementing modularization as a start up strategy, purchasing takes on a slightly different role than described so far. Because all choises of components are leveraged and evaluated, purchasing will spend more time on supplier activation, than supplier consolidation, i.e. searching for possible new suppliers in other industries. Unfortunately, startup companies rarely have a large capital and their strategy to reach profit as soon as possible overshadows the benefits of modularization. If the company can allow an initial prolonged product development to create sustainable modules, the company can reap the benefits of modular production[26] as well as modular product development.

Implementing Modularization

As modularization projects within a company derive at cook books to implement modularization, the company will embrace the cookbook as a guideline of product development, and the modularization team will investigate new areas of the product portfolio to undertake modularizational analysis. The cookbook, explaining the specifications of modules, will be re-evaluated to accommodate technological improvements

[24] Sanchez, Mahoney (1996)
[25] Schilling, Steensma (2001)
[26] Erixon et. Al. (1994)

in the industry. The cook book will be implemented in the separate functions of the company (procurement, marketing, R&D, manufacturing and quality) and used as a tool to reach the benefits associated with each function. By doing so, previous processes may be altered in each function. It is important for the company to stay true to the cook book in order to reach economies of scale associated with modularization, and the cook book is not altered too frequently. However, innovation rate in the industry will define how often a cook book needs renewal, thereby sustaining the modular cook books to accommodate new generations and innovations. This will be a central part of the company in the future.
A derivative of modularization in product development is the modularization in factory. As the company implementing modularization increase decoupled development, factory layout will accommodate such a decoupling and produce modularly. In order to alter the layout of a company and produce in modular fashion, the company must have modularized the entire scope of factory output. When this is done, product line #1, #2 and #3, will be replaced with module line #1, #2 and #3, followed by an assembly line, where the decoupled modules are connected. By implementing module lines in production, quality testing of modules become increasingly easy, and decouple points of the module can easily be tested and verified. The modularization of factory is, just as every modularization of product development, situation specific, and cannot be described in a framework. Rule of thumb in modularization of factory remains to accommodate modular product development by utilizing decoupling to determine module lines and quality test at decoupling points. Assembly lines are introduced to accommodate 'hamburger assembly' or 'base part assembly'[27].

[27] Erixon et al. (1994)

Theoretical Conclusion

I will state the essential elements of conducting modularization and ensuring success of implementing such a modularization from a theoretical perspective:

- Market demand affects your modularization, and is essential to determine in order to know what to modularize and what not to. Specifically if demand has large variance or high demand frequence.
- By reusing modules Time To Market is decreased
- By designing modules which are over-engineered to serve several products you eliminate a substantial amount of components
- By defining modules, you can reach greater product variance with fewer components.
- By defining module decoupling with standard interfaces, and reusing well documented modules you can increase quality
- When modularizing, cross functional involvement is essential to reach the synergy benefits of modularization described above.

Practical Approach to Modularization

In this part of the project I will describe how real world companies have implemented and used modularization.

In order validate the theoretical approach of modularization, I have conducted a multiple case study to determine whether the involvement of all functions lead to a successful modularization. The empirical evidence to prove cross function modularization is essential, is conducted by interviewing companies which have all used modularization in different degrees in order to improve their competitive position in their markets. By conducting this empirical case study I intend to explain how theoretical approach to modularization fit into a real world analysis. By doing so, I am evaluating the theoretical framework of how functions affect the succes of a modularization by comparing it to actual modularization. This is done by analyzing how case companies differ from the theoretical approach of including all functions in modularization in order to achieve all benefits tied to modularization. This analysis will build explanations of how real world examples differ from the theoretical approach, and why such a differentiation occurs

Case Company Examples

In this section of the report I will conduct an empirical case study, in order to determine how companies have used modularization, and what is important for these companies. I have interviewed all of the case companies on the same questionnaire. In the questionnaire for the companies I conduct a series of questions in order understand the company modularization learning curve, at what scope they used modularization and how they are using modularization. Below is a simplification of their answers, rated to indicate how true to modularization principles they are in their answers. The questionnaires will be evaluated by comments, to explain what factors influenced their answers.

Questionnaire

The questionnaire ratings are as follows:

#) Question?			
Case Company	High	medium	low

MODULARIZATION STARTUP INITIATIVES		
	1) How did the awareness of modularization arise?	
	Case company A	Observation & Evaluation
	Case Company B	Need for change to survive
	Case Company C	Strategy to increase innovation in products. Increase quality
	2) On what level was modularization used? Strategic, production, development	
	Case company A	Skunk work. PD
	Case Company B	Strategic. 'Full modularization'
	Case Company C	Strategic full implementation
	3) How were the opportunities of modularization identified as a fit for the company? Component sharing, cost cutting, speed to market, service, etc.	
	Case company A	Component sharing
	Case Company B	Lower PD cost. Scale production. Increase Quality
	Case Company C	Reusing knowledge, increase quality, meet market demands
	4) How was the idea of modularization adapted inside the company? Industry trend, idea bank, board meeting, etc.	
	Case company A	Skunk. Not adapted as a tool
	Case Company B	Knowledge gathering. Case study trip to USA.
	Case Company C	PD conference.
	5) What were the qualitative goals for modularization when initiated?	
	Case company A	No initiation. Continuous improvement
	Case Company B	improvement in Quality, reaching economies of scale, lower development costs
	Case Company C	Increase quality, improve PD capabilities. Reuse knowledge

Case Company A: Because Case Company A has no communicated strategy to use modularization, initial foundational work has not been implemented and communication about the usage of modularization has

not been done. This does not mean they do not use any form of modularization, but focusing by conceptual modularization principles has not been done, therefore awareness of modularization use is limited.

Case Company B: As questionnaire indicates there was a well documented understanding of modularization provides great insight to challenges and realization of setup of modularization. Interestingly is the reason to use modularization a need for change in order to remain competitive, which may cause company to desperately search for costs cutting options instead of need for increased innovativeness.

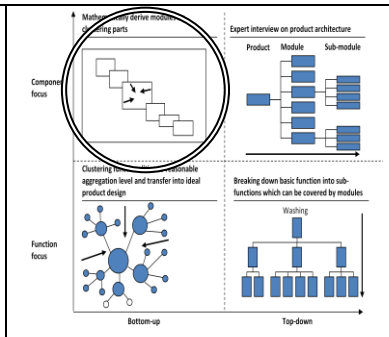
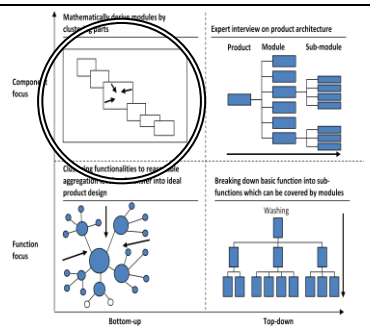
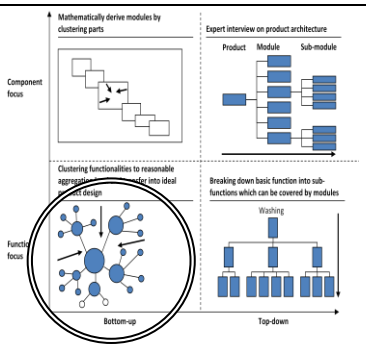
Case Company C: Case Company C implemented modularization for all the right reasons, and allowed for great modularization insight pre-modularization. As questionnaire will indicate, creating innovational competitiveness by reuse of knowledge to lower product complexity, is great alignment with modularization benefits.

INITIATION OF MODULARIZATION PROJECTS/STRATEGY

6) How was the implementation of modularization initiated? Consultants, trial and error, knowledge acquisition, etc.?

Case company A	Autodidact. By realizing opportunities and saving cost
Case Company B	Case study trip to USA. Best in Practice Consultant lecture. Then Trial & Error
Case Company C	One-time consultant. MBA in modularization. Knowledge sharing. Best in practice

7) What was the focus of modularization?

Case company A	Case Company B	Case Company C
		
Component bottom-up	Component bottom-up	Function focus bottom-up

8) What was the scope of modularization? Design, procurement, manufacturing, etc.

Case company A	No scope stated. PD

	Case Company B	Companywide, include all functions in modularization
	Case Company C	PD, Quality and Manufacturing.
	a. How was involvement from other functions used?	
	Case company A	No involvement as project. Some sporadic involvement from other functions
	Case Company B	By Integrated PD. Involvement part of daily activities
	Case Company C	Quality, PD, Manufacturing. By specifying tacit knowledge for reuse.
	b. How did the modularization initiatives communicate/adapt into other functions? Consequences of modularization	
	Case company A	No communication. Hierarchical delegation to meet interpretation of modularization.
	Case Company B	Active communication. Did not create the 'sense of urgency' required.
	Case Company C	Strategic communication. Flyer, themedays etc.
	c. How was delimitation of modularization defined?	
	Case company A	None.
	Case Company B	low end product line were not to be included in modularization, due to overdimensioning eliminating low end product of reaching higher economics of scale
	Case Company C	No delimitation

Case Company A: once again, the limitation of no communicated strategy of modularization affects the answers. As the company has historically used incremental improvements, they have found opportunities of sharing components, reusing knowledge and over-engineered 'modules' to reach cost savings. Also the company middle management specifies a 'language' across head functions of marketing and product development that resembles modularization.

Case Company B: Initiation of Modularization was well researched pre implementation and trial run of one line proceeded to become the new strategy. Even though communication was done, a sense of urgency to adapt modularization was not successfully incorporated with the rollout of strategy which did not provide the modularization with initial understanding and consensus of implementation. The integrated Product

Development organization was eventually supported by a separate modularization division to provide the backing of modularization needed. Delimitation of low end product line which was not to be included in modularization was done according to market needs, as the low end line had such a large volume that it was evaluated the modularization could not stretch to include low end product line at the cost. It was evaluated that the low end product line could reach higher cost savings by economics of scale, than including modules over-engineered for low end purpose.

Case Company C: As questionnaire indicates, focus of modularizing main selling product family indicated high commitment to modularization. Involvements of several functions ensured one of the main focuses, reusing knowledge, but failing to introduce all divisions indicate that company is less focused on procurement and marketing & sales, than manufacturing, R&D and quality. Communication by proactively explaining modularization indicate focus of heightening awareness among employees.

ORGANIZATIONAL ADAPTATIONS	9) What organizational changes were made to accommodate modularization? Daily activities implementations, modularization team, companywide project, etc.	
	Case company A	None.
	Case Company B	Eventually separate organizational team to encounter all Modularization aspects
	Case Company C	High organizational changes. From several product teams to modular organization.
	a. What roles were assigned to accommodate modularization?	
	Case company A	No assignments.
	Case Company B	Sr. PD Engineer. Handpicked team
	Case Company C	Product decoupling aligned organizational decoupling
	b. How were these assignments evaluated?	
	Case company A	Head of PD delegates.
	Case Company B	Subjective evaluation by Sr. PD Engineer.
	Case Company C	PD phase became modular phases.
	10) Where in the organization is the modularization anchored? Who is the sponsor for modularization and where in the organization does that person hold?	

	Case company A	Head of PD is only modularization “user”
	Case Company B	Top management passive but supportive. Middle management driver.
	Case Company C	Top management full backing of strategy

Case Company A: As organization is usually designed top down, the lack of communicated strategy to use modularization cannot permit organization of restructuring employees to have this as a responsibility area.

Case Company B: A separate organization division to accommodate modularization was eventually implemented as Integrated Product Development organization need additional modularization focus. This separate division was lead by experienced R&D manager who handpicked the team based on his subjective opinions. Unfortunately, this subjective opinion did not ensure that functional diversity to separate division, and the functional representation within the division became R&D focused.

Case Company C: Questionnaire indicates high focus on organizational changes, and decoupling organization to fit modules align perfectly with the approach of modularization,

MODULARIZATION PROCESS	11) How was the modularization processed? Methods, best in practice, workshops, etc.	
	Case company A	Autodidact modularization dictates to achieve Modularization principles. No methods, no workshops
	Case Company B	Best in Practice case studies from USA trip. Research of Best in Practice from other industries. One product line modularized initially, others followed.
	Case Company C	Internal consultant. MBA. Collaboration with Uni. And Best in Practice. Modules derived and implemented.
	a. How were the participants trained in modularization techniques? Trial and error, introduction meeting, extracurricular courses, etc	
	Case company A	No participants. No training
	Case Company B	Training was lacking but present. Derived initial skepticism.
	Case Company C	MBA in modularization. Themeday.

	b. What stage gate goals were used in the modularization process?	
	Case company A	Complying with PD's requirements. No formal process
	Case Company B	Create awareness. Build Knowledge. Define Architectures. Prepare tech. and concepts
	Case Company C	Unknown.
	12) How did the modularization project/strategy progress? From initiation to conclusion.	
	Case company A	No initiation. Has been derived from years of observation with head of PD
	Case Company B	Unexpected time length. Unexpected cost of implementing. Both were expected to be lower
	Case Company C	Main product family modular. The remaining families follow

Case Company A: as head of Product Development dictates to accommodate modularization benefits there are certainly some answers that point towards principles of modularization, but lack of involvement from other functions and no external learning process does not allow them to reach any synergies tied to modularization.

Case Company B: Steep learning curve for modularization proposed planning, that which did not meet schedule, indicates that all elements of modularization was not evaluated properly. However training steps and concept stage gates indicate awareness of modularization pitfalls.

Case Company C: Post modularization preparation was essential, which ensured them a great foundation to evaluate implementation and use of modularization. Communication of strategic change was communicated, even though no proactive training to ensure modularization understanding was streamlined. Dedication to modularization principles indicated by taking the main product family as initial modularization focus.

MODULARIZATION	13) How was the modularization initiatives implemented?	
	Case company A	By years of evaluating Case Company A PD. Sporadic areas of focus
	Case Company B	Derived at initial modularization for one product line then following the remaining

		product lines except low end
	Case Company C	One product family. Rest were to follow
	a. How were the findings of modularization initiatives communicated to heighten awareness about the projects?	
	Case company A	No communication
	Case Company B	Communication did not create enough awareness
	Case Company C	Ongoing communication
	b. How was the implementation of modularizational principles made? Rolling gradual changes, 'once over' changes, etc.	
	Case company A	Rolling gradual changes
	Case Company B	Module of initial product line 'once over' implementation. Else gradual rolling.
	Case Company C	Once over initial implementation, then rolling changes.

Case Company A: Head of Product Development has logically derived at principles similar to modularization's, and implemented them as areas arised. However, market needs required high volumes of low variance which sought alternatives to modularization

Case Company B: The implementation of modularization was done by modularizing one product line and afterwards incorporating the remaining lines in modularization. Communication to explain implementation and strategy, but was not communicated in order to convince employees that this was more than just a project. Eventually this was realized as most of the product lines were included in modularization.

Case Company C: Questionnaire indicates a solid effort to implement modularization in alignment with principles of modularization.

MODULARIZATION EVALUATION	14) What qualitative outputs were gained from modularization?	
	Case company A	Component sharing and reuse of solutions to drive scale and lower PD cost.
	Case Company B	Production effectiveness, time to market, quality
	Case Company C	Increased product quality, reused knowledge
	15) What quantitive outputs were gained from modularization? (documentation is greatly appreciated)	
	Case company A	None measured. Or estimated.
	Case Company B	30% Time to market reduction 25% Production cost reduction
	Case Company C	Scale of common modules. Quality improved. PD lowered. No quantitive record
	16) How is the customer experience of the company's product increased with modularization?	
	Case company A	Over engineered solutions with Upgradeable products to include 'add ons'
	Case Company B	Time to market. Some customers do not get customized solution, and have to choose solution from selection that fits to module
	Case Company C	
	17) How was the modularization approach/strategy embraced?	
	Case company A	No embrace of modularization
	Case Company B	
	Case Company C	Not embraced by procurement and marketing. Economical department did not understand the goals of modularization.
	a. What role did top management have in implementing modularization? Passive spectator, persistently push modularization decision, involve in modularization, etc.	
	Case company A	None
	Case Company B	Once committed, full support
	Case Company C	Proactive supporter

	b. What role of involvement did middle management have? Passive spectator, persistently push modularization decision, involve in modularization, etc.	
	Case company A	Subjective interpretation of modularization principles to increase development quality
	Case Company B	Driver of modularization. Both initiation and execution.
	Case Company C	Push modularization
	c. What role of involvement did salaried employees have? Passive spectator, persistently push modularization decision, involve in modularization, etc.	
	Case company A	Passive unaware subjects to principles of modularization
	Case Company B	Initial resistance
	Case Company C	unknown
	d. How were the methods, findings and concepts of modularization communicated to the rest of the company? Update meetings, workshops, modularization officers, etc.	
	Case company A	No formal communication
	Case Company B	No formal communication.
	Case Company C	Ongoing communication.
MODULARIZATION EVALUATION	18) What elements were key to the success of the modularizational initiatives?.	
	Case company A	Component sharing. Upgradeable products.
	Case Company B	Patience from top management to implement modularization.
	Case Company C	
	a. How were problems associated with modularization projects/strategy identified and solved?	
	Case company A	No initiation.
	Case Company B	Low cost products were not modularized in order to drive scale on set of components that were not over-engineered to fit different needs
	Case Company C	modularization was consolidated to eliminate *some* of the over engineered modules and

		reach higher economics of scale
	b. What experience for future use, can you gain from the modularization initiative?	
	Case company A	Unknown
	Case Company B	Communication increase. Specification of market needs and company capabilities
	Case Company C	more thorough analysis of market in order not to over engineer solutions unnecessarily

Case Company A: Use of delegation to specify how modularization principles are used with little to no collaboration with other functions of the company. Product portfolio is greatly influenced directly by market needs, and it's lack of variance limits the use of modularization somewhat. If quantitive measures of cost reductions gained by using modularization principles, which are inclined to be present, evaluation would rate higher

Case Company B: Focus and execution of modularization was in high alignment of modularization. Top management proved patience for modularization, which indicate well communicated purpose by the middle management, who were the instigators of modularization. Market needs determined that all products were not included into modularization, due to higher economics of scale saving potential by avoiding over-engineered modules. Communication to initially explain change strategy in company evaluated as a way of improvement for the future, in order to create awareness of goals using modularization.

Case Company C: As indicated by the Questionnaire, the modularization benefits initially described were not reached to full, and communication to all divisions to embrace modularization somewhat failed. Even though full support for modularization and implementation as a strategy was founded in initial solid research, market needs did not match the variation speculated to justify a full implementation. This lead to some modules being broken off into sequential design, as over-engineering of modules did not reach economics of scale level standardization would. Market need analysis proved over evaluated to fit full modularization, and should have consolidated the implementation plan of modularizing select part of the product portfolio.

19) How would you rate the importance of the following (on a scale from 0-5)?

Case company A

Preparation. Support documents, data collection etc.					
Participant consensus of Modularization challanges/goals					
Participant diversity, to meet all challenges across company operations					
Top management support of modularization					
Thorough maticulous work ethics in modularization team (speed less important than validity					
Rigid clearly defined roles in modularization team					
Goal oriented motivation with loose organizational ties with modularization team					

As no formalized strategy to use modularization is communicated, there are very little involvement and support for modularization.

Case Company B

Preparation. Support documents, data collection etc.					
Post modularization this rating would be 5					
Participant consensus of Modularization challanges/goals					
Post modularization this rating would be 4					
Participant diversity, to meet all challenges across company operations					
Top management support of modularization					
Post modularization this rating would be 5					
Thorough maticulous work ethics in modularization team (speed less important than validity					
Rigid clearly defined roles in modularization team					
Post modularization this rating would be 4					
Goal oriented motivation with loose organizational ties with modularization team					

As seen in participant consensus, Case Company B did not view the training of employees to grasp the full consequence of modularization as a highly important factor. As the questionnaire also indicates, this was underestimated, and should be of higher importance. As indicated participant diversity is fairly important

to modularization, and Case Company B share the belief that cross functional modularization is important. Similar to participant consensus, Top management support was pre modularization rated lower than it would be rated after the modularization implementation. Top management patience with implementation indicates that modularization had backing from top management. The post modularization upgrade of role defining indicates that initial organizational changes were not sufficient to accommodate modularization.

Case Company C

Preparation. Support documents, data collection etc.	
Participant consensus of Modularization challanges/goals	
Participant diversity, to meet all challenges across company operations	
Top management support of modularization	
Thorough maticulous work ethics in modularization team (speed less important than validity	
Rigid clearly defined roles in modularization team	
Goal oriented motivation with loose organizational ties with modularization team	

Interestingly Case Company C heavily invested in understanding and communicating modularization in initiation and startup phase, but rate the importance of such documents low. As interview will indicate, interpretation of support documents can be analyzed until eternity, but evaluating to perfection will never be realized. In contrast, goal oriented loose organizational ties are valued high by the interview. All of this is considered subjective by the person interviewed, stating that he rates ‘action over words’.

18) How would you rate the accuracy of the following statement (on a scale from 0-5)?

Case Company A

Marketing is an important function in modularization for your company	
Purchasing is an important function in modularization for your company	
Manufacturing is an important function in modularization for you company	
R&D is an important function in modularization for your company	
Quality is an important function in modularization for you company	
Company operation size is proportional to modularization team participation	

As Case Company A primarily use autodidact interpretation of modularization principles in R&D, there is very little consensus of cross functionality. The case company did not wish to speculate as to how importance should be valued as they have yet to initiate a formularized modularization strategy.

Case Company B

Marketing is an important function in modularization for your company	
Purchasing is an important function in modularization for your company	
Manufacturing is an important function in modularization for you company	
R&D is an important function in modularization for your company	
Quality is an important function in modularization for you company	
Company operation size is proportional to modularization team participation	

As shown above, and indicated in the interviews, Case Company B agree to the statement that modularization heavily depends on the company operations, and use modularization by incorporating several functions in projects. As Case company B evaluate, some functions are more important to modularization than others, but all are evaluated to have a great influence on the outcome of modularization.

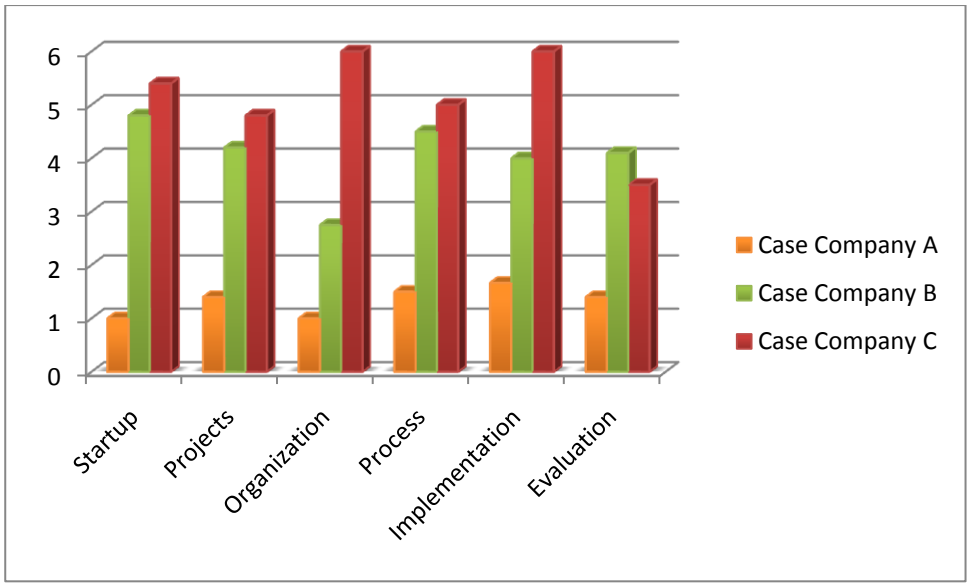
Case Company C

Marketing is an important function in modularization for your company					
Purchasing is an important function in modularization for your company					
Manufacturing is an important function in modularization for you company					
R&D is an important function in modularization for your company					
Quality is an important function in modularization for you company					
Company operation size is proportional to modularization team participation					
post-modularization this rating should be 5					

In this rating of importance, marketing did not receive a high rating to include in modularization. In contrast the consequences of not evaluating market needs forced Case Company C to consolidate the scope of their initial modularization. In retrospect, the employee interview evaluated, that even though modularization team size was not proportional to operations when implemented, this should normally conceive a rating of 5.

Summation of interviews

By summarizing the findings in interview empirical study we find the following:

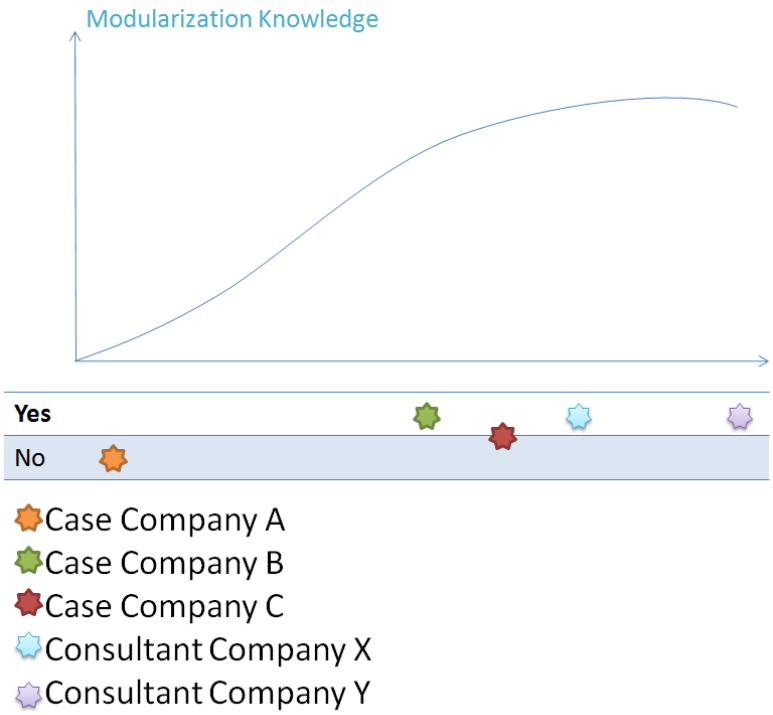


As above mapping indicate, the three differ in degree of modularization. Where Case Company A indicate to have low modularization, Case Company B and C are respectively higher. Interesting findings in the questionnaire is the curve of Case Company C, where evaluation rating is below par of the company's other ratings. As Case Company C initially implemented modularization full scale and later on consolidated some

of the modules to drive higher scale, it is understandable that the evaluation of the modularization scores lower. As mentioned earlier expected variance, which modularization would beneficially accommodate, were not as high as anticipated.

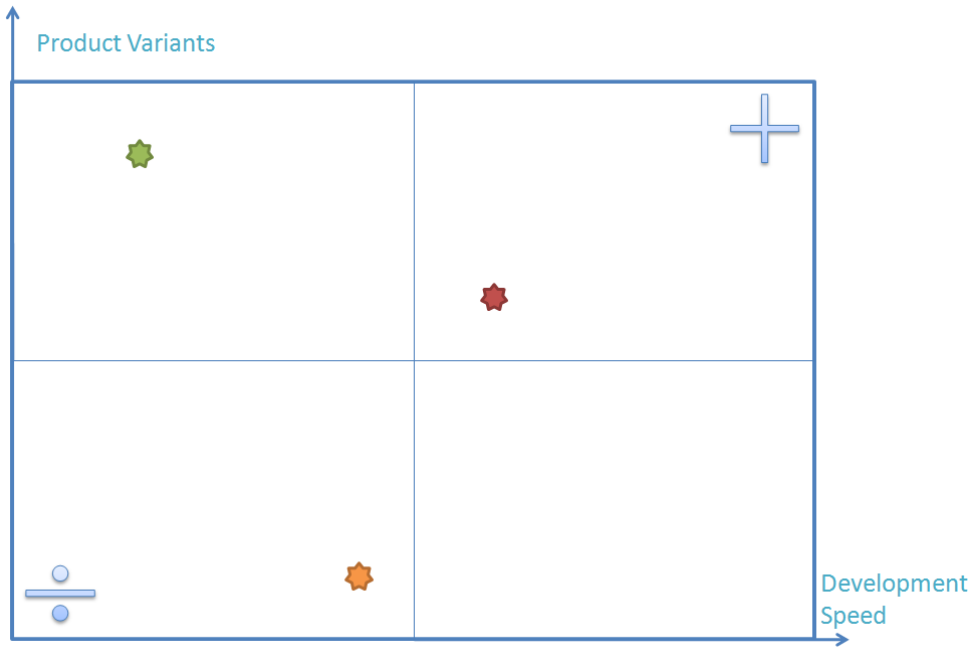
Learning curve of modularization

The learning curve of modularizational knowledge explains how great the company's knowledge of modularization is. Even though a company knows very little about modularization, that does not mean they do not use modularizational principles in their company. But because of the lacking modularization knowledge, the company is unable to benefits at full modularizational potential. Some of this knowledge can be gained by experience of modularizing but the majority of gained knowledge, as investigated in the interview, can be subscribed to knowledge acquisitions, best in practice research and other initiatives to understand the strategy in the startup phase. This knowledge is also indicated by the interview summary-startup in mapping above.



Figur 14 Modularization knowledge

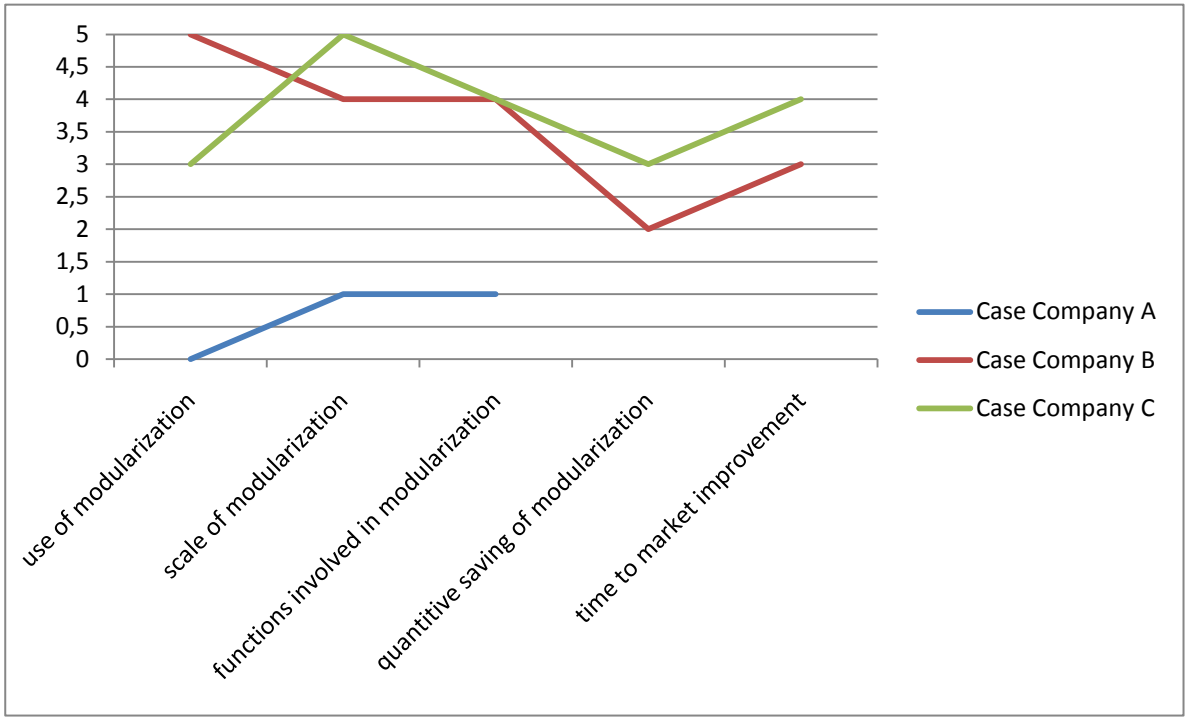
As described previously a great influential factor of modularization is market needs. Market need highly affect the possibility of benefitting from modularization, in terms of variance in products and development frequency. In order to show how Case Companies are influenced by modularization a mapping of the market need for case companies are indicated.



Figur 15 Market needs in modularization

As illustrated, and backed by modularization interviews above, the three case companies are mapped differently. While case company A have low product variance, the benefits of modularization is reduced due to low product variance. This indicates that a full modularization for case company A would not allow them to reach competitive improvements compared to other alternatives. This does not mean modularization principles cannot be implemented to increase competitiveness, but that the synergies of modularization cannot be reached. Case company B has a higher use of modularization, as variance is present, however the development frequency limit their reach of competitiveness of full modularization. Case company C also benefit from modularization, but as interviews explain consolidate some of the over-engineered solutions to accommodate varience, by reaching larger economics of scale in standardization.

A summation of benefits by modularization is illustrated by the following graph.



Here we see how scale and scope of modularization in the different companies provide them with benefits and how functional involvement is included as a means of reaching these benefits. The mapping of this is derived by analyzing interviews on a scale of 0-5. As explained previously Case Company A was unable to estimate the savings and improvements directly related to modularization, I can only speculate whether the savings derived within the company can be accredited to modularization principles initiated or not.

Case Company Conclusion

As I can conclude by analyzing the three case companies, modularization is very much of interest; however the use of modularization varies from company to company as expected.

Convergences can be found in the following areas:

- The Market needs and the knowledge acquisition heavily determines the scale and scope of modularization.
- The companies formally communicated to commit to modularization agree to use several function to obtain modularization.
- The companies formally communicated to commit to modularization agree to form organization in modules.
- The companies formally communicated to commit to modularization increase quality in modular products.

External validation

Apart from conducting case studies with companies who use modularization, I have also conducted studies in consulting companies. These consulting companies vary in size and market spanning from regional consulting in smaller to mid size companies in Scandinavia to worldwide power players in different industries. Both consulting companies carry a selection of expertise herein modularization. In order to conduct interviews on modularization, I asked similar questions to the case companies, without specifying specific examples thereby discussing modularization in more general terms.

Below is the answer from Consulting company X and Y:

1) Why is modularization interesting for industrial companies?
   "Modularization is because it accommodates a mixture of globalization specific needs in different markets. Different performance and cost levels to match in order to be competitive. Which forces you to save investments for new R&D and to reach scale. Companies are not capable to cope with the complexities anymore, so complexity needs to be reduced in order to have more focused quality work and get the innovation to the market. With too complex a product it is hard to reach first to market advantages with innovative products."
   "For example, a wind turbine manufacturer with decent market share and performance in Europe, face competition from China, which is a huge market for wind, with completely different performance levels. In China there are less heavy winds, which mean peak performance is different. Less requirements regarding grid performances and noise. Which allows the Chinese competitor to operate on a completely different cost and performance level. How should the European company react on this? The European wind turbine manufacturer have to consider implementation of current products in Chinese market and still be competitive, or do they have to implement a new platform, and how can we profit in Europe by having the additional volume in china? How could a product architecture be determined without overspecifying one or underspecifying the other. These sort of questions arise in all industries, which means modularization is of interest in all industries."
2) How do you advice companies to change organizationally when implementing modularization?
   "Typically these questions will arise initially, and we advice to postpone the decision. Because the companies need to understand the concept of modularization. When this is understood it is clear that organization should be across modules and not regions, products or market segments. This is true for development, purchasing and manufacturing in order to have this logic of carrying knowledge in modules. Modularization is always cross functional. To really understand the tradeoff between differentiation versus commonality you need a thorough customer insight from marketing and sales, and you need technical implication understanding from R&D and manufacturing, and understand scale effects from suppliers, that means purchasing. Only with these people you can reach the benefits. You need these people to make the right decisions based on it. You need cross product portfolio expertise, across segments lines and regions, you need to have one responsible person from each function per module. This way the team represent the entire product and the entire market."
   - Would you agree that a full implementation of modularization should be organized proportionally to the company's operations?
     "*No, but one member from each function should be represented in the modularization*

team. For example: if R&D is 20 people and marketing is 10, that does not mean that you have two R&D people and one marketing."

3) Do you see a difference in the scope of modularization depending on the industry? Business to business/ business to consumer, high-tech industries/low tech industries?
   -"The innovationrate, high-tech vs low-tech, the higher the innovation pase, the more difficult it is to use static architectural content. Here it is important to have a flexible architecture that can easily implement a new generation by decoupling wherever such a generation shift may occur. In other industries reuse is of high importance in order not to reinvent the wheel all the time." "If you take a premium truck, it is more or less the exact same in china as in Europe, where as the low cost truck in India have horsepowers of 25 or so, where in Europe they are 115. So here performances are so different they cannot be driven by the same platform due to inability to stretch such an architecture that wide. So they have to be constructed on different platforms."
   -"No difference from conceptual point of view. It comes down to the question: is the receiver willing to pay for additional features. Modularization always tries to solve the challenge that you differentiate your necessary and standardize your possible. To solve this tradeoff you have to determine what is the value of the receiver having the differentiation versus what are the costs. For example if a customer wants a very specific steam plant, and is willing to pay for the very specific specification, we should offer it to him. But if he does not want to pay for the specific specification, and wants his steam plant anyhow, there is an opportunity to force him into the standard. This thorough understanding of customer needs is crucial in any industry."
4) Where do companies usually run into problems when implementing modularization?
   "*Very often modularization is an R&D only effort. If modularization is done without the different functions, you miss important insights to solve this tradeoff challenge. It's easy to consolidate the car industry. If you have to choose only one module for the future, you just pick the most expensive one, and you are done. But you do not want standardization with modularization, you want to meet customer needs."*
   "Second common pitfall is to identify KPI as 'number of common parts'. If this is your main KPI this is easy to do, you just consolidate the most expensive parts or the highest specified ones and you are done. "
   "*third pitfall is that modularization is only implemented at high level strategically, and nobody understand what it meant, and everybody had an interpretation of the modularization, which meant no work was aligned. So you need to define it down to PD process in order to clearly communicate: 'what does this mean for product XYZ for the market' ensure employee responsibility."*
   "Fourth pitfall is that modularization is not implemented in IT infrastructure. Because otherwise it is impossible to track and control manually."
   "Lastly. Modularization does not get enough managerial attention, which in the end causes top management to overrule modularization, because they did not understand the benefits."
5) To some extent, modularization can be described as a collaboration of using tools like standardization of components, mix and matching, increasing batch sizes in production.
   - Do you agree with this?
     "*Yes but used with an overall purpose. If you only use the tools as isolated exercises, it is not enough. Modularization is much more than a structure for different tools and*

processes. Synergy of the uses of these is what modularization is all about."

6) Since you have conducted modularization projects numerous times, how is your estimation of the quantitive outputs of modularization, non specific average percentages?
"Saving depend on starting point. What are typical targets? Material cost savings, investment in tooling and R&D, quality, manufacturing and assembly, time to market. In car industries for example, weight is important because of the CO2 focus. If all of the modules are heavier than the original design then weight will go up and the car will not be environmentally friendly. Overall savings were double digit, 10% to 15% below of what they were before. Part of this will be invested into additional content, because modularization is never over and is ongoing. scale savings: 10 to 15% is not out of scope. Quality depends on what you have done before, but numbers are about 30%, however I would be more conservative and estimate quality savings at around 10 to 20%. Time to market savings really depends on the industry. Difficult to give an average number. Manufacturing expenses depends on investments and tooling, and how much comes from supplier. If the saving of modularization is material saving, then the tooling saving will be at the supplier, and lower the price of purchased parts. If it is done by yourselves, the material cost savings are probably a bit lower whereas the tooling in manufacturing are higher. Double digit is probably normal (10%). "

External Conclusion

This insight from consulting companies with great experience in modularization converges with the findings in the case companies:

- The Market needs and the knowledge acquisition heavily determines the scale and scope of modularization.
- The companies formally communicated to commit to modularization agree to use several function to obtain modularization.
- The companies formally communicated to commit to modularization agree to form organization in modules.

Modularization pitfalls describe some of the very issues the case companies are dealing with:

- Such as R&D being the sole driver of modularization (case company A)
- And modularization not getting enough managerial attention (case company A).

In both cases modularization principles are used, and even though it is far from a full modularization implementation, modularization projects may be initiated and evaluating new savings and costs.

Conclusion

Combining of the findings from a theoretical approach and from a practical approach leads me to find convergences and divergences.

Practical conclusion:

- The Market needs and the knowledge acquisition heavily determines the scale and scope of modularization.
- The companies formally communicated to commit to modularization agree to a cross functional process to obtain modularization.
- The companies formally communicated to commit to modularization agree to form organization in modules.

Theoretical conclusion:

- Market demand affects your modularization, and is essential to determine in order to know what to modularize and what not to.
- By designing modules which are over-engineered to serve several products you eliminate a substantial amount of components
- By defining modules, you can reach greater product variance with fewer components.
- By defining Module Decoupling with Standard Interface, and reusing well documented modules you can increase quality
- When modularizing, cross functional involvement is essential to reach the synergy benefits of modularization described above.

Both Theoretical and Practical conclusions lead to an overall conclusion: Modularization is a major driver for-

- Improved Quality Level
- Major Cost Saving
- Shorter Development Time
- Lower Investment for Future Development
- A Company Platform for Agile Growth

With this Conclusion I have proven theoretically, with use of knowledge gained from literary articles and practical empirical evidence from Multiple Case Study Company A,B,C and Consultant Company X,Y that Modularization improve competitive performance.

Future investigation

As this concluded there is a collaboration between market need and scale of modularization. For further investigation, multiple case-studies in industry-specific markets may determine how modularization can be proposed in one specific industry, and find divergence and convergence in other industries.

Master Project Structure

More headlines, more text, more process.

Modularization is not a new subject to the world of literature. Neither has it been new to the production industry where Scania A/S has been using this production strategy for more than 60 years. It is widely known for its implementation in airline and automotive industry, where it has wreaked great recognition as a cost saving and production utilizing tool. But to find theory, or case examples about modularization is one thing, implementing them is an entirely different animal. Because modularization is so situation specific, it can only be vaguely described in processes and procedures. Few have effectively formed a work method to use modularization, for which they are now widely credited in the field of modularization. Therefore it is hard to formulate a theoretical discussion in the field of modularization. One can write about the evolution of modularization, but contradictions in literature are scarce. Even though this field has been known for a while there seem to be some gaps in the literature as how to approach modularization and identify the team goals which are critical to obtain a successful modularization project. During my internship at Electrolux North America in 2010, talks with modularization team members seemed to discuss the manor of how the data collection for the modularization was done rather than how the project progressed. When understanding how modularization works, this brings one to speculate whether processing modularization data and presenting solutions is the easy part, or if Electrolux had worked past the obvious problem areas of designing the team and formulating the process to such an extent that the team members didn't notice the work behind the modularization.

In the literary world Sanchez (2000)[28] has linked the organizational perspective with the act of modularizing, and refer to the decoupling in product design to be inherited in the organization. Sanchez also briefly touch the roles within the modularization project and refers to *architects* and *technology workers* but fail to specify a thorough analysis of the role within such a project, due to more strategic focus in his paper. However, since modularization, when implemented, is so situation specific and every project differs each time, the roles and the structure of the modularization project is very important to allow influence from all functions in a firm. The approach and adaptation of each function can be described in order to obtain maximum synergy effects of modularization at minimal costs in resources. If a modularization project is done without the total involvement and dedication each function, backlog will build up before the project is considered closed, ultimately costing more resources for the company that initiate the modularization project, in other words, modular management. Mikkola (2003)[29] also describes modularization quite thoroughly in her aptly named article: Managing Modularity of Product Architectures:

[28] Sanchez (2000)
[29] Mikkola & Gassmann(2003)

Toward an Integrated Theory. Mikkola derives at a very scientific and concise mathematical formula of how and to what extend to modularize, which is supported by two case studies. Even though Mikkola derive's through a mathematical function how to modularize, I find it difficult to believe the complexity of a product portfolio of a large company in any given industry can be calculated by any function with the such an absolute certainty that a company product strategy will follow its recommendation. However using a mathematical function to put findings into perspective, could be used tested for validity and used as guidance accordingly. I do not consider Mikkola's approach to 'manage modularity' but more than a propositional tool to open dialog with management or as validity enhancement to this reports interpretation of Managing Modularization.

As described earlier a derivative of modularization is mass customization where an interaction with the customer adapts the product specifically to each user. Such a tool is very powerful to accommodate specific customer needs where large variations in product requires great deal of customizing of the company. In mass customization there are more non-situation specific measures to be described, which is thoroughly described by Lars Hvam et. al. (2008)[30] where the setup of customer interfaces in a mass customization feature is set up, and how it affects the Product Variant Master or configuration system. Hvam et al. describe very thoroughly how different roles in a 'configuration' project are important. The 9 roles described, may be focused on developing a configuration system more than modularizing, but many of the aspects pointed out are transferable. Hvam et al. identifies the importance of approach in assigning a team the task of designing a configuration system in order to meet as many requirements as possible and not just focus on one. This is very much what is described in this report, where the different approaches create a synergy effect which enables a modularization project to redesign the scoped part or system to incorporate the requirements, and focus on key elements, from different functional approaches. In mass customization, with a configuration system, specification processes are incredibly important in order for a system to be designed with constraints and logical connectivity's. This very much applies to modularization, even though specification strictness is more essential in a configurational system. By defining specifications and determining interface points and its interaction, decoupling will be made easier thus enhancing the basis for modular product development.

Since modularization is still a relatively new field, there is still a lot of methods and papers to come, but where this subject differs from others is the situation specifics from one project to another. Modularization is hard to pin down into one process or one method, because every product architecture in each company is different. When modularizing it is not only the architecture which differs. If the company serve a market

[30] Hvam et al (2008)

which is very rigid there may not be as much reason to involve marketing departments than if the company were serving a very diverse and dynamic market. One method has seem to be adapted widely when it comes to modularizing, however. Gunnar Errixon's Modular Function Deployment[31] tool is often referred to and used as a step by step process of how to investigate which part of the architecture should be modularized and which should be standardized. As far as participation and execution of MFD, descriptions of roles and approach is narrowed to explain the employees involved should have a thorough understanding of the product. This does not constitute a very open minded modularization, in my opinion. If the participants of the MFD, which is used as a basis of the company modularization strategy, are all from the same department or of the same persuasion of how the product should perform, the modularization project will not include approaches from procurement which may have been able to save cost in standardization, or marketing which may have been able to determine future customer trends, or manufacturing which may have been able to smoothen the implementation process. In worst case scenario the modularization may fail to identify the real challenges rendering the proposition of product development strategy useless. Again the literature fails to underline how the importance of diverse participation can make or break a modularization conclusion. In my opinion, this can be interpreted into *doing the right things, rather than doing things right*. Having this being said, understanding of industry variations in case companies may lead to different results. However, highlighting the difference in modularization project participation from one industry to another, may prove to be just as important a point.

Errixon et al. (1994)[32] further resonates that factory layout can benefit from modular product development in the same way as to decouple production and assembly in the same manner as modularly designed. I would hesitate to give a factory overhaul in order to produce modularly when outsourcing and offshoring is as much a part of the world production industry as it is, and consider the possibilities in producing the parts of the product architecture, which does not create key differentiation, in LCC's. This way, the core competences are kept locally.

Because Modularization is so situation specific, and the subject of cross functional importance of modularization is in focus, an interview to find how this is valued in companies that have already modularized, is beneficial. At the very administrative level, the planning and the rationalization of participation and reflection of same, is clearer than one might achieve by being a participant in modularization. This administrational position is also capable of explaining the choices made in order to incorporate variables like market, product complexity and scope. The focus chosen requires a knowledge

[31] Erixon et al. (1994)
[32] Erixon et al. (1994)

concerning the modularizational techniques used in the given situation, and the initiation and setup of this modularization. Such a person is likely to be busy in our economic climate, since modularization is very much a production effective strategy, and savings in all industries have recently been of utmost importance.

Reference and Appendix

	Company	Contact
Case Company A	Linak A/S	Svend Erik Jensen – Development Manager
Case Company B	Danfoss Drives A/S	Niels Gade – Director of Systems, Technology and Innovation
Case Company C	Foss Analytical A/S	Niels Degn – VP Product Innovation
Consultant X	McKinsey Company	Dr. Daniel Kauer – Associate Principal
Consultant Y	Valcon A/S	Martin Olander – Development Strategy Leader

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