UNDERSTANDING THE PHENOMENON OF MODULARIZATION

Poul Kyvsgaard Hansen, Mogens Myrup Andreasen, Ulf Harlou,
Ebbe Gubi and Niels Henrik Mortensen

Keywords: Modularization, Managing Modularization, Platforms

1. Introduction

Modularization in products and services has a significant attention in all kinds of industries. However, though many companies have gained experience there is still a significant confusion about managing the modularization initiative. In general, the phenomenon of modularization is not well known. The cause-effect relationships related to modularization are complex and comprehensive. Though a number of research works have contributed to the study of the phenomenon of modularization it is far from clarified. Recognizing the need for further empirical research, we formulate a research framework with the purpose of uncovering the current state in Danish industry and to identify tentative managerial implications.

2. Theoretical and empirical background

The concept of modularization has strong strategic impact. However, despite the many reported success stories there still seems to be confusion about managing modularization initiatives to obtain specified benefits. The potato model in figure 1 may describe some of the many different "cuts" that presently are applied to the modularization phenomenon.
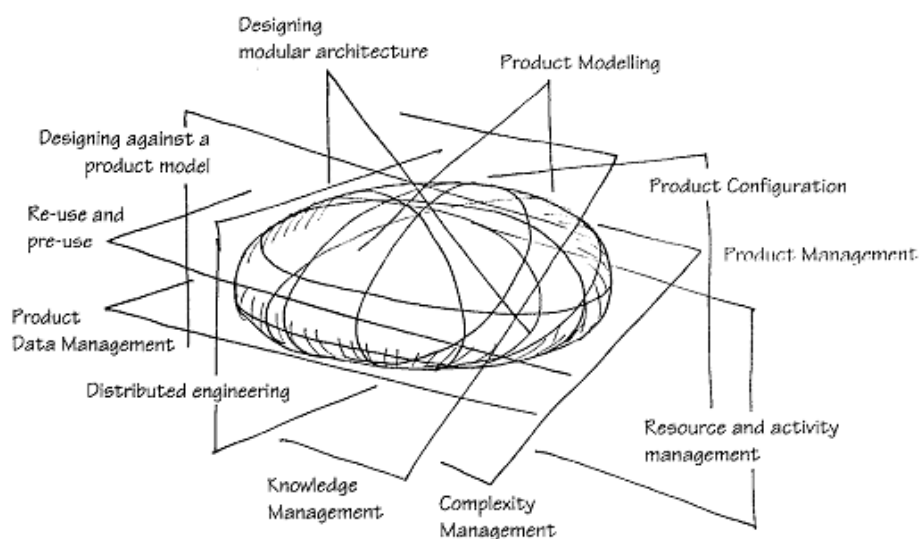

Figure 1. Potato model of modularization inspired views [Andreasen et. al. 2001]

The idea of product modularization is widely recognized as a major success factor in terms of meeting economic and commercial goals of a product program. Convincing examples can be found in the automobile industry [Baldwin & Clark 2000] and in consumer electronics with Sony, Black and Decker, and Hewlett Packard [Meyer & Lehnerd 1997] as the most outstanding examples.

2.1 Modularization across organizational bounders

Organizational barriers are important explanations for the difficulties of managing modularization initiatives. It is generally recognized that the motivation for modularization has to be sought in other organizational units, for example:

- Product modularity reduces costs in the product life cycle due to the possibilities of economy of scale in production
- Product modularity reduces delivery time due to the possibilities of postponement
- Product modularity enhances speed in the product development process due to the possibilities of distributing the activities and due to the inherent structure supporting the project management
- Product modularity enhances speed in the introduction of new product variants due to the reuse of components and structures
- Product modularity enhances the variety due to the flexibility in configuration of the final product
- Product modularity enhances organizational flexibility due to the ease in communication of the product structure
- Product modularity enhances organizational learning due to the inherent structure for storage of knowledge
- Product modularity reduces risk in product realization process due to the exchangeability of modules

Most potential benefits of modularization initiatives seem to relate to the supply chain [Erens & Verhulst 1997].

These empirical and theoretical contributions indicate a need for a cross-organizational understanding and management of modularization initiatives.

2.2 Product architectures and platforms

In many cases the modularization of products is documented or communicated by the product architecture or product platforms.

A product can be regarded in both functional and physical terms:

- The functional elements of a product are the individual operations and transformations that contribute to the overall performance of a product.
- The physical elements of a product are the parts, components, and sub-assemblies which ultimately implement the product's functions

Product architecture is defined as the assignment of the functional elements of a product to the physical building block of the product. One of the most important characteristics of a product's architecture is its modularity. The opposite of a modular architecture is an integral architecture. Hence, modularity is a relative property of a product architecture. Products are rarely strictly modular or integral [Ulrich & Eppinger 2000].

Important questions concern if, when, and how the product architecture is made explicit. Often the product architecture emerges informally during the concept development – in sketches, function diagrams, and early prototypes. In many cases the product architecture will emerge but will only be expressed explicitly in fragments.

Some authors argue that both product performance and the majority of effects on the whole supply chain can be determined when the product architecture is designed [Erens & Verhulst 1997]. This indicates that the development methods of making product architectures explicit in the early phases of the product development process should have a high priority. Regarding the critical problems of realizing such methods, empirical studies report that the functional aspect of product architectures is

generally better understood, studied and documented than the interface aspect.

Several authors refer to the product platform term as a way to document and communicate product architectures. This opens for a platform strategy, which aims at generating product platforms and thereby plans the launch of product families rather than single products. The focus on product platforms originate from the quest for design simplifications in product development in the early 1990's, but it was not until the mid-1990's that companies in fierce competitive situations were faced with the need to implement a platform strategy. Some of the main benefits gained from a platform strategy include reduced development and manufacturing costs, reduced development time, reduced systemic complexity, better learning across projects, and improved ability to upgrade products [Muffatto 1999].

These empirical and theoretical contributions indicate a need for a deeper understanding of the relations between modularization and activity structures when seeking to manage modularization initiatives.

2.3 Modularization of products, activities, and knowledge

The effect of modularization can be interpreted as an encapsulation of complexity. When the task of developing and managing a system is exceeding the human capabilities one way of managing a complex system or problem is to break down the system into manageable parts. By encapsulating parts of a product by means of a module, the complexity can be reduced to handling and specifying the interfaces between modules [Baldwin & Clark 2000].

Most theoretical and empirical contributions are focused on the physical or functional aspects of product modularization. However, the concept of modularization can be applied to activities and knowledge as well.

The pattern of activities of handling product development and the related production is heavily influenced by the degree by which the components and the modules are coupled and the degree by which the components are re-used or pre-used in a number of products. Consequently, an activity architecture will lead to less complex and easy, manageable activities and tasks [Miller 2000].

The correspondence between activities and product structure is likewise found in [Baldwin & Clark 2000]. They claim that the design activities (task structure) and the design structure (the description of the artifact) have to be identical in order to have an efficient design process. However, if the definition of the product or activity modules is not followed by increased planning activities there is a potential risk that the modules define a filter that blinds the company to opportunities or needs to create new products or incorporate new technologies.

Knowledge re-use may happen informally, based upon memory, or based upon a structuring of knowledge, information or data in an externalized form (reports, notes, models, databases, etc.). In many cases development and production activities are organized in teams focusing on specific components and related technologies. Hence, the structure of the knowledge processes is likely to reflect the structure of the product [Sanchez 2000].

The close relation between the product structure and the explicit or tacit knowledge can potentially enable a knowledge map. Obviously, the potentials are even more likely to be realized if the product structure is modular. However, as stated above, when the product structure is embedded in critical patterns of activities and knowledge structures companies often find difficulties in changing [Henderson & Clark 1990].

These empirical and theoretical contributions indicate a need for a deeper understanding of the relations between product structures and knowledge when seeking to manage modularization initiatives.

3. The case study and the tentative findings

Each of the three aspects discussed in chapter 2 need further theoretical and empirical studies. Following this observation we have initiated empirical study aiming at mapping the modularization initiatives and the obtained effect in Danish companies. The study has been conducted as loosely structured interviews based on the perspectives described in figure 1. For each company one product type or product family has been selected in advance and interviews have been made with the sales

function, the production function, and the product development function. After analysis of the initial interview data we plan to make more in depth studies of the critical or generally interesting issues uncovered during the interviews.

Our ambition is to cover at least 30 Danish companies. The tentative findings are reported in [Hansen et. al. 2001]. In the following one of the cases is shortly summarized.

3.1 Case report from Company B

Company B develops and manufactures audio and video equipment. The company has for a number of years been focusing on defining core competencies and outsourcing parts of the traditional production. This has led to a significant increase in the efficiency of the whole supply chain.

Following the success within production of components the company considered applying similar methods in new product development. This included outsourcing as well product development as production of components. The final assembly was still to be done internally. In the automobile industry, this approach has proven to be successful but the batch sizes in company B was much smaller.

For some years, the company had outsourced part of the software development but the experiences were often negative. Some of the internal software people pointed to the role of ownership as the problematic part. It was felt difficult to create this feeling of ownership among the software suppliers.

Considering these experiences the company defined a new approach in the product development process. The initial concept development was done internally. As soon as top management approved the concept the involvement of pre-selected partners was initiated. This phase was named the "Architectural Phase".

During the architectural phase the product specifications were only loosely and mainly qualitatively defined. The main focus was put on defining the modules and the interfaces in particular.

The architectural phase was split into five smaller phases: 1) Involvement of partners, 2) Development of physical modules, 3) Evaluation, 4) Development of interfaces, and 5) Evaluation and accept. In each of the development phases many alternatives were considered. During the evaluation phases the different stakeholders (assembly, service, purchase, logistics, quality assurance, test, etc.) were confronted with the alternative solutions. The fact that the solutions were physical and that there were alternatives made it possible for the stakeholders to comment and judge the different solutions.

After the final accept of the architecture the traditional product development process began. During this process the different partners formulated and negotiated specifications. Since each partner were responsible for defining the specifications of their part of the final product there was created an ownership of these specifications – and thereby a more thorough responsibility of their part of the final product.

The result of the process has been a product with 10 well-defined modules. Three of these have been fully developed by external partners. External partners produce seven of the modules. The product can be assembled manually without use of any specialized tools.

Company B is so convinced about the power and the way of handling the architectural phase that they have launched a training program aiming at training a new category of employees: Product Architects.

A new project has recently been launched within the core products of Company B. This project is to follow the same principles as the one reported above. By doing this, the company can increase the capacity of their product development function and thereby add more features for customization.

4. A framework for modularization initiatives

A tentative framework that includes the aspects discussed in chapter 2 has guided the empirical studies. During the empirical studies the framework frequently has been reviewed, changed, and supplemented. Observations obtained during the studies have been classified according to the structure defined by the framework.

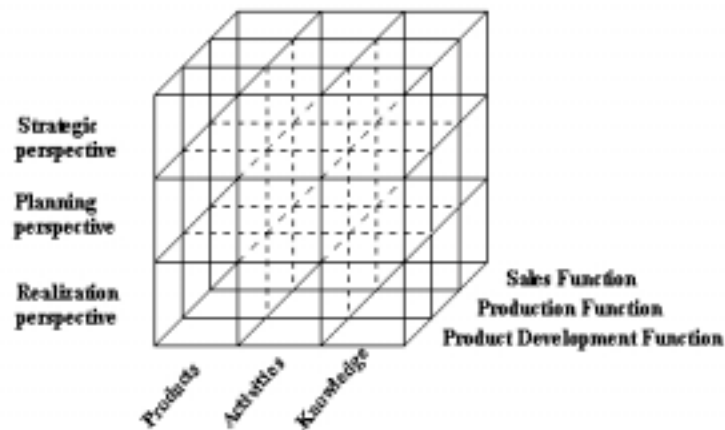The current state of the framework is illustrated in figure 2.

Figure 2. Framework for modularization phenomena

The handling and management of the phenomenon of modularization requires several different perspectives. Our efforts are primarily focused on exploring modularization in a company wide perspective. The framework in figure 2 is designed to classify theoretical contributions and empirical findings regarding modularization. Modularization can be defined as an encapsulation of complexity. This complexity can refer to a structural or functional dimension of products, activities, and/or knowledge (the x-axis in figure 2).

Organizational functions do not have identical images/requirements of an ideal modular product. However, the degree of awareness of these differences between the functions and the explicitness of the functional images/requirements is largely determining the degree of success of the modularization initiative. In the framework (the z-axis in figure 2) we differ between three organizational functions: Sales (including after sales activities), Product Development, and Production (including logistics).

Finally, we view modularization in different time perspectives (the y-axis in figure 2): 1) A Realization perspective, where effects must be realized, 2) A Planning perspective with methods, procedures, plans, etc., and, 3) A Strategic perspective with platforms, architectures, etc.
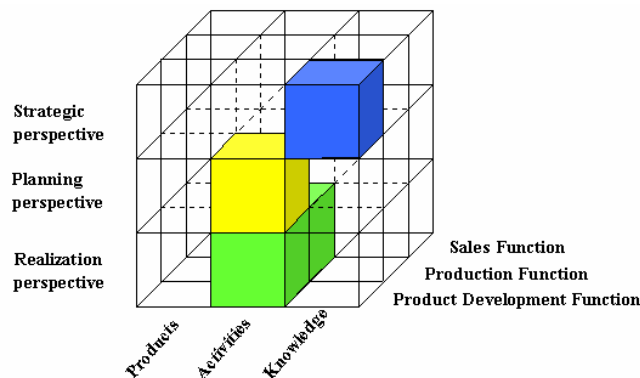

Figure 3. Observations from company B structured in the framework

Figure 3 illustrates the classification of the findings from Company B reported in chapter 3.1. The primary effects are related to the "Activity" - "Product Development Function" and "Activity" – "Production Function". One important effect is shortening of the development time by introducing a modular product structure and organizing independent parallel development activities for each module. Another effect in the production function is simplifying the assembly by feeding the final assembly with tested modules delivered partly from suppliers.

The main planning technique applied is the "Architectural Phase" where the modular product structure and the interfaces are defined in collaboration with suppliers before any development activities take place.

There is a minor use of pre-defined knowledge documented in a semi-structured technology platform.

5. Conclusion and further work

Our empirical study has so far supported the initial idea of modularization being a highly configurable phenomenon. The companies included have treated the problem of modularization in very different ways. Some of these ways have proven to contain elements of generality – a generality that might add to a theory about modularization.

During the empirical study, we have identified a number of contingency factors and parameters for configuration. However, these can still hardly be combined into one theory.

The framework in figure 2 needs to be explored and further developed in both theoretical and empirical studies:

- We will put more focus on the strategic element exploring different elements of strategic platforms and architectures.
- The planning perspective will be developed by adding techniques for visualizing and analyzing product structures.
- The realization perspective will be further developed by intensifying the focus on module drivers.
- The relations in the framework will be explored at all levels and from different views.
- Four Ph.D. projects will deliver detailed case studies on application of the framework.

References

Andreasen, M.M., McAloone, T. & Mortensen, N.H., "Multi-Product Development – platforms and modularization", Department of Mechanical Engineering, Technical University of Denmark, 2001

Baldwin, C.Y. & Clark, K.B., "Design Rules – Volume 1. The power of modularity", The MIT Press, Cambridge, Massachusetts, 2000

Erens F. and Verhulst K., "Architectures for product families", Computers in industry, No. 33, 1997, pp. 165-178

Henderson, R.M. & Clack, K.B., "Architectural Innovation – The reconfiguration of existing product technologies and the failure of establishing firms", Administrative Science Quaterly, 34, 1990, pp 9-30

Meyer, M.H. & Lehnerd, A.P., "The power of product platforms", The Free Press, New York, 1997

Miller, T., "Modular Engineering – An approach to structuring business with coherent modular architectures of artefact, activities, and knowledge", Ph.D. Thesis, Department of Control and Engineering Design, Technical University of Denmark, 2000

Muffatto, M., "Introducing a platform strategy in product development", International Journal of Production Economics, 60-61, 1999, pp. 145-153

Sanchez, R., "Product and Process Architectures in the Management of Knowledge", in Robertson & Foss (ed.), "Resources, Technology and Strategy", Routledge, London, 2000

Hansen P.H.K.; Andreasen M.M.; Mortensen N.H.; Harlou U.; Jensen T., "Managing Modularization" EISAM, 8th. International Product Development Management Conference, Twente University, The Netherlands, 2001, pp 403-414

Ulrich, K. T. and Eppinger, S. D., "Product Design and Development", McGraw-Hill Inc., New York, 2000

Poul Kyvsgaard Hansen, Asc. Professor
Aalborg University, Depertment of Production, Center for Industrial Production
Fibigerstraede 16, 9220 Aalborg, Denmark
Telephone: +45 96358935
Telefax: +45 98153030
E-mail: kyvs@iprod.auc.dk