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MODULARITY AND DISTRIBUTED PRODUCT DEVELOPMENT

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1. Introduction

Companies are facing an increasing simultaneous competition on speed, cost, and quality. At the same time many companies are continuously working on defining and shaping their core competencies. Competencies that do not qualify as core competencies are frequently outsourced. One consequence of this is the increased distribution of product development and manufacturing activities.
Inevitably these simultaneous changes complicate the product development process, and this calls for new or adjusted methods in the product development processes.
This paper describes a specific change in product development methods at the Danish company Bang & Olufsen. A change which is focused on handling the new challenges by introduction of a higher degree of modularity and methods that assure that the specific architecture of a product supports later activities in the product development and manufacturing process.

2. Background

Bang & Olufsen (B&O) develops and manufactures audio and video equipment with particular focus on design and on user interface. Most of the production, R&D, the administrative management, and the marketing headquarters are situated in Struer, Denmark. B&O employs approx. 3000 people of which the majority works in Struer. In 2000/01 the turnover equaled DKK 3.8 billions, and 80 pct. of sales were exported. The company vision is defined as “Courage to constantly question the ordinary in search of surprising, long-lasting experiences”. Figure 1 illustrates a few B&O products.

Figure 1. Examples of Bang & Olufsen products

A traditional Stage-Gate model inspires the product development process at B&O. However, the initial idea development phase is separated sharply from the rest of the process. During this phase, a few experienced employees generate the first ideas about new products in close cooperation with external designers. When the product idea leaves the initial phase the physical design and the requirements regarding user interface of the product is determined. Often the specified physical design challenges the engineers in the subsequent phases to the level of their capabilities, but rarely have design changes been accepted.

The small organizational unit which handles the initial phase is termed “Idea Land” and it is believed to be one of the main reasons for the continuing financial and commercial success of B&O. Nearly all small competitors have closed down or have been absorbed by much larger companies like Philips, Panasonic, Sony, etc.

B&O has been able to maintain a small niche within the high end of the market and thereby to obtain a significantly higher price for their product. However, a number of observations indicate that competition is getting fiercer. Some competitors are able to copy the features of the B&O products and launch products at high speed, with a good quality but at a lower price. Other competitors are challenging B&O by launching products for the same market niche and with comparable product features.

Facing the harder competition B&O focuses increasingly on the overall competitiveness. Unique innovative products are not enough to stay competitive. The prime focus areas for an improved competitiveness are the whole supply chain and the product development process. One recent development initiative attempted to cover both areas. The initiative focused on improvement of the architectural phases with the purpose of generating a modular product structure that would support both logistic requirements and distribution of product development activities. This initiative is discussed in more details in chapter 4.

3. Theoretical background and research challenges

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. It is also widely recognized that the reasons for success often are related to the influence of the modularization on other organizational functions and aspects rather than related to the features and functionality of the product itself. Convincing examples can be found in the automobile industry [Baldwin & Clark 2000] and in consumer electronics with Sony [Sanderson & Uzumeri 1995], Black and Decker, and Hewlett Packard [Meyer & Lehnerd 1997] as the most outstanding examples.

The effect of modularization can be interpreted as an encapsulation of complexity. When the task of developing and managing a system exceeds 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.

Despite convincing success stories as referred to above, many companies experience significant problems in realizing the potential benefits of modularization. Organizational barriers and missing insight into other organizational functional areas are important explanations for the experienced difficulties in managing modularization initiatives. It is generally recognized that most of the potential effects facilitated by modularization have to be realized 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 postponement in production
- Product modularity enhances speed in the product development process due to the possibilities of distributing the activities and to the inherent structure which supports the project management
- Product modularity enhances the variety due to the flexibility in configuration of the final product
- Product modularity enhances organizational learning due to the inherent structure of storage of knowledge
- Product modularity reduces the risk in the product realization process due to the exchangeability of modules

An unambiguous theory on realizing or understanding these relations does not exist, but there seems to be an agreement on the axiom that a great deal of the manufacturing costs is disposed during product development. Therefore, many academic efforts are inspired by the "Theory of dispositions", for example [Olesen 1992]. This theory treats relationships between parameters of a product and the parameters of the system that realizes the product. Furthermore, it states that a large portion often estimated to 70-80 pct., of a product's lifecycle cost is "locked" in the design phase. Figure 2 illustrate this suggested relationship between allocated (disposed) and used product costs in a product development project.

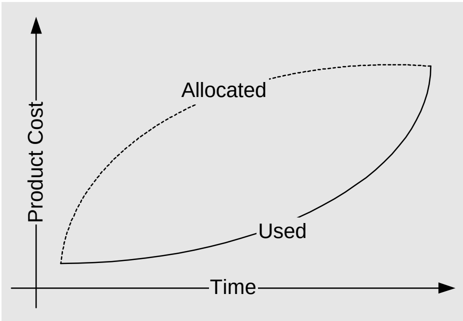

Figure 2. Relations between allocated and used cost

One concept that would comprise the problems illustrated in figure 2 is Design for Supply Chain Management (DSCM). A key concept in DSCM is delayed product differentiation. This is also known as postponement, which means delaying product differentiation either in form or in place. Product designs that allow for delayed product differentiation usually involve a modular structure of the product. According to [Pagh & Cooper 1998] this postponement can be split into manufacturing postponement and logistic postponement. The manufacturing focus will be on capacity exploitation while the logistic focus will be on flow [Chikán 2001].

Both manufacturing and logistic operations involve external suppliers increasingly. Following the general trend of specialization and focus on internal resources this calls for supplier involvement in the product development process. Taking into account that up to 70 pct. of product costs are related to supplied materials and parts and keeping the theory of dispositions in mind, the benefits of early supplier involvement in product development processes seem evident.

Whether the collaboration is internal across organizational functions or external with suppliers, an urgent need to communicate the structure of the product exists. This has placed crucial focus on the term "Product Architecture".

3.1 Product architecture

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 [Vaino-Mattila, 2000].
Several authors refer to the product platform term as a way to document and communicate product architectures. This opens for a platform strategy that 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 [Muffato 1999].
In the following will be described an effort by a medium-sized Danish company to implement elements of these thoughts.

4. The Beosound1 case

Late in 1997 a product idea – internally named A12 - was launched from Idea Land at B&O. A12, which eventually developed into Beosound1 was described as a movable sound system which integrates a CD player, FM radio and powerful active loudspeakers in a surprising design. The idea was well received by the product management, but there was a limitation in development resources and consequently the project was put on hold.
In spring 1998 a new manager, BG, was appointed for the Audio division, and he saw the A12-project as a vehicle to test and implement some changes according to the existing product development model. The most important changes concerned the architectural phase. This phase had been introduced a few years earlier but had not stabilized in terms of contents.
BG had the idea that the architectural phase should facilitate the clarification of the most important features of the extended product life cycle. This clarification would require two new roles in the product development process, product architects (who allocate the dispositions) and supply chain architects (who later carry out the dispositions). The key concern during the architectural phase was defined as the supply chain.
A number of specific goals concerning cost and quality were set up and, additionally, a number of more strategic goals were formulated:

- The product should consist of modules.
- The modules should be delivered tested and ready for assembly directly at the assembly line.
- External involvement in product development as well as production.
- Increased speed from idea to launch.

After being granted permission to overrule the formal product development procedure, BG initiated the project. The product architects were appointed along with supply chain architects. Ideally, the two types of architects should work in parallel, but it turned out that the supply chain architects focused more on general experience than the particular intentions laid out in the described product idea. Consequently, the product architects took over the initiating role and generated a number of product concepts. These product concepts were presented to the supply chain architects who now reviewed them according to the general experience. This approach facilitated a dual focus on both the innovative aspects of the new product and the existing experience in the operations function.
The architectural phase was split into two distinct phases. First, the definition of the physical modules was considered and, second, the interfaces between the modules were considered (see figure 3).
The full architectural phase resulted in a product composed of 10 modules (see table 1 for specification). Furthermore, at the end of the architectural phase the assembly and service concept were fully defined. Following the definition of the 10 modules and the associated interfaces, the assembly concept turned out to be the most simple ever experienced in the company history. Each module was expected to be delivered tested and ready for the final assembly. Virtually, the final assembly could be performed manually in a few minutes.

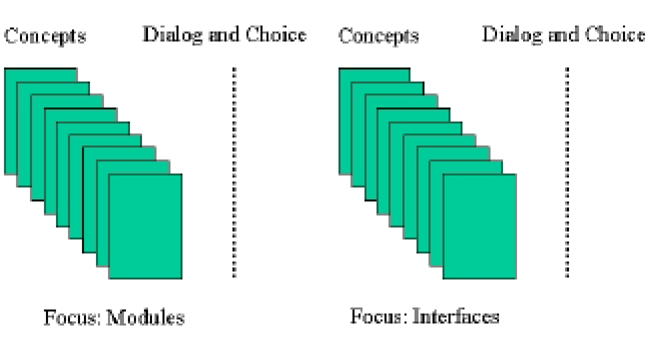

Figure 3. The two distinct parts of the architectural phase

4.1 Distribution of product development and production activities

One of BG's ambitions was to include potential suppliers in the architectural phase. In the Beosound1 case there was a specific need to draw on both product development suppliers and production suppliers. To test this concept one of the well-known suppliers was included early in the process, and four other suppliers were included after the architectural phase. Table 1 illustrates the distribution of the product development and production activities (the names AAA, BBB, etc. are synonyms for the suppliers).

Table 1. Distribution of product development and production activities

Function	Product Development	Production
Speaker unit	AAA	AAA
Antenna	B&O	B&O
Mainboard	B&O	BBB
Power supply unit	CCC	CCC
Loader (CD)	DDD	B&O
Display (IR)	B&O	BBB
Keyboard	B&O	EEE
Front	B&O	B&O
Top	B&O	FFF
Back part	B&O	FFF

The experience gained was different depending on the complexity of the outsourced task and on the degree of outsourcing. Regarding the speaker unit, both the product development and the production were outsourced. In this case there was a feeling of administrative relief within the project management because that they felt the supplier took full ownership of the specifications of the module. On the other hand, in the case of the loader the ownership of the specifications was still in-house, and therefore the project management felt a significant administrative burden in handling this outsourced task.

4.2 Implications for new product development

The experience gained in the Beosound1 project is currently being transferred into changes in the overall product development model at B&O.

Acknowledging that the role of the product and supply chain architects has to be developed and shaped, a comprehensive training program has been launched.

When a project is initiated, only a few members are appointed to the project team, all of them being from the product development department. These members are called the product architects, since they establish the product architecture. Subsequently additional members are invited to join the team, some of them from operations. It is proposed that in future a realization group will be established parallel to the product architects. The task for this group is to draw up the supply chain scenarios, based on a conceptual description of the project, and to evaluate these before the architectural phase is completed. The group will consist of members from each of the three production units, Mechanics, Electronics and Assembly and, furthermore, personnel from the Central Purchasing Department, who are responsible for supplier relations and hence supplier involvement in product development. Finally, the group will be assisted by a member from the Supply Chain Development department, a supply chain architect, in order to impart overall supply chain knowledge. In this manner cross-functional knowledge should be present.

The supply chain scenarios in the architectural phase will be based on a few universal parameters (links, distance, supplier capability, maturity of technologies etc.) supplemented with the experience of the members of the realization group. Therefore, the selection of team members is based on their level of experience in the company as well as their knowledge about the company supply chain. After having gained some first experience with the framework it will be analyzed and revised for further use in the company. This could in time diminish the need for personal experience of the team members.

5. Conclusion

In this paper the feasibility of some of the recent contributions have been discussed and demonstrated according to realizing effects from product modularization. The example demonstrates that the potentials are promising even for small and medium sized companies. Furthermore, the example indicates that a crucial factor for success is concerning the way the product architecture is made explicit early in the product development process.

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