

Modularity Adoption in Product Development: A Case Study in the Brazilian Agricultural Machinery Industry

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ABSTRACT

Facing a competitive and globalized market and with increasingly demanding customers, companies must constantly seek the development of practices in the development of new products. One of the current practices is the adoption of modularity. In that sense, the objective of this paper is to conduct an analysis of this practice in a Brazilian company, which manufactures agricultural machinery. The applicability of modular design in current products is focused. Therefore, a case study approach has been chosen. First, a review of the scientific literature was conducted, followed by field research, for collecting data based on interviews with product engineers and technical documentation. The case study shows the applicability of the modular design concept in a combine header, by increasing the number of repeated components. The modular header approach facilitates the implementation of engineering changes and allows greater standardization of components. In addition, it contributes for greater flexibility, as it is possible to create a wider range of product configurations and satisfy specific customer needs. The proposed modular design can provide further benefits such as product cost reduction due to larger lots of parts. In recent years, the company's forecasts have indicated that the market will require high-power harvesting machines with greater capacity. Therefore increasing diversification in the composition of the header product family is demanded. The use of modular headers can facilitate proper reaction to variable market demands, as each module can be produced, stored and adapted according to production orders.

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INTRODUCTION

In recent decades, the Brazilian industry of agricultural machinery has become very representative for the country. Confronting a globalized and competitive market, accelerating the pace of technological innovation through product differentiation, the increasing demand from consumers for high quality and value-added products, has made the development of new products become one of the most challenging activities in organizational management.

Competitive advantage is achieved by the companies through the application of methods, techniques and tools that aim on manufacturing higher quality products and at the same time reducing lead-time. As a result, companies are able to launch new products within less time. One of the possible alternatives is the adoption of modularity, introduced in the

last ten years in the automotive industry, both in Brazil and abroad.

Modularity is a strategy for the construction of processes and products starting from more complex subsystems, which are developed individually, but with integrated operation enabling the production of different products through a combination of subsystems ([Baldwin and Clark, 1997](#)). It is based on the principle of dividing a complex product into independent subsystems, generally smaller, whose main objectives are to make complexity manageable, to enable parallel work and to accommodate future uncertainty ([Baldwin and Clark, 2004](#)). Case studies that illustrate the use of modularity principles are more common in the automotive industry ([Camuffo, 2000](#)). However, cases in the agriculture machinery industry are scarce and therefore needed, in order to further demonstrate the potential of such an approach, even in smaller market segments.

The objective of this paper is to investigate the adoption of modular design and modularity in the development of new products in the agricultural machinery industry. A case study approach is used to understand the development practices adopted by a model company and verify the applicability in the existing products.

In order to achieve this goal, an object of analysis (a given product, recently developed) has been investigated due to its complexity and features. In this paper, we describe the theoretical concepts behind product development processes and modularity, and then detail the methods and research techniques adopted. Finally, the results are presented, followed by discussion and main conclusions.

PRODUCT DEVELOPMENT PROCESSES (PDP)

The global dynamics of competitive markets and the increasing variety of products combined with increased demand of consumers have required the introduction of new products faster, with reduced costs and high quality. Consequently, the structure of the product development becomes an essential activity in building and sustaining competitive advantage of companies considering one of the most important activities for surviving in the market.

According to [Clark and Fujimoto \(1991\)](#), [Ulrich and Eppinger \(2004\)](#) and [Pugh \(1990\)](#), the product development process (PDP) is the transformation of market opportunities in information to manufacture a commercial product, taking account the possibilities and technological constrains.

[Rozenfeld et al. \(2006\)](#) suggest that developing products consists of carrying out predetermined sets of activities through which market needs, technological possibilities, restrictions, and competitive strategies are investigated, leading to design specifications, prototyping, testing and preparation of suitable production processes, in order to allow manufacturing to produce it. Product development also involves follow-up activities after the product release for any necessary changes to those requirements, plans to discontinue the product in the market and incorporate lessons learned along the PDP.

A peculiarity of the PDP in relation to other business processes is the nature of its activities, which are based on a design-build-test cycle. The four elementary steps that constitute project activities are: (i) to recognize the problem; (ii) to generate design alternatives; (iii) to analyze the feasibility of each alternative; and (iv) to determine the most appropriate solution. Therefore, integration and overlapping of activities between the phases are essential, since activities continually provide important details and therefore can influence each other's outcomes ([Clark and Fujimoto, 1991](#)).

A formal PDP increases the probability of project success by reducing risks, as project goals are agreed among all those involved. Furthermore, it establishes a planning that shows the way to be followed, defines each team member's role and responsibilities and the measure of project progress. It also

induces constant communication, direct and effective among all those involved ([Romano, 2003](#)).

MODULARITY AND MODULAR SYSTEMS OR PRODUCTS

Modularity is related to product architecture. It is the way functional elements are arranged in relation to physical elements. The architecture of a product can be classified as modular or integral. In integral architecture, functional elements are closely intertwined. Thus, there is great interdependence of subsystems. If a component needs to be replaced, it is necessary to have a full redesign of the product, which implies in costly redesigns. On the other hand, in modular architecture, the physical elements are responsible for a few functional elements. This strategy seeks to consider the final product as the union of more simplified subsystems ([Baldwin and Clark, 1997](#)). Thus, each module can be designed independently, with greater importance given to the definition of interfaces between modules. Modularity can be classified in three categories ([Baldwin and Clark, 2000](#)): project, process or use. Due to the scope of this paper only the project modularity will be detailed.

Modularity can further be described as the possibility to easily change a product's feature size, function or capability, to create a product family through the standardization of specifications and interfaces between modules. An example of popular product modularization is the Swatch watch, as presented by [Pellegrini \(2004\)](#). Swatch was able to launch a compelling product at lower costs, by applying modular design principles with a limited number of components, yet using automated assembly.

A modular system has the following aims ([Baldwin and Clark, 1997, 2004](#)): (i) to facilitate the management of complex products by dividing it into modules; (ii) to enable activities in parallel, since modules can be developed simultaneously; and (iii) to adapt product or production to future uncertainties and demand, as the final product can be changed by the modification of any of its modules.

A modular product is considered one whose functions or capabilities can be altered by varying parts of the system. According to [Pahl et al. \(2005\)](#), modular products are: machines, assemblies and components that perform various global functions by combining different building blocks or modules. For [Baldwin and Clark \(1997\)](#), modular products are products, systems or components that perform their functions by combining different modules.

On the other hand, modules are components, subsystems and mechanisms that interact with different modules resulting in different product variants. Thus, modularity allows the production of different products by combining standard components. [Liang and Huang \(2002\)](#) advocate that a product is modular when the component interfaces have been completely specified and standardized. Developing modular products requires certain knowledge of some laws. The laws

of similarity and the standard decimal-geometric numbers are mandatory (Baldwin and Clark, 1997).

Figure 1 illustrates the basic building blocks set out to create a modular composition of trains. The number of items in the example presented by Pahl et al. (2005) is reduced to only three modules and the possibility of combining these modules makes it possible to create a wide range of product configurations.

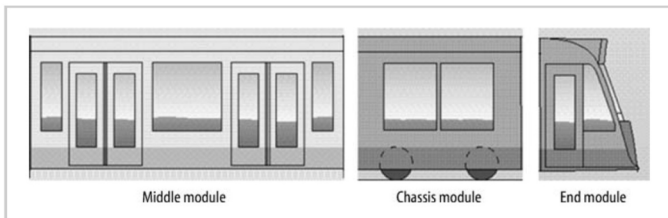


Fig. 1. Basic modules of a modular tram. Source: Pahl et al., 2005.

Figure 2 shows the combination of different modules in the example above, resulting in different product variants. According to Ulrich and Tung (1991), the use of standardized components to obtain a variety of products allows the classification of five types of modularity, which can be found in industrial environments, as shown in Figure 3:

- a. Component sharing: when one or more alternative components are compatible with the same basic product;
- b. Component swapping: when the same component is used in other products;
- c. Fabricate to fit: when one or more standard components are attached to the group of additional components of different sizes;
- d. Bus modularity: when it is possible to join in a particular basic component different components in the same position or different positions; and
- e. Sectional modularity: when it is possible to join several component to each other through standardized interfaces in order to create a structure of components.

According to Eggen (2003), a special case of modularization is one in which the platform is developed based on the range of products. An effective platform is fundamental to achieve success with a product family and serves as basis for a number of new related products. Products designed to share a common platform but have specific accessories and features requested by various consumer surveys constitute a family of products.

Salhie and Kamrani (2000) have proposed that a modular project is a design technique that can be used to develop complex projects, using similar components. According to these authors, modular products satisfy various functions through the combination of different modules or building blocks. An important aspect of modularity is the

creation of a base unit in which different modules can be plugged in, allowing that a wide variety of versions of the same module can be produced.

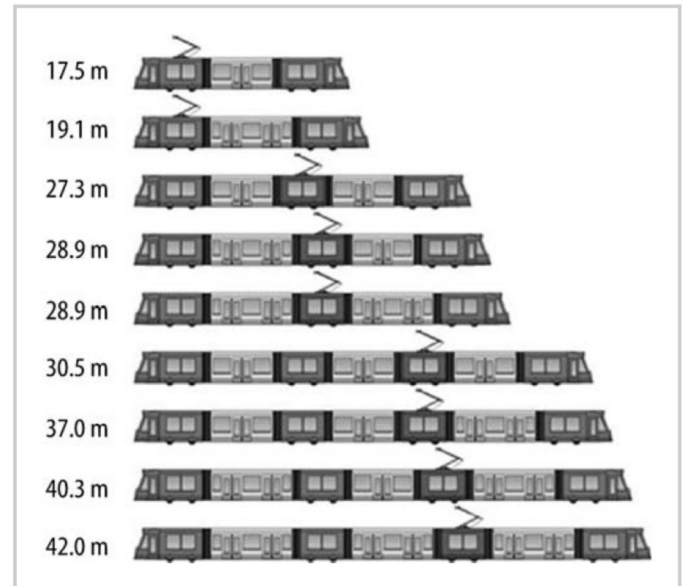


Fig. 2. The trans of the COMBINO. Source: Pahl et al., 2005.

For Ericsson and Erixon (1999), the product's structure is the key to managing complexity. A good product structure can be obtained using the concept of modularity. The development of modular product design converge to many positive effects and its appropriate use has the following advantages:

- a. Extension the variety of products: Ulrich and Eppinger (1995) argue that products with modular design may offer greater variety without adding excessive complexity in the production system. In some cases, simplification of the design may be the best alternative, for others the objective of modularity can be gains of scale and production, reducing production costs. The strategy in this case is to divide the product design and production process on common platforms for all product family;
- b. Reduction of investments and development costs: modular designs reduce product costs by sharing functions or components that can be used in different models or product family. The costs of new products development can also be reduced by the use of common platforms and the creation of standardized components;
- c. Rapid development of technology: modularity allows great flexibility. Thus, several new combinations can be made and a great new range of products can be developed. Thus, there are advances related to the faster development of technology because the company can respond faster to market expectations;