Effectiveness and efficiency through modular product architectures

Modular product architectures allow for flexibility and lower costs while keeping complexity under control
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Product modularization is currently a hotly debated topic in the industrial sector. The automotive industry, specifically the Volkswagen Group, has once again been a forerunner when it comes to implementation. The Volkswagen Group uses modular product architectures in an effort to resolve the dilemma between economies of scope (the need for product variety) and economies of scale (the need to maintain a competitive price position). We are convinced that this can be done.

Over 20 years of dealing with product architecture issues have shown that product modularization can be a beneficial strategy in any industry!

But what exactly does having a modular product architecture entail? Are there any best practices for developing the right kind of modular product architecture? How does one differentiate between successful and less successful module development?

In this issue we have compiled expertise and answers to these questions based on a case study recently conducted by the Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen and the practical project experience of the Schuh Group. One thing is clear: In highly complex competitive environments with a tremendous variety of products, those who can master the modularization game will come out on top.

As always, we look forward to receiving your questions and comments.

Kind regards,
Effectiveness and efficiency through modular product architectures

Modular product architectures allow for flexibility and lower costs while keeping complexity under control

Stephan Woehe (Schuh & Co.)/Jens Armoscht (WZL)

Product modularization is currently a hotly debated topic in the industrial sector. As is so often the case, the automotive industry has emerged as a leader by taking a particularly active approach to communicating about this issue. As a global player with numerous brands, the Volkswagen Group relies on three key modules as success factors to not only be the world’s number one automobile manufacturer in the medium term with regard to sheer unit volume, but also to generate above-average profits.

What is it exactly that makes modular product architectures so interesting and are there any best practices for differentiating between successful and less successful module development? This is a question investigated in the “Managing complexity with modular product architectures” study conducted by the Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen. The results are particularly valuable for companies on the verge of deciding whether to develop a modular product architecture for the first time or those that may be ready to restructure their existing modular product architecture.
Product modularization improves speed

In recent years, competitive dynamics and, as a result, customer demand for product customization have increased significantly in virtually all industrial sectors. This is partly due to new, low-budget competitors in global markets and partly due to greater technological performance. One of the key reasons for developing modular product architectures is to increase the time it takes to react to unexpected changes in the market (Fig. 1).

If a company wants to maintain or even expand its market share, it is forced to come up with an intelligent way to respond to the previously contradictory demands for customization and low costs.

Modular product architectures resolve the dilemma between variety and costs

Given the constraints described above, development departments are increasingly finding themselves in a tight spot. Sales teams are demanding products with even more customizable features in order to gain new customers and retain existing ones. At the same time, pressure is mounting to keep costs as low as possible. Production and purchasing are calling for high volumes to reap the benefits of economies of scale. To simplify manufacturing and negotiations with suppliers, the number of different parts should be kept to a minimum. To reduce throughput times and assembly costs, assembly demands that the products in the product range be structured as similarly as possible. Since development and construction still account for the bulk of all costs, those responsible still find themselves confronted with great expectations. In cases where it has been possible to develop a good modular system, the impact on costs can be significant. In practice, modular systems have been realistically shown to reduce development and production costs by around 20% (Fig. 2).

Fig. 1: What are the effects of a modular product architecture?

How does a modular product architecture support you in differentiating yourself from competitors?

<table>
<thead>
<tr>
<th></th>
<th>Strongly agree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Strongly Disagree</th>
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<tbody>
<tr>
<td>Higher quality</td>
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<td>39%</td>
<td>25%</td>
<td>41%</td>
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<tr>
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<td>47%</td>
<td>28%</td>
<td>9%</td>
<td>6% 6%</td>
</tr>
<tr>
<td>Greater innovation</td>
<td>6%</td>
<td>23%</td>
<td>37%</td>
<td>12%</td>
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</tr>
<tr>
<td>Becoming a technology leader</td>
<td>14% 29%</td>
<td>28%</td>
<td>15%</td>
<td>8%</td>
<td>7%</td>
</tr>
<tr>
<td>Faster reaction times</td>
<td>30%</td>
<td>47%</td>
<td>14%</td>
<td>2%</td>
<td>6% 8%</td>
</tr>
</tbody>
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Number of responses n=87
Multiple answers possible: no
A successful modular architecture does not simply happen, but must be deliberately planned.

In most cases, modules are used in a product portfolio to standardize the components that have less of a differentiating factor for customers. In this context, the market strongly influences the degree to which modularization can be achieved in the final products.

From a technical standpoint, it is often beneficial to structure the product into extremely small modules, thus resulting in a high number of modular components in the final product. This type of solely technology-based approach can result in a very complex module, thus contradicting the actual intention of the module, i.e., to achieve economies of scale. In most cases, small modules also lead to space, quality, and cost problems due to many necessary interfaces.

A well-designed modular system has as few modules as possible, with those modules available in just a few different versions. They also cover a large share of production and development costs and allow for sufficient product differentiation.

In order to come as close to this ideal as possible, it is necessary to conduct a sound and broad analysis of the market. Input from product management is absolutely essential. Which product segments are to be served now and in the future as well as the products’ most important distinguishing features and similarities must be clear.

Based on this information, the most important questions for designing a modular product architecture can be answered. These fundamental questions are: Which parts of the product are to be modularized and which are not? How many modules are needed? (Fig. 3).

Many companies are reluctant to decide which products will be offered in the future. Although they want to have a modular product architecture, they tend to derive it from the next pending development project. This approach usually results in suboptimal modular product architectures since the resulting modular architectures are often not capable of inte-

Fig. 2: The cost effects expected from product modularization

What financial implications (lower costs, higher costs) result from applying product modularization?

<table>
<thead>
<tr>
<th>Component</th>
<th>Lower costs</th>
<th>Constant</th>
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<tr>
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<td>Logistics costs</td>
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<td>Assembly costs</td>
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<td>9%</td>
</tr>
<tr>
<td>Total costs</td>
<td>95</td>
<td>3%</td>
</tr>
</tbody>
</table>

Number of responses n=83
Multiple answers possible: no

Development costs 34%
Logistics costs 34%
Material costs 18%
Production costs 9%
Assembly costs 3%
Total costs 3%
Grating changes made to the next product generation. This is particularly true if the modular product architecture is solely derived from the company’s top product. Successful companies define the modular product architecture independently from a specific product development project and gradually fill in the content based on specific projects. This means that they have a product architecture development process that precedes the product development process.

Modular product architectures require rigorous monitoring by management

Aligning a company based on a modular product architecture requires a common mission on the part of management and staying power on the part of the responsible parties. In many areas it may be necessary to change existing processes in order to effectively develop the modular architecture and use it efficiently.

Modular product architectures require making compromises at a detailed level in order to optimize the whole. This must be done by everyone involved: from marketing and sales to product management and development all the way to production and assembly.

With modular product architectures, one of the greatest levering tools for lowering costs is to standardize production and assembly facilities. For companies that are still producing at multiple locations, this can represent, among other things, a significant encroachment on the freedom of these plants. Nevertheless, this is necessary since otherwise all of the modular product architectures would diverge as a result of gradually making local modifications to the parts or modules. In addition to increased economies of scale, this standardization also offers new forms of flexibility since production can be transferred between plants to react to shifts in the market or changing quantities. To a certain extent, this also can make it much easier to utilize available capacities. At the same time, IT systems (i.e., the backbone of modern companies) must also continue to be developed so that they are capable of optimally supporting the efficient use and upkeep of a modular product architecture. The same applies to the processes in development, purchasing, and logistics.

If management is convinced of the benefits of a modularization strategy, then it must also rigorously support and promote the implementation process. Today’s managers have recognized and are actively taking on these challenges (Fig. 4).

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![Fig. 3: The development focus of modules of successful companies](image)

![Fig. 4: Modular product architectures are an issue for top management](image)
Success factors for designing modular product architectures

If you look at the companies surveyed to find characteristics for successfully designing modular product architectures, six decisive factors stand out:

1. Support for the long-term creation of commonly used standards is generated throughout the company. Top management actively supports the standardization efforts and is committed to them.

2. All of the functional areas involved, including suppliers, are integrated into the module design process from a very early stage. The areas of development, purchasing, production, assembly, and logistics work together to analyze and take advantage of standardization potential.

3. Before the design process begins, every “standard” is rigorously evaluated based on a binding scheme in terms of its feasibility, costs, and benefits.

4. Fixed characteristics for the modules are defined based on standardized product functions. These can either relate to the component standards or to the standards for the functions, technology, geometrics, or constructed space. Since these standards inevitably link together the modularized products, product planning is based on integrated module specifications.

5. In order to minimize variance within the product modules, product characteristics are classified based on their degree of differentiation and the complexity costs attributed to them. The products are configured based on functional structures.

6. In order to reduce unplanned module changes, module roadmaps are used for planning the long-term use of modules in specific products. The modules are designed based on the requirements of all products using the modules. Module specifications combine and document the requirements.

In addition to the empirically determined success factors stated above, our more than 20 years of consulting experience on this issue have shown that patience and consistency on the part of management are also basic prerequisites for success. Modular architectures are not developed in a couple of months. This is not because it would be too difficult from a technical standpoint, but because it requires everyone involved to change the way they think and work. This shift cannot happen overnight. The first modular design will not always lead to the desired result. Nevertheless, it is normally worthwhile to see the failure as an opportunity to learn from mistakes and try again. Giving up altogether, however, would most certainly be the worst solution.

Before deciding whether to implement product modularization at your company, you should think long and hard about whether it is the right solution for your business and your strategy. If the answer is yes – and it will be in many industrial sectors – you can confidently continue with your plans. Of course, we would be happy to guide you if you need an expert along the way.

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Complexity management requires specific architecture decisions

Stephan Krumm/Marcus Rennekamp

In recent years, manufacturers have been faced with a massive increase in the complexity of their products. In many sectors, this has proven to be both a serious problem and a strategic success factor. Although the top management teams at these companies are forced to make three specific architecture decisions, unfortunately this is neglected far too often in practice.

Increasing product complexity is a megatrend across virtually every industry. For example, while it used to be fine for a car manufacturer to serve the entire market with a manageable range of mid- and luxury-class sedans, coupes, convertibles, and SUVs, today there is a clear sense of fragmentation within the markets, to which manufacturers are reacting with a wide range of models. In Germany alone, there are currently over 500 different models on the market. There has not just been a massive increase in the variety of models, series, and equipment options, but the product lifecycles have also become more dynamic.

A study on strategies in the machinery and plant engineering sector paints a similar picture: component and machine manufacturers are faced with increasing differentiation in market requirements. As a result, half of the companies surveyed are assuming that the variety offered within their product ranges will increase in the years to come. It thus seems that there is no end in sight to this spiral of increasing complexity. In most markets, there are no increases in quantity, just variety. To some extent, this increase in product complexity has a tremendous impact on the value-added processes along the entire supply chain. An overwhelming number of parts and components must be kept in stock and managed. Every additional product variation reduces valuable opportunities for using economies of scale in sourcing and production. Yet on the other hand, competitors in Asian countries such as China are putting enormous competitive pressure on the production cost structures of manufacturers in Europe, North America, and Japan, thus making precisely these economies of scale urgently necessary.

In an effort to master the business complexity in this tense environment, top management is forced to make three fundamental architecture decisions, which, however, are neglected far too often in practice.

1. Product architecture decisions,
2. Value-added architecture decisions, and
3. IT architecture decisions

For this reason, we have devoted the core content of this issue of the Complexity Management Journal to these three fundamental architecture decisions. The rest of this article provides you with a brief introduction.
Decision no. 1: The right product architecture

The period for which technical innovations can ensure a unique selling proposition is getting shorter and shorter. In order for German manufacturers to live up to their premium claim, their technology needs to be one step ahead of the competition. At the same time, they must keep the quality promise that customers have always associated with their strong brands and, on the other hand, keep their own costs within reasonable parameters. Walking this tightrope requires providing the variety of products demanded by the market with as few different internal parts and components as possible. This is realized by using intelligent product architectures in the form of integrated structures, platforms, and modules. This allows for the components that are used repeatedly, also known as “commonalities” to be realized in the current product range and across product generations.

In addition to physical commonalities, commonalities in terms of specifications, functions, or product characteristics are also conceivable. As the specifications implemented in a product become more heterogeneous, a greater effort must be made to tap into other levels of commonality apart from physical commonalities. Technological commonality makes it possible to maximize the technological benefits, whereas commonalities in terms of specifications, functions, and product characteristics ensure quick realization (Fig. 1).

The stability of this kind of product architecture is largely influenced by the product’s lifecycle.

In the past, companies relied on platform concepts, which allow for commonalities in the form of identical parts to be used across several product lifecycles. Nowadays, many companies have platform concepts in place. In the past, these platforms were often individually developed according to different guidelines based on different architectures and structures and using different technical solutions. This is also where the main risks of a platform strategy arise. On the one hand, there is the risk of inadequate differentiation due to developing more and more similar variations on a single platform, which can result in cannibalization within the product range. On the other hand, differentiating prices and implementing a clear price hierarchy for products with similar platforms within a single segment has proven difficult.

This means that in the future companies will have to transition more to developing different model series from a common, scalable modular product architecture (Fig. 2). Compared to the platform approach,
the modular architecture principle expands the understanding of commonalities by taking similarities between different product families into account, among other things.

This use of modules across series and models generates synergies when it comes to both developing new modules and introducing new products. Decoupling the development cycles in the sense of “release engineering” results in all of the products having a degree of innovation that can be achieved with optimized costs. A modular product architecture also makes it much easier and, above all, more cost effective to derive niche models. Improved lifecycles for technology also mean that it is possible to get an even better return on the necessary investments.

A module’s commonality-based product architecture must be built based on consistent logic that is compliant with customer requirements and free of conflicts. In practice, this can pose tremendous challenges for companies. On the one hand, developing many highly varied products such as machines, systems, equipment, and vehicles has traditionally been organized into specific, series-based projects, which interferes with the consistent use of commonalities due to a lack of coordination during the pre-series and series development processes. On the other hand, the current approach for developing modules still tends to be purely intuitive with very few systematic processes in place. Potential solutions lie in the design and organizational implementation of a comprehensive product architecture development process (PADP). This “PADP” is characterized by the fact that it is neutral from the actual product development processes and is more dominant in terms of setting time and structural guidelines (Fig. 3).

Another challenge in designing product architectures involves making intelligent use of commonalities across countries, regions, and brands. Fundamental differences emerge when implementing commonalities in national and international contexts. In the international context, there are many more influencing factors that determine whether implementing a commonality is feasible and makes sense. At the same time, implementing commonalities is more difficult since the national entities often have a certain degree of autonomy on matters involving R&D. For this reason, companies
must succeed in overcoming information barriers within the development organization.

In practice, an onion skin model has proven to be an effective methodical tool because it visualizes, characterizes, and prioritizes commonalities. Based on differentiating between different types of commonalities and coordination mechanisms, individual modules and components can be characterized in the onion skin model. This characterization helps to determine how to handle individual modules and components and declare them as globally binding, make them available to the national entities, and organize the exchange of information before and during the development process (Fig. 4).

**Decision no. 2: The right value-added architecture**

Making a value-added architecture decision means: using modified processes to complete the right tasks at the right site. This essentially involves answering three questions:

1. Which site masters which processes, methods, and technologies now and in the future?
2. Which site produces which quantities now and in the future?
3. Which site produces which variations now and in the future?

The principle to be applied here is: as complementary as possible, as flexible as necessary.

Complexity cost savings potential in production can only be fully tapped by synchronizing modular product structures with modular process structures. This involves analyzing how the change drivers within the product structure impact the respective steps of the manufacturing and assembly processes and assessing how they influence costs. The
resulting transparency not only allows for production costs and investments in equipment to be holistically optimized based on the product structure, but also allows for measurable increases to be achieved in process maturity and quality.

**Decision no. 3: The right IT architecture**

Modular product architectures can only achieve success and the expected level of profitability if they are incorporated and embedded into existing product development processes.

The product architecture development process (PADP) is also taking on a more important role in terms of product lifecycle management (PLM). This means that IT architecture decisions must always be made in close connection with decisions on product architecture and the underlying development processes when introducing and further developing the PLM. These decisions can by no means be made on a one-time basis, but in a repetitive process of aligning the strategy, the process structure, the functions, and the data models of the PLM.

This requires both a dedicated understanding of the processes in the existing workflows and a critical evaluation of the performance of the existing IT systems. In this context, the following questions have proven to be particularly important:

- Is the IT architecture able to structure, version, and maintain customer requirements in the context of the current state of development?
- Is the system able to create explicit product module interfaces directly in the module?
- Can the system coordinate a cross-functional module development team in order to enable collaboration during the development of module interfaces?
- Is it possible to manage the development of interfaces separately from the development of product components?

- How can configuration rules be derived from the module interfaces?

- Can the system communicate interface specifications throughout the entire product lifecycle in order to facilitate concurrent engineering?

**Conclusion**

Increasing product complexity is forcing top management at manufacturing companies to make fundamental architecture decisions concerning their product design, valued added processes, and IT systems. In practice, these decisions tend to be put off or are neglected entirely since:

1. They cannot be made intuitively, but require a consistent and precise understanding of customer requirements, products, and value-added processes.

2. They are complex in and of themselves, often have strong interdependencies, and thus cannot be considered in isolation.

3. They can have a significant impact on the future orientation and profitability of the company and thus should not be made lightly.

In order to manage product complexity in the future, companies need:

1. A product architecture that is consistently tailored to the market and that allows for commonalities at all levels,

2. A specially-adapted product architecture development process,

3. A high-performance, consistent PLM infrastructure to support this process, and

4. A constant comparison between the product architecture and the company’s existing value-added processes and structures.

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Implementing sustainable modular product architectures with the IT to match

Stephan Woehe (Schuh & Co.)/Alexander Lewald (PTC)

Discrete manufacturers are faced with an increasing demand for product customization, thus resulting in higher costs as well as greater product complexity. While searching for flexible, adaptive solutions, many producers realize that they need to look at conventional development processes as well as their IT systems in a completely new way.

**Implementing sustainable and adaptable modular product architectures is a real challenge**

In recent years, many companies have gathered experience with modular product architectures, though many of them have only had moderate economic success. Even Lego, the forefather of “building block” modularization, faced serious obstacles with implementation and had to go through a comprehensive restructuring process in 2004/05. Jorgen Vig Knudstorp was the first external CEO to successfully master the turnaround. When reflecting on the situation back then, he now says: “We got arrogant. We stopped listening to the customers.” Lego fell victim to a diversification strategy that was too complex and hard to control. The existing IT systems did not adequately support the new requirements. This is just one example of the many companies that face challenges when introducing adaptive modular product architectures (Fig. 1).

The following symptoms are observed time and again:

- Companies typically have a business strategy, but only a few have used it to derive PLM (product lifecycle management) and IT strategies. IT decisions are often made based on single projects without being clearly related to the business strategy. As a result, the added value that PLM offers to the company is often negligible or non-existent.
- In everyday work, customer deadlines and approved product launches are given greater priority than the consistent monitoring and implementation of an adaptive modular product architecture.
- Preparing and introducing a modular product architecture sometimes takes so long that important basic assumptions are no longer valid since market conditions rapidly change.

**Challenges of implementing an adaptive modular product architecture**

Although many manufacturers recognize the benefits of an adaptive modular system, they also regard the implementation as a rather complex task. The challenge faced is twofold: manufacturers first need to redefine their existing product architecture and then alter their company processes and workflows to support the new product architecture. In many cases, the second task, i.e., introducing new
processes, represents the greatest challenge. The following aspects have helped companies to master the transition towards an adaptive modular product architecture.

**Reconciliation with the corporate strategy**

The new adaptive modular product architecture is often defined by a development department that is generally only concerned with simplifying the design process.

**Comprehensive process understanding**

Introducing an adaptive modular product architecture requires a tremendous amount of effort and commitment from the technical development department. First, the head of technical development must clearly define the modular product architecture. Next, the modules, the interface specifications, and the change management process for monitoring these specifications need to be documented. Finally, the modules need to be built and tested. Although these phases require a great deal of commitment from technical development, this department cannot implement and provide an adaptive modular product architecture by itself. The product architecture manager must be completely familiar with the product development processes of all departments within the company and must also

“Without proper support from IT, moving from the PowerPoint strategy to the actual modular product architecture would be virtually inconceivable.”

Stephan Wöhe
know which implications modularization will have on these processes.

If the employee responsible for the modular product architecture has a precise understanding of the relationships between the product architecture and the company-wide product development processes, e.g., drafting proposals, he/she is in a better position to ensure a complete and fast introduction.

**Careful preparation of employees**

The new adaptive modular product architecture must be defined, implemented, and provided by the various cross-departmental interest groups. Coordinating these interdisciplinary groups can be a challenge. When implementing an adaptive modular product architecture within a company, there can be problems if responsibilities for deliverables are not clarified or if the strategic responsibility for developing the product modules and module interfaces is not defined.

**Using high-performance PLM technology (product lifecycle management)**

Another important question to consider is to what extent the existing IT system supports an adaptive modular product architecture.

A high-performing PLM system also needs to be able to do the following:

- **Structure requirements:** The system must be able to structure, version, and maintain customer requirements and characteristics trees in the context of the current progress of development in order to guarantee transparency of the changes (Fig. 2).

- **Develop modules:** The system must be able to produce explicit product module interfaces directly within the module. It must allow for ideas and intellectual capital to be recorded and developed in structured product representations with a high level of detail. At the same time, it must support the realistic, interactive, and intuitive definitions for the appearance, behavior, and production options for a product (Fig. 3).

- **Facilitate cooperation beyond the company’s borders:** The system must be able to coordinate module development teams within the extended company in order to facilitate cooperation in developing module interfaces. All interest groups
involved in the planning, development, procurement, production, documentation, and maintenance processes for a product must be able to communicate effectively with one another.

- **Keep requirements, modules, interfaces, and components updated:** Because of the strategic importance of module interfaces, the system must control the development of these interfaces separately from the development of product components. The system must record the entire product content in a single, secure, logical repository, automate and monitor the most important product development processes, and coordinate all those involved throughout the entire product lifecycle.

- **Configure requirements, modules, interfaces, and components:** The system should define configuration rules from the module interfaces. It must also allow users to combine content components into simple or complex structures and manage elements derived and developed from them (Fig. 4).

- **Communicate efficiently beyond organizational borders:** The system must communicate interface specifications throughout the entire product lifecycle in order to allow for concurrent engineering. It should make it possible for the internal and external parties involved to make quick, efficient decisions for dynamic product content to be provided as needed to the right target groups and in the right format.

### Conclusion

An adaptive modular product architecture can only be successful and reach the expected levels of profitability if it is incorporated and embedded into existing product development processes. The structure, culture, and philosophy of the relevant company must also be considered when developing an implementation strategy. If the heads of various departments do not support the necessary process improvements (e.g., marketing, technical development, production, customer services), the implementation of the adaptive modular product architecture can fail before it has even begun.

A successful launch requires that the company’s strategy and values have been understood and communicated, that the responsibilities of the people most affected by the launch are known, and that which interdepartmental product development processes will be affected can be predicted. An IT system that completely supports the new architecture and a carefully prepared launch plan can greatly assist firms in mastering this challenge.

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Optimizing a modular product architecture in line with the market to reinforce the competitive position at Voith

Anno Kremer (Schuh & Co.)/Jerry Mackel (Voith)

When management of the joint shafts division at Voith GmbH in Heidenheim, Germany, contacted the Schuh Group in 2010, they were dealing with a classic problem that many German mechanical and plant engineering companies face: Standard industry margins and an excellent competitive position with large, customer- and product-specific products, and unsatisfactory margins and a declining share of the market with the more standardized segments in the product range. The lead time was also too long for this part of the product range. As a result, the goal for the jointly defined project was quite clear.

Optimizing the product range and modular product architecture in line with the market to reinforce the competitive position of standard industrial joint shafts

A modular approach was deliberately chosen for the project, partly to minimize the risk for Voith (staggered test phase for the consultant) and partly to guarantee time-optimized, concurrent processing (clear interfaces between the modules). The individual modules focused on the following areas:

Module 1: Range and variety analysis

Module 2: Value design
   2a: Complexity cost analysis
   2b: Customer benefit analysis

Module 3: Series design
   3a: Range design
   3b: Module design

Module 4: Implementation planning

All modules interact and build upon one another.

The range and variety analysis is essentially like taking a look in the rear-view mirror to reflect on the last three years. It is used to derive important findings for the new range and the optimized modular structure. But, as all drivers know, just looking in the rear-view mirror will inevitably lead to disaster. This is why Module 2 provides a systematic analysis of future perspectives before beginning the design of the target range and product architecture in Module 3. This ensures that both the time (past and future) and content perspectives (external complexity (range) and internal complexity (product architecture) are considered as part of the integrated approach.

Creating transparency is always the first task

When examining the existing range, all characteristics that described variance were systematically
analyzed using the Complexity Manager software. The tool allows for different analyses and representations of the actual variance sold over recent years (Fig. 1).

This showed that different versions were ordered very rarely. Of course, this fact alone is not enough to determine that this configuration should not be included in the new range. The full picture only becomes clear after systematically analyzing the customers behind the orders and the products offered by the most important competitors.

In addition to the external perspective, transparency must also be created regarding the internal costs that arise due to variance (complexity costs). This is the only way to find the right leverage to optimize the range and modular product architecture later on. The resource-oriented process cost calculation was used as the tool here. It allows for a relatively simple, yet meaningful assessment of the complexity costs.

You can’t get where you want to go only by looking in the rear-view mirror

In addition to the systematic analysis of the past, an attempt must also be made to anticipate market developments in the future. An integrated optimization of the product portfolio and, in the second step, a modular product architecture based on the optimized product portfolio can only be achieved by considering both perspectives.

Apart from the obligatory assessments of future market developments (volume, unit numbers at the variant level, target prices, etc.), a portfolio of success factors was also established. This instrument allows the most important guidelines for the new product portfolio to be defined and complements the market assessments. For the product-specific success factors (criteria affecting purchasing decisions), the portfolio of success factors indicates the importance to the customer (Y-axis) and the current level of fulfilment compared to the most important competitors (Fig. 2).
These can be used to derive the main areas for action and thus the guidelines for the new product portfolio and modular product architecture:

1. Price flexibility must be increased through:
   – Improved benefit argumentation through higher quality shafts
   – Greater economies of scale through reduced variance

2. Delivery time must be reduced through:
   – A higher degree of pre-material planning based on reduced variance

3. Reaction time (for offers) must be reduced through:
   – A higher degree of standardization. This allows for the use of pre-configured elements

At the same time, customers do not seem to place as much emphasis on design complexity in this segment (as opposed to the customer-specific large joint shafts). This is a further indicator for a potentially higher degree of standardization.

The design of the product portfolio and the modular product architecture is based strictly on the results of the analysis and the defined framework conditions

In the standard segment, the new range significantly reduces the variance of characteristics while still meeting customer needs to the same extent. As a result, the theoretically configurable variance (configuration leeway) has been reduced by 67%. Based on the types sold in the past, this corresponds to a roughly 40% reduction in actual variance (Fig. 3).

As mentioned above, this was achieved without reducing the market performance provided in the standard segment. Only existing overlaps in the range caused by selling two series with overlapping customer benefits were eliminated. By concentrating on the higher quality series, it is even possible to offer the customer an additional benefit. As a result, the new modular product architecture could be based on a streamlined product portfolio, which made work much easier for the designers.
The new modular design has two clear objectives

The main problem with the existing product structure was the low reuse of the most cost-intensive components. This led to exploding unit costs and longer lead times as a result of order-based material planning (Fig. 2). The new system was able to fundamentally improve precisely these disadvantages.

The example of profile components makes it clear that the new modular product architecture allows even more variants to be achieved by setting a reasonable limit for neutral (projectable) pre-material planning of 20 units per year (Fig. 4). This also applies to the other important components (e.g., pipes) and allows for a significant reduction of lead times for standard shafts while reducing costs at the same time. This means that the originally defined objectives have been fully achieved.

“After optimizing the existing modular product architecture, we achieved a 67% reduction in the theoretically configurable variance and a 40% reduction in the actual variance. This completely met our expectations.”

Dr. Jerry Mackel
The result: Greater customer benefits with shorter lead times and lower production costs

After six months of intensive project work, the results can be summarized as follows:

1. Lead time for 75% of the product range reduced to eight weeks (down from currently as many as 20 weeks or more for some types for which material planning is difficult)

2. Greater customer benefits from using high-quality hollow shafts in the standard segment at competitive prices

3. Identical market performance with considerably reduced variance (at the module and component level)

4. Production costs reduced by an average of approx. 10-15% across the entire product range

Expectations are high as the new product range is currently being launched on the market. So far, the feedback has been promising.

**Fig. 4: Profile components – Reduction of types and use of parts (standard shafts)**

*Projected, **Not yet in new series
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