TRANSPORTATION & MOBILITY

AN ENTERPRISE STRATEGY FOR EFFECTIVE VEHICLE MODULARITY

Industry White Paper

INTRODUCTION

To increase sales and market position, automotive OEMs must have comprehensive strategies for developing innovative products while continuing to reduce costs, increase quality and accelerate time to market. One of the most promising strategies to achieve these objectives is modularity. Vehicle modularity can be described in three main categories; Product Architecture, Production Processes and most recently "Strategic" Modularity. Historically modularity was used in the manufacturing environment to reduce complexity and accelerate assembly completion time.

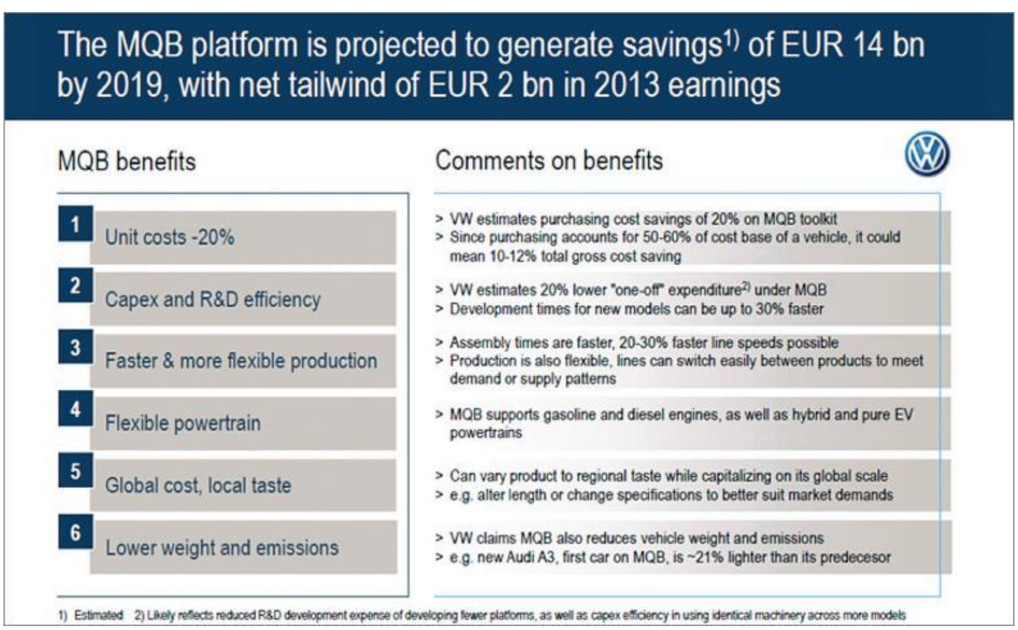
In the context of the global automotive industry, the concept of modularization has gained increased attention, since it has been linked more specifically to the design and/or assembly strategies of large auto manufacturers (OEMs) and as an approach that facilitates the introduction of successful new products.

BENEFITS OF MODULARITY FOR THE AUTOMOTIVE INDUSTRY

A key enterprise differentiator in today's automotive environment is the ability to design and manufacture vehicles rapidly, with high quality and at the lowest cost. A modularity approach is one of the strongest enablers to achieving these objectives, supporting:

- Time to market reduction by lessening the need for new part design, sourcing, engineering validation as well as tooling and facilities development;
- Reduced product cost through lower cost for unique facilities, materials, tooling and equipment;
- Investment efficiency by focusing engineering and manufacturing changes only in those areas requiring modifications;
- Quality improvement by eliminating quality issues associated with unproven parts, tools, processes and information;
- Launch readiness by eliminating unnecessary new manufacturing processes, equipment and facilities.

The advantages for automotive manufacturers are substantial. It is estimated that modularity cost savings for one-off expenditures can reach 20%, with development time reduced by 30% and per unit costs lowered by as much as 20%. The largest contributors to cost savings include labor wage reduction, material cost savings and increased assembly productivity.



Source: Morgan Stanley

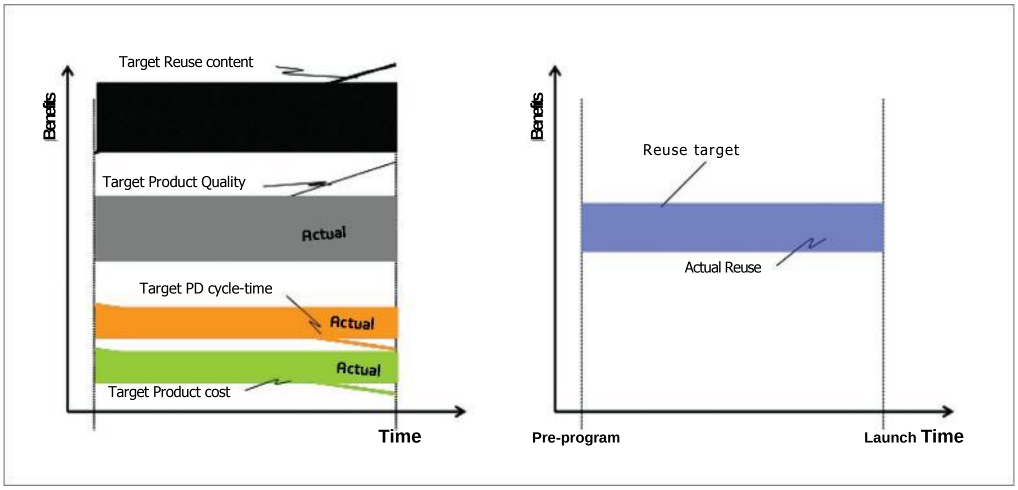
MQB Platform Savings

SUCCESSFUL MODULARITY IMPLEMENTATION CHALLENGES

A significant number of OEMs are adopting modularity strategies. While many initiatives are underway, the realization of benefits particularly within automotive organizations has been, to date, limited in scope and scale. Companies cite a range of factors that undermine initiatives, particularly:

- Process issues in managing dependencies across multiple programs and platforms;
- Number and diversity of vehicle architectures;
- Measurements which discourage modularity adoption, together with an inability to measure enterprise costs;
- Organizational issues associated with siloed structures, a lack of clear roles and responsibilities, and the management of disparate groups across the extended enterprise.

The following chart summarizes most of the observed experiences of automotive and other manufacturing companies.



Modularity and Reuse findings

The underlying reasons for these challenges are often due to the way in which the product development process has been organized, together with governance strategies and measurements that create incentives for design engineers to get products to market faster, and the lack of knowledge/IT tools to organize and classify data. Particularly, companies cite issues in three key categories:

Organization

- Current processes and metrics to encourage modularity and commonality/reuse are weak to non-existent;
- Organizational (siloed) structure does not support easy communication of modularity and commonality opportunities – roles/responsibilities and cultural change are unclear;
- Lack of understanding how to integrate modularity strategies with supplier management;

Processes

- Market dynamics and the evolution of the vehicle architecture impose challenges on preserving common strategy/development threads across programs and platforms;
- Schedule pressures and program timing reduce opportunities for modularity driven commonality and reuse. Planning is an issue, with system and component requirements not understood far enough in advance, and their impact on manufacturing processes and associated line side material requirements;
- Incomplete or unclear requirements;

- Understanding the effect of the bill of dependencies on modularity and their impact on the supply chain.

Measurements

- Difficulty in defining targets, including modularity at the reference architecture level;
- Modularity initiatives are obscured by New Product Introduction (NPI) program metrics and deliverables (schedule and cost measures were frequently cited);
- Belief that a module-based common solution is "more expensive" discourages modularity. No method may exist to measure the enterprise cost of a non-commonality decision;
- Legitimately different requirements discourage modularity/commonality

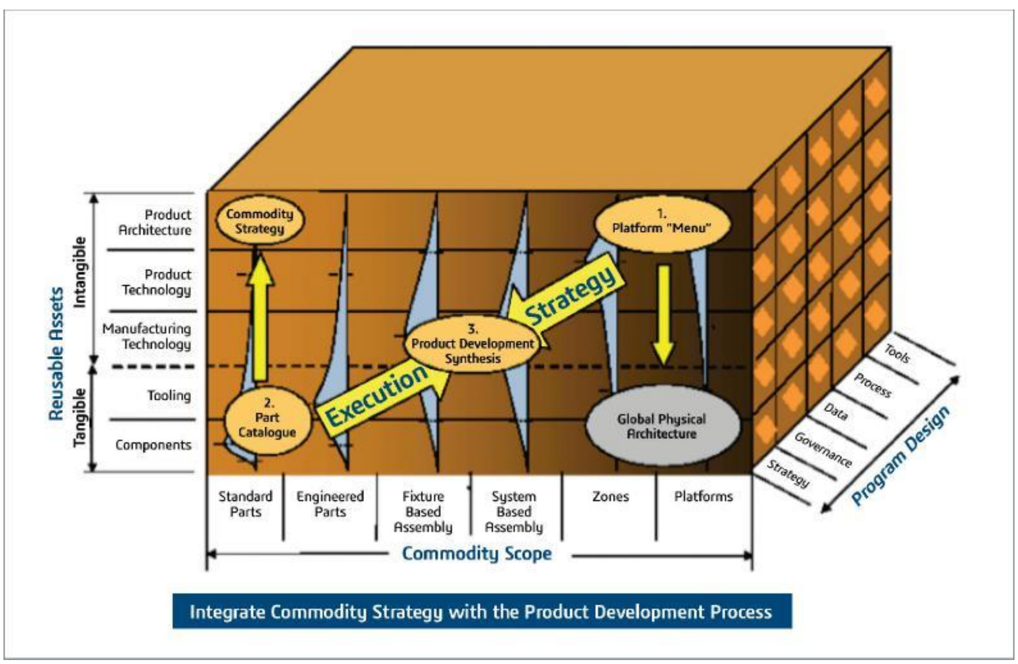
DASSAULT SYSTÈMES VISION: PRINCIPLES TO ENHANCE THE PRODUCT DEVELOPMENT PROCESS

Different commodities (from standard parts to systems) have varying degrees of suitability for reuse of tangible and intangible assets. For example standard parts like fasteners and radiator caps have high degree of potential for reuse of tangible assets, leading to high degree of commonality of end designs and manufacturing tools. Conversely, the highly-engineered and custom commodities, like body structure, have low potential for tangible asset commonality due to styling variations between product lines, but provide a high degree of potential for reuse of intangible assets such as product architecture, and product technologies.

Though the potential for commonizing the actual design is less for these highly customized products, the value of re-use of intangible assets is significant and needs to be addressed in any successful modularity strategy. Additionally, for most complex and engineered products like automobiles, there is a heavy top-down influence of higher level product architecture on the component commonality feasibility. This is mainly driven by the inter-component compatibility performance requirement and constraints from the performance compatibility requirements.

When effective, both of these strategies mainly contribute to improved material margin, as this is generally the key target. There are, however, other overlooked positive tangible benefits with modularity initiatives such as reduced design time, enhanced quality and reduced capital investment opportunities.

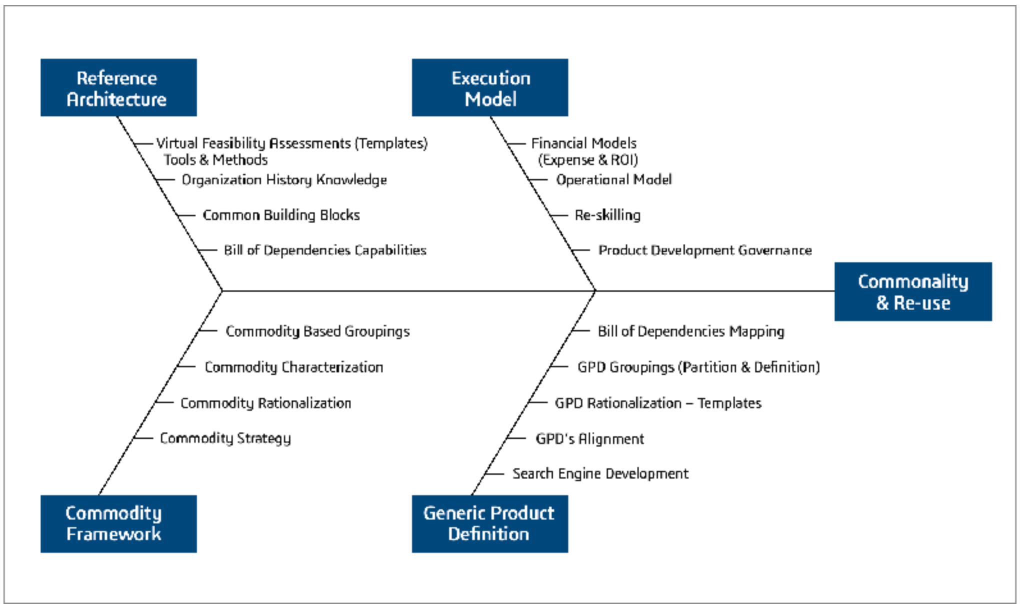
To address the totality of the modularity 'opportunity', Dassault Systèmes proposes a three-level strategy for automotive OEMs:



Three Level Commonality Strategy

- The first level is Platform Level Modularity, which drives down fixed costs of both the facilities and tooling, likewise, enabling rapid product development through re-used IP, as discussed earlier;
- Secondly, a Part Level Commodity strategy is needed to achieve economies of scale, improve part quality levels and minimize late engineering changes
- Finally, an explicit layer of commonality capability is required which sits between platform and part level commonality, and uses precise methods and supporting IT-based engineering and design tools.

Dassault Systèmes (DS) analyzed the experience of organizations in their adoption of modularity programs, and has produced a generic framework for successful modularity implementation. The framework identifies Critical Success Factors, together with key enablers for global deployment and execution. This view of modularity use includes both tangible and intangible assets, and positions modularity at the core of the full product development lifecycle. The Critical Success Factors (CSF's) identified have been developed based upon observations of approaches taken to commonality within DS customers. The enablers associated with each CSF have been prioritized and specifically adapted to help the automotive sectors, in particular, to 'jump-start' their modularity strategy.



Critical Success Factors and Associated Enablers

Feasibility Reference Architecture(s)

- The Feasibility Reference Architecture operates between Generic Physical Architecture (GPA) and product engineering release, and is used for virtual feasibility assessment for both tools and methods. It is developed using historical knowledge, and inclusive of all CBBs, and their Bill of Dependencies – i.e. the effects of one CBB upon others

Commodity Framework

- The Commodity Framework comprises of structures, tools, techniques and governance to support enterprise-wide commodity development practices, in line with both corporate strategy and market demands.

Generic Product Definition Approach

- The Generic Product Definition Approach allows 'Intelligent' architectures to be derived from the overall GPA in support of Platform 'Menu' Strategy. It enables, a requirements driven approach to be taken within the product selection process.

Executional Model

- The Executional Model comprises the definition and operation of governance structures, metrics, and measurements together with the development of skills and behaviors required for effective control and coordination across the organization. This will be achieved through precise management systems such as architecture development council(s), development council(s), commodity council(s) and executive council(s).

KEY TECHNOLOGY ENABLERS

Requirements Management

In order to ensure that the module will meet its performance targets, it is necessary to have the capability to derive, manage and verify requirements/specifications data. Current practices in many large manufacturing companies are built around a "requirements driven" design process. That is, an engineer/designer accesses data from many different types of requirement documents (i.e. Word, PDF, Excel, etc.). Examples include specifications composed of; functional, government, environmental, manufacturing, and service requirements. These documents are decomposed at many levels; from high-level vehicle technical specifications, to sub-system technical specifications, to component technical specifications. From these documents the users then move directly to their CAD models and begin the process of creating geometric models to meet the performance characteristics of their specific component. Typically there is no traceability between the system specifications and the product geometry.

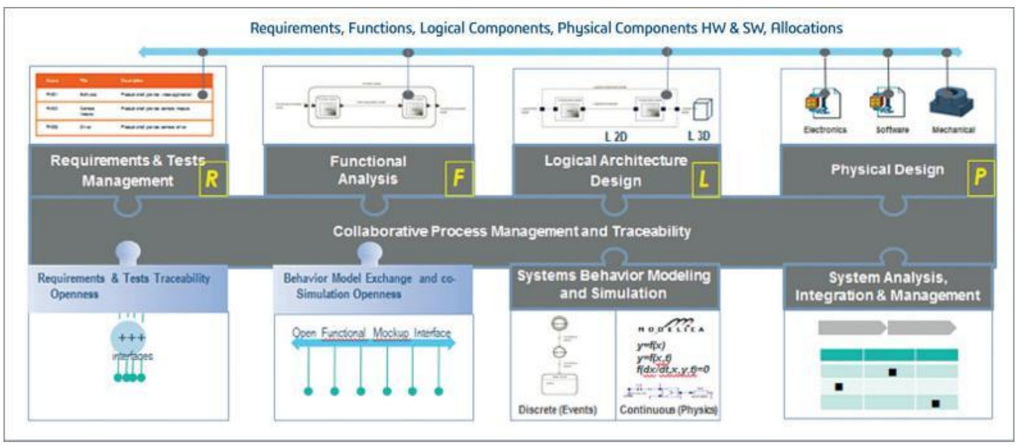
To enable modularity, business requirements, VOC (Voice of Customer) requirements, and competitive benchmark information needs to be managed in such a way that allows users to define and relate the requirements to the needs of the business. This allows requirements to be associated formally in the structure, or informally through the desired ad-hoc relationship and also allows users to see the complete context of the requirements relative to the customer needs and business objectives when making decisions. It is essential that these requirements must be both traceable and executable within development process and follow-on engineering activities described throughout this document.

Product Function/Portfolio Management

A major goal in strategic modularity is complexity reduction from both product and manufacturing aspects. In order to manage complexity it is vital to both capture and reconcile the actual "function" the sub-system or module will perform, as well as where it fits within the vehicle structure. Reducing the inherent complexity will allow the engineers to better determine (what) specific modules will allow them to (how) meet the specific requirements they need to satisfy.

If we are to better understand the decomposition and critical questions of "what" and "how," then we must increase our scope of the development framework beyond requirements structures and part structures. We must include a framework that is suited to answer these questions, and it must be fundamentally and independently valued as part of the development process. Inserting two structures to answer these questions can significantly increase our understanding of the development process and product.

The structures inserted between requirements (R) and physical (P) part structures include the functional (F) and logical (L) structures. The functional definition and relationships help us to understand "what" we are developing, and the logical structure helps us define "how" we are going to accomplish our goals. The combination of these new structures transforms the traditional view to the requirement, functional, logical, and physical structure view. We can then reconcile this structure to the product portfolio in order to populate the specific vehicle BOM (Bill of Materials).



Requirements, Functional, Logical, Physical Components

Complexity Management

The integrated system solution needs to create a marketing feature structure that represents how vehicles will be organized to satisfy customer needs. Marketing features in the structure are associated to parts within the enterprise BOM and/or CAD part structure, including a configuration engine, in this single environment. Selections within the marketing feature structure are then used to create resolved BOM/CAD structures according to marketing requirements/definition.

This structure must be setup to directly correlate to order guides that are used by customers to define/specify vehicle features when making purchasing decisions. Marketing features in the structure are associated to parts within the enterprise BOM through inclusion rules. These BOM parts are associated to the CAD part structure. The relationships between the marketing feature structure and the BOM/CAD structures are then managed with a set of configurable rules. These rules provide the configuration mechanism for selecting features and resolving a BOM. Platform requirements are related to objects as appropriate for the purpose of maintaining traceability and establishing context for decision making.

Interface Management

Interface management includes identification, definition, and control of interfaces and is a fundamental element that helps to ensure that all the pieces of the system work together to achieve the system's goals and continue to operate together as changes are made during the vehicle’s lifecycle. Precisely defining interfaces early in the vehicle program is crucial to successful and timely product development. As the total system is decomposed into modules, functional interfaces between the areas are identified. These interfaces typically have functional data parameters pertaining to an electrical signal, matter, energy or geometry (i.e. physical) interface. The ability to manage these interfaces and understand when an issue at an interface point will cause a module to dis-function is a powerful capability.

Collaboration and Technology Transfer

Since the supplier will be a more integral part of the engineering process they must have the ability to securely view, retrieve, modify, and share relevant data and information online with the OEMs. In addition there is a critical need for a robust business process management capability to enable suppliers to seamlessly participate in the execution of a manufacturer’s critical business processes. This includes the capability to perform both synchronous and asynchronous knowledge sharing, including integrated process management, co-reviews, and repositories to manage lessons learned. Since the interaction with suppliers will grow substantially, the need to share and protect IP is also critical. Therefore a security model to support supplier access according to the OEM policies will be necessary, along with the ability to provide history and traceability to all supplier interactions.

To support synchronous collaboration real-time access to relevant project information is required, allowing the supplier to become an integral part of the module design, quality, execution processes. Multiple suppliers can be assigned responsibilities to different modules, allowing suppliers to work together on the same vehicle program, but with differing visibility and access. Part quality plans can be assigned at the same time, ensuring that suppliers follow standardized improvement and planning methodologies and best practices.

Process Planning & Robotic Programming

Modularization, due to the functional independence it creates, has been called the goal of good design function. The industry has made an effort to modularize products to be flexible to the needs of end users and marketing. This effort has led to the creation of product families. Occasionally, modules are created with some aspects of production in mind. However, this modularization is done without fully understanding the implications of the production design. Although often yielding highly functional products, once the entire manufacturing process is accounted for, this unstructured modularization often leads to costly redesigns or expensive products.

Modularity requires maintaining independence between components and processes in different modules, encouraging similarity in all components and processes in a module, and maintaining interchangeability between modules. Modularity with respect to manufacturing necessitates understanding the various manufacturing processes undergone by each attribute of each component.

Design for Assembly (DFA) can lead to significant savings during production. One aspect of assembly cost is minimizing the number of components in the product. Modular products tend to have fewer components for assembly. By increasing pre-assembly and using common interfaces, modularity decreases the cost of assembly. Modules are usually dictated by the supplier subassemblies and are not necessarily the best possible choice for lowest cost.

Design for Manufacturability (DFM) improves product design to decrease production costs. Increasing commonalities within components and subsystems, a key part of modular design, leads to fewer tooling sets and few changes in set up. In addition, modularity increases the number of components using a particular process or set up, thereby yielding a positive economy of scale.

An important consideration when defining the manufacturing modularity of a product is the chosen level of abstraction of the manufacturing process itself. The manufacturing of a product is made up of many tasks. These tasks are, in turn, made up of sub-tasks. A product may be modular (independent and similar) when examined from the standpoint of the overall manufacturing processes (e.g., injection molding versus forging) but at some task level, the structure may not be very modular with respect to the manufacturing process (e.g., similarity of fixturing components within a module). Therefore, when defining the relative manufacturing modularity of a product, one must do so with respect to the tasks and sub-tasks of the manufacturing process. This is parallel to considering the level of abstraction of the product.

Process planning and line balancing capabilities under the "Digital Manufacturing and Production" domain enables a natural interactive 3D environment for creating, sharing, and experiencing manufacturing processes and robotics programs. Users are able to design, plan, simulate, and optimize a production system in a virtual world, prior to the actual launch of production. This will help in maximizing production efficiency, lowering costs, improving quality, and reducing time to market from the perspective of modularity. Users can efficiently and reliably determine the time required to perform a specific job sequence based on commonly used time measurement methods or company-proprietary time standards and determine the impact of common processes.

CONCLUSION

There is evidence to confirm that adopting modularity as a strategic approach can:

- Increase product variety and strategic flexibility
- Achieve economies of scale
- Reduce lead-time,
- Lower capital/overall costs
- Increase feasibility of product/component change

Achieving modularity and reuse has been a challenge to many manufacturing organizations. Challenges have mainly originated from limited capability of system-driven product planning and product validation. The Dassault Systèmes framework helps define the interdependency of key business and technical enablers needed to enable a successful modularity strategy for automotive OEMs. In addition, DS is in a unique position to provide key technical enablers through integrated R/F/L/P, vehicle configuration, interface management and collaboration solution capabilities.

Dassault Systèmes provides unique technologies to address many modularity challenges. This is due to the native associativity of models, where complex systems are more easily described and designed, and knowledge reuse is optimized, increased, captured, and retained. In addition, failure modes are more easily detected and understood leading to potential increased quality, decreased costs, and time savings by performing these tasks in a virtual environment, prior to physical prototyping, testing, and iterative design cycles.

Additionally, when design targets are not met it is immediately evident which requirements are violated and conversely, when requirements are changed, which designs are affected. Application of these technologies will enable methods to capture architectural context and learning, apply lessons learned much earlier in the development process for module selection, and provide valuable context for detailed decision making later in the development cycle.

For additional details, learn more at: **www.3DS.com/transportation**

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