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Design Platform - A Coherent Model for Management and Use of Mixed Design Assets

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Abstract. For many companies, it is a challenge to balance product variety and cost, i.e. external and internal efficiency. Product platforms has been the dominant solution for a business targeting mass-customization. The main idea is to dived the product into modules that can be shared among different product variants. This has been a success on the consumer market, however, many manufacturing companies are engineer-to-order (ETO) oriented, such as original equipment suppliers (OES). They design a unique solution, often in close collaboration with other companies, based on different product concepts and/or core technologies. For these companies, there is a strategic need for a platform model influenced by the principles of mass-customization, although, not limited to only include modules. In this work, a novel platform model, called Design Platform is described. The model has been developed and applied in cooperation with four companies. The Design Platform provides a coherent environment for management of heterogeneous design assets to be used in product development and supports an improved ability to master fluctuating requirements and systematic introduction of new technologies.

Keywords. Customization, Engineer-to-Order, Design Platform, Product Development, Fluctuating Requirements, Technology Development

Introduction

Export of products account for about 70% of Sweden's exports and represent a significant body of Sweden's prosperity [1]. To maintain and strengthen manufacturing competitiveness and innovation, new methods are needed to meet the requirements of the global market, the changes in customer needs, the technological progress, the introduction of new business models, and new regulations. According to the Swedish Association of Automotive Suppliers [2], the suppliers accounts for 75% of the added value in the automotive industry and they take more and more responsibility for product development. Production at low cost is required and positive volume effects are expected by contracts with several vehicle manufacturers. The supply chain is leading the initiatives and the implementations of new technology in different strategic areas. To offer new technological solutions that increase customer value strengthens both the supplier's and the OEM's competitiveness. A supplier who strategically lead the development in an area must invest in research and development as the

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responsibility, initiative and risk is shifting. New methods and tools are needed to integrate new technologies in new products efficiently and quickly and achieve volume effects. From a vendor perspective, this is a big challenge as requirements and interfaces are highly diverse between different systems that the product will be integrated into, markets the product to be delivered to, the use of the product and the customer's individual preferences. Adapting to adjacent systems are usually necessary to achieve a feasible solution, while effective production must be ensured in order to keep costs low. New technical solutions are need to industrialize the adaptive system that easily can adapt to changing customer requirements. Furthermore, the engineering work in product development, quotation and order processing must be well-organized to allow for a high degree of customization at low cost through efficient production. For many manufacturing companies, customization is required. One strategy is to develop a modular product architecture that enables variant formation by configuration. A higher degree of customization is often required for system suppliers and modularization must be supplemented by parametric models and design methods. Configuration of modular products are the focus of most research, but little has been done regarding more heterogeneous descriptions. Some support exists in Knowledge Based Engineering (KBE) but a holistic approach covering the whole chain between technology development, product development and customization activities is missing.

This paper reports results from a 3-year research project, entitled Challenge Fluctuating and Conflicting Requirements by Set-Based Engineering, that ended in the beginning of 2017. Swedish industry has a long-standing tradition of continuous and systematic investment in technology development in strategic areas. The project was based on the national strategy that this has to be further strengthen, bringing more value to the customers, improving the sustainability of products, and to sustain and increase the industry sectors competitive edge. For supplier, however, customization and proactive technology development are major challenges due to the large differences between the various systems that their products are to be integrated into, the markets the product are intended for, the use of the product and the customer's individual preferences. To reach a feasible solution, adaptation to adjacent systems is necessary while efficient production must be ensured to keep costs low. The overall objectives of the project where to build a better understanding of these challenges and introduce a new method for increased ability to efficiently develop and describe adaptive technology solutions and subsequently adapt these in the product development projects to comply with changing and conflicting requirements. The expected long-term effects of a broader application of the results would be a better and quicker introduction of new technologies in combination with an increased degree of market adaptation and customization, which strengthens competitiveness and innovation capability.

Four companies participated in the project and joint activities (Figure 1) were combined with focused case studies, development of

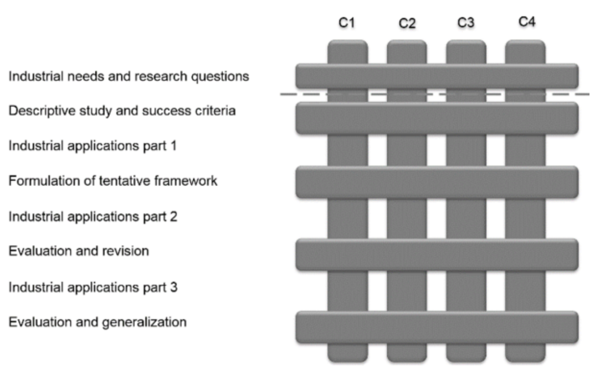

Figure 1. Project set-up.

demonstrators and cross-case studies. The overall research approach used in this work is based on the one suggested by Blessing and Chakrabarti [3] for development of design support. This work reports the findings and the development of a general method applicable for the four companies. Information about the cases has been gathered from meetings, workshops, demonstration of applications, reviews of documents and in-depth interviews.

1. Is there a need for new platform models?

Customisation refers to the ability and strategy that aims towards design and manufacture of tailored products for an individual customer. Depending on where the actual customization starts, four different business models can be identified: (1) Engineer-to-order, (2) Modify-to-order, (3) Configure-to-order and (4) Select variant [4]. For the latter two, product platforms have gained a lot of success as an enabler for efficient customisation. The definitions of product platform range from a platform consisting of components and modules [5], a group of related products [6], a technology applied to several products [7], to a platform consisting of assets such as knowledge and relationships [8]. This is also reflected among suppliers, as shown in [9], where the company platform description is categorised on four levels of abstraction and compared to their customisation strategy. Platforms are generally described to be of one of either two kinds: (1) The module based (discrete) characterised by sets of components being clustered into interchangeable modules that together form the product. The module-based platform can either be integral, where functions are shared by several modules, or modular, each function is delivered by only one module. (2) The scalable platform that becomes adaptable due to letting some of the design variables vary which leads to a stretching or shrinking of the product instances [10]. The research in the field of product platforms has mainly adopted an artefact oriented approach supported by the evolution in PLM and configuration systems, i.e. the rules have been defined and organized in accordance to a product structure. This approach has been further supported in engineering by the different commercial KBE tools available today for modelling of design knowledge. The process approach, on the other hand, has gained more success in the area of computing, where engineering tasks defined in different applications are connected for the purpose of simulation and optimization.

Many suppliers act in the business-to-business market and are involved in the actual development of the final product in collaboration with their customers; e.g. an OEM, a manufacturing company that needs special production equipment or a service provider that use unique products in the operation. These suppliers have a product concept for a specific application, however, this concept is more or less implicit, i.e. it is not fully described and managed in a structured coherent way, and it includes more assets and resources than pre-defined modules, if any. They frequently respond to different customers' requests for quotation by submitting specific offers and it is vital to respond quickly and with a sufficiently accurate price [11]. If the price is set to high a competitor will get the order, on the other hand, if the price is set to low there might be a financial loss in the long run. If a contract is won, a project is initiated for the final development of the specific solution based on the needs and requirements of the customer. The development project is executed in close collaboration with the customer and can run for years and changes in the requirement specification are frequently faced [9]. Other characteristics of these businesses are low production volumes and/or high technology change rate which makes it impossible to launch large product platform development projects with a pre-planned number of product derivatives [12]. The product concept evolves with the knowledge and experience gained from executed product development projects. To continuously learn and build corporate knowledge is a core process of Lean Product Development (LPD) called knowledge value stream [13]. The knowledge value stream consists of capturing and reuse of knowledge about markets, customers, technologies, products and manufacturing capabilities. In order to make use of the created knowledge it should be generalised and visualised as far as possible to support a flow across projects and organisations. Another important methodology that falls within LPD is Set-Based Concurrent Engineering (SBCE) that opposed to a traditional point based approach supports the development of solution sets [14]. Each discipline draws a space and the sets of candidate solutions can be found in the intersection of the different disciplines' spaces. The impact of changes in requirements can be evaluated and either is the number of candidate solutions decreased, or new solutions have emerged, or no solution exists. In the latter case, the search for a solution can be supported by untightening the requirements. Positive effects when applying the SBCE-principle has been observed in industry [15] and suppliers would most likely benefit from increased support to systematically learn from executed development projects (knowledge value stream) and building an ability to adapt when requirements are changed (SBCE).

For many ETO industries, a modular platform approach is not applicable due to the specific needs of every customer. Still, there are similarities in the products that are designed, the tasks that are executed and the utilised resources. If the product constructs cannot form a platform, other approaches can be used. However, while many modelling approaches exist for products and processes, very few address the integration of both. In fact, no integrated product and process model exists that gives equal weight to product modelling as to process modelling [16]. A platform approach has been shown to be an enabler for efficient customisation, reuse and production standardization. In source [17], the question is raised if companies even have a choice regarding implementing a platform or not to stay competitive in the future since platforms can exist on several levels making them useful to all kinds of products. However, the common platform definition that builds upon pre-defined modules and components has been shown to be insufficient for companies working with an ETO business approach [18].

2. Supporting platform based development at systems suppliers

Four companies participated in the project, (see Table 1).

Table 1. Main characteristics of the four companies.

Company	Business area	Nr employees at site	Nr employees total
C1	Automotive	300	3 000
C2	Product and production system	70	150
C3	Aerospace	2 000	44 000
C4	Automotive	600	10 000

C1. The company develops and manufactures its own products for and international market and is also a system supplier for the global automotive industry. Roof rack is one of the products and being able to quickly launch a roof rack considered very important as a roof rack with accessories are often acquired in the purchase of a new car. The requirements for roof racks are changing as car bodies are different, but also contradictory as they must be clamped tightly while the bodywork do not get damaged. The company needed a general method that facilitates the engineering work to adapt to fluctuating requirement and verify the solution.

C2 offers its customers complete product and production solutions. The company is also software vendor and developer of specific software applications. The company sees opportunities to partially re-use solutions in new projects and to smoothly introduce new technology into the re-use solutions but lack structured methods for this.

C3 is a global actor in the development, production, service and maintenance of components for aircraft, rocket and gas turbine engines with high technology content. Performance requirements, system change during the lifetime of the product and conflicting requirements concerning, e.g.. performance, weight, strength, heat resistance and production, must be balanced. The company has extensive experience in the automation of design and production preparation for quick adjustment to changing requirements specifications. The company was in need of improved methods to efficiently develop and describe new technical production solutions that can be quickly adapted to the varying requirements.

C4 develops and manufactures its own products and is a system suppliers to the global automotive industry. All vehicle manufacturers have different specifications and requirements has to be assessed and balanced continuous throughout the joint development projects. The company needed a general method to develop and describe new innovative technical solutions enabling efficient customization.

2.1. Re-modelling the product realisation process

Difficulties in using the linear models designed to describe a product's life cycle was identified early in the project. The companies also described a situation where they want to use some kind of a platform description except a truly modular one. The two most common ways to provide customized product is to either develop a set of specific products that customers can choose from, or develop a modular platform that is used for sales to configure a variant that the customer is satisfied with. The individual customer enters the process late the actual time of the purchase and do not have any impact on the development of the product. The customer interaction is different for system suppliers. The customer is not a consumer but a different organization, e.g. a final manufacturer (OEM), the requirements are unique and require different degrees of special solutions, and product development is done in a dialogue for a period of time when the requirement specification all too often changes. These companies do not have the opportunity to invest in large platform development projects and it is not considered appropriate when the requirement changes are difficult to predict and rapidly technology development occurs in some essential areas. New support to continuously build up an archive of good solutions, components, methods and knowledge and create effective methods for using these engineering assets at the scoping, the quotation design and the final development of unique solutions are needed. Companies also need to develop an ability to cope with difference in requirements from different customers and changes during the development work. In Figure 2, a common product life cycle model (top) and the model introduced in the project to provide a comprehensive picture of the development content and the need for a system supplier (bottom).

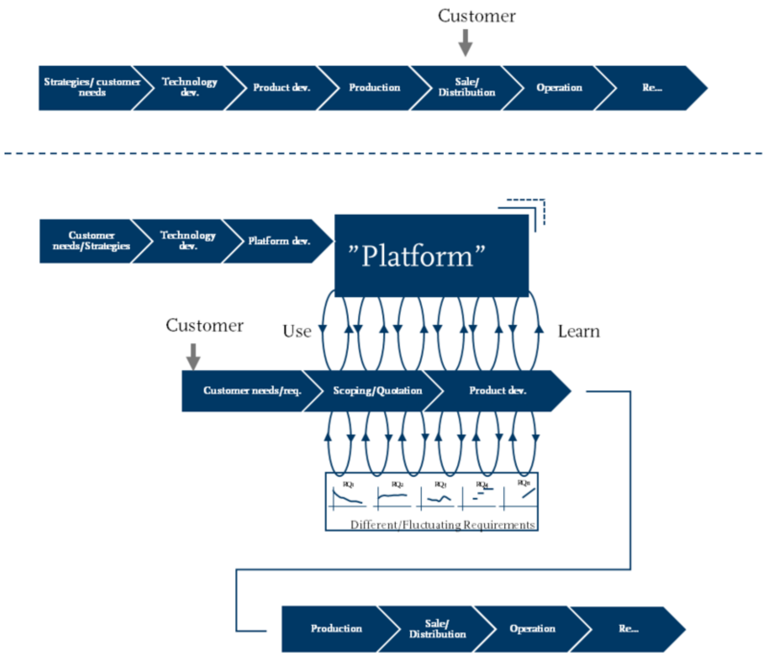

Figure 2. Life-cycle models for Make-to-Stock (top) and Engineer-to-order (bottom).

2.2. A coherent model for management and use of mixed design assets

The concept Design Platform (DP) was introduced by the authors together with detailed descriptions of the four companies' processes, strategies to manage fluctuating requirements, supporting methods for efficient customisation and needs for improved support [19]. The need to increase re-use and to gradually build up a source of articles, components, methods, guidelines, etc., based on previous projects while technology can bring new solutions, was identified by the companies as essential. It was also important to create an ability for efficient evaluation of changes in requirements during the development work together with supporting methods to generate alternative solutions if current solutions could not cope with the changes. These needs resulted in the development of the new platform model, Figure 3.

Different types of development assets from different disciplines and of different levels of concretization is collected, organized, and mapped in a DP. A DP can include modules but the scope is limited to that. A DP can also be continuously developed and creates a "toolbox" for the development team where different resources can be found and used to create a customer unique solution. A company's DPs builds a product system with engineering assets that the organization can work with systematically to improve, in the same way as a manufacturing company is working systematically with their production systems. Deficiencies and deviations can be captured and corrective action initiated. The status of various assets can be assessed and areas where gaps exists identified. New technologies can be introduced and mapped to be available in future development projects.

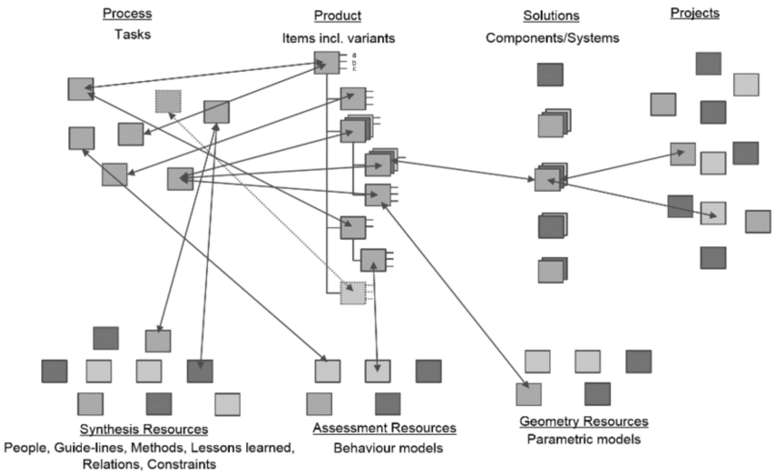

Figure 3. Constructs and relations of the Design Platform model.

2.3. Examples of assets developed in the project

A DP will consist of a variety of assets to generate and evaluate product definitions, product properties, specifications for product realization etc. In both synthesis and analysis phases, needs, requirements, constraints, and effects related to different stakeholders and disciplines are taken into account. It requires knowledge, practices, processes, guidelines, methods and tools to ensure that the final product meets all the requirements and that development can be pursued efficiently. A DP can include anything from a company expert available for consultation, checklists, lessons-learned, generic product structures, parametric CAD models as well as calculation sheets, simulation models and custom software applications. The work can be done manually, semi-automated or executed automatically if the domain is completely digitalized. Within the research project, a number of models, methods and demonstrators have been developed to exemplify and demonstrate the possibility to work according to the DP-principle. The work on this was done as industrial cases at three of the companies participating in the project and the different demonstrators represent subsets of the general DP model.

C1. A method of automatically FEM analysis of variant designs have evolved, figure 4. A large number of variants of fixing brackets are designed annually and lead-time in development is critical. The method reduces the work effort and lead time, and eliminates unnecessary loops between design and analysis.

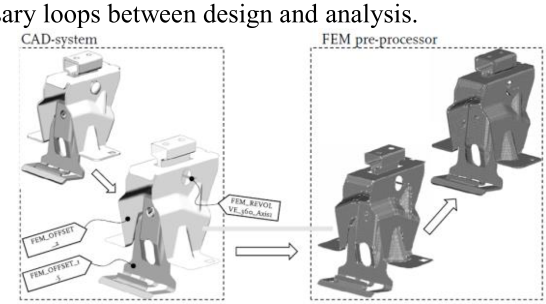

Figure 4. Engineering asset that enables automatic FEM analysis.

C3. Two methods have been developed and are part of the manufacturability evaluation of large sets product concepts automatically generated. One method evaluates the weldability and the other inspectability (Figure 5). The methods have been implemented in the company's development environment for concept design where hundreds of variants are generated and evaluated automatically based on performance, product features and manufacturability. The focus has been on introducing production aspects in the early phases of system development of unique solutions and creating an ability to manage changes in customer requirements.

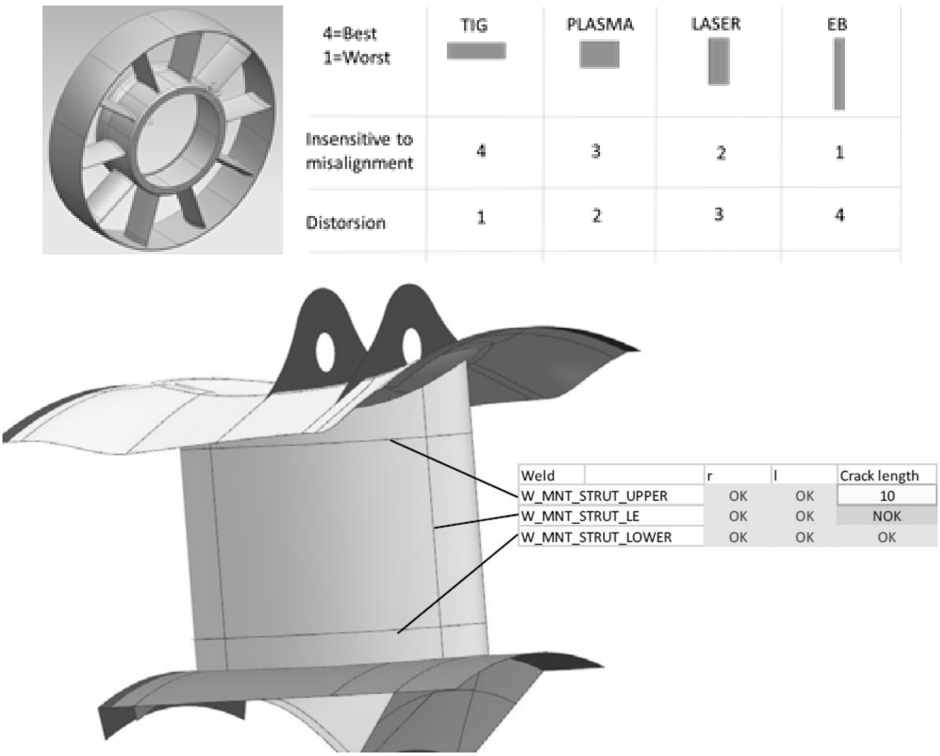

Figure 5. Engineering assets for producibility assessment; weldability (top) and inspectability (bottom).

C4. An approach for quotation and order design has been developed. The approach is supported by a model in which different types of assets for the development work has been structured and associated. A demonstrator has been developed in which existing components, CAD models, calculation methods are published. This is a comprehensive toolbox that designers can use to develop a solution and supports the re-work when changes in requirements arise during the project (Figure 6). Requirements vary from customers and change frequently during the development that can last for several years. The ability to efficiently assess the impact of a change in requirements and quickly find a workable solution enables a better dialogue with customers, promotes recycling, reduces costs and shortens the lead times in product realization.

2.4. Evaluation

The shared DP model evaluated at the end of the project. The companies agreed to that the DP model was applicable, it was possible to implement and a valid concept of generalizing and re-use processes, methods and resources, i.e. engineering assets. A shared view on a development platform was emphasized as a major advantage, as well as the ability to include different formats for storing knowledge. Changed working principles that may be require was as stressed as the major challenge to fully implement a DP model. A critical element in implementing the DP-based approach was to communicate the importance of the DP model to individuals not having a holistic view of the business. Other critical factors were ease of use, implementation effort, accessibility, training needs and to be able to measure the value of the changed working procedure. The companies agreed that the concept of platforms had evolved, from focusing solely on the components to include several different classes of engineering assets. The platform model is believed to reduce misunderstanding in the dialogue with customers. The project also lead to internal discussions at the companies and further development efforts. Finally, one participant stated that the DP model had "led to a bigger understanding of the need to see the whole picture - different disciplines can get a picture of each other's problems and challenges". This will hopefully lead to smoother development processes and quicker identification of design spaces where valid solutions can be defined.

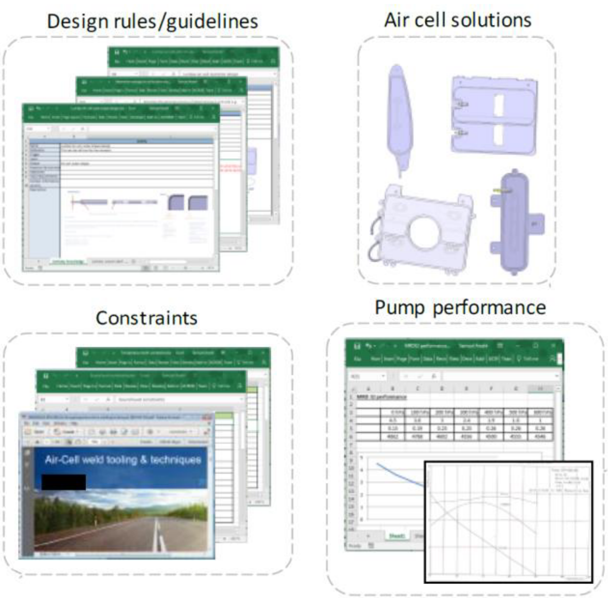

Figure 6. A selection of different engineering assets in the toolbox.

3. Conclusion

System suppliers in the automotive and the aerospace industry are very active in the development of new technologies and systems that needs to be adaptable to meet different needs, variations in system interfaces, and changes in requirements. Significant improvements of the ability to efficient and quick design customized solutions as well as manage changing requirements to stay competitive are needed. This work has resulted in increased understanding and knowledge about the development process at system suppliers and their need to build knowledge, describe different engineering assets and support reuse. A new platform model, Design Platform, has been developed which is the basis of the overall method introduced at the companies and to be further developed for use in practice. The company representatives are positive regarding the usefulness of the concept, however, they also express a need of support in implementation and ways to motivate the investment.

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