Development of a Business Process Matrix for Structuring the Implications of Using Configurators in an Engineer-To-Order Environment

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Olga Willner*, Manuel Rippel, Matthias Wandfluh, Paul Schönsleben

ETH Zurich, BWI Center for Industrial Management, Zurich, Switzerland
{owillner}@ethz.ch

Abstract. A methodological application of mass customization principles in engineer-to-order (ETO) processes is expected to lead to shorter lead times, increased quality as well as cost reductions. Product and process configurators, commonly used in mass customization processes, have to be adjusted according to ETO product and process requirements for their successful application in an ETO environment. In this paper the organizational requirements for a successful adaption of configurators to ETO processes are identified and structured. A Business Process Matrix capable of categorizing the implications of using product and process configurators in an ETO environment is developed.

Keywords: Engineer-To-Order, Customization, Product Configurator, Business Process, Value Chain

1 Introduction

The publication "From Future Perfect" by Stan Davis in 1987 brought about the advent of mass customization. Mass customization was defined as the capability to produce a wide range of product variants close to mass production prices through flexible and agile processes [1]. Pine [2] operationalized the concept for broad practical application through identifying the core technical enablers for mass customization such as a modular product design or the application of advanced manufacturing and information technologies. At present, in a vast number of industries mass customization production processes can be taken for granted [3]. A technical as well as organizational realization of a broad range of variants is well advanced and solidly based on standardized processes. In particular, a deployment of product and process configurators contributes substantially to ensure efficient and standardized business processes in a mass customization environment [4].

Recent academic research in the field of mass customization almost exclusively focuses on the transition from being a mass producer to becoming a mass customizer. The transition in the opposite direction, the move from being an engineer-to-order (ETO) company to becoming a mass customizer is often neglected [5]. ETO companies are defined as companies delivering products which are engineered or optionally reengineered according to the specific requirements of a customer [6]. ETO business

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processes can be characterized to be highly order specific, knowledge-intensive and of high complexity [7]. A methodological application of mass customization principles in ETO processes is expected to lead to shorter lead times, increased quality as well as cost reductions.

Product and process configurators, commonly used in mass customization processes, have to be adjusted according to ETO product and process requirements for their successful application in an ETO environment. Product structures as well as organizational processes may have to be aligned to novel conditions. A deployment of configurators, originally designed for mass customization purposes, in an ETO environment has a multitude of implications on the business processes along the value chain. The objective of this paper is to develop a Business Process Matrix for categorizing the implications of using configurator solutions in an engineer-to-order environment. This is expected to lead to a structured overview of the most relevant action fields for the implementation of an efficient ETO process along the value chain.

2 Research Methodology

The presented results are based on literature analysis and face-to-face interviews. First, literature research was carried out. Academic papers with the words "Engineer-To-Order", "Design-To-Order", or "Mass Customization" used in conjunction with "Product Configurator", "Product Structure" or "Processes" in title, key words or abstract were collected and reviewed. Second, interviews with decision-makers of six Swiss-based production companies from various manufacturing sectors (e.g. production equipment, elevators, pumps) were conducted. To produce robust results, representatives of small and medium enterprises (SMEs) as well as large enterprises were interviewed. The investigated companies varied in maturity levels regarding the deployment of product configurators in ETO processes. The interviews centered on the current state of integrating configurator solutions in ETO processes; both product structure and organizational issues were discussed in detail.

3 Results

In the following, a Business Process Matrix for identifying and structuring the organizational implications of using product and process configurators in an engineer-to-order environment is developed. First, the structural setup of the matrix is determined. Then, the core enablers for a successful application of configurators in ETO processes are introduced. Finally, the content of the matrix is derived from literature research and interviews conducted.

3.1 Derivation of Business Process Matrix

The solution space of the Business Process Matrix is spanned by a horizontal axis, depicting the business processes, and by a vertical axis, depicting the functional areas of a business organization. Business processes are defined as “a set of logically related tasks or activities performed to achieve a defined business outcome” [8]. In this Business Process Matrix the ETO business processes “Sales”, “Design” “Make” and “After Sales” are applied on the horizontal axis [7, 9]. Functional areas are the basis for a functional organizational structure [8]. For this Business Process Matrix the functional areas “Marketing & Sales”, “Procurement”, “Engineering” and “Production and Logistics” have been identified as being significantly involved in ETO processes. The objective of this matrix is to depict (a) how the tasks along the ETO business process chain are divided between the different functional areas; (b) which information in the form of data is required by whom; (c) which software tools are the enablers for sharing the required information; and (d) which benefits for the business process are achieved through the use of a configurator. To achieve this, the categories “Tasks”, “Input data”, “Software tools” and “Benefits of configurator” are discussed within the fields of the matrix. The varying impact of the application of configurator solutions on the individual matrix fields is depicted by a color gradation.

3.2 Enablers for configurators in ETO processes

In this section the core enablers for an application of product and process configurators in ETO processes are introduced and illustrated.

Product Modeling

An essential prerequisite for an efficient application of configurator solutions in an ETO environment is the description of product structures in product family models. Product structures can be modeled by the application of adaptive or generative methods. In case of an adaptive approach, a suitable parent version is determined from the existing variants to then be adapted to the requirements of the new variant by either developing plus/minus bill of materials (BOM) and operational routings or including dummy positions in product structure templates [9]. A modeling of product structures based on a generative approach takes place through a rule-based configuration of product variants. The definition of new product variants is achieved by the change of parameter values, expressing rules and constraints, that exist in a product configurator [9]. The development of a product family logic, based on modularity and hierarchy principles, contributes to an increased reuse of parts [9, 10]. The definition of a stringent product family logic provides the backbone for leveraging the full benefit of a configurator solution.

Integrated Information Technologies

Information technologies (IT) are one of the core enablers of mass customization [11], and even more so of engineer-to-order processes. A diverse range of software products is required for an effective management of ETO business processes, e.g. the sales and after sales phases are often backed up by Customer Relationship Management (CRM) software, the design phase by Computer Aided Design (CAD) systems, the make phase by Enterprise Resource Planning (ERP) systems, Computer Aided Manufacturing (CAM) systems and Manufacturing Execution Systems (MES) [12], and Product Data Management (PDM) and Product Lifecycle Management (PLM) provide support through the complete business process chain [13].

In configurator solutions (here consisting of the modules “sales configurator”, “product configurator” and “process configurator”) a variety of functionalities are embedded which support different phases of ETO business processes. In the sales phase, the application of a sales configurator supports the generation of valid offer documents. This includes the conversion of customer requirements into commercial specifications (parameterized definition of sales configuration). To be of further use in the design and make phase, commercial specifications have to be converted into technical (dimensioned commercial specifications) and production (including bill of materials and operational routings) specifications, as required by CAD and ERP systems [4]. Whereas the main output of the product configurator is the generation of BOMs based on parameterized product structures, the process configurator provides the appropriate process plans and operational routings.

Applying configurators as stand-alone solutions does not provide a considerable added value. An integration of configurator solutions into the existing IT landscape is crucial to enable an automation of processes, a close collaboration between departments and a proficient exchange of data.

3.3 Business Process Matrix

The Business Process Matrix provides a structured approach for decoding the interrelations between business processes and functional areas caused by the deployment of configurators in ETO processes. The matrix is designed with a practical application in mind. In the following, the principal requirements of the different ETO business processes on the configurator solution are described:

Sales

A potential customer order in the ETO segment is often initiated by an invitation to tender [7]. The generation of a valid offer document, including mapping of customer requirements, definition of commercial characteristics as well as quotation of prices and lead times, is the general objective within the tender stage. Since the success rate for winning a tender is a mere 30% in the ETO sector, fast and cost-efficient processes are required during the tender stage [14]. Therefore, the Marketing & Sales department, usually the interface to the customer during the entire business process chain, has to collaborate closely with various functional areas, e.g. estimated prices and lead times have to be provided by Procurement and Production, the conceptual design has to be developed by Design, the feasibility of the proposed product has to be verified by Production & Logistics.

The integrated application of a configurator solution is disposed to support the collaboration on a technical as well as organizational level. First, a parameterized definition of commercial as well as technical specifications becomes feasible through its deployment. Second, rule-based feasibility and validity checks can be automatized leading to shorter process times and a prevention of manual errors. Third, historical project data systemized and structured by the configurator solution can be consulted for reference.

Design

In the ETO segment, products are designed or altered according to order-specific requirements. This tasks reaches from the development of a conceptual design and selection of major components and systems [7] to the concise definition of BOMs and operational routings. On the way, feasibility checks and evaluation of consequences of redesign on functionality and prices might have to be performed.

The application of a configurator solution, backed up by a stringent product family logic can contribute to a systemic reuse of standard and pre-defined components [9, 10]. An increased reuse of parts and components is beneficial for both consistency of business processes and workload of functional areas, e.g. the feasibility of standardized price calculations increases, BOMs and operational routings for subassemblies can be reused, fewer inventories to achieve the same service level required.

Make

Production processes in the ETO sector are often highly unpredictable and of low controllability [14, 15]. Bertrand [15] characterizes the ETO market situation as dynamic (strong fluctuations in mix and sales volume in shot and medium term), uncertain (unknown product parts, uncertain lead times, prices and capacities, process uncertainties) and complex (multi-project character of the situation, complex capacity situation). On the other hand, ERP systems are designed to only support production of a limited number of product variants [16, 17] and presume BOMs and operational routings to be static and accurate during production.

A rule-based and consistent preparation of product and process data with the aid of the configurator solutions contributes to a generation of BOMs and operational routings easier processable by ERP systems. Consequently, a preparation of product and process data with the aid of the configurator solutions contributes substantially to process standardization, reduction in errors and decrease in complexity.

After Sales

In many markets, after sales is a business process elementary for success [7]. For the provisioning of a proficient after sales service, it is indispensable to know which parts are installed in specific machineries and to have quick access to the right spare parts. Product knowledge aggregated in configurator solutions should therefore be made available to software used in after sales service (e.g. CRM, PDM, PLM systems). Also knowledge relating to operations and maintenance should be fed back from After Sales to Engineering to be used for future improvements [7].

		Business Processes			
		Sales	**Design**	**Make**	**After Sales**
Functional Areas	**Marketing & Sales**	***Tasks:*** generation of a valid offer document (includes mapping of customer requirements, definition of commercial specifications, quotation of prices and lead times) ***Input data:*** customer requirements ***Software tools:*** sales configurator, CRM software ***Benefits of configurator:*** parameterized definition of sales configuration, accessibility of systemized historical project data, partly automated cost calculations			***Tasks:*** configuration of services packages, negotiation of service level agreements ***Input data:*** customer requirements ***Software tools:*** CRM software, PDM system, PLM system ***Benefits of configurator:*** accessibility of systemized historical project data
	Procurement	***Tasks:*** estimation of prices and lead times, preliminary selection of subcontractors and suppliers ***Input data:*** commercial specifications, supplier data, historical project data ***Software tools:*** product configurator, procurement software ***Benefits of configurator:*** accessibility of systemized historical project data	***Tasks:*** selection of subcontractors and suppliers, transfer of specifications to suppliers, negotiations on prices and lead times with suppliers **Input data:** BOMs (preliminary), CAD drawings (preliminary) ***Software tools:*** product configurator, procurement software ***Benefits of configurator:*** automated providing of product and performance specifications to suppliers	***Tasks*** : validation of purchased parts (correct ETO design, correct amount, on time) → supplier evaluation ***Input data:*** goods receipt notes, feedback from production ***Software tools:*** procurement software, ERP system ***Benefits of configurator:*** -	***Tasks:*** procument of spare parts, negotiations on prices and lead times with spare parts suppliers **Input data**: customer requirements, BOMs ***Software tools*** : PDM system, PLM system ***Benefits of configurator:*** preparation of historic project data for PDM and PLM systems
	Engineering	***Tasks:*** preliminary development of conceptual design, feasibility check and evaluation of consequences of redesign on functionality and prices, conversion of commercial specifications into technical specifications (preliminary) ***Input data:*** commercial specifications ***Software tools:*** product configurator, CAD system **Benefits of *configurator:*** rule-based automation of validity checks, automated generation of BOMs and CAD drawings, parameterized definition of technical specifications, accessibility of systemized historical project data	***Tasks:*** development of conceptual design, feasibility check and evaluation of consequences of redesign on functionality and prices, conversion of commercial specifications into technical specifications ***Input data:*** commercial specifications, preliminary technical specifications ***Software tools:*** product configurator, CAD system ***Benefits of configurator*** : accessibility of systemized historical project data, rule-based automation of validity checks, automated generation of BOMs and CAD drawings, systematic reuse of standard and pre-defined components	***Tasks:*** final design changes ***Input data*** : CAD drawings, BOMs ***Software tools:*** product configurator, CAD system ***Benefits of configurator:*** automated adaption of BOMs and drawings	***Tasks:*** recording of feedback relating to operations and maintenance for future improvements (e.g. Design for Maintainability) ***Input Data*** : customer feedback ***Software tools:*** product configurator, PDM system, PLM system ***Benefits of configurator*** : accessibility of systemized historical project data
	Production & Logistics	***Tasks:*** feasibility check (preliminary), capacity check (preliminary), estimation of lead times ***Input data:*** technical specifications (preliminary), BOMs (preliminary), CAD drawings (preliminary) ***Software tools*** : process configurator, ERP system, CAM system, MES ***Benefits of configurator:*** support of feasibility and capacity check (based on rules as well as information from previous projects)	***Tasks:*** final feasibility check, final capacity check, operational routings (preliminary) ***Input data:*** technical specifications, BOMs, CAD drawings **Software tools:** process configurator, ERP system, CAM system, MES ***Benefits of configurator:*** support of feasibility and capacity check (based on rules as well as information from previous projects)	***Tasks:*** component manufacturing, assembly, inventory management, operational routings ***Input data:*** BOMs, CAD drawings, operational routings (preliminary) ***Software tools:*** process configurator, ERP system, CAM system, MES ***Benefits of configurator:*** rule-based and consistent preparation of product and process data	***Tasks:*** production of spare parts, spare parts inventory management ***Input data:*** BOMs, CAD drawings, operational routings ***Software tools:*** ERP system, MES ***Benefits of configurator:*** -

☐ low benefits ☐ average benefits ☐ high benefits

Figure 1: Business Process Matrix

3.4 Implications

The structural deduction of the matrix and its contents illustrate that the Business Process Matrix developed in this chapter is suitable for structuring and contextualizing the organizational adjustments required for the implementation of configurators. Hence, the matrix can be understood as methodological reference in the context of adjusting organizational structures for the successful adaption of configurators to an ETO setting. The matrix depicts that a multitude of fields of action have to be considered when introducing product and process configurators to an ETO environment.

A concise specification of parameterized product structures and, possibly, modular component families is obligatory for the set-up of a fast and efficient product configuration process suitable for ETO products. Furthermore, the selected configuration system has to be fully integrated in the present IT infrastructure and interfaces to existing IT solutions (e.g. CAD, ERP, PLM systems) along the business process chain have to be provided. In this context, a common logic for the conversion and enrichment of data along the dimensions commercial, technical and production characteristics has to be determined. And above all, a close collaboration between all functional areas along the business process chain has to be ensured. Without doubt, an integrated setup of IT systems can contribute considerably to the design of fast and efficient ETO processes. However, due to the immense complexity and low predictability of ETO processes this alone is not sufficient. Only through a company-wide, or even preferable along the whole supply chain, incorporation of skills such as an integrated knowledge management, intercultural competencies and a comprehensive technical-organizational understanding the creation of a competitive ETO process becomes feasible.

4 Conclusion

The literature analysis and interviews conducted reveal that a standardized application of configurators in ETO processes still provides a multitude of organizational and technical challenges. This paper contributes to the development and dissemination of a methodology suitable for identifying and structuring the organizational challenges resulting from the deployment of configurators in an ETO environment. A Business Process Matrix for categorizing the implications of using product and process configurators in an engineer-to-order environment is devised. The matrix highlights the most relevant action fields for the implementation of an efficient ETO process along the value chain. Both literature analysis as well as input from practitioners contributed to the design of the Business Process Matrix.

In future research, the authors intend to test and strengthen the Business Process Matrix in practical use cases in various manufacturing companies. This case-based approach is expected to reinforce the practical relevance of the model developed in this paper. The insights gained from the use cases will be applied to refine the Business Process Matrix at hand.

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5 References

1. Davis, S.M.: Future perfect. Addison-Wesley, Reading, Mass. (1987)
2. Pine, B.J.: Mass customization the new frontier in business competition. Harvard Business School Press, Boston, Mass. (1993)
3. Piller, F.T., Moeslein, K., Stotko, C.M.: Does mass customization pay? An economic approach to evaluate customer integration. Prod Plan Control 15, 435-444 (2004)
4. Forza, C., Salvador, F.: Managing for variety in the order acquisition and fulfilment process: The contribution of product configuration systems. International Journal of Production Economics 76, 87 -98 (2002)
5. Haug, A., Ladeby, K., Edwards, K.: From engineer-to-order to mass customization. Management Research News 32, 633 - 644 (2009)
6. Caron, F., Fiore, A.: 'Engineer to order' companies: how to integrate manufacturing and innovative processes. International Journal of Project Management 13, 313-319 (1995)
7. Hicks, C., McGovern, T.: Product life cycle management in engineer-to-order industries. Int J Technol Manage 48, 153-167 (2009)
8. APICS: Dictionary 13th Edition. APICS - The Association for Operations Management, Chicago, IL (2010)
9. Schönsleben, P.: Methods and tools that support a fast and efficient design-to-order process for parameterized product families. CIRP Annals - Manufacturing Technology, (2012)
10. Brière-Côté, A., Rivest, L., Desrochers, A.: Adaptive generic product structure modelling for design reuse in engineer-to-order products. Computers in Industry 61, 53-65 (2010)
11. Piller, F.T.: Mass customization and SAP R/3TM - business solutions like SAP R/3 as an enabler of mass customization. Working Paper, University of Wuerzburg, Germany (1997)
12. Flynn, B.B., Sakakibara, S., Schroeder, R.G., Bates, K.A., Flynn, E.J.: Empirical research methods in operations management. Journal of Operations Management
9, 250-284 (1990)
13. Warschat, J.: Enabling IT for mass customization: the IT architecture to support an extended enterprise offering mass-customized products. International J. Mass Customisation 1, 394-401 (2006)
14. Konijnendijk, P.A.: Coordinating marketing and manufacturing in ETO companies. International Journal of Production Economics 37, 19-26 (1994)
15. Bertrand: Production control in engineer-to-order firms. International Journal of Production Economics 3, 3 - 22 (1993)
16. Aslan, B., Stevenson, M., Hendry, L.C.: Enterprise Resource Planning systems: An assessment of applicability to Make-To-Order companies. Computers in Industry 63, 692-705 (2012)
17. Van Veen, E.A.: New developments in generative BOM processing systems. Prod Plan Control 3, 327-335 (1992)