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A modular-based approach for Just-In-Time Specification of customer orders in the aircraft manufacturing industry

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ABSTRACT

The demand for flexibility in the configuration of highly customized capital goods such as aircrafts is rising. Customers request specifying product options later than required by the currently defined order fulfilment process of the OEM. However, late changes of previously configured products can cause disturbances in global production networks.

In this paper, a modular-based approach is presented, allowing customers to specify options just-in-time depending on the respective lead times following an Engineer/Order-to-order (EOTO) strategy. The concept of Just-In-Time Specification with its respective phases of order specification and steps of production planning is described and applied to the aircraft manufacturing industry.

Introduction

Aircrafts are products entailing high capital commitments on the one hand and a wide range of customer-specific variants on the other hand. The cabin configuration of the aircraft is strongly influenced by the customer's requirements and preferences leading to high engineering efforts for every newly designed aircraft version, the so-called Head of Version. The request for customization is rising due to airlines facing growing competition, particularly in the low-cost business [2]. A rating of the potential for an application for product configuration with the selection of features at the latest possible point in time was given by thirty experts in the area of global production in a survey conducted at the 1st Expert Conference for Global Production. Twelve of them rated the potential as "high" and eleven as "rather high" among the given alternatives "low", "rather low", "rather high" and "high". Consequently, the demand for more sophisticated customization as well as higher flexibility when defining the product configuration, e.g. the aircraft configuration, is increasing.

Due to customization requests, the architecture of each aircraft version delivered to one client is unique, even within the same aircraft family. Any customization on one component could imply some modifications on other connected components. Furthermore, there is the recurrent request for short-term changes of the aircraft configuration by customers after the regular specification freeze, so-called customer late changes. On average, there have been several customer late changes per delivered aircraft at Airbus in the past causing additional efforts for the engineering department responsible for processing customer late changes. One third of customer late changes were related to Head of Versions, but two thirds to Rebuilds, that are rebuilds of Head of Versions and thus actually are not meant to deviate from the Head of Versions. Most of the customer late changes are related to the cabin configuration that is an important indicator for the workload accruing in final assembly.

Moreover, customers worldwide order aircrafts with individual requirements regarding the order fulfilment process, e.g. requesting specific production locations, delivery locations and delivery dates.

In addition to such commercial constraints, aircraft manufacturers have to deal with industrial constraints regarding their global production and supply chain network. From a production planning perspective, the challenge not only lies in ensuring aircraft assembly on time and of high quality, but also in how and when to allocate orders to plants and periods such as months as well as to assembly lines and cycles in the existing global production network. When conducting such planning tasks, the various constraints driven by the customers as well as the suppliers

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of parts have to be taken into account in addition to the constraints of the internal global network of final assembly facilities.

Considering that today's aircraft specification process is limited by a fixed deadline, i.e. specification freeze, for order specification which is potentially set earlier than necessary while customers require a faster reaction to market trends, the need for a new concept of product configuration arises. To do so, manufacturers need to provide new interaction tools as a service helping customers to identify potential customization possibilities and to set easily their own preferences. Connected to other business tools, data gathered from such tools should help designers and production planning managers to anticipate the integration of these needs in the development process as soon as possible.

The benefits of using product configurators to improve the customization facilities during the ordering process are widely discussed in literature [47]. Increasing variety of products, simplifying the customer ordering process and connecting the product architectures and production strategies are examples of these benefits [24,44]. This conducts to cost saving and reduction of lead time along the whole development process [21,24].

However, answering to such customization requests using product configurators requires high flexibility of the production and supply chain processes. Smart co-definition of product structure and production network should be deployed to anticipate the customer changes and ensure the management of these changes' propagation across the product development process (i.e. aircraft), spanning all product, process and resource dimensions.

In this paper, a modular-based approach for Just-In-Time Specification (JIT Specification) of customer orders linking the product configuration phase with order fulfilment strategies as well as the production planning phases is proposed. The modular-based approach is applied to the Airbus A320 family, the world's best-selling single-aisle aircraft family of one of the global leading aircraft manufacturers.

The paper is structured as follows: in Section "Modular-based approach for the Just-In-Time Specification service", a modular-based approach for Just-In-Time Specification is introduced. The application of this approach to the aircraft manufacturing industry is presented in Section "Application of the modular-based approach for Just-In-Time Specification to the aircraft manufacturing industry". Finally, Section "Business models discussion" discusses the industrial business models exploiting the proposed approach. A conclusion is given in Section "Conclusion".

Modular-based approach for the Just-In-Time Specification service

It is actually agreed that focusing on innovative physical solutions for improving product quality is not enough to cope with the high pressure and competitiveness of the nowadays globalized markets. Companies should propose additional offers that increase the added value and attractiveness of their products [40]. Better understanding of customer needs and stronger relationships with customers along the product development process is one way to address this issue. In the aircraft manufacturing industry, the development process is very long and any decision has strong impact on the final results. Moreover, the ordering and production of one aircraft for a customer is challenging because the customer already requests for changes. It is of the interest of the manufacturing company to answer as far as possible to these challenging needs.

To cope with high customization requests and changes of requirements during the development process as well as the order fulfilment process, the aircraft manufacturer could offer new free services to his customer giving the possibility to select and/or modify some pre-defined product features, at different points in time. Customization itself is not a new paradigm; several platforms are often proposed to support mass customization strategies [32]. The positive impact of a product configurator on the customer–provider relationship performance is clearly highlighted by Trentin et al. [43]. By such tools, the customer is continuously involved in the product configuration process, with reference to the whole development process.

However, due to the particularity of the aircraft manufacturing domain, not all characteristics are available for customization. In all cases, customization possibilities should be carefully prepared and managed very early in the design process to avoid any negative impact of the customers' orders on the production planning. In this paper, the concept of JIT Specification is proposed as a customization support for the final assembly of multi-variant series products such as single-aisle aircrafts.

Just-In-Time Specification service

The JIT Specification service can be offered for free to customers such as airlines and aircraft leasing companies, which are considered as target customers of the aircraft manufacturer. By the JIT Specification service, the customers' requests influence the customization of the aircraft and the subsequent allocation of the orders within the production network. This can be managed as a customer-driven co-evolution of the product structure and production strategy.

To manage such co-evolution strategy, an interactive process involving several stakeholders is required as it is shown in Fig. 1.

Three main stages have to be distinguished in this process:

- **Design**: This is the preparation stage, which involves the product designer and production process engineer to define potential solutions as new offers to the customers. The customizable product is composed by a set of standard components common to all products from the same family and additional options to be selected by the customer to be implemented on his own product. In parallel, the production process is designed to define the implementation solution of the designed product. The main strategy of the design process is to anticipate the large variety of customer preferences based on preliminary surveys and previous customers' feedbacks. This contributes to enhance knowledge about real customers' needs. Thus, several alternatives of the main product architecture are created at the back office of the JIT specification configurator using a modular-based approach. Every alternative is an encapsulation of a common element and

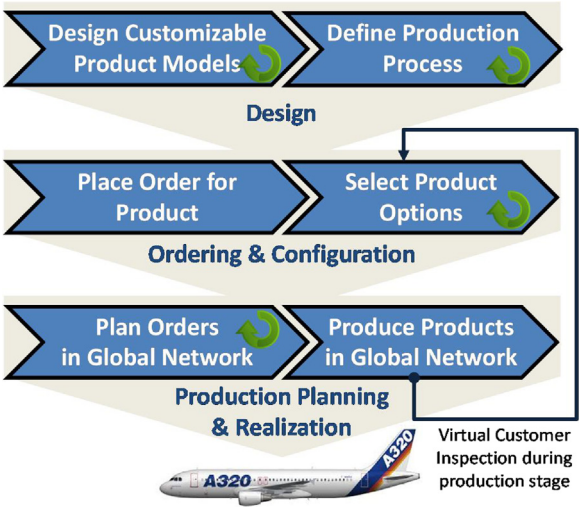

Fig. 1. Global JIT Specification process.

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