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REQUIREMENTS MANAGEMENT AS A PLM TOOL IN SUPPORTING MASS CUSTOMIZATION

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Abstract: *In modern global economy, companies can distinguish themselves from the competition only by closely aligning their products with customer-defined needs. This is the basis of successful New Product Development (NPD) process. In this paper will be represented the interaction of two concepts - Mass Customization and Requirements Management, which enables companies to translate the voice of the customer (VoC) into viable integrated product functional requirements, design features, component selection and reuse, and product design modules that are able to provide a better balance between customer requirements and company capabilities at the early stage of product design.*

Keywords: Requirements Management, Mass Customization, PLM, Siemens Teamcenter

1. INTRODUCTION

Right products are the products that meet the needs of customers, as well as company's revenue, performance, quality and compliance-related objectives [1]. In today's highly dispersed global economy, meeting the needs of customers is not easy. Companies may have to deliver products to global markets defined by ever-changing market demands, customer profiles, regulatory guidelines and consumer preferences. They may have to develop their products in an extended enterprise that spans multiple geographic, organizational and technological borders [2].

Product Lifecycle Management (PLM) is recognized as one of the most effective approaches for better, fast and cheaper product development and management. Mass Customization is one of the key technologies in PLM to provide tailored product to end customers with the cost of mass production [3]. When creating Mass Customization strategies, companies must consider the customer requirement bases, the competition and the available technology.

In reality, requirements are always changing. Customers often shift their preferences, or reach a better understanding of their actual needs, after looking at an initial design [4]. However, companies cannot expect to be successful if they do not align their products with the requirements, needs, preferences and expectations of their customers.

Moving from make-to-stock and make-to-order to Mass Customization and personalization is becoming a common practice. Mass Customization is a hybrid manufacturing concept existing to provide highly value added products. It is about delivering the desired product after the needs of an individual customer have been expressed [5]. Mass Customization pulls the customers up in the design process. Learning more about customer's needs and behaviors would help in developing the intelligence that leads to design of products which properly meet their expectations [6]. This can be provided by PLM systems, which integrate people, data, processes, and business systems and provide a product information backbone for companies and their extended enterprise [7].

The research approach taken in this work has been based around theory development, to represent potential of integration of Requirements Management as PLM tool and Mass Customization

2. MASS CUSTOMIZATION WITH THE SUPPORT OF PLM

Manufacturing companies have been under pressure to meet conflicting goals of efficiency and consumer choice. On one hand customers demand that orders are met faster and at lower cost. On the other hand, they are demanding highly customized products with a wide variety of options [8]. To remain competitive, manufacturing companies are under tremendous pressures to make their manufacturing processes efficient and agile. Through agile manufacturing, it becomes possible to produce customized products tailored to meet customers' needs at mass production costs and speed [9].

This practice is also known as Mass Customization, a business strategy introduced by Joseph Pine in his book *Mass Customization: The New Frontier in Business Competition* (1993). Mass Customization offers individual customers, not just markets, what they really want — choice [10]. Today, Mass Customization accounts for approximately 20 percent of all consumer goods. By 2035 mass-customized products are projected to exceed 50 percent of all goods sold [11].

Customer integration plays a key importance in a mass customization strategy [5]. Integration means getting the customer involved in designing or configuring a product, which is by definition, an essentially central element of Mass Customization. By integrating the customer into the

design or configuration process, a possible adversarial relationship between a customer and provider may be transformed into a synergy [12]. Companies can obtain more stable processes, high variety of production planning and better control [13], but also gain from specialized information systems, order tracking and improved ability to interact with individual customers.

With the development of technologies in user interface, customers are enabled to choose from offered options in a modular manner [14]. Each customer provides unique information so that the product can be tailored to his or her requirements. The production process must be very flexible in order to meet those requirements [15].

Efficient new product development is hard to imagine out of PLM strategy and contemporary software solutions [16]. In collaborative customization the customer is the product designer. The product designers' responsibility shifts from designing a product to designing components which are then configurable by the customer, the ultimate designer [11]. Designing and developing product families has been well recognized as an effective means to achieve the economy of scale in order to accommodate an increasing product variety across diverse market niches [17]. All product variants share some common structures and product technologies, which form the platform of the product family [18]. Product platform is a set of subsystems and interfaces developed to form a common structure from which a stream of derivative products can be efficiently developed and produced [19].

The configurational approach to product family design is also frequently called module-based product family design [20]. Product modularity is emphasised as essential for the implementation of product configuration systems [21]. A successful design requires that an extremely high level of standardization is applied to the components used by the customer in their particular configuration. These components must be designed with a focus on optimizing manufacturability [11]. Mass Customization via product family design (Figure 1.) has been recognized as an effective weapon to provide tailored products to meet market needs but in the same time to support mass production with low manufacturing cost [3].

PLM aims at reintegrating the manufacturing organization by closing all the knowledge loops and positioning the product at the focal point of the whole organization. It is a strategic business solution and knowledge management system for integrating people, information and processes across the extended enterprise through a common body of knowledge [6].

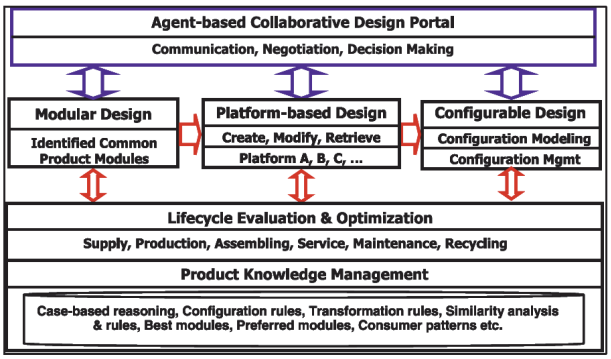

Fig. 1. *A systematic view for Mass Customization [3]*

There is a question that appears at this point - can PLM systems support Mass Customization by managing customers' requirements?

3. REQUIREMENTS MANAGEMENT

The role of Requirements Management has become more essential than ever before in determining the success of product development. Independent studies have repeatedly shown that no development process will result in a successful product offering unless the products companies deliver are rigorously aligned with up-to-date and accurate marketplace requirements and customer expectations [2]. More than 50 percent of all product introductions fail because they do not meet customer requirements [22]. But "requirements completeness" does not really exist and it is more rewarding to consider "requirements sufficiency" with the level of detail in the requirements growing through a development project [23]. Introducing consumer participation into the company's value creation process, increases customers sense of involvement in the end product and brings real first hand consumer knowledge back into consumer product manufacturing [24]. Understanding the voice of the customer and applying a holistic approach to understanding and implementing complex systems and products is a crucial part of any product development initiative [22].

Requirements describe the product that the customer will buy. They communicate the customer's specifications to the various disciplines involved in the product's development. Requirements provide answers to the following questions:

- What problem should be solved?
- What is needed to solve the problem?
- Why is the solution needed?
- How is the solution going to be accomplished?

To ensure that the finished product meets those specifications, developers follow the requirements throughout the development process. Gathering, refining, implementing, testing and using requirements to manage a NPD project is a collaborative process involving many people [25]. When the product conforms to all requirements, it is ready for delivery, and more importantly, it has the functions and the quality that the customer demands [26].

Product requirements do not specify how the features or the capabilities will be designed. They can be classified into two groups – functional and non-functional requirements. Functional requirements address what the system does and define any requirement that outlines a specific way a product function or component must perform. Non-functional requirements address items such as the technical solutions, topics that address the number of people who need to use the product, where the product will be located, the types of transactions processed, and types of technology interactions [27].

Requirements Management process comprehends activities that encourage the customers' collaboration throughout the entire product development process. These activities are: to gather the market and customers' needs, to select and understand the needs, to convert the needs into product requirements followed by their ranking and

finally, to follow the requirements up through the product development process [28]. Requirements Management consists of five principal components: definition, process, structure, traceability and automation (Figure 2).

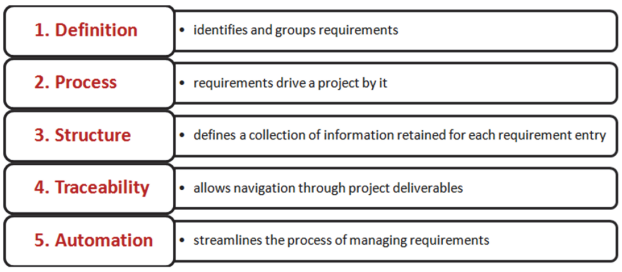

Fig. 2. *Components of Requirements Management [25]*

Companies are increasingly using PLM systems to obtain customers' requirements and produce customized products in a timely manner at reasonable costs. These systems provide systematic and repeatable solutions companies can leverage to ensure that they deliver the rights products to market. The implementation of Requirements Management process and its proper utilization allows the formalization and better traceability of customers' requirements. As a result, companies' opportunities to develop products that fulfill market requirements increases substantially.

4. SIEMENS PLM SOFTWARE'S TEAMCENTER – A TOOL TO CONNECT MASS CUSTOMIZATION AND REQUIREMENT MANAGEMENT

PLM allows the enterprise to create, capture and share the product-related requirements, expectations and preferences of targeted customers and markets and align these requirements with specific innovative content that customers want for a price they can afford at the time when it is needed.

Siemens PLM Software's Teamcenter® suite provides a proven collaborative requirements management solution (Requirements Manager) that enables companies to align their product decisions with the demands of their customers and to build the voice of the customer directly into their product lifecycle - thereby facilitating requirements-driven design, Design for Six Sigma, systems engineering, built-in disposal/recyclability and other highly valued business initiatives [29]. Requirements Manager provides a mechanism to facilitate the capture and analysis of customer needs and then associate those needs with formal requirements (e.g. performance, maintainability, reliability, manufacturability, usability, and ergonomics characteristics) that the product and/or product related processes must deliver. These requirements may be associated with the product across potentially all stages of the product lifecycle [30].

Through Teamcenter integration, the customer can actively influence the design from requirements development and association to product testing and acceptance [26]. As a result, Teamcenter enables global product development teams to fully understand how product requirements evolve across the product lifecycle and the impact that these changes will have on product design, as well as the impact that design changes will have on the product's requirements [2].

Requirements Manager solves problems in the most crucial phase of development, the decision-making stage, when plans and expectations are consolidated as requirements. Requirements must be identified and developed at the project's inception, so that problems are revealed and understood before the actual product development begins [26]. An automated tool can track the progress of each requirement through each state of its life cycle [25].

Requirements Manager provides for:

- development of requirements in the initial stage of product development;
- early association of requirements with the product design and individual components;
- ongoing maintenance of requirements, each as a separate item with specific properties.

PLM combines the advantages of configuration management with option and variant management. It facilitates Mass Customization by enabling to rapidly and costs effectively deliver customized product offerings that satisfy the needs of individual customers and targeted market segments. As it was said earlier, Mass Customization is based upon the configurational approach to product family design. Customers, as ultimate designers, create their personalized products by configuring standardized components. In this way, companies capture VoC, transform it into product requirements, according which structured requirement specification can be created. Customers' requirements, captured as VoC, are shown on the example of the requirements for body weight scale on the Table 1.

Table 1. *Customers' requirements for the product*

Quality category	**Customers' requirements**
Performance	- precise body weight measuring - fast body weight measuring - satisfying measuring scope
Additional Requirements	- simple moving, lifting and laying down - small weight of the device - simple body weight measuring (automatic) - simple device setting - simple display of results - simple reading of results - low price - platform that is not cold - platform that is not slippy
Reliability	- no need for maintenance during the product lifecycle
Compliance	- no contamination for the environment after disposal - safe (no sharp edges)
Durability	- enables several daily measurements through several years - insensitivity to shock - corrosion resistant
Service	- no need for service during the product lifecycle
Esthetics	- square shape - available in several colors
Expected Quality	- manufacturer reputation - law price

An example of the requirement specification structure for this product, created in Requirements Management, is shown on the Figure 3. Multiple levels in a requirement specification structure allow flexibility in the organization of requirements. These requirements can be reused in future, which provides the transition from developing requirements specifications to deriving requirements specifications.

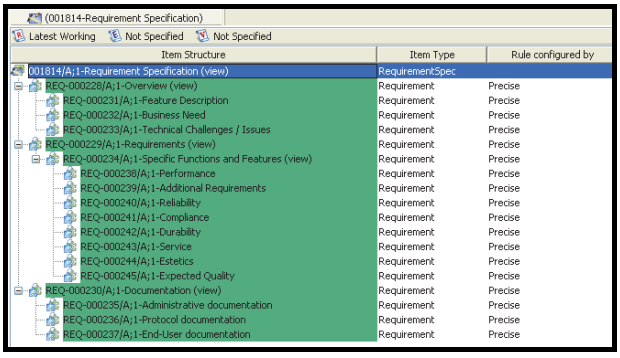

Fig. 3. *The requirement specification structure for the body weight scale*

Solution must be able to provide two-way change traceability that can be automated to send changing requirements to engineering and manufacturing teams and changing engineering/manufacturing impacts to product managers [1]. Each proposed change on requirements has to be analyzed and traced across multiple and diverse disciplines. These disciplines are able to trace and reconcile the impact of any changes in their own specialty through the help of a requirements framework, because changes in parts or systems can be directly traced and visualized back to requirements. The ability to trace and visualize the impact represents a major benefit of fully integrating requirements management with PLM.

A trace link creates a directional relationship between two objects, a relationship conveyed by the terms defining and complying. A defining object specifies a condition that a product or a component must fulfill. A complying object must partially or completely fulfill a condition specified by a defining object. Such a relationship establishes a traceable path in which one object precedes the other [26]. With respect to requirements compliance, traceability enables companies to relate requirements to specific product configurations and trace this design impact through the product lifecycle to prove actual compliance [1]. Visualization of the body weight scale is shown on the Figure 4.

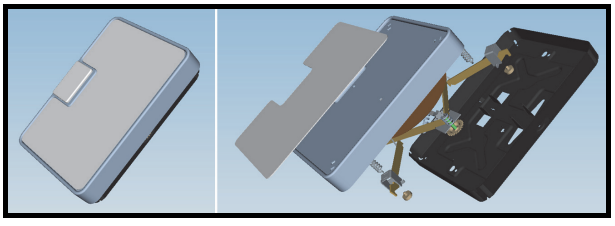

Fig. 4. *Visualization of the product*

This PLM solution should enable companies to [22]:

- deliver products that meet customer needs;
- hit revenue and performance targets;
- capitalize on market opportunities;
- achieve customer satisfaction;
- improve productivity and quality;
- ensure regulatory and contractual compliance;
- leverage existing software investments and expertise;
- minimize risk.

5. CONCLUSION

The modern consumer is more demanding than ever before, so large number of companies use Mass Customization to successfully create greater value for their customers and competitive advantage for themselves. By involving customers and suppliers at early stages of NPD and manufacturing processes, companies can enhance their ability to customize their offerings, according to requirements. This means that customers are partners of the company and co-designers of the final product solution.

But the consequences of implementing Mass Customization strategy without preparing properly the planning and operating system of the company, may be disappointing bringing disadvantages such as increasing material cost, higher manufacturing cost, lower on-time deliveries and poor supplier delivery performance.

PLM solutions have the ability to support Mass Customization by managing product requirements. Requirements Management enables companies to translate the VoC into integrated product requirements, which are essential for customizing products that fit customers' needs, wishes and demands. Apart from that, PLM systems enable global cross-functional teams to collaborate in real time on the development process, each contributing their unique experience and perspective. In that way, the products' time-to-market gets shorter, giving another advantage to Mass Customization processes of companies on the competitive global market.

The companies which are using kind of software like Siemens PLM Teamcenter notice personal and team productivity, shorter time-to-market, increased product quality and minimized product and lifecycle costs.

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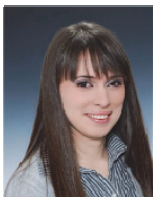

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