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Mass customization and Modularity: a theoretical position in the past decade

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Abstract

This paper aims to illustrate the theoretical position on the mass customization strategy and modularity during the decade of 2000s. Literature points modularity as one of the best ways to achieve mass customization. In order to delineate this decade scenario, we have conducted a search of these themes on the Web of Science database. The objective is to illustrate the theoretical position on the mass customization strategy and modularity during the decade of 2000s. Only journal papers, refined by subject areas related to engineering and management, and published between 2000 and 2009 were considered. A total of 70 papers were collected for a bibliometric review with the tool HistCite. Results of this search were analyzed using a series of bibliometric criteria, presenting the twenty most cited papers among the 70 selected publications, a relation graph among papers and authors, papers and citation count distributions across the years, authors and countries with the higher quantity of topic related publications, and finally, an analysis of journals in which these papers were published. Furthermore, a subject classification based on the 70 studied papers is presented, thus identifying predominant topics such as supply chain studies, modularity methods and literature review. In conclusion, this investigation indicated the rising of new fields of study, such as modularity and mass customization in services, and summarizes the opinion unveiled by the researched papers' authors about future investigation opportunities.

Keywords: mass customization; modularity; bibliometry.

1 Introduction

Mass customization can be defined as the challenge of meeting the individual needs of customers while maintaining the efficiency of manufacturing similar to mass production (Jiao and Tseng, 2004). According to the literature, the development of Mass Customization has as basic assumption the use of flexible manufacturing system (FMS) and practices applied during the Product Development Process (PDP). Tseng and Jiao (1996) present an approach called Design for Mass Customization (DFMC), based on the premise that mass customization can be effectively achieved during product design, more precisely in the concept development stage. Thus, the DFMC aims at considering issues of scope and scale economy still in the early stages of product development, evolving from a unique product development process to the development of a family of products.

By the means of the strategy of multiple products based on families that share platforms, it is possible to reduce time and costs of product development, increase reliability and variety of products, reduce management complexity and make business strategies more flexible (Muffato, Roveda, 2000). Two methods allow to dealing with the variety in products based on platforms: projects with modular basis and projects based on scale (Alizon *et al.*, 2009). According to Muffato and Roveda (2000), platforms tend to be more flexible with modular architecture.

Module, according to Miller and Elgard (1998), is an essential and self-contained functional unit in relation to the product to which it belongs, having standardized interfaces and interactions which allow (through combinations) the composition of products; modularity is an attribute of an system related to its structure and functionality (a system which has modularity has self-contained functional units with standardized interfaces); and modularization is the activity in which the modular structure occurs. The term "self-

contained", used by the authors, refers to a function performed within the module and limited to it. Da Silveira *et al*. (2001) argue that products from mass customization should be modular, versatile and constantly renewed. In order to apply or develop research related to modularity and mass customization, it is necessary to understand how both themes relate to each other and which advances were already achieved by researchers throughout recent years.

Pine (1993) argues that modularity is a key to achieving mass customization. According to Duray (2002), modularity is a key aspect to reach volume of scale (the mass), while the engagement of the customer results on customization. The goal of modularity is mainly to earn flexibility for mass customization through the design of products relying on customer specifications and using modular components (Duray, 2002). According to Kuderer (2006), modularity also helps to overcome the complexity that customization brings to the manufacturing systems, acting as a tool to break down the product structure into smaller units, which are easier to administrate. The research question in this paper is what researchers have investigated and advanced in the last ten years?

Thus, the objective of this paper is to perform a survey of the publications concerning modularity and mass customization during the 2000s viewing to identify influential papers and authors, journals and countries that have mostly contributed to the growth of knowledge in this field, as well the current trends. The investigation was performed in the Web of Science database.

2 Research Method

Bibliometrics is a set of laws and empirical principles that help determining the theoretical foundations of Information Science (Guedes, Borschiver, 2005). Citation analysis allows exploring the contexts in which innovations occur and thus develop a more reliable sense of how the work and ideas of a researcher are received by the community and other researchers (Cronim 2000). In addition to the citations, by the means of bibliometrics it is possible to analyze the scientific performance of organizations, agencies and countries based on the counting of publications and citations in the literature (Narim, Hamilton, 1996). For the execution of bibliometrics, the steps below were followed:

- Choice of the Database and Keywords: To search for articles that make up the bibliometric analysis, a search in the Web of Science database was carried out, which despite having a limited number of academic publications, presents a set of high-quality publications (Cronim, 2000). The terms "mass customization" and the root modul were used as keywords, ensuring the search for the words "module", "modularity", "modularization" and "modular", forming the following search algorithm: "mass customization" AND modul*. The search chosen was the one for "topic", which includes the title, the abstract and the keywords of the paper (results: 284 papers).
- Refinement of the search: The result obtained with the search algorithm went through filters to compose the final stratum for bibliometric analysis. Only journal articles were considered, excluding articles from congresses and symposia as well as books, dissertations and theses (results: 144 papers). Afterwards, a second filter was used, now by areas of knowledge where the following areas were considered: Engineering Manufacturing, Operation Research Management Science, Engineering Industrial, Management, Business, Engineering Multidisciplinar and Planning Development (results: 122 papers). Next, all journals that contained only one single publication on the subject were excluded (results: 101 papers). The last filter applied to the search relates to time, where the years 2000 to 2009 were selected. After all these refinements, the final stratum of the search included 70 articles that were saved in plain text format and worked with the help of HistCite software.
- Statistics of articles and journals: The HistCite software was developed by Eugene Garfield, the inventor of Science Citation Index, in order to help researchers to visualize the results of bibliographic searches on the Web of Science database, allowing the analysis and organization of search results (Thomson Reuters, 2011). Using the HistCite it is possible to analyze the most cited

authors for a given subject, most prolific countries and institutions, most cited papers, publication distribution across time, among others.

3 Results

The first analysis of the articles resulting from the search was the analysis of citations. This analysis shows the most cited articles among the 70 papers reviewed. In this bibliometrics, only two articles were cited more than 10 times and only 13 articles were cited more than once. Analyzing the 70 articles from Web of Science, 43 articles are not mentioned even once by the other articles studied in this bibliometric analysis.

Figure 1 shows the 20 most cited articles, distributed across a network of relationships based on citations. Through the relationships it is possible to see a group of papers mentioning both Duray *et al.* (2000) and Salvador *et al.* (2002), the two most cited articles in this bibliometrics, forming a principal network. It is also possible to notice a second group of papers on the right side of the graph, which are papers that do not cite and are not cited by the group of papers that make up the twenty most cited ones. The graphic was redesigned to offer a better understanding of the relationships, and was based on the original graphic created in the HistCite® software (Thomson Reuters, 2011). The size of the spheres shows the number of citations and the distribution in the lines shows the date of publication of the paper.

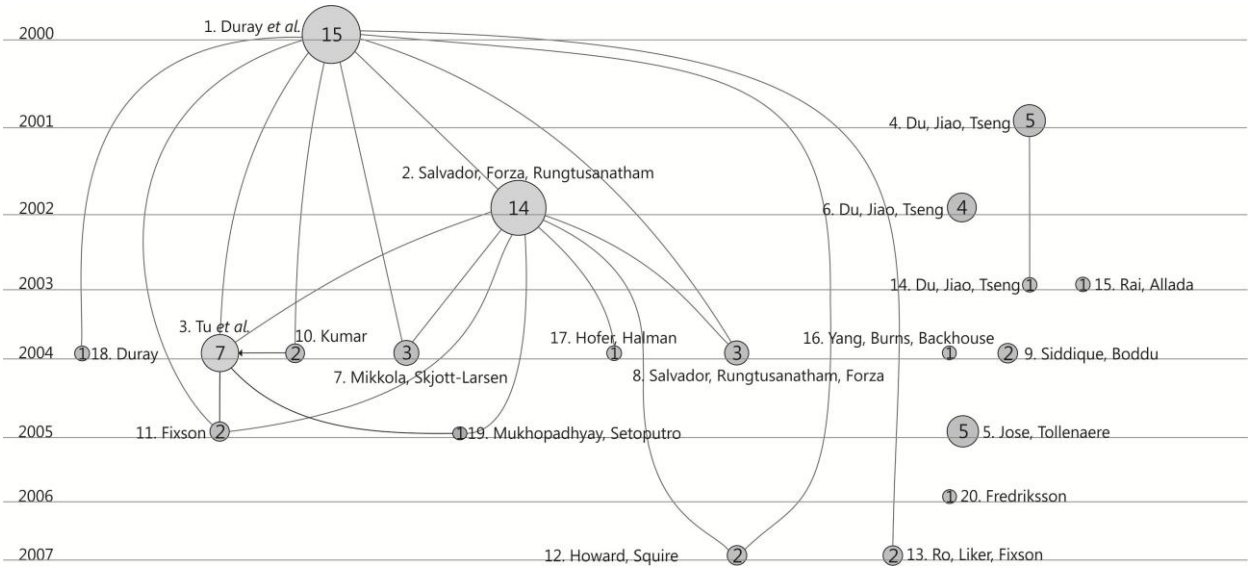

Figure 1: Network of relationships

Duray, Ward, Milligan and Berry, in his 2000 paper, present Mass Customization (MC) as a paradox breach, because MC combines craft production with mass production methods. The authors allege in their paper that despite the phenomenon of mass customization exist in practice, the academy does not adequately invest in this new way of competition. The authors develop a configurational model to classify the customization based on the customer involvement in the project and on the product modularity.

The 2002 paper of Salvador, Forza and Rungtusanatham explores how manufacturing characteristics affect the type of modularity to be incorporated into the architecture of a product family as well as the modularity relationship with the outsourcing of components. The paper is based on studies of multiple cases of product families belonging to six European companies. Among its theoretical results is the description of a new type of modularity, not described in the literature yet, the combinatorial modularity.

Tu, Vonderembse, Ragu-Nathan, Ragu-Nathan (2004) present the concept of MBMP (Modularity-Based Manufacturing Practices) and develop an instrument to measure MBMP, as well as build a framework that relates customer closeness, MBMP and the ability of mass customizing. Based on 303 responses obtained with members of the Society of Manufacturing Engineers, statistical significance and positive relationships among the three constructs studied were found.

The second analysis concerns the distribution of papers by year of publication, in which is possible to see that in the years 2004 and 2007 there was a significantly above the average production in relation to other years. In 2004, the AI Edam-Artificial Intelligence For Engineering Design Analysis And Manufacturing and Production Planning & Control journals represent half of the publications of the period, with four publications each. In 2007, two journals also have nearly half the total publication of the year: IEEE Transactions On Engineering Management, with five publications, and Concurrent Engineering-Research And Applications, with three publications.

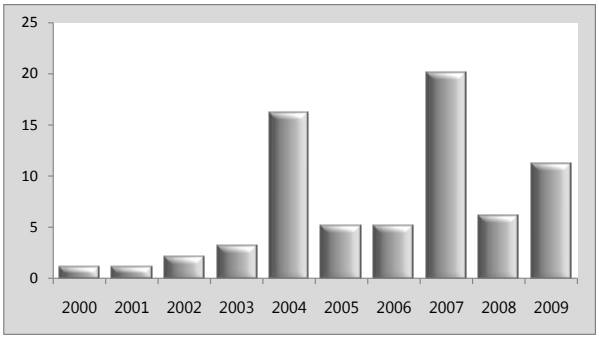

Figure 2: distribution of papers by year of publication

The papers analyzed in this bibliometrics were published in 18 different journals. The journal that has the largest number of publications on the subject is the International Journal of Production Research, with nine publications, followed by the Concurrent Engineering – Research and Applications, with eight publications. The third journal with the highest number of publications is the Ai Edam-Artificial Intelligence for Engineering Design Analysis and Manufacturing, with five publications. As mentioned in the methodology, journals with only one publication on the subject were discarded.

Although it contains the largest number of publications, the International Journal of Production Research does not contain publications of high-impact factor, if taken into account the number of citations of its publications. The Concurrent Engineering – Research and Applications presents only two papers cited by the collection, however, these two papers present a higher citation index, appearing among the twenty most cited articles of the collection. The two most cited articles from the collection were published in the same journal, the Journal of Operations Management, this one appearing as the journal of greatest relevance in the subject and also presenting two other relevant publications.

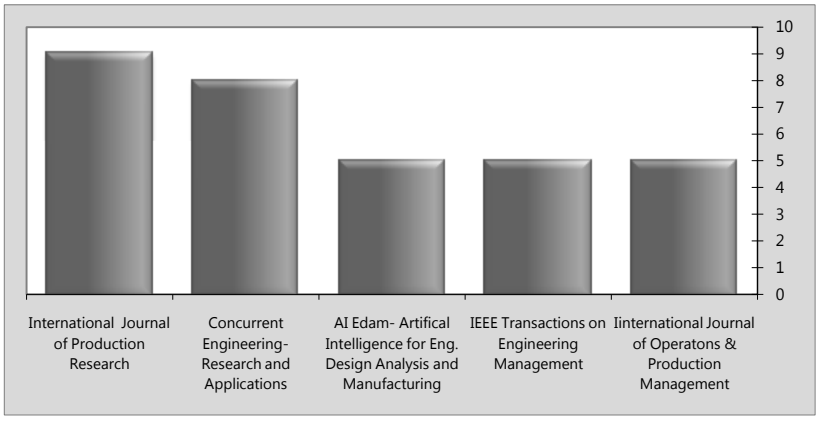

Figure 3: Distribution of papers by Journals

The distribution of papers by country of origin in the research shows that the United States and China hold more than half of the publications concerning MC and Modularity present in the Web of Science database. The distribution made by the HistCite® software (2011) shows 17 different countries as countries of origin of articles and five articles without defining the country of origin.

Among the 158 authors, only 19 had more than one publication. The authors Huang GQ, from the University of Hong Kong, and Jiao JX are the ones presenting more papers in the collection, each with four publications. With three papers each, there are the authors Agard B., Du, X.H., Salvador F. and Tseng, M.M.

4 Analysis by article category

Through the analysis of the 70 papers it was noticed the presence of common approaches and subjects. Papers were then, identified according to such common criteria, resulting on the classification presented by figure 4. It should be noted that many papers may be easily classified in more than one subject, as they may approach relation between subjects, such as the relation among modularity and supply chain (Huang, Zhang, Lo, 2007).

	Customer	Architecture	Modularity	Application-cases	Supply Chain	Production	Other
2009			• Kong *et al.*	• Brun, Zorzini	• ElMaraghy, Mahmoudi • Squire *et al.* • Qu *et al.*	• Agard, Penz • Agard, Da Cunha, Cheung • Song, Kusiak	• Gu, Xue, Nee • Voss , Hsuan • Moon *et al.*
2008		• Li, Huang, Newman • Olivarez-Benitez, Gonzalez-Velarde	• Zhuo, San, Seng	•Rugtusanatham, Salvador		• Kuroda, Mihira	• Li, Xue, Gu
2007	• Siddique, Ninan	• Galan, Racero, Eguia, Garcia • Williams *et al.* • Van Wie *et al.*	• Meng, Jiang, Huang • Meehan, Duffy, Whitfield • Holtta-Otto, de Weck • Jacobs, Vickery, Droge • Mikkola • Gupta, Roth	• Kumar • Ro, Liker, Fixson • Yang, Qi, Lu, Gu	• Huang, Zhang, Lo • Howard, Squire	• Wang, Lin • Thomas, Warsing • Tu, Xie, Fung • Blecker, Abdelkafi	• Ming *et al.*
2006	• Shao *et al.*		• Zhang, Thor, Britton	• Fredriksson		• Da Cunha, Agard, Kusiak • Dekkers	
2005	• Tang, Chen, Ji	• Yeh, Wu • Fixson • Jose, Tollenaere	• Mukhopadhyay, Setoputro				
2004	• Siddique, Boddu	• Jiao, Zhang, Prasanna • Zha, Sriram, Lu • Hofer, Halman	• Tu *et al.* • Germani, Mandorli	• Zangiacomi *et al.* • Partanen, Haapasalo • Lin • Duray	• Coronado *et al.* • Salvador, Rungtusanatham, Forza • Mikkola, Skjott Larssen	• Yang, Burns, Backhouse	• Fung, Chong, Wang • Kumar
2003		• Du, Jiao, Tseng	• Rai, Allada	• Akkermans *et al.*			
2002		• Du, Jiao, Tseng	• Salvador, Forza, Rungtusanatham				
2001		• Du, Jiao, Tseng					
2000	• Duray *et al.*						

Figure 4: Categories and subjects

The first category consists of the papers focused on costumer integration and participation in the process of mass customization. Siddique e Boddu (2004) present in his paper the integration of the customer in the process via the Internet, in a program that automatically generates a three-dimensional image of the product according to the configuration chosen, a price estimate and the sequence information for the line

assembly. The paper of Duray *et al*. (2000) offers a model for classifying mass customization based on consumer involvement. Shao *et al.* (2006) present an approach that generates customer groups according to their product specifications (clustering), and the association of these characteristics with the configuration alternatives.

The second category identified concerns papers related to architecture, platform and product families. Among the issues found, the presentation of the APF concept (Architecture of Product Family) by Du *et al*. (2001), as a conceptual structure to an organizational logic for the generation of product families, methods to assist the choice of platform (Williams *et al*., 2007), methods for conducting the best possible formation of families aimed at producing (Galan *et al*., 2007); bibliographic review about the platform concept, presenting methods for modularization and formation of platforms (Jose, Tollenaere, 2005), frameworks for architecture evaluation based on commonality, platform and modularity (Fixson, 2005) among others.

The third category identified presents the papers focused on different aspects of Modularity. In addition to the discussion of the benefits achieved by the strategy and its competitive effects (Jacobs *et al*., 2007), there are also papers dealing with the types and levels of modularity (Holtta-Otto, De Weck, 2007) as well as presenting methods to drive the modularization at the early stages of product development (Zhang, Tor, Britton, 2006; Meng, Jiang, Huang, 2007; Zhuo, San, Seng, 2008).

The fourth category identified is about the papers that present studies concerning the application of principles of mass customization and modularity in different productive sectors, such as the electronics industry (Partanen, Haapasalo, 2004), the footwear industry (Zangiacomini *et al.,* 2004), the steam turbines industry (Yang *et al.*, 2007), as well as from different countries, such as European multinational corporations (Akkermans *et al.*, 2003) and Taiwanese production networks (Lin, 2004), in addition to studies in specific companies, such as Volvo Cars (Fredriksson, 2006). Furthermore, the papers that presented studies on the transition from mass production to mass customization (Rungtusanatham, Salvador, 2008) and mass customization to mass personalization (Kumar, 2007) were also included.

The fifth category identified in this bibliometrics was the papers related to the supply chain. Among the papers included in this category, there are four of the papers presented as the 20 most cited. The article by Mikkola and Skjott-Larsen (2004) presents mass customization, postponement and modularization as three interrelated strategies complementary to the management of the supply chain. Other issues addressed in this category are the configuration of the supply chain according to the level of customization offered (Salvador *et al.*, 2004), the role of product architecture in the supply chain design (Howard, Squire, 2007), as well as the relationship between the suppliers' capabilities, the supply chain collaboration and the responsiveness of the buyer (Squire *et al*., 2009), among others.

The sixth category presents studies that focus on aspects related to production, its planning and control. Among the selected papers are studies related to: postponement strategy (Yang *et al*., 2004), cost control system (Tu *et al*., 2007), data mining (Shao *et al*., 2006; Da Cunha *et al*., 2006; Song, Kusiak, 2009); module stocks for final assembly (Agard *et al*., 2009); defect tracking through the house of quality (Wang, Lin, 2007), among others.

Among the articles studied some stood out due to the presentation of more specific subjects or new views on the subject. Among these, Adaptable design was studied by Gu *et al*. (2009) and Li *et al*. (2008), the adaptation of modularity concepts and mass customization for services is presented by Voss and Hsuan (2009) and Moon *et al*. (2009), as well as MC is presented as one of the key technologies for the approach called Product Lifecycle Management (PLM). In the paper by Fung *et al*. (2004), there is an examination of the relationships between the product style and the consumer trends and preferences, bringing the idea of intangible modules to upgrade common products.

5 Research Trends

Many authors, at the end of their papers, indicate potential for improvement in this field of study by the means of the presentation of gaps in their researches, the possibility of adding new parameters and characteristics to their studies, through the test of methods and proposals in other areas, and even guidelines for the improvement and continuity of their works. However, more general issues also arise as opportunities for future work, which also point to ways for the maturation of the subject. One such issue is presented by Tu *et al*., in 2004, raising the need to study the nature of the relationship between the modularity and innovation. Duray (2000) cites the importance of future researches to include services as part of the model of mass customization, as well as the exploration of the implications that the products coming from MC have in the market, its benefits and the satisfaction generated on the client and the costs associated with these practices. Voss and Hsuan (2009) also cite the need for development and improvement of studies in the area of customization and modularity in services, as well as development of approaches and tools to help projects related to this.

Questions related to the life cycle are cited by Jose and Tollenaere (2005), as well as the need to develop methods that assist the generation of platforms that bring practical results and relate to aspects such as costs. Benefits and costs associated with product customization strategies implemented by companies could be analyzed from a comparative perspective, with case studies being analyzed (Brun, Zorzini, 2009). Fixson (2005) cites as an opportunity for future researches the study of the linkages between the product architecture and its connections with process and supply, as well as with costs, quality and time.

Kumar (2004) cites directions for research in supply chain and MC, for example, researches related to operations strategy (price, quality, flexibility, delivery and service), functional strategies (product design, product development, stock, lead time, purchasing, transportation, distribution and retail strategies), issues of adjustment between mass customization and capabilities of supply and software development chain that help the client with the co-design of products (product configurators).

6 Conclusion

This article presented a bibliometric analysis on the subject of Mass customization and Modularity. The bibliographic review by the bibliometric method allowed to draw a picture of what has been handled in relation to these matters in the 2000s, identifying the most influential works, the authors engaged in the subject, countries and journals with the highest number of publications and researches in the area, as well as the most discussed topics.

Through citation analysis it was possible to see the great impact of the papers by Duray *et al*. (2000) and Salvador *et al*., from 2002, which are the papers of major impact in the collection of articles used in this bibliometrics due to the high number of citations. According to the distribution of publications over time it is possible to see a growing trend in the number of publications during the decade, with special attention to the years 2004 and 2007, which show an increase in the number of publications compared to other years. The analysis by category of articles presented seven different topics related to MC and Modularity and its distribution over time, demonstrating the appearance of new areas to explore, for example, the application of MC and Modularity in services. The research trends presented by some authors lead to a direction of what may be the scope of papers found in the next decade, as well as gaps not sufficiently explored yet by the academy.

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References

Agard B, da Cunha C, Cheung B. (2009) Composition of module stock for final assembly using an enhanced genetic algorithm. *International Journal of Production Research*, 47, 5829-5842.

Agard B, Penz B. (2009) A simulated annealing method based on a clustering approach to determine bills of materials for a large product family. *International Journal of Production Economics*, 117, 389-401.

Akkermans HA, Bogerd P, Yucesan E, van Wassenhove LN (2003). The impact of ERP on supply chain management: Exploratory findings from a European Delphi study RID B-4374-2010. *European Journal of Operational Research*, 146, 284-301.

Alizon, F. ; Shooter, S. B. ; Simpson, T.W. Henry Ford and the Model T: lessons for product platforming and mass customization. *Design Studies*, 30, 588-605.

Blecker T, Abdelkafi N. (2007). The development of a component commonality metric for mass customization. *IEEE Transactions on Engineering Management*, 54, 70-85.

Brun A, Zorzini M. (2009). Evaluation of product customization strategies through modularization and postponement. *International Journal of Production Economics*, 120, 205-220.

Coronado AE, Lyons AC, Kehoe DF, Coleman J. (2004) Enabling mass customization: extending build-to-order concepts to supply chains. *Production Planning & Control*, 15, 398-411.

Cronim, B. (2000) Bibliometrics and beyond: some thoughts on web-based citation analysis. *Journal of Information Science,* 27,1-7.

Da Cunha C, Agard B, Kusiak A. (2006). Data mining for improvement of product quality. *International Journal of Production Research*, 44, 4027-4041.

Da Silveira, G.; Borenstein, D.; Fogliatto, F.S. (2001). Mass customization: literature review and research directions. International *Journal of Production Economics*, 72, 1-13.

Dekkers R. (2006). Engineering management and the Order Entry Point. *International Journal of Production Research,* 44, 4011-4025.

Devos, P. (2011). Research and bibliometrics: A long history… *Clinics and Research in Hepatology and Gastroenterology*, 35, 336-337.

Du XH, Jiao JX, Tseng MM. (2001) Architecture of product family: Fundamentals and methodology RID A-9212-2010. *Concurrent Engineering-Research and Applications*, 9, 309-325.

Du XH, Jiao JX, Tseng MM. (2002). Graph grammar based product family modeling RID A-9212-2010. *Concurrent Engineering-Research and Applications,* 10, 113-128.

Du XH, Jiao JX, Tseng MM (2003). Modelling platform-based product configuration using programmed attributed graph grammars RID A-9212-2010. *Journal of Engineering Design*, 14, 145-167.

Duray R, Ward PT, Milligan GW, Berry WL. (2000). Approaches to mass customization: configurations and empirical validation. *Journal of Operations Management*, 18, 605-625.

Duray, R. (2002). Mass customization origins: mass or custom manufacturing? *International Journal of Operations & Production Management*, 22, 314-328.

Duray R. (2004). Mass customizers' use of inventory, planning techniques and channel management. *Production Planning & Control*, 15, 412-421.

ElMaraghy HA, Mahmoudi N. (2009). Concurrent design of product modules structure and global supply chain configurations. *International Journal of Computer Integrated Manufacturing*, 22, 483-493.

Fixson SK. (2005). Product architecture assessment: a tool to link product, process, and supply chain design decisions. *Journal of Operations Management,* 23, 345-369.

Fredriksson P. (2006). Mechanisms and rationales for the coordination of a modular assembly system - The case of Volvo cars. *International Journal of Operations & Production Management*, 26, 350-370.

Fung RYK, Chong SPY, Wang Y. (2004). A framework of product styling platform approach: Styling as intangibile modules. *Concurrent Engineering-Research and Applications*, 12, 89-103.

Galan R, Racero J, Eguia I, Garcia JM. (2007). A systematic approach for product families formation in Reconfigurable Manufacturing Systems. *Robotics and Computer-Integrated Manufacturing*, 23,489-502.

Germani M, Mandorli F. (2004). Self-configuring components approach to product variant development. *AI EDAM-Artificial Intelligence for Engineering Design Analysis and Manufacturing*, 18, 41-54.

Guedes, V.; Borschiver, S. (2005) Bibliometria: uma ferramenta estatística para a gestão da informação e do conhecimento, em sistemas de informação, de comunicação e de avaliação científica e tecnológica. *Proceedings CINFORM - Encontro Nacional de Ciência da Informação VI*, Salvador – Bahia.

Gupta S, Roth AV. (2007). Martin K. Starr: A visionary proponent for system integration, modular production, and catastrophe avoidance. *Production and Operations Management*, 16, 1-12.

Hofer AP, Halman JIM. (2004). Complex products and systems: Potential from using layout platforms. *AI EDAM-Artificial Intelligence for Engineering Design Analysis and Manufacturing,* 18, 55-69.

Holtta-Otto K, de Weck O. (2007). Degree of modularity in engineering systems and products with technical and business constraints. *Concurrent Engineering-Research and Applications*, 15,113-126.

Howard M, Squire B. (2007). Modularization and the impact on supply relationships. *International Journal of Operations & Production Management*, 27, 1192-1212.

Huang GQ, Zhang XY, Lo VHY. (2007). Integrated configuration of platform products and supply chains for mass customization: A game-theoretic approach. *IEEE Transactions on Engineering Management*, 54, 156-171.

Jacobs M, Vickery SK, Droge C. (2007). The effects of product modularity on competitive performance - Do integration strategies mediate the relationship? RID A-8013-2009. *International Journal of Operations & Production Management*, 27,1046-1068.

Jiao, J.; Tseng, M.M. (2004). Customizability analysis in design for mass customization. *Computer-Aided Design*, 36, 745-757.

Jiao JX, Zhang LF, Prasanna K. (2004). Process variety modeling for process configuration in mass customization: An approach based on object-oriented petri nets with changeable structures RID A-9212-2010. *International Journal of Flexible Manufacturing Systems*, 16, 335-361.

Jose A, Tollenaere M. (2005). Modular and platform methods for product family design: literature analysis. *Journal of Intelligent Manufacturing*, 16, 371-390.

Kong FB, Ming XG, Wang L, Wang XH, Wang PP. (2009). On Modular Products Development. *Concurrent Engineering-Research and Applications*, 17, 291-300.

Kuderer, K. (2006). Benefits of Modularity. The 4th student conference on Development of. Modular Products, 74-81; 2006.

Kumar A. (2004). Mass customization: Metrics and modularity. *International Journal of Flexible Manufacturing Systems*, 16, 287-311.

Kumar A. (2007). From mass customization to mass personalization: a strategic transformation. *International Journal of Flexible Manufacturing Systems*, 19, 533-547.

Kuroda M, Mihira H. (2008). Strategic inventory holding to allow the estimation of earlier due dates in make-to-order production. *International Journal of Production Research*, 46, 495-508.

Li L, Huang GQ, Newman ST. (2008). A cooperative coevolutionary algorithm for design of platform-based mass customized products. *Journal of Intelligent Manufacturing*, 19, 507-519.

Li Y, Xue DY, Gu PH. (2008). Design for product adaptability. *Concurrent Engineering-Research and Applications*, 16, 221-232.

Lin BW. (2004). Original equipment manufacturers (OEM) manufacturing strategy for network innovation agility: the case of Taiwanese manufacturing networks. *International Journal of Production Research*, 42, 943-957.

Meehan JS, Duffy AHB, Whitfield RI. (2007). Supporting 'design for re-use' with modular design RID A-4040-2010. *Concurrent Engineering-Research and Applications*, 15, 141-155.

Meng XH, Jiang ZH, Huang GQ. (2007). On the module identification for product family development. *International Journal of Advanced Manufacturing Technology*, 35, 26-40.

Mikkola JH, Skjott-Larsen T. (2004). Supply-chain integration: implications for mass customization, modularization and postponement strategies. *Production Planning & Control*, 15, 352-361.

Mikkola JH. (2007). Management of product architecture modularity for mass customization: Modeling and theoretical considerations. *IEEE Transactions on Engineering Management*, 54,57-69.

Miller, T.D.; Elgard, P. (1998). Defining Modules, Modularity and Modularization : Evolution of the concept in a Historical Perspective. *Proceeding of the 13th IPS Research Seminar*, Dinamarca.

Ming XG, Yan JQ, Lu WF, Ma DZ, Song B. (2007). Mass production of tooling product families via modular feature-based design to manufacturing collaboration. *PLM Journal of Intelligent Manufacturing*, 18, 185-195.

Moon SK, Simpson TW, Shu J, Kumara SRT. (2009). Service representation for capturing and reusing design knowledge in product and service families using object-oriented concepts and an ontology. *Journal of Engineering Design*, 20, 413-431.

Muffato, M.; Roveda, M. (2000). Developing product platforms: analysis of the development process. *Tecnovation,* 20, 617-630.

Mukhopadhyay SK, Setoputro R. (2005). Optimal return policy and modular design for build-to-order products. *Journal of Operations Management*, 23, 496-506.

Naik, G. (2010). China avança em pesquisa e desenvolvimento. The Wall Street Journal. Disponível em <http://online.wsj.com/article/SB129237291875466773.html>. Acesso em 21 nov. 2011.

Narin, F.; Hamilton, K.S. (1996) Bibliometric performance measures. *Scientometrics*, 36, 293-310.

Olivares-Benitez E, Gonzalez-Velarde JL. (2008). A metaheuristic approach for selecting a common platform for modular products based on product performance and manufacturing cost. *Journal of Intelligent Manufacturing*, 19, 599-610.

Partanen J, Haapasalo H. (2004). Fast production for order fulfillment: Implementing mass customization in electronics industry. *International Journal of Production Economics*, 90, 213-222.

Pine, B.J. (1993). Mass customization: the new frontier in business competition. *Harvard Business School Press*, Boston.

Qu T, Huang GQ, Chen X, Chen HP. (2009). Extending analytical target cascading for optimal supply chain network configuration of a product family. *International Journal of Computer Integrated Manufacturing*, 22, 1012-1023.

Rai R, Allada V. (2003). Modular product family design: agent-based Pareto-optimization and quality loss function-based post-optimal analysis. *International Journal of Production Research*, 41, 4075-4098.

Ro YK, Liker JK, Fixson SK. (2007). Modularity as a strategy for supply chain coordination: The case of US auto. *IEEE Transactions on Engineering Management*, 54, 172-189.

Rungtusanatham MJ, Salvador F. (2008). From mass production to mass customization: Hindrance factors, structural inertia, and transition hazard. *Production and Operations Management*, 17, 385-396.

Salvador F, Forza C, Rungtusanatham M. (2002). Modularity, product variety, production volume, and component sourcing: theorizing beyond generic prescriptions. *Journal of Operations Management*, 20, 549-575.

Salvador F, Rungtusanatham M, Forza C. (2004). Supply-chain configurations for mass customization. *Production Planning & Control*, 15, 381-397.

Shao XY, Wang ZH, Li PG, Feng CXJ. (2006). Integrating data mining and rough set for customer group-based discovery of product configuration rules. *International Journal of Production Research*, 44, 2789-2811.

Siddique Z, Boddu KR. (2004). A mass customization information framework for integration of customer in the configuration/design of a customized product. *AI EDAM-Artificial Intelligence for Engineering Design Analysis and Manufacturing*, 18, 71-85.

Siddique Z, Ninan JA. (2007). A grammatical approach for real-time design of engineer-to-order products. *Journal of Engineering Design*, 18, 157-174.

Song Z, Kusiak A. (2009). Optimising product configurations with a data-mining approach. *International Journal of Production Research*, 47, 1733-1751.

Squire B, Cousins PD, Lawson B, Brown S. (2009). The effect of supplier manufacturing capabilities on buyer responsiveness The role of collaboration. *International Journal of Operations & Production Management*, 29, 766-788.

Tang ZJ, Chen RQ, Ji XH. (2005). Operational tactics and tenets of a new manufacturing paradigm 'instant customerisation'. *International Journal of Production Research*, 43, 2873-2894.

Thomas DJ, Warsing DP. (2007). A periodic inventory model for stocking modular components. *Production and Operations Management*, 16, 343-359.

Thomson Reuters. Products and services – Histcite. (2011). Acesso em 29 dez. 2011. Disponível em <http://thomsonreuters.com/products_services/science/science_products/a-z/histcite/>.

Tseng, M.M.; Jiao, J. (1996). Design for mass customization. *Annals of the CIRP*, 45.

Tu Q, Vonderembse MA, Ragu-Nathan TS, Ragu-Nathan B. (2004). Measuring modularity-based manufacturing practices and their impact on mass customization capability: A customer-driven perspective. *Decision Sciences,* 35, 147-168.

Tu YL, Xie SQ, Fung RYK. (2007). Product development cost estimation in mass customization. IEEE *Transactions on Engineering Management*, 54, 29-40.

Van Wie M, Stone RB, Thevenot H, Simpson T. (2007). Examination of platform and differentiating elements in product family design. *Journal of Intelligent Manufacturing,* 18, 77-96.

Voss CA, Hsuan J. (2009). Service Architecture and Modularity*. *Decision Sciences*, 40, 541-569.

Wang H, Lin ZQ. (2007). Defects tracking matrix for mass customization production based on House of Quality. *International Journal of Flexible Manufacturing Systems*, 19, 666-684.

Williams CB, Allen JK, Rosen DW, Mistree F. (2007). Designing platforms for customizable products and processes in markets of non-uniform demand. *Concurrent Engineering-Research and Applications*, 15, 201-216.

Yang B, Burns ND, Backhouse CJ. Postponement: a review and an integrated framework RID E-5520-2010. *International Journal of Operations & Production Management*, 24, 468-487.

Yang QH, Qi GN, Lu YJ, Gu XJ. (2007). Applying mass customization to the production of industrial steam turbines. *International Journal of Computer Integrated Manufacturing*, 20, 178-188.

Yeh JY, Wu TH. (2005). Solutions for product configuration management: An empirical study. AI EDAM-*Artificial Intelligence for Engineering Design Analysis And Manufacturing*, 19, 39-47.

Zangiacomi A, Zhijian L, Sacco M, Boer CR. Process planning and scheduling for mass customised shoe manufacturing. *International Journal of Computer Integrated Manufacturing*, 17, 613-621.

Zha XF, Sriram RD, Lu WF. Evaluation and selection in product design for mass custornization: A knowledge decision support approach. AI EDAM-*Artificial Intelligence for Engineering Design Analysis and Manufacturing*, 18, 87-109.

Zhang WY, Tor SY, Britton GA. (2006). Managing modularity in product family design with functional modeling RID F-8930-2010. *International Journal of Advanced Manufacturing Technology*, 30, 579-588.

Zhuo L, San WY, Seng LK. (2008). Integrated approach to modularize the conceptual product family architecture. *International Journal of Advanced Manufacturing Technology*, 36, 83-96.