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IFAC-PapersOnLine 48-3 (2015) 1428–1433

Supply chain configuration towards customization: a comparison between small and large series production

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Abstract: This paper describes an approach to evaluate how a supply network is ready for customization: starting from historical data collected from the focal firm, a configuration model of supply chain based on discrete-event simulation is created to analyse the network structure of a company and to evaluate how it can perform if the production switch from large to small series production. The simulation approach relies on experimentation through executable models which allows to create what-if scenarios. This type of approach offers several advantages: it offers a realistic observation of the supply chain behaviour and allow an analysis of the supply chain dynamics. It provides an observation of the behaviour of the network over time, to understand the organizational decision-making process, analyse the interdependencies between the actors of the chain and analyse the consistency between the coordination modes and the decisional policies. The model is then applied to a case study in the fashion sector.

Keywords: supply chain, discrete-event simulation, mass customization, supplier performance

1. INTRODUCTION

Mass Customization is becoming more and more important because it "restores the voice of the customer to production, imbuing products with the valuable stamp of individuality"[1]. According to a recent study by Bain&Company[2], the percentage of users that have tried customization options are less than 10%; but from 25% to 30% of those same users are interesting to try it.

Moreover, the nature of the customer demand has shifted from increased product variety and features to more functionalization, higher quality in products and services as many online configurators show. But changing the approach from mass production to mass customization is still challenging: the traditional mechanistic organization, aimed at achieving low-cost mass production, is segmented into very narrow compartments (often called functional silos) each of which perform an isolated task. This is particularly relevant within the fashion industry that should be further studied adopting this kind of approach. If customization is the target, organizations structured around cross-functional teams can create horizontal functions to integrate different competences (Pine & Victor, 1993). Beside internal re-organization also the network structure should change, to be adapted to mass customization.

In this paper, we propose an approach to study how the configuration of the supply chain can change to pass from mass production to mass customization. This is based on the assumption that a company need to pass from the management of large orders to small orders which means from large quantity of the same product to small quantity of larger variance of products. A discrete-event simulation model has been defined to analyse the supply network structure and to evaluate how it will perform working both on small and large series production and how suppliers performance can influence the overall network capability to answer to customer requests. The model has been tested with the historical data collected from a company willing to apply customization and working with suppliers able to provide both large and small orders.

1.1 Customization in the fashion industry

The literature has emphasized the importance of creating products based on real consumer demand (Fiore et al., 2002). Customization is configured as a model based on a greater contact with the real needs of the customer and represents growing markets also in fashion companies. A recent study established that more than 3 million visitors each month access the site www.Nikeid.com to personalize their own shoe (Kim et al., 2009). In fashion industry product differentiation is being one of the key factors to compete in the market and achieve tangible differentiation from competitors (Fiore et al. 2002). Personalization is largely based on the collection of customer's data and the development of proper ICTs such as the product virtualization, 3D scan tools, product configurators or CAD

[1] Forrester Research, 2010: The Customer Experience Index
[2] Bain &Company, 2013: Making it personal: Rules for success in product customization

10.1016/j.ifacol.2015.06.287

to allow real time personalization opportunities and support manufacturing processes (Anderson-Connell et al., 2002; Fogliatto et al., 2012; Jiao et al., 2003, Paourabdollahian et al., 2013). A company may decide to offer just some customizable products, on the contrary could adopt a fully made-to-measure offer able to embrace all aspects of its production. The personalization within the footwear sector remains however still a challenge for the whole industry considering the complexity of the whole production processes connected the to the assembly of many different shoe parts, realized by different materials and manufacturing technologies. The essence of mass customization is therefore located in the company ability to perceive and capture latent market niches and, subsequently, to meet the different needs of these target customers. Along this vein, mass customization resides in a rapid response to market without compromising the customised variety, and achieving at the same time proper economies of scale for an efficient production (Jiao et al., 2003; Dong et al. 2012). In this way, mass customization can combine the advantages of several manufacturing productions becoming a hybrid model between mass production and pure customization, and could be defined as the mass production of individually customized goods that try to find a trade-off between the need of efficiency and flexibility (Pine et al., 1993; Fiore et al., 2002; Jiao et al., 2003).

1.2 Supply chain models for customization

The adoption of a proper supply chain for customization has been partially discussed in literature. There are many approaches in relation to the design the most suitable supply chain. Many authors (e.g. Fisher, 1997; Li and O'Brien, 2001; Childerhouse et al., 2002; Christopher et al., 2006; Wong et al., 2006; Puig et al., 2009) tried to identify the right supply chain design accordingly to the best sourcing and production configuration on the basis of the product type however without deepening the customization issue. They discussed the possibility to optimize the cost/agility trade off for instance by sourcing and producing globally to reduce production costs or to meet consumer's needs on a timely basis. In (Shamsuzzoha et al., 2014) it is discussed how to support the creation of agile networks for CTO (Customization-to-order) based on a web platform where many service are available among which network configuration, supplier selection, etc.

However from a supply chain point of view, customization generates a new challenge, since it requires overcoming the dualistic paradigms based on efficiency, wastes elimination and cost saving (lean approach) and flexibility/market sensitive strategy to respond to real time changes in demand (agile approach) (Bruce et al., 2004; Christopher and Towill, 2000; Stratton and Warburton, 2003; Masson et al., 2007). Lean and Agile approaches can be complementary (instead of dichotomous) and they can be mixed together in a solution called Leagile (Christopher and Towill, 2000; Purvis et al., 2014). This hybrid solution is based on the idea of developing the Lean approach in the upstream phases of supply chain, in order to structure efficiently the available resources, and configure agile processes in downstream phases closest to the consumer in order to be able to respond quickly to frequent fashion changes. The debate in literature however does not consider the customization issue that should better integrated within the supply chain definition.

The supply chain design implies obviously also a proper definition of relationships with suppliers. The danger of not being agile enough to take advantage of market changes or in a very volatile market, like the footwear context, and to structure efficient processes creates the need for collaboration within the entire supply chain, by developing more and more a vision based on a network competition (instead of only a standalone company competition) that focuses on the real consumer needs. Nowadays fashion companies have to find a new trade off and collaboration between global and internal activities to provide personalized products in short times to customers. Where and how to locate production and sourcing activities in a global scenario have become an increasingly important part of firm’s competitive strategy (Taplin, 2006; Christopher et al., 2006; Brun et al., 2008; Şen, 2008; Belso-Martìnez, 2010; Kinkel, 2012; MacCarthy et al., 2013; Macchion et al., 2014) and are critical decisions to achieve competitive advantages accordingly to a personalization strategy.

2. MODELLING SUPPLY NETWORK FOR CUSTOMISED PRODUCTION

2.2 The model for supply chain configuration

The aim of this work is to support companies in comparing the performance of a supply chain along different scenarios, which means to apply different production strategies. In particular a simulation model has been developed to understand and to analyse the structure of production network, and reveals relationships between focal companies and suppliers to determine the impact on the throughput of the production along the network. This type of approach offers several advantages: it offers a realistic observation of the supply chain behaviour and allows an analysis of the supply chain dynamics (Umeda et al., 2006). It provides an observation of the behaviour of the network over time, to understand the organizational decision-making process, analyse the interdependencies between the actors of the chain and analyse the consistency between the coordination modes and the decisional policies (Tako and Robinson, 2012). In particular a model for the fashion sector has been developed according to experience gained with several companies during which it was possible to define a common structure of their supply chain. Most frequently companies receive orders, which are characterized by many different products, and in some cases customers (retailers) ask for product models already in the collection but with a different variant (different colour, for example). As a proxy of the implementation of the customization strategies it is taken the dimension of the customer order, where the customer is the retailer asking for products for its shops. The model is created to compare the performance of supply chains for provision of large orders of the same products towards small orders of many different products.

The main objective is to measure the effect of supplier performance on the overall production performance. Since the daily production rate and processing time depend on the product models to be manufactured, a sensitivity analysis of the efficiency on the throughput rate and resource utilization is provided. The fig.1 shows the overall flow of the model. For each supplier, the Key Performance Indicators (KPI) are taken into consideration using data about order delivery time, quality of delivery, flexibility etc. Using these data and information of the orders, the figure shows that different network configurations are generated taking into consideration different combination of suppliers, and for each network configuration the overall performance is calculate thanks to the simulation.

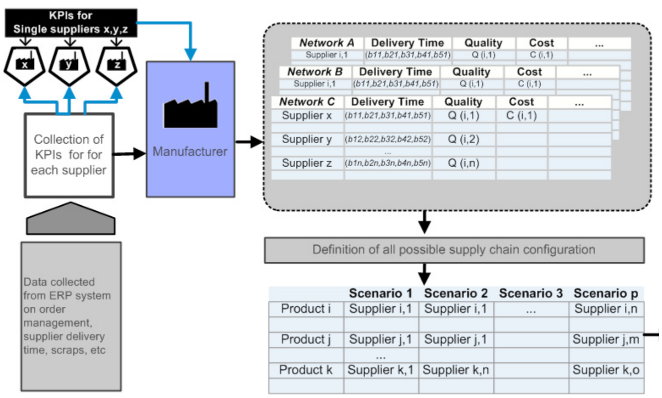

Figure 1: Overall view of the model steps

From the possible network configuration it is possible to define scenarios for the combination of components from different suppliers.

The simulation allows obtaining the performance of the "as-is" configuration of the network, with the current suppliers and according to their performances. After this step, different "to-be" scenarios are defined to analyse how increasing the performance of some suppliers and/or decreasing the strategic importance of the worse suppliers can change the overall performance. The overall performance is evaluated along three main drivers: delivery time, quality and costs.

Comparing the results obtained by these hypothesis with the original performances, it is possible to choose what network structure will be the best one to chase the strategic targets of the focal company.

The consequences of the integration of customized production have been investigated by using the simulation tool SIMIO (®). The main goal of the study was to analyse how the existing production processes and organizational structure can be aligned to a new production strategy, which shift from large to small series production towards mass-customized production into the existing production system.

The scenario for introducing small series production into an existing production system and the model supports the manufacturer. The assumption that the technological level of the companies is taken as a status quo. The scenarios comparison is based only on the change of the network performance. The model was verified and validated by means of empirical data and production costs.

3. THE APPLICATION OF THE MODEL

3.1 The case study and preliminary analysis of data

The analysis of the performance of the focal company and its supply chain is recognized as an important step to understand the characteristics of a production network and to assess its behaviour under alternative strategies. Production and network analysis are significant for manufacturing companies to improve their capability to optimize usage of resources. By analysing suppliers performance, it is possible to understand the way the production nodes can be networked each other, and how they can collaborate to propose new practices to fulfil the gap between current performance and expected targets.

The proposed approach is applied to an Italian SME producing fashion products. The company has a revenue of 40 million euros, with a target customers of medium-high price, all over Europe. The company strategy is based on high quality products, establishment of a long lasting relationship with reliable suppliers, offering good ratio quality-price. The company produces every season roughly 300 new product models with the possibility for customers to further customized. A large order is roughly 500 pieces of the same type while a small order is maximum 50 pieces.

In the model two important supplier categories are considered for a total of more than 60 suppliers. Before applying the simulation model, data collected from the company ERP have been analysed, and it emerged that suppliers can provide different typology of components both in small and large quantity, and they accept orders with many different kind of product models. The available data allowed also to analyse the performance of the suppliers clustering them per order dimension, reliability in terms of time and quality performance: it turned out that suppliers have different performance according to the dimension of the order they deliver: usually they are more performant with small orders, because they deliver them more quickly and more accurately than the big orders. The different performance in product delivery, between small and large orders, is more evident in one category of suppliers than in the other. The average quality of supplied materials is not dependent on size of orders, this is the reason why it was used an unique value for the quality of delivered goods for both small and big orders.

3.2 The application of the model

The supply network configuration model is based on the following assumptions:

- It manages different types of products and related components
- 30% of product models are produced only by the focal company, 30% by the contractor and 40% by both.
- There is one centralized warehouse, where all suppliers send materials and components, both for the focal

company and the contractor. In the warehouse, there is no stock of finished products.

- The warehouse and the distribution centre are located at the shoe producer's site.
- The working time of the contractor includes an extra time to consider both the delivery time of materials to contractor and the shipping time of the final products to the distribution centre.

The production process simulation is based on two inventory strategies: Just-In-Time (JIT) and Re-Order Point (ROP) approach. The comparison of these 2 strategies allows to understand how strong is the correlation between the amount of inventory, the capability to answer to customer needs and the increase in the delivery time due to reduced amount of stocks in JIT.

The simulation is activated by customer orders received by the company's sales office. When the customer orders enter the production, there is a check on materials/components available in the warehouse and, if they are not available, the order is queued until they arrive at the factory. The orders are dispatched to the producer or to the contractor according to the queue already at the two factories.

The product orders which can be produced by both the companies (shoe producer and contractor) are sent to the one with the shortest queue. When the order arrives to the sales office, the production order is sent to the suppliers, while shoe producer starts the production with the existing inventory capacity. It is assumed that suppliers send the ordered quantity once every five days or if the cumulated orders' quantity reaches a determined value.

When components and materials arrive at the centralized warehouse there is a quality check and, in case of scraps, the system sends back to the suppliers a new order to cover the discarded amount. In case of Re-Order-Point approach, since the inventories cover the mean consumption along the suppliers' lead time, the re-stocking order will be sent to the suppliers only when the stocks reach the re-order point. This makes the delivery time shorter but at the same time it is necessary to have larger inventories. There is a trade-off between costs and delivery time.

3.3 Results

The following table summarizes the main scenarios considered in the simulation. All these scenarios have been run both with the JIT and the ROP inventory model, in order to compare the performance of the established network when producing large or small orders. In this case, the shift between large and small order is 10-15 time less as quantity managed per each product model. The results are valid only for the specific company and cannot be generalized for other companies willing to change the way they manage the orders.

	Scraps	Lead Time
SC1	Initial values	Initial values
	Quality variation (SCQn)	
SCQ1	scraps - 10% of SC1	Initial values
SCQ...	...	Initial values
SCQ6	scraps - 60% of SC1	Initial values
	Lead time variation (SCTn)	
SCT1	Initial values	Lead time -10%
SCT ..	Initial values	...
SCT6	Initial values	Lead time -60%

Table 1 - The scenarios

The table below shows the impact on components inventory when applying IJT strategy and comparing management of small and large orders: for the analysed company, it has more impact if the focal company manages to influence the delivery time of suppliers (scenarios SCTx in table 1), than the quality of their products (scenarios SCQx in table 1) (comparison of the blue arrow).

Moreover the management of supplying process based on small orders allows to have larger influence on the inventory, since improvement in the performance of suppliers reduces the amount of inventory more than in the case of large orders (comparison with the red arrow in table 1). This means that the suppliers can answer in a flexible way to focal company needs.

	Δ components inventory (%)			
	Suppliers component L		**Suppliers component S**	
	Small orders	***Large orders***	***Small orders***	***Large orders***
SCQ2	(-1.43%)	(+0.27%)	(-1.48%)	(-0.43%)
SCQ4	(-2.12%)	(+0.41%)	(-1.68%)	(-1.00%)
SCQ6	(-3.57%)	(-0.6%)	(-3.58%)	(-2.23%)
SCT2	(-5.06%)	(-2.25%)	(-2.35%)	(-2.99%)
SCT4	(-7.08%)	(-3.27%)	(-3.54%)	(-6.56%)
SCT6	(-9.66%)	(-4.91%)	(-3.04%)	(-12.72%)

Table 2: Variation in the inventory of components due to different performance of the suppliers

In JIT scenarios, an improvement in suppliers' lead times is translated into an almost proportional improvement in lead time to customers for small orders and a less than proportional improvement for large orders (fig.2). The improvement in quality of materials, with reduction of scraps does not vary too much the global network performance, with a small decrease of lead times to customers.

Analysing the ROP scenarios, inventories are much bigger than the average inventory in JIT scenarios. In contrast, the average lead time to customers of ROP is lower than the average time in JIT, while the maximum lead time to customers in ROP is smaller than in JIT for small orders and bigger for big orders. The main costs in ROP case are due to larger inventory.

	Δ lead time to customer	
	small orders	large orders
SC1	0	0
SCQ2	(-2.29%)	(-1.82%)
SCQ4	(-8.40%)	(-1.37%)
SCQ6	(-7.63%)	(-3.95%)
SCT2	(-7.63%)	(-1.37%)
SCT4	(-6.11%)	(-5.61%)
SCT6	(-13.70%)	(-5.92%)

Table 3: Variation in the Lead time due to different performances of the suppliers

In all ROP scenarios average inventories is higher than in JIT and the improvement of suppliers' lead times is transferred almost directly (proportionally) to values of initial inventories, with a corresponding reduction. An improvement in quality of received materials (reduction of scraps) does not impact much on the network performances, with just a small improvement in lead times to customers and, even smaller, in inventories levels.

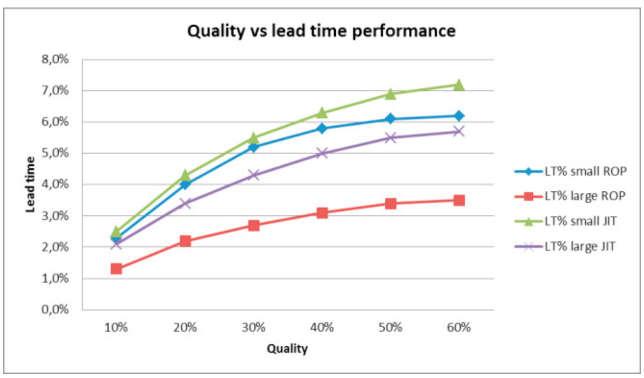

Figure 2: Performance of the JIT and ROP scenarios

4. CONCLUSIONS AND FUTURE DEVELOPMENTS

In this paper, the model is based on simulation of alternative supply network scenarios characterized by large versus small orders and generated according to the availability to produce of each partners. Evaluation of performance based on delivery time and quality of suppliers provision, as two parameters for customization are included in the solution to deploy supply chain redesign to build robust supply chains.

Moreover, this model can be used also to reengineer supply networks, for example changing the number of the suppliers and choosing how to allocate orders between suppliers or contractors. The use of simulation allows also to evaluate the impacts of the various actions that can be held in the supply network: thanks to the what-if analysis it is possible to predict how the global performance will vary with the changes in the supplier performances or in the network structure. This is based on an extensive study of the available data in ERP and PLM systems.

The case study confirmed the effectiveness of the proposed model to solve a decision problem linked to the choice of how to modify the actual supply network to pass from large to small order production. This analysis can support the development of an action plan on the supply network configuration to optimize the overall performance. Many of these information are forecasts, and can help companies to prevent the possible problems and to evaluate if this set change will rise minimal troubles or not. The proposed model can also be easily applied to different business contexts that would like to deal with this kind of problems, after a required customization of the parameters (performance indicators) and of the simulation model. The idea is to extend the model to give the possibility also to evaluate the impact of the introduction of new technologies (i.e. laser marking and additive machines), with a comparison between the "as is" situation and the "to be" situation with the new machineries and to decide where to use those machineries along the network or to evaluate the impact of customization on sustainability.

ACKNOWLEDGMENT

This work is partially sustained by the project MADE4FOOT (Innovative Methodologies, ADvanced processes and systEms for Fashion and Wellbeing in Footwear. FdF-SP2-T1.1), funded under the Italian Flagship Programme "Fabbrica del Futuro" and by NANOFOOT, EU project under the Research for SMEs Programme GA no. 606570, 2013-2015).

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