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CUSTOMIZATION IN THE MANUFACTURING INDUSTRY: SURVEY RESULTS IN SOUTHEASTERN BRAZIL

Alexandre Reis Graeml
Universidade Positivo / Universidade Tecnológica Federal do Paraná, Brasil
João Mário Csillag
Fundação Getulio Vargas, São Paulo, Brasil

ABSTRACT

This paper discusses the advantage of using kanban, postponement, modularization, just-in-time, production sequencing, milk-run and cross-docking by companies that intend to increase their flexibility, agility and reliability in order to support web-based businesses. It presents the results of a survey carried out with more than 600 manufacturing companies in the state of Sao Paulo, Brazil, and evaluates the changes that are taking place in operations, in order to make companies better suited to provide customized products, which are made to meet the individual requirements of each customer.

Keywords: Internet, customization, personalization, manufacturing industry

1 INTRODUCTION

Standardization may have been a very useful concept for the Industrial Revolution, contributing to much lower production costs. Cheaper products could be bought by large portions of the population that would otherwise have been kept out of the market.. When Henry Ford decided to commercialize a single model of his company's product, with no mix flexibility whatsoever (the T-model cars were all black!), his intention was to simplify the production and manufacture a car that even his most humble laborers could consider buying. About one hundred years later, flexible

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Endereço para correspondência/ *Address for correspondence*

Alexandre Reis Graeml, Universidade Positivo / Universidade Tecnológica Federal do Paraná E-mail: alexandre.graeml@fulbrightmail.org Phone number: 55 41 3352-4424 Address: Rua Ricardo Lemos, 454 apto. 501 CEP 80540-030 Curitiba-PR, Brazil

João Mário Csillag, Fundação Getulio Vargas, Sao Paulo, E-mail: joao.mario.csillag@fgv.br Phone number: 55 11 287-0148 Address: FGV-POI – Av. 9 de Julho, 2029 CEP 01313-902 Sao Paulo-SP, Brazil

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automation of production processes allows for product flexibility without giving up the cost advantages usually related to series production. Moreover, although cost is still relevant in most cases, value is a key concept in markets where there is intense competition. Many say that the customer now rules... And the customer is becoming each time more individualistic and self-conscious.

More than ever in the past, customers wish to have their individual needs and whishes considered in any business relationship, and converted into products and services that address those needs and whishes effectively. That could be a problem, if each customer's demand needed to be dealt with as a unique and completely different request. Fortunately, that does not need to be the case.

The possibility of the customers personalizing products, i.e. choosing the desired configuration among the options made available through the Web site of the company, changes the logic of any manufacturing process, since the product doesn't need to be available for prompt delivery and can be made to order. As a consequence, a few previously used production methods and techniques have become more relevant than they were before, as they are found to work well for e-businesses. This paper will deal with some of the methods and techniques that allow for the production of customized items. These techniques may provide flexibility of volume and mix, faster cycle times and/or more reliability, which are performance criteria that are valued by customers, according to Slack *et al.* (1999) and that are emphasized in e-business. If the production process is designed to take advantage of the available technology and sound operation management practices, products can be manufactured in a way they include all individually desired features. This is what customization is about: producing personalized products and services based on standardized modular platforms. Modules are put together in different configurations that address the customers' individual and specific needs and the result is perceived as if products were being made to order, in spite of them having been produced in a production line, as standardized products used to.

The advantage of using *kanban*, *postponement*, *modularization*, *just-in-time*, production sequencing, *milk-run* and the consolidation of materials/products for transportation will be discussed here, as they all relate to the possibility of offering more flexibility, speed and reliability to operations.

We will, then, present the results of a survey that was carried out with manufacturers in Sao Paulo - the most industrialized state in Brazil - the purpose of which was to understand how such companies are incorporating the use of the Internet into their competitive strategy and their daily business practices. Having acknowledged the fact that the market is becoming more demanding, with respect to the attention given to specific individual needs, this paper evaluates the responses with respect to the methods and techniques employed, trying to identify those that could help organizations to ensure the production of customized items. We believe that the results will help Brazilian manufacturing companies to reflect about how to provide more value to their customers without loosing the cost advantages that their traditional production processes already provide them. As for academia, the authors think that the paper will provide a better understanding of the practices that are currently being used in the field allowing for further development of theories about how the studied practices relate to one another and how they contribute to more effective organizations.

2 PRODUCTION PRACTICES THAT MAKE MASS CUSTOMIZATION FEASIBLE

There is a trend, which began long before the Internet appeared in the business scenario, of production process automation. This is particularly the case among manufacturing companies. The use of information systems has, recently, allowed a more flexible kind of automation and has also made it possible for some sort of personalization of the products to occur, based upon information made available to operations teams from databases. The Internet has had a magnifying effect with respect to the level of possible personalization, since the customer can directly intervene in the process, feeding these databases with more information and, consequently, the production system with data specifically related to their individual needs. This changes the dynamics of manufacturing, which can really benefit from techniques and practices in order to offer flexibility and agility, such as mass customization, kanban and postponement, as discussed further below.

Mass Customization

Mass customization is an attempt to achieve the benefits of scale economy and customization at once. It can be obtained as a result of the design of modular products, capable of being rapidly configured according to the customers' taste, without representing a burden to the production process. Some companies attempted to use production systems like these as early as the beginning of the 1990's, i.e. ones capable of manufacturing customized products, adjusted to the specific needs of individual customers, without giving up the advantages of scale production,. Levi's even conceived of a business model in which customers visited a department store; personnel took their measurements and helped them choose the cloth; they would then pay for the product and go home to wait for their pair of jeans to be delivered to their home address. In other words, the retail employee was able to transmit the required information for the production of an "almost" tailor-made product from a computer terminal in the store directly to Levi's' production line, which allowed for "pulled" production of the item depending upon the actual demand (MCKENNA, 1995; PEPPERS, 1998). Unfortunately, Levi's ended up abandoning this project, because it was not able to manage the conflict of interests with retailers, who felt threatened by the new trading model, which could have had the effect of excluding department stores from the process, in the future.

Interestingly, however, Internet operations such as North-American catalogue shop Land's End and Brazilian shirt shop Closet.com.br now insist on this tailor-made (customized) clothes mass production, using a direct sales model. The clothing industry is just one of the sectors in which the Internet promises to be a key element for the sale of customized products produced in scale, however. There are many web sites today that allow customers to configure product and trigger the production process from the comfort of their homes. Some examples are computer assemblers (e.g. Dell's expertise with direct sales was easily converted to the new media), bicycle factories (e.g. sevencycles.com asks all sorts of questions about the buyer's cycling style and ergonomics, in order to specify the right product), shoe manufacturers (e.g. nike.com and other competitors allow customers to customize products, which are then made to order and delivered to the customer's address), doll manufacturers (e.g. MyTwinn.com customizes dolls to resemble the owner's looks) and even candy producers (e.g. M&Ms

allows Internet customers to choose colors and even monograms to be printed on their chocolate chips).

From the manufacturer's point of view, mass customization is attractive for several reasons: (1) as products are made to order, there is no need for stocking finished goods; (2) as the customer defines the features and the configuration of the product, there is better alignment between what is needed and what is offered; (3) the product or service has more value to the customer, who may be willing to pay more for it, as a result of the better alignment of offer and needs; and (4) customers who place personalized orders help the manufacturer to better understand the market, thereby also improving its forward planning for the mass market.

From the customer's point of view, the major advantage is the receipt of a product or service that is better adjusted to one's needs. Of course, this advantage comes along with an increased effort to configure the product. Therefore, the company has to make sure that the required effort is kept as low as possible. Customers won't be interested if the effort is higher than the perceived improvement in the results.

In spite of all the advantages, there are difficulties that need to be overcome in order that customization be definitively incorporated into production processes: made to order production, which is usually associated with customization strategies, reduces the likelihood of efficient use of the manufacturing system, as Steger-Jensen and Svensson warn (2004). So, made-to-order may lead to increases in both costs and production complexity.

For customization to take place at manufacturing time without great efficiency loss, therefore, the product or service needs to have been conceived with that purpose in mind. It is also important to develop production processes that allow for a good balance of inventory, equipment and labor, in order to achieve a reasonable environment for build-to-order production. The system needs to have been designed to be lean and capable of producing only what the customer wants when s/he wants it (TREBILCOCK, 2004).

2.2 Kanban

Traditional manufacturing production involves pushed processes. This means that each link in the value chain, after having carried out its activities, dispatches the result of its work to the next link downstream, regardless of any specific request of this type. This production system generates *work-in-process* inventory whenever there is any production capacity imbalance or whenever there is any unforeseen interruption of work anywhere along the chain, as a consequence. Furthermore, those involved in production don't get to know whether, and at which rate, the output of their labor is being used by production stages ahead.

After the 1970's, particularly as a result of Japanese influence, manufacturers began adopting the philosophy of pulled production, in many areas. Two key advantages of this approach are the reduction of inventory levels and better understanding of both the market and any production process problems that need to be overcome. The tool developed by the Japanese to signal the need for additional process parts and to ensure that they are manufactured in due time, in order to replenish the next production/assembly stage, is kanban (SCHROEDER, 2000). This technique consists on

the use of cards or other visual cues presented to the supplier to warn it that the production/delivery of items under its responsibility needs to be resumed.

Although, at first sight, this production system seems to make the operation more vulnerable to problems in the production process, in practice, this is not the case. As the process needs to be fault free, since the results of any failure would have a direct impact on the organization's ability to fulfill customers' requests, those involved pay much more attention to the reliability of the production process. In addition, kanban ensures that only products for which there is demand are manufactured, which is a key issue in business environments where the consumer is in control. This is the typical Internet purchase situation.

2.3 Postponement

Sometimes, companies find it interesting to organize their operation in a way that part of the production process is pushed and the remaining process is pulled by the customers. Slack *et al.* (1999) refer to the pushed part of the production process as being the speculative stage. After the customer tells the supplier exactly what s/he wants, thereby defining the product or service to be produced, operations performs its activities in an ordered manner.

The reason to use a mixed approach, i.e., pushed-pulled, is to try to achieve the best of "both worlds". On the one hand, this ensures that customers receive what they want in a diligent and efficient way, even if unpredictable situations occur (an advantage of pushed production). On the other, firms benefit from only making production decisions once the customer has manifested his/her interests (a benefit of pulled production), which allows for personalization of the product. The strategic decision to be taken when a pushed-pulled production system is adopted is to define what to postpone, i.e., to determine the frontier between the pushed and the pulled part of the operation. This represents the point after which the product can be differentiated, depending upon specific demands (COTTRILL, 2003).

In order to make it easier to determine this point and, thus, the stage after which work can be performed, modular design may be used (see item below).

Postponement

A good postponement strategy may prevent the cycle time for delivery of customized products from becoming much longer than the time required to deliver mass production items (CSILLAG and SAMPAIO, 2002).

Postponement is a particularly useful technique to reduce cycle times to "spoiled" customers, who find it very easy to configure and order products through the Web and think that the seller should be able to manufacture, transport and deliver the product with the same diligence and agility.

Postponement also contributes to the reduction of the operation's uncertainty level, since some of the decisions are transferred to a moment subsequent to the customer’s expression of his/her wishes and needs, thereby reducing speculation about demand behavior. The concept may be extended to several activities, depending upon the type of uncertainty one wishes to reduce or eliminate. It is possible to postpone the

development of the product, the purchase of materials, the production or assembly, packaging, labeling or distribution (ZINN, 1990; YANG, BURNS and BACKHOUSE, 2004).

Modular designs, as discussed below, make postponement easier, because the production of modules may be carried out in a "pushed" manner, while assembly may be "pulled".

2.4 Modularization

For Baldwin and Clark (1997), modularity means creating a complex product or process that has smaller subsystems as the starting point, which can then be designed in an independent way in spite of retaining their characteristics of being one only thing. The development of modular projects allows for a large mix of possible products to be obtained from just a few components (SCHROEDER, 2000).

Modularization helps to introduce mass customization and other strategies that, in turn, allow for more flexibility in the firm's operation. The concept is not new. In the 1960's, Starr (1965) argued that products should be made out of pre-assembled modules in order to optimize final assembly and also to contribute to diversified output without significant impact to production costs. The simplification of the assembly process, resulting from fewer modules (as compared to single parts) allows for faster assembly. Modularization makes postponement feasible, i.e. final production/assembly can be delayed until there is demand for a specific item. That results in inventory savings. Modules can be conceived to allow for different versions of the product, which can then be assembled according to customers' diversified needs.

The more recent concept of mass customization is a powerful business proposition, particularly when modularity's potential is leveraged by the use of the Internet as a channel for direct communication with consumers.

3 LOGISTICS PRACTICES THAT MAKE MASS CUSTOMIZATION FEASIBLE

The practices that are presented next, while not having their performance directly affected by the Internet except for the improvement they provide with regard to communication with business partners, are important within the new context of Web-based operations where customers request personalized products that must be designed, manufactured, assembled and made available for consumption in short periods of time.

3.2 Just-in-time (JIT)

In many cases, better information sharing may effectively replace the flow of goods to be produced/assembled closer to the consumer. The impact of the use of the Internet and other IT would also be noticeable in decisions regarding the level of inventory (SKUs) and regarding the location of production and inventories.

Changes may also take place in the products themselves, the production processes or the way business partners coordinate their activities so that they may produce and deliver products to the consumers. Sophisticated logistics schemes would be used, which would only be possible thanks to better coordination and integration of the parties involved in the provision of materials and parts, production and distribution of finished goods. Techniques, such as *parts sequencing* within the production line, *milk-run* in inbound logistics and *cross-docking* in the distribution of products, become

important to ensuring competitiveness in the new context. All these practices contribute to the achievement of a *just-in-time* operation, which has become more relevant now that customers have begun designing and customizing the products they wish to buy through the Web.

In order to work according to the *just-in-time* philosophy, a company needs to keep inventory levels as low as possible. Doing this is not only a way of achieving *just-in-time*'s major objective, which is to ensure continuous improvement, however (MORTON, 1999). The reduction of inventory levels is necessary because high levels of inventory may disguise quality problems and inefficiencies, machinery break-down issues or set-up problems (CORRÊA and GIANESI, 1993). Thus, JIT's emphasis on reducing inventory levels also tends to make such problems evident, allowing for their identification and correction.

3.3 Production sequencing

Sequencing procedures intend to ensure that the right parts or modules are made available to the production/assembly line at the right time and in the right order. In other words, *just-in-time* involves the supply of a specific item at the time it becomes necessary. *Just-in-sequence*, by contrast, takes that concept further and involves not just precision, with respect to the timing, but also the sequence in which items are handed in to the production process to meet specific needs with respect to the item being processed (Automotive answers the "made-to-order" call, 2004).

3.4 Milk-run

Traditionally, suppliers deliver materials, parts and components that they produce, dimensioning volumes to be transported according to the convenience of the transportation equipment and not based on the customer's immediate needs. This practice may disturb the customer's inbound logistics, causing large concentrations of vehicles in the inbound logistics yard; peaks of vehicle concentration at delivery times; a lack of reliability in the delivery of components; and the need for physical space to store items that cannot be immediately sent to the production line.

Milk-run is, therefore, a system for the collection of materials or distribution of finished goods (WOOD, 2004). In the case of its application to inbound logistics, a single truck is used to collect materials from several sites and to deliver them to the destination, respecting pre-established schedules (i.e. collection/delivery windows).

Although milk-run is usually used with the purpose of reducing the delivery batch size, thereby allowing for a better match of supply to demand, load consolidation can also be used to reduce the costs associated with logistics. It may not be wise to use *full truck load* (FTL) simply to reduce transportation costs, but it may also be unreasonable to transport *less than truck load* (LTL) just to reduce storage, handling and financial expenditures.

In an attempt to optimize external logistics costs (i.e. transportation) as well as internal logistics costs (i.e. storage and handling), companies may choose to consolidate loads. In other words, they may use a single piece of equipment to perform the transportation of two "half-loads" coming from nearby suppliers.

Milk-run reduces the quantity of an item that needs to be transported at each trip, while increasing the frequency of deliveries. This allows the operation to work with lower levels of inventory, which is especially good for organizations that make at least part of their production to order. As it stimulates pulled operations, it better suits companies that sell products through the Web, i.e. those that do not need to have the product readily available when the customers demand them but that still have to be quick in addressing customers' needs so that they do not need to wait long for their orders.

3.5 Cross-docking

Sometimes, particularly when the suppliers are far away from the customer but close to one another, it may be interesting to use a consolidation center close to the suppliers. Reid and Sanders (2004) refer to *transport cross-docking* as the consolidation of LTL loads and small size items for the purpose of achieving transport scale economies. The increase in the frequency of trips between the consolidation center and the customer makes it possible to reduce inventory levels and work closer to a *just-in-time* situation, without great impact to overall transportation costs.

Another reason for the use of a warehouse to receive and consolidate loads of material and parts prior to the delivery to the operation is to ensure *just-in-time* delivery to the production line. This is known as *manufacturing cross-docking* (REID and SANDERS, 2004). In this case, it is more common for the warehouse to be located closer to the manufacturing facilities, in order to reduce transport time uncertainties. Such warehouses are also used to perform sub-assemblies, consolidate kits of parts and organize parts to be delivered *just-in-sequence* to the plant.

4 FLEXIBILITY AT THE RIGHT MEASURE

The production process and the product need to be designed in a way to provide the required flexibility during fabrication so that customers get what they want, i.e., product features configured by them from the comfort of their house using Web technology.

Care should be taken when developing flexible products/services and processes, in order to allow customization for (or by) the customer in a sensible way.

Too much flexibility may puzzle customers, making it difficult for them to decide what they want and also increasing the costs and complexity of the production process. Although people want to emphasize their individuality and to be in control of the purchases they make, in practice, people are not so different one from the other. Even when companies offer a great mix of products from which to choose, customers seem to use their "individuality" and "free will" to choose very similar items to those chosen by other consumers. Companies need to be warned against the danger of being overly flexible in their production processes and products.

Simple products may be easily mass customized without much problem: mouse pads, pens and key-rings that are distributed as gifts by companies are a good example. However, most such items do not allow for functionality customization. Rather, they are limited to "cosmetic" changes. To customize the functionality is more difficult. Quality perception of a product, once it is used, usually relates to its functionality and not to its appearance, however, although appearance may be important to the initial choice to

purchase. If a great level of customization is allowed, including functionality customization, functionality may actually be reduced due to the customer's intervention, as the average customer is not well prepared to take decisions on product engineering. A good example of this is the dilemma faced by the manufacturer of precious stone cutting equipment, whose customers desired more flexibility so that they could determine what cut they wanted. The manufacturer, however, alleged that while there were no engineering restrictions preventing the company from providing the flexibility, customers wanted such flexibility would be harmful to the customers, as they would waste a lot of material attempting to perform technically infeasible stone cuts (POLLACK, 2002). In that company's opinion, the cutting system should only allow customers to configure the product/service in ways that provided good results in order to avoid unhappy customer responses due to their own functional choices.

In brief, flexibility in excess may puzzle customers or generate stress due to the quantity and difficulty of the choices involved; it may also reduce the functionality of a product/service and generate additional production costs that surpass the benefits provided by meeting specific needs. Therefore, organizations should be careful to choose an appropriate level of customization to offer to their customers, taking into consideration the risks involved in providing flexibility in excess.

5 METHODOLOGICAL APPROACH

An electronic survey was sent to all manufacturers with valid e-mail addresses contained in FIESP's database[1]. Companies were contacted through an e-mail message that had an MS Word automated form attached to it. 655 usable responses were obtained, which corresponds to a return rate of ca. 8%. The structured questions followed a Likert scale. Participants could choose from a list of alternatives presented in a *drop-down* menu (see Figure 1) that made the process of filling in the questionnaire fast and easy. Respondents only needed to click the mouse on top of the suitable alternative from drop-down menus.

What is the level of usage of the tool [name of tool] made available by the Internet?	What is the level of change caused by the Internet and other IT in the way your company performs [activity]?

[1] Fiesp is an association of companies in the manufacturing industry in the Sate of Sao Paulo, the most industrialized state in Brazil.

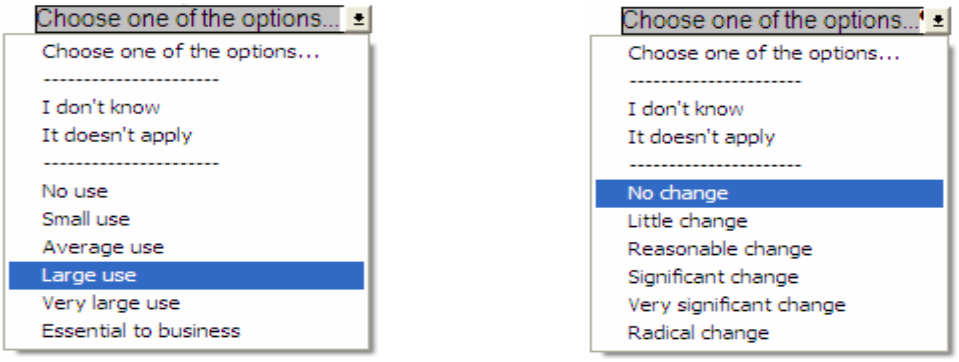

Figure 1 Drop-down menus like the ones used in the surveys

The questionnaire was pre-tested with respect to the content by a group of executives working in the field who, conveniently, happened to be taking one of the author's extension courses. This group gave important feedback that ensured that the final set of questions was more accessible and understandable to the "actual" participants. With respect to the format, the authors randomly separated one per cent of the whole database and sent the questionnaire via e-mail to those companies a month in advance. No changes in format were necessary, after consideration of the pre-test answers and, by the time the larger group of companies was invited to participate in the survey, the researchers already had a reasonable idea of the return rate that could be achieved, based upon the return rate of the pre-test sample.

The survey included questions about technologies, methods and techniques that the organizations use or intended to use in the future that were particularly relevant to this study. The tabulated data were handled using Excel and Minitab, for the generation of graphs and statistics.

As the study was conducted based on a convenience sample of companies that agreed to respond to the questionnaire, any inference made about the behavior of the population of industrial companies in the country is open to debate, which is, clearly, a limitation of the study.

The researchers were especially concerned with issues of similarity between sample and population because, as the survey was on companies' use of the Internet, contacting companies via e-mail could be biasing. Therefore, although no simple and definite solution was found to ensure sample representativeness, measures were taken to improve the survey's acceptability. One hundred companies, whose recorded e-mail addresses proved invalid, were contacted by telephone in order to obtain alternative (working) e-mail addresses. In addition, one hundred companies that did not have any e-mail address in the database were also contacted by telephone and an existing e-mail address was requested. The great majority of them provided a valid e-mail address, at that juncture, which allowed the researchers to assume that those companies were not vastly different to the ones that already had valid e-mail addresses recorded in the database.

Comparisons were also carried out with respect to demographic data available in the database about the population. No evidence was detected of significant differences

between sample and population. On the contrary, χ^2 tests, based upon the location of companies (region within the state of Sao Paulo) and size, were favorable. The authors have no reason to believe that the sample they obtained is not representative of the population.

6 RESULTS OF THE SURVEY

Below, we present the results of the survey carried out in more than 600 Brazilian manufacturers, which asked them about several practices that impact the way they manufacture their products and that had a special focus on the possibility of offering customized products in order to meet the specific demands of each customer.

6.2 Just-in-time

Large companies that participated in the survey use *just-in-time* to a greater extent than smaller ones, although the difference is not so significant. Thirty per cent of the large companies surveyed use *just-in-time* at least moderately. Among mid-sized companies, 26.1% do so while small companies use *just-in-time* less frequently (only 11.8% use *just-in-time* at least moderately, as shown in Figure 2).

6.3 Customization/configuration of products

Among large companies, 18.2% consider that the impact of the Internet and other IT on the configuration/ customization of products has been at least moderate in the past 3 years (see Figure 3). This percentage is slightly smaller for mid-sized companies (17.1%) and, curiously, a little higher for small ones (20.8%). Originally, the authors thought that, perhaps, smaller companies were benefiting from the opportunity to offer better suited products to individual needs. The assumption was that they might be more dependent on their customers and, therefore, feel the need to pay more attention to their specific needs. This reasoning did not survive the analysis of the survey's results regarding the current use of customization by the participants, however. The companies that claimed they made the most intense use of customization were the mid-sized ones (Figure 4), which were precisely those that stated that the impact of customization has been the least in the past 3 years. Mid-sized companies that use customization at least to a moderate extent represented 32.6% of the sample. For large companies, that percentage was 26.3% and for small ones, 23.3%. It was not possible to identify the reasons for this apparent inconsistency in the data shown in Figure 3 and Figure 4, which is an interesting topic for future research.

6.4 Product modularization

When analyzing the information provided by the respondents about modularization, one thing that was called the authors' attention was the fact that large companies consider it much more important than smaller ones (19% of large companies claimed that they used modularization at least to a moderate extent, while mid-sized companies and small companies presented much lower percentages: 9.9% and 7.3%, respectively). The percentage of mid-sized and small companies that said that they do not intend to use modularization within the next 3 years or that believe that it does not apply to their businesses was very high: 69.4% and 67.3%, while 38.1% of large

companies had the same opinion), as can be seen on Figure 5.

6.5 Manufacturing Postponement

As can be seen on Figure 6, the level of use of manufacturing postponement is very low for mid-sized and small companies. For large companies, 18.8% use this practice at least to a moderate extent. The percentage of companies that believe the technique does not fit their business is large.

As it was expected, the graphs obtained for the use of modularization (see Figure 5) and postponement (see Figure 6) are very similar. Modularization makes it easier to adopt postponement, as it defines more clearly the point after which the production process will be "pulled", i.e., the point where modules will be connected to one another to form different possible configurations of finished goods.

6.6 Milk-run

The use of milk-run by the companies that took part in the survey was low. Though a few respondents mentioned using it a lot and considered it essential to their businesses, the quantity of cases was insignificant. This was somewhat predictable. Although the technique is useful for operations that intend to keep low levels of inventory, adopting just-in-time supply, it presents challenges that make it only suitable to very specific circumstances. Furthermore, its introduction in the country has only happened in the last few years. Thus, it was not a surprise to find out that most surveyed companies do not use this technique nor did they intend to use it within the next 3 years. Only 5.5% of large companies, 6.0% of the mid-sized ones and 4.2% of the small ones used the technique at least moderately. The percentage of companies that intend to begin using it over the next 3 years was also modest: 5.6% of the large, 7.8% of the mid-sized and 8.1% of small firms. Most companies consider the technique not useful for their businesses or just do not intend to begin using it at any time in the near future (77.8% of the large companies, 81.9% of the mid-sized ones and 82.9% of the small ones).

6.7 Cross-docking

By analyzing the answers to the question about cross-docking, one realizes that small and mid-sized companies give very little importance to it, which is different from the response given by large companies. Only 1.8% of the small companies responded that they use cross-docking at least moderately and only 9.6% intend to begin using this technique within the next 3 years. 87.1% of small companies do not intend to use it in the near future. For mid-sized companies, figures were not that different: 4.0% use it at least moderately and 6.0% intend to begin using it within the next 3 years. 84.0% do not intend to use it. Large companies, for their part, provided different responses. While still not using cross-docking intensively (only 12.5% of them make at least moderate use of the practice, currently), they are more receptive to using it in the future. 25.0% say they intend to begin using it soon. 37.5% consider that it is not suitable to their businesses or do not intend to use it in the next 3 years.

Figure 2 Current use of just-in-time and views regarding future use

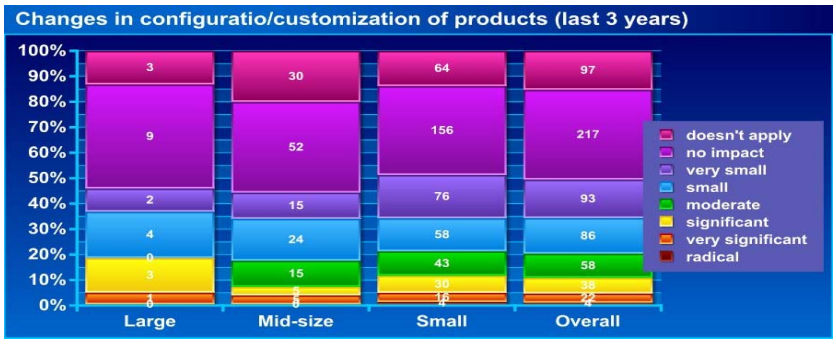

Figure 3 Internet's impact on product configuration/customization over the past 3 years

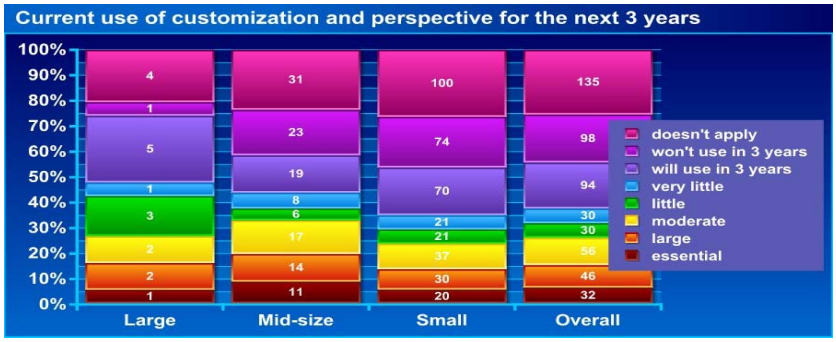

Figure 4 Current use of customization and views regarding future use

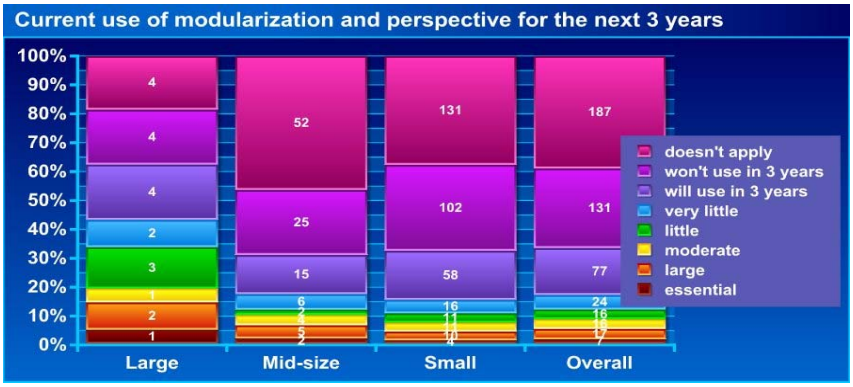

Figure 5 Current use and views regarding future use of modularization by manufacturers in Brazil

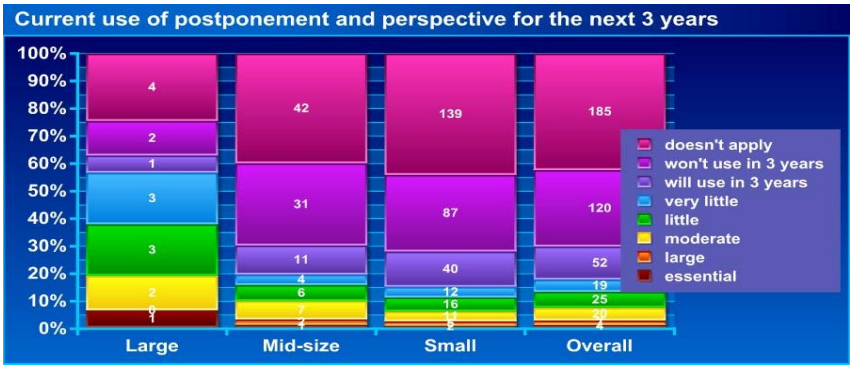

Figure 6 *Current use and views regarding future use of postponement by manufacturers in Brazil*

7 PREDICTION OF CUSTOMIZATION LIKELIHOOD

As stated earlier, customers are becoming more demanding with respect to the fulfillment of specific needs and organizations. The literature review carried out as well as the authors' experience with the issue indicate that, to deliver customized products or products that the customers can configure through the Web, companies need to modify their processes so that they may become both more flexible and more agile. Several practices that may contribute towards these objectives have been discussed as have their likely impacts on an organization's performance goals.

Having collected data on many different variables, the authors have attempted to determine the extent to which it was possible to predict a company's likelihood to perform manufacturing customization based upon the production and logistics techniques it uses. In order to do that, several multiple linear regressions were calculated.

The two independent variables that, on their own, provided the best explanation of the level of customization adopted by the surveyed companies were "*modularization*" (21.2%) and "*postponement*" (19.6%). As the two variables are highly correlated (0.608), though, when they are used together in order to explain the "*level of customization*", the degree of explanation (R-Sq) is much lower than the sum of isolated contributions of each variable, i.e. not going beyond 25.6% (<< 21.2% + 19.6%), as shown in the Minitab output below.

```
Customization = 1.30 + 0.415 Modularization + 0.373 Postponement
Predictor          Coef     SE Coef          T        P
Constant         1.2966      0.1329       9.76    0.000
Modularization  0.41484      0.07714       5.38    0.000
Postponement    0.37348      0.07938       4.70    0.000
S = 1.991       R-Sq = 26.0%     R-Sq(adj) = 25.6%
```

The variables *postponement* and *just-in-time*, in their turn, represent practices that are partially conflicting with one another. *Postponement* involves delaying tasks that do not contribute to the differentiation of the product, which are the only ones performed in a pulled manner. The authors found it impossible to eliminate the variable "*just-in-time*" or "*postponement*" without losing its predictive ability (around 5%). This

is probably due to the fact that some companies that customize products do so by following a just-in-time production logic, i.e., they work in a make-to-order manner. Other companies do so by postponing distinguishing steps.

The linear regression model that provided the best explanation for the dependent variable "*level of customization*" was the one that took into account, in addition to the variables "*modularization*" and "*postponement*", "*just-in-time*" and "*virtual intimacy*", as shown in the Minitab output, below.

```
Customization = 0.714 + 0.372 Modularization + 0.248 Postponement
                + 0.213 Just-in-time + 0.195 VirtualIntimacy
Predictor          Coef     SE Coef          T        P
Constant         0.7141      0.1630       4.38    0.000
Modularization  0.37176     0.07797       4.77    0.000
Postponement    0.24804     0.08264       3.00    0.003
Just-in-time    0.21307     0.05386       3.96    0.000
VirtualIntimacy 0.19474     0.06601       2.95    0.003
S = 1.887       R-Sq = 33.4%     R-Sq(adj) = 32.7%
```

The independent variables selected were able to explain 32.7% of the behavior of the variable "*level of customization*". The R-sq statistic was used to determine this relationship (Hair *et al*., 1998). Although this is not a significantly high value, it is sufficient to demonstrate the interconnectedness of the independent variables identified and the level of customization adopted by the firms. The company's size did not seem to be relevant, according to the results of the quantitative analysis conducted.

8 MANAGERIAL IMPLICATIONS AND FINAL CONSIDERATIONS

The adoption of manufacturing and logistics techniques that provide greater production flexibility is a must, at least for companies that intend to offer greater variety of output, something that is highly stimulated by the use of the Internet as a new sales channel. Customers are now able to configure products and choose the intended functionality directly from the company's website. However, companies need to be cautious about the possibilities provided by the Internet, as Keenan *et al.* note (2002). The Web may be a good way of finding customers willing to buy made-to-order products but restructuring a traditional plant to cope with a great number of variations of each product; keeping quality standards; and meeting individual requirements are not simple tasks. They require careful planning. The product and the production process need to be conceived, from the outset, with these purposes in mind. Ruddy (2002) stresses that while mass customization means the possibility of having specific needs taken into account, quickly and for a reasonable price, for the consumer, for manufacturers it means developing a sophisticated infrastructure that involves suppliers, the company and its customers as co-developers of the desired products.

Comparing the data on *customization* contained in Figures 3 and 4 with that of Figures 5 and 6 on *modularization* and *postponement*, one realizes that, curiously, the companies surveyed are more concerned with the possibility of providing product/service customization than they are with the need to adopt manufacturing techniques that would allow this to happen in a more efficient manner. Perhaps they are

already noticing changes in their customers' behavior and are attempting to respond to new demands, without more deeply reflecting on the consequences of adaptation to their production processes.

According to the results of this study, large companies are ahead of the others with respect to the adoption of the discussed practices. This may provide them with more flexibility in terms of production and logistics, as they attempt to achieve efficient mass customization. Thus, they represent a possible future benchmark for smaller companies, although they also need to develop better skills as they evolve.

The authors believe that the adoption of practices that provide more flexibility to operations will intensify over the next few years - at least for companies that begin offering more output variety, which is a feature stimulated by the use of the Internet as a sales channel for products and services. However, this trend will surely not be restricted to companies that choose to sell through the Web. The Internet is teaching customers that it is possible to get products that are a better fit to specific requirements. Customers will expect to find compatible levels of service when dealing with traditional brick-and-mortar companies, as well.

Thus, the relevance of the discussion about the techniques and practices presented here goes beyond their impact on businesses that are solely based on the Internet. It is also important to other forms of business as well. As our society assimilates the Internet as a way for people and companies to interact and do business, the expectations that develop for that media are being transferred to traditional channels in both whole and partial ways. In short, customers will demand more flexibility from traditional businesses in the future if only because of the inevitable comparisons that are likely to take place with e-business.

Businesses that are solely based on the Web need to become faster and more reliable, in order to compete with traditional businesses with respect to these criteria. Traditional businesses, in their turn, need to review their production processes to increase flexibility and mix, performance criteria for which virtual businesses usually have better performance. The methods and techniques discussed in this paper may help companies that make products to order to improve speed and reliability, making them more attractive to customers. On the other hand, they may also improve the flexibility of traditional businesses, in order to retain their competitiveness, when faced with the possibility of customer-led customization of products, which the Internet is making more popular at every turn.

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