Flexibility and rigidity in customization and build-to-order production

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Abstract

This paper deals with the efforts of firms to tailor their products to the needs of individual customers. The overall aim is to analyse the features of the evolving activity structures where customized offerings are created with ‘near mass production efficiency’. The paper begins with a literature review outlining modularity and build-to-order production as key features of customizing. The empirical setting of the case study is Volvo Cars’ activity structure for build-to-order production. This structure is compared with previous means of making products available. The conclusion of the study is that activity structures for build-to-order production require extensive coordination, exchange of information, and interaction across company boundaries. The analysis shows that these structures rely on flexibility in some dimensions, while in others they build on rigidity. The paper concludes with implications for suppliers regarding how to combine flexibility and rigidity in order to be able to customize at reasonable costs.

Keywords: Build-to-order; Customization; Flexibility; Rigidity; Activity structures

1. Introduction

A flood of recent publications attests to the widespread belief that we are in the midst of a fundamental technological change in manufacturing, communication, distribution and retailing—a virtual renaissance of customization. (Lampel & Mintzberg, 1996:28)

The conclusion quoted above was formed on the basis of an extensive literature review where the authors found that 234 articles on customization appeared between 1981 and 1990, while the corresponding number for the period 1991–1995 amounted to 2324 (ibid.:28). According to more recent reviews, the enhanced attention to customization has continued (for example, da Silveira, Borenstein, & Fogliatto, 2001; Jiao, Quinhai, & Tseng, 2003). Salvador, Forza, and Rungtusanatham (2002) conclude that although customization has not “completely swept away the remains of mass production”, there are clear signs that it is “becoming more and more a widespread concern” (ibid.:62).

The increasing interest in ‘customization’ is explained on the one hand by the fact that customers are “demanding highly customized products and services” (Feitzinger & Lee, 1997: 116). On the other hand, customization has been marketing driven and provided selling firms with an approach that is claimed to improve the competitive position of the company (e.g. Kotha, 1995; Pine, 1993; Stump, Ataide, & Joshi, 2002). Implementation of the new approach was made possible primarily through the development of more flexible manufacturing systems (e.g. da Silveira et al., 2001) and new developments in information technology (e.g. Jiao et al., 2003). Other important prerequisites for increasing customization relate to improvements in supply chain coordination (Lancioni, Smith, & Oliva, 2000), and greater differentiation of distribution networks (Ford, Gadde, Håkansson, & Snehota, 2003). The literature indicates that ‘customization’ covers a wide range of approaches with very different extents of attention to the individual customer. These approaches range from solutions uniquely tailored to an individual user to “slight variations of standard config-
3. Customization and build-to-order production

Customization implies adaptations towards individual buyers. Customizing offerings in relation to single buyers is not problematic per se. On the contrary, tailored solutions were the common norm before the establishment of mass production systems and craft manufacturing continued to be so in many sectors of industry throughout the era of mass production (Piore & Sabel, 1984). What is problematic, however, is to customize at reasonable input of cost and time (Pine, 1993). Adaptations to individual requirements are always costly because they tend to undermine the potential for standardizing operations, thus increasing complexity and reducing the scale of the operations. These characteristics make customization a challenge because buyers tend to require individualized solutions at the same time as they demand shorter lead-times (Feitzinger & Lee, 1997) and reduced costs (Oswald & Boulton, 1995).

Increasing customization requires reorganisation of the activity structures in production and distribution in order to enhance process flexibility. The main determinants of this transformation relate to the implementation of modular product design, and the postponement of product differentiation (e.g. Berman, 2002; Feitzinger & Lee, 1997; van Hoek et al., 1999). One of the best illustrations of this combined approach to transformation is a case study of Hewlett Packard (Feitzinger & Lee, 1997). Through the reorganisation of its activity structure the company managed to improve three processes: they dramatically increased product variety, they slashed the time required for fulfilment, and they were able to reduce costs. The crucial role played by the principle of modularity in these performance enhancements are expressed in the following three dimensions (ibid.: 117):

- modular product architecture: implying that a product is designed to consist of independent modules that can quickly be assembled into different product variants.
- modular process architecture: implying that manufacturing processes are designed to consist of independent activities that can be rearranged.
- modular logistics and supplier configurations: implying the capability of taking individual customer orders as the starting point for the operations.

The benefits of modularity enables the postponement of final assembly of a product until customer orders have been received. By taking customer orders as the point of departure for its operations, a supplier stands to gain in two respects. First, inventories can be reduced (given that lead times are reasonable). Second, by relying on a set of modules, the supplier can assemble customized product variants at short notice.

The market opportunities related to customization and build-to-order production have attracted suppliers in various industries (e.g. Kotha, 1995; Pine, 1993). Most of the early
studies dealt with home appliance products, computer hardware, and electronics, which are supposed to allow for ‘simpler’ means of customization (Henke, 2000). One illustrative example is that a PC consists of seven basic modules that are standardised and interchangeable and readily available for assembly (Curry & Kenney, 1999). These features provide opportunities for various types of activity structures. Assembly operations thus take place at different positions in the network, e.g. manufacturers, distributors, retailers, and even end customers (Hultén, 2002). Moreover, computers are delivered directly to end-users in, for example, the Dell distribution system.

Cars are more complex than PCs, televisions, or refrigerators, making customization a more complex issue. However, the potential gains from customization are much greater in the automotive industry, and so the way is paved for reorganization of the activity structure. The efforts of car manufacturers in this respect have been described in, for example, Agrawal, Kumares, and Mercer (2001) and the 3DayCar Project (2002). Both these reports conclude that customization is increasingly applied in the automotive industry. Svensson and Barfoed (2002) found in their study that 75% of British customers purchased new cars that had been individualized in some way. The corresponding figure ten years previously was 25%, and the scope of individualization was also more limited.

The principle of customisation is, consequently, a prime concern in the car industry (Agrawal et al., 2001; Alford, Sackett, & Nelder, 2000). Car manufacturers apply modularity and build-to-order production to their internal operations, as well as to those of their suppliers, in order to reduce costs and lead times in manufacturing and assembly (Sako, 2003). Modularity has also been suggested as a means of enhancing performance in the car design process (Salerno, 2001). Such potential effects are important for both high volume manufacturers, who pre-define the product variety offered, and low-volume manufacturers who can allow single customers to influence the design of their specific cars (Alford et al., 2000). Modularity is further considered a means of enhancing supply chain efficiency and flexibility (Doran, 2004).

Considerable expectations have been expressed in relation to the benefits of modularity and build-to-order production in the car industry. For example, in the mid 1990s, Toyota launched an all-out effort to offer car buyers individually customized products (Lampel & Mintzberg, 1996). At the same time, Nissan argued that the new opportunities available would make it possible to produce “any volume, anywhere, anytime, of anything for anybody” (ibid.: 24). These efforts, however, had to be abandoned because they led to dramatically increasing production costs which, in turn, impacted on the buyer’s costs.

The conclusions of this review are twofold. The first is that individualised offerings enhance customer benefits. However, the second conclusion is that increasing customization also requires sacrifices on the part of customers, in terms of increasing costs. Suppliers dealing with customization must take both these effects into consideration. Build-to-order production enables a supplier to expand the product range, thus providing opportunities for flexibility regarding the buyer’s choices. However, if this flexibility is allowed to expand without limits, the costs related to flexibility multiply and may outweigh the benefits. This means that the activity structure for customization and build-to-order production, in order to be economically efficient, needs to preserve some of the rigidity associated with mass production.

4. Build-to-order production at Volvo Cars

In the sections below, we describe Volvo Cars’ approach to customization and build-to-order production. Data were gathered during a four-year case study involving the logistics, production and purchasing departments at Volvo and some of Volvo’s suppliers. The study focused on the operational issues of Volvo’s build-to-order system, such as the coordination of the logistics and production activities. Although most of the literature dealing with customisation and modularity emphasizes the importance of supply chain coordination (see Alford et al., 2000; MacCarthy, Brabazon, & Bramham, 2003; Salvador et al., 2002), few researchers have studied how such logistics and production activities are actually coordinated (Doran, 2002). Issues related to production and logistics have received only scant attention in the literature (Åhlström & Westbrook, 1999; Selladurai, 2004). Other areas have been more carefully scrutinized in relation to customization, for example, Internet applications (Ghiassi & Spera, 2003), inventory reorganisation (Tibben-Lembke & Bassok, 2004), product configuration modifications (Salvador & Forza, 2004), and spare parts operations (Suomola, Sievänen, & Paranko, 2004).

4.1. Production and logistics activities at Volvo Cars

Volvo reorganized production and logistics activities and implemented build-to-order production in the early 1990s. The objective was to achieve operational efficiency and flexibility to realize its intended business reorientation—from a production to a customer focus (Hertz, Johansson, & de Jager, 2001; Liu, Roos, & Wensley, 2004). A second major step in this transformation was taken with the launch of the S80 model in 1998. The S80 was based on a new product platform and designed according to modular principles. Volvo also created a modular assembly system, in which suppliers were given a great deal of responsibility (Fredriksson, 2002).

In the following four years, four new models based on the same product platform were introduced. In spite of the rationalisation benefits related to the common platform the number of product variants increased dramatically. The five models are available in 14 colours, and a car buyer can...
choose from 9 engines and 5 transmission alternatives. A buyer can also choose between left and right-hand steering, giving a total of 6,300 variants. Many other options are available, such as 22 types of interior trim and 9 wheel variants. Volvo can offer more than one million car variants. Tailoring each car to individual customer specifications requires a flexible, well-organised activity structure.

The cornerstones of Volvo’s production and logistics activities are its two main assembly plants in Torslanda, Sweden, and Gent, Belgium. In this paper we focus on the operations related to the Torslanda plant where about 160,000 cars were produced in 2003. Volvo’s in-house production units account for approximately 25% of the value of the components and systems, while external vendors supply 75%. For the car models based on the current platform, the Torslanda plant uses about 170 suppliers, a substantial reduction compared with previous platforms. Some of these vendors are involved in pre-assembly of components, and supply Volvo’s final assembly line with ready-to-install modules. These suppliers deliver their modules in the same sequence as car bodies are put on Volvo’s assembly line. The actual sequence is determined when the car bodies enter the line, and the module suppliers have only a few hours to perform their activities. They therefore have built module assembly units (MAUs) within 15 min driving distance of the Volvo plant. A total of 15 MAUs delivering 26 different modules such as seats, cockpits and exhaust systems are located close to the plant. Volvo’s overall network, including its 2400 dealers, is illustrated in Fig. 1.

The modular supply and sequencing principle is illustrated in Fig. 2. When a car body enters the final assembly line, it has been dedicated to a specific buyer and given a unique identity. All the options chosen by the car buyer in terms of exterior colour, engine and transmission types, interior trim, etc., are linked to this identity. Variant specific modules must therefore be available at each station on the assembly line when the specific car body arrives. The suppliers delivering to the first assembly station have about four hours at their disposal, whereas those delivering to the end of the line have closer to ten hours.

Transportation of modules between the MAUs and the final assembly line is handled by Volvo. Their trucks drive “milk rounds” with pick-ups one or two times per hour from each supplier. The pick-up frequency fluctuates in accordance with Volvo’s assembly line pace. While the modules constitute a substantial part of each car, they also contain many of the features that differentiate car variants from each other. The modules are therefore available in different variants, for example there are 3500 types of seats, and more

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**Fig. 1.** Volvo’s production and logistics network.

**Fig. 2.** Pre-assembly and delivery of module variants.
than 10,000 power-pack combinations. Furthermore, most modules are physically large and represent considerable capital investment. The cost of buffering all the potential modules would thus be extremely high, while the current activity structure allows Volvo to deliver a wide range of product variants to its customers in a cost-efficient way. One of the prerequisites for this capability is Volvo’s planning system.

4.2. Plans and planning processes

The starting point for the build-to-order activities is a specific order from a dealer or one of the sales companies, who communicate directly with Volvo’s planning system and feed the buyer’s specification into the system. The key to controlling the costs associated with the flexibility of the buyer’s specifications of product features is to allocate the operations related to this order in a way that allows for the most appropriate utilization of the activity structure. The particular order is therefore related to the overall production schedule of the Torslanda plant and the planning system provides the dealer and the car buyer with a preliminary delivery date. It is estimated by combining forecasts and orders from dealers with the production capacity of Volvo and its supplier network. In this way, Volvo’s planning system coordinates the time for assembly of the particular car in order to reassemble potential economies of scale.

The Logistics department is responsible for the overall planning process. The planning system generates a production forecast covering what cars are to be assembled. This forecast is generated by the production planning system with no human involvement. It is based on the current order queue, capacity restrictions in the system, and Volvo’s priorities concerning different markets. The production forecast is updated on a monthly basis and distributed to departments at Volvo and to suppliers, about six weeks in advance. It is primarily used to give the preliminary delivery dates to dealers when they place orders and to assist suppliers in the component production planning process.

The planning system also generates a long-term production plan outlining what car variants are to be assembled in what sequence, covering the coming 62 weeks. This plan is updated weekly and improves the planning conditions for Volvo’s assembly department and suppliers, since it is based on both orders and forecasts. A short-term production plan, the ‘Call-off’ is also generated by the planning system. The Call-off is updated daily and covers the coming 12 weeks. The first eight days of the Call-off are fixed, in the sense that Volvo is committed to assembling the specified car variants in a predetermined sequence. From the ninth day, the Call-off is a forecast and Volvo can change it within the limits specified by the production forecast.

Volvo’s product variety involving huge numbers of component and module variants makes the planning process complex. The production schedules must ensure a relatively smooth workload at the final assembly line. Otherwise, costly line set-ups have to be made frequently, and temporary personnel hired and fired. The capacity restrictions in the planning system protect the final assembly line, as well as the MAUs, from overly large variations in workload. However, it is the economies of scale in the operations of component suppliers that are most sensitive to fluctuations in demand for different car models and variants. In order to limit these variations, Volvo’s Logistics engineers take hundreds of restrictions into consideration when production schedules are decided. This hands-on involvement supplements the restrictions in the automatic planning system and is crucial in terms of reaping potential economies of scale in component manufacturing.

When the logistics department has analysed the specific order in relation to the total restrictions in the planning system, the second, and final, delivery date is given to the dealer and the car buyer. In this way Volvo’s centralised planning department coordinates the chain of production and logistics activities in order to balance the flexibility in terms of customer service levels with efforts ensuring certain rigidity in the activity structure. The outcome of these efforts is strongly dependent on the information exchange between the actors in the network.

4.3. Information exchange

Volvo’s planning of its build-to-order production process is strongly dependent on information from the customer side in terms of sales forecasts and actual orders. The sales forecasts are worked out by Volvo’s marketing organization and are based on estimated sales of specific car models and variants in the various geographical markets. The forecasts build on sales trends for Volvo and other car manufacturers, launches of new and refined products, and the socio-economic factors prevailing in various markets. These forecasts cover several years and are updated regularly. The forecasts form the basis for Volvo’s long-term production planning, in particular for the planning of internal assembly capacity.

Volvo’s planning information is also shared with suppliers. Based on its long-term sales forecasts, Volvo has signed contracts with all suppliers regarding prices and expected volumes over the life cycle of a car model. The expected volume peak then provides a basis for the agreement on the maximum capacity the supplier must make available to Volvo. The information in Volvo’s planning system is regularly transferred to suppliers. Suppliers use this information to plan their replenishment and production processes, thereby ensuring that they will be able to deliver the component and module variants ordered by Volvo. The production forecast is the basis for the suppliers’ planning processes since Volvo’s actual orders are only allowed to deviate from the forecast within limits specified in the contracts. Suppliers also receive the two production plans described above. Volvo sends these plans to suppliers every time they are updated.
The MAUs have particular planning problems. If one module flow stops, so will Volvo’s assembly line and therefore all the other module flows. The five most important MAUs (i.e. those with modules in more than one thousand variants) are therefore involved in Volvo’s planning process. These MAUs meet every second week and provide input to the planning system. Moreover, all MAUs are invited to Volvo Cars every second month to receive information regarding long-term plans.

4.4. The need for interaction

The interaction and negotiations between Volvo and the actors on its supply and demand sides are the cornerstones of the coordination of the activity structure. Volvo and its suppliers, distributors, sales companies, and dealers jointly analyse capacity constraints, product ranges, expected sales volumes, and so on, in order to achieve a balance between production and logistics costs, and customer service. Basically, the planning information and the activities of the firms are determined by long-term sales forecasts for the product range as a whole and for the different variants.

However, the information exchange mediated through the centralised planning system needs to be supplemented. The uncertainty of the forecast for individual product variants may be substantial, and when actual sales deviate from forecast the plans have to be revised. Moreover, when activities in production and logistics are directed by orders, the delivery lead time required will vary in relation to the capacity constraints and the order queue for that particular variant. If the delivery time is perceived as too long, the car buyer may prefer to choose a product variant that can be delivered at shorter notice. The buyer is also allowed to change the specification of the order until eight days before production begins. Interaction is subsequently required when the buyer wants to change an order and/or select another variant. The desired changes become matter of discussion between Volvo’s production planning department, the dealer and/or the sales company, and the car buyer. Interaction between the customization firm and the actors on its demand side is thus an important means of generating and updating production plans.

Volvo also interacts with actors on its supply side. The MAUs are particularly important counterparts for interaction both when production plans are generated and later. The capacity situations of the most important MAUs are taken into consideration in the planning process. MAUs are allowed also to set temporary restrictions in Volvo’s production planning system if they face sudden problems and are unable to deliver a specific module variant. Volvo then adjusts its assembly of car variants and its ordering of module variants accordingly (but only for a few days at the most). Disturbances in Volvo’s internal manufacturing processes may also cause such changes, e.g. if the paint shop is for some reason unable to deliver car bodies with particular colours.

The MAUs play a crucial role in the interaction process, representing both themselves, with their own internal constraints, and their component suppliers in turn. Volvo’s interaction with the supply side is primarily focused on cost efficiency, and handling of disturbances in production and logistics activities. In order to balance customer service and costs, central planning based on predetermined exchange of information needs to be supplemented with ad hoc interaction among the actors in order to handle situations that arise when planning assumptions do not come through.

5. Analysis

As discussed in the Introduction, it is a common view that the establishment of systems for customization requires transformation of activity structures. To understand the reasons for and the effects of this transformation, we begin the analysis by presenting some central concepts useful for analysis of the prerequisites for efficiency in activity structures. We continue by discussing the features of the activity structures for mass production (building on the ‘logic of aggregation’) that were replaced in this transformation by structures relying on the ‘logic of individualization’ (Lampel & Mintzberg, 1996).

5.1. Efficiency in activity structures

For this analysis we rely on two concepts developed by Richardson (1972): similarity and complementarity. Richardson makes a distinction between similar and dissimilar activities implying that activities are similar when they require the same capabilities and resources for their undertaking. For example, the manufacturing operations needed for two different products may use the same machining equipment and/or require the same skilled workforce. Increased similarity among activities is thus related to standardization and economies of scale, and the main rationale behind mass production is to increase the similarity among activities.

The second concept is complementarity. According to Richardson, activities are complementary when they have to be undertaken in a specific sequence, such as in supply chains. Some activities are closely complementary, implying that it is necessary “to match not the aggregate output of a general-purpose input with the aggregate output for which it is needed, but with particular activities” (ibid.: 891). Sequential activities become closely complementary at the point where a product is customized to a particular user. Changing this decoupling point impacts on the extent of complementarity among activities and makes them interdependent.

When activities are closely complementary across boundaries of firms it is necessary that “two or more independent organizations agree to match their related plans
in advance” (ibid.: 890). Inter-firm matching of plans is thus a prerequisite for customization, and involves two dimensions. The first is the joint organizing of the activity structure on the basis of the principles discussed above. Establishing systems for just-in-time deliveries between buyer and supplier is an example of joint organizing of closely complementary activities. The second dimension is the coordination of this activity structure, both within individual companies and across boundaries of firms.

Coordination of activities that are interdependent across firm boundaries requires extensive interaction among companies (Dubois, 1998). As illustrated by the Volvo case, these conditions are at hand in customization and build-to-order production. Similar findings are reported by for example van Hoek et al. (1999:517) who observe that for efficient coordination of such processes: “close cooperation with both internal and external supply chain partners is required”. One of the most important prerequisites for coordination of customized processes is exchange of information among the parties in the supply chain (see for example, da Silveira et al., 2001; MacCarthy et al., 2003).

5.2. Activity structures based on the logic of aggregation

The activity structures used in the regime of mass production were aimed primarily at exploiting the potential benefits related to increasing similarity among activities. Economies of scale were captured through massive standardization: “standardization of taste that allowed for standardized design, standardization of design that allowed for mechanical mass production, and a resulting standardization of products that allowed for mass distribution” (Lampel & Mintzberg, 1996:21). The sequential dependence among the activities showed two different patterns in this activity structure. Some of the components used by car producers were completely standardized, implying minimum interdependence concerning the features of the products. Other components and systems delivered by suppliers were adapted to the particular requirements of the specific car producer, making activities between supplier and assembler closely complementary. In the downstream operations in the supply chain, no close complementarity was at hand since cars were intended for a mass market. Generally, therefore, in this network structure most activities crossing the boundaries of firms were complementary, but not closely complementary. Inventories, both on the input and output sides of the producing firms, functioned as buffers, thus minimizing the need for coordination among companies (see Fig. 3). Car buyers had no opportunity to affect the product features of the cars—they had to buy what was available.

The first steps in the transformation of this type of activity structure were taken when car producers reorganized their manufacturing operations in the mid 1980s. Inspired by the experience from the Japanese motor industry, European and American car manufacturers began to require just-in-time deliveries from their suppliers (Gadde & Håkansson, 1993; Lamming, 1993). This change was supposed to provide the same benefits as in the Japanese car industry: reduced inventories, lower costs, and improved delivery performance. However, when car assemblers cut their inventories, supplier inventories had to be increased substantially to secure availability of components. In cases where suppliers were located far away from assemblers, intermediate inventories were established close to the car manufacturer. The warehouse business in Detroit flourished and one company even used the name ‘JIT-warehousing’ (Gadde & Håkansson, 1993). Obtaining the desired effects thus called for further modifications of the activity structures as described below.

JIT-deliveries increased the sequential interdependence among the activities on the input side of car producers. Handling these interdependencies at reasonable costs required reduced lead times in manufacturing. Without such changes the economies of manufacturing would have suffered severely, owing to the shortened production runs. Moreover, reduced inventories and increased variety called for enhanced coordination of production and logistics activities of both component suppliers and car assemblers. In these efforts developments in information technology played a significant role (Dubois, Gadde, & Mattsson, 1999).

From the output side of the car assembler and further downstream the supply chain, however, these changes had
little impact on the activity structure and car buyers still had to rely on what was available.

5.3. Activity structures based on the logic of individualization

Volvo’s current activity structure in production and logistics illustrates perfectly what Lampel and Mintzberg (1996) identify as ‘the logic of individualisation’. This logic provides consumers with the opportunity to affect the features of the cars they are going to buy. Developments in manufacturing, logistics, and information technology made it possible for producers to exploit the differentiation in consumers’ tastes, and mass distribution was increasingly supplemented with tailor-made delivery systems. Distribution and logistics systems had to be redesigned, because customization begins with the downstream activities—closest to the marketplace (ibid.: 25). The individualisation efforts in logistics are known under various acronyms, such as JIT (just-in-time) see for example White and Pearson (2001), ECR (efficient consumer response), e.g. Kurnia and Johnston (2001), and QR (quick response), e.g. Perry and Sohal (2000). These types of delivery systems rely on other principles than those based on buffers and inventories that made products available in time and place during the era of mass production.

User involvement in the specification of the car features impacts on the complementarity among activities by increasing sequential interdependence. In the current Volvo system, all activities between the buyer and the assembly operations are closely complementary. Many of these interdependencies run all the way back to the MAUs, thus increasing the complexity of the activity structure (see Fig. 4).

The implementation of the logic of individualisation impacts on the potential for standardisation. Customized solutions reduce the similarity among activities and the economies of scale in Volvo’s assembly operations, as well as in the operations in the MAUs. However, in the activity structure designed by Volvo, component production is decoupled from the close complementarity stemming from the customers’ ordering of build-to-order cars. Component production may thus benefit from similarities and economies of scale in the operations although the component level is also characterised by variants.

The main difference between the structures based on the logics of aggregation and individualisation relates to roles of inventories and buffers, and activity interdependence. In the activity structure relying on the logic of individualisation, inventories and buffers are minimised. Activity structures with these characteristics need more coordination and planning than those building on aggregation.

6. Discussion

This paper explores the characteristics of activity structures designed to realize the type of customization where production and distribution activities are directed by customer orders and performed differently, depending on the product variant demanded. Our study illustrates that these activity structures rely on logic that is fundamentally different from earlier structures, based on mass production and speculation. The main feature of build-to-order production is the close complementarity in the activity structure. These characteristics make activities strongly interdependent, which makes coordination of production and logistics activities a prerequisite. Coordination among actors is based on joint planning concerning both long-term forecasts and schedules, and customer specific orders. Information exchange among firms forms the basis for the joint planning. Owing to the close complementarity, the activity chains are vulnerable to disturbances and changes in plans. The study illustrates how firms need to interact to solve problems appearing when conditions change and assumptions do not come to fruition.

Our main conclusion, however, is that in order to customise at reasonable cost a supplier must combine the potential for flexibility offered by the principle of build-to-

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Fig. 4. Activity structure building on postponement and the logic of individualization.
order production with elements of the rigidity associated with mass production systems. Operational economy in build-to-order production is captured through reduced inventories and the decoupling of customized activities downstream from component manufacturing upstream. In the case study, the MAUs were shown to be significant in relation to these efforts. The role of a MAU is in some respect similar to that of an inventory, because both function as buffers in the activity structure (von Corswant, Dubois, & Fredriksson 2003). In this way the close complementarity required in the supply chain running from the MAU and downstream can be combined with similarity in upstream operations.

An even more important feature relates to the similarities a component manufacturer may access by combining orders from different customers. The suppliers operating the MAUs produce many of the components included in the modules and they also supply other components and subsystems. Component manufacturing is centralised to the large plants of these suppliers, which supply other car assemblers as well. Even when the activities performed for different customers are not identical, component manufacturers can utilize some of their resources in relation to more than one customer. If the capacity needed by Volvo decreases, suppliers may be able to fully utilize their resources by directing them to other customers. Efficiency in activity structures thus needs to be considered in a network context, because the performance in one particular supply chain depends on how it is combined with other supply chains (Gadde & Håkansson, 2001). Accordingly, the product variety that can be allowed for within specific cost and time limits is dependent on each supplier’s ability to coordinate its use of resources among different customer orders. Any single company’s potential to realize volume and variant flexibility in a particular supply chain is thus dependent on how the activities in this chain are linked to activities in other supply chains.

7. Implications

The most significant implication of the study is that suppliers have to combine flexibility and rigidity to be able to customize at reasonable costs. Our managerial implications are focused on rigidity because this aspect is seldom dealt with in relation to customization. Three means of exploiting rigidity are offered: one relates to the customizing firm and the features of its offerings, one deals with the activities directed downstream and one is about the activities on the supply side.

The hallmark of customization is to allow a buyer to select among a huge number of optional product features to identify a solution fitting his or her particular needs. The key aspect in this respect is modularity, which allows for creating product variety by changing some of the features of individual modules, while the basic architecture and relations among components are standardized. The greater the variety in the range of optional solutions provided, the more likely it is that the individual user will find a satisfactory solution. The first implication for a supplier, however, is that the potential range of optional choices must somehow be constrained. Without limitations in the selection range, the number of product variants would explode. These conditions in turn might completely erode the economies of manufacturing for the supplier. The customizing firm therefore has to delimit variety. For example, in the Volvo case, the most powerful engines can only be combined with a stiffer wheel suspension.

Another important aspect relates to the supplier’s decision concerning which of the potential combinations of these features are made available for selection. Volvo restricts the number of possible interior combinations in order to secure efficiency in operations. Moreover, to ensure colour matching between seats, instrument panels and door panels, only specific combinations of colours are allowed. By limiting these options, suppliers may be able to increase the scale of the operations.

The second implication is that the range of selection options may be further constrained through actions influencing the actual choices of buyers. This aspect of rigidity is favoured by offering buyers specific combinations of predetermined product features in packages. By promoting these packages through marketing efforts and pricing them favourably, the supplier may affect the choices of buyers in ways that generate rigidity without necessarily being perceived as inflexible. In the car industry, dealers have obvious opportunities to impact significantly on buyers’ choices. In the Volvo case the car variants share many features through the dealers’ packaging of options. It is most likely that the recommendations from dealer representatives have an influence on the buyer’s decisions. Customizing firms, therefore, may stimulate the sales of particular product variants through the pricing and rebate conditions they arrange with dealers.

The third implication relates to the decoupling point—i.e. the point at which a product variant becomes specific in relation to a particular customer. By moving the decoupling point from the assembly line upstream, the customizing firm gains more opportunities to individualize while still minimizing interference with assembly activities. In this case study, Volvo Cars increased its flexibility by moving the decoupling point for some of its modules upstream. However, moving this point all the way back to component suppliers would have destroyed the economies of manufacturing. The MAUs provide the rigidity that is necessary for ensuring scale in the operations of component manufacturing. In this way the MAUs contribute substantially to the flexibility of the choices for car buyers.

Finally, MAUs are important for providing variant flexibility at reasonable costs by decoupling component production from customization activities. At the same time the MAUs imply considerable constraints for transformation
of the current activity structure. They represent large investments and determine, to a large extent, what future changes of the structure that are economically feasible. In this way the MAUs are similar to all other investments—either they represent physical or organizational adaptations. Adaptations among firms are normally undertaken in order to increase the flexibility in the joint operations of the two companies. At the same time they induce rigidity by reducing the individual firm’s flexibility when it comes to changes of business partner. Therefore, customization with respect to offering a huge range of product variants at reasonable cost and lead-time is dependent on a complex interplay between flexibility and rigidity in different dimensions. The outcomes of the individual firm’s efforts in this interplay are strongly contingent on its cooperation with actors on its demand and supply sides.

References


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