Mass customisation – an automotive perspective

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Abstract

Increasingly automotive manufacturers are aiming for mass customisation, providing such a variety of products that nearly everyone can find what they want. More product variety is causing escalating costs and complexity in manufacturing. It is not clear how the manufacturing system engendered by lean production will respond to this challenge. Manufacturers are experimenting with models of the assembly and supply chain as a cost-effective solution for customisation increased is yet to emerge. These models represent a continuum of supplier involvement in the assembly process, as manufacturers seek to establish the optimum balance between cost reduction, retention of control and devolution of responsibility to the supply chain. The authors argue that an effective approach must be developed to support decisions on initiatives aimed at promoting customisation and preventing escalating costs and complexity in manufacturing. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

In the past two decades, vehicle manufacturers (VM) have forged strategic alliances to develop core competencies and penetrate new markets. Western VM have achieved a parity of performance with their Japanese competitors in manufacturing and vehicle development. Similarly, Japanese VM have established facilities to transplant their lean production (LP) and vehicle development processes in the US and Europe. Those VM who have best exploited these alliances are consolidating their position in the global market, and seeking opportunities to extend their global enterprise. This may be at the expense of less successful VM, who are subject to acquisition by their powerful competitors.

The parity of performance in core processes is forcing VM to seek competitive advantage not simply by following the lean principles that everyone will know and be implementing, but by defining other domains of competition, as Cusumano suggests [1]. VM must aim for mass customisation – providing such variety that nearly everyone can find what they want at a price they can afford [2]. This paper discusses mass customisation, and its application in the automotive industry. Mass customisation emerged as manufacturers, enabled by their proficient LP systems, explored ways to better meet the needs of customers. Approaches for mass customisation are reviewed to identify three distinct strategies for the automotive industry — core, optional and form customisation. The authors suggest
that the demands for cost-effective high volume manufacturing will force a focus on optional customisation.

Strategic responses to extend market coverage are discussed, and design initiatives enabling VM to expand the range of products offered to customers are explored. The authors argue that while these strategic and design initiatives are well developed, it is not clear how the model of vehicle manufacturing engendered by LP will meet the challenge of mass customisation. VM are experimenting with models of the assembly and supply chain to counter escalating costs and complexity in manufacturing. These models can be seen as a continuum of supplier involvement in the assembly process. Each model represents an attempt by the VM to find an optimum balance between total manufacturing costs, the retention of control of the supply chain, and the devolution of risk and responsibility to suppliers. As supplier involvement with the assembly process increases, some of the issues constraining mass customisation can be removed or their effects reduced.

2. Strategies of customisation

2.1. Mass customisation

Manufacturers responded to fierce competition with shorter product life cycles and quicker delivery of new products to the market. With product development times only one-third of their competitors and needing only a fraction of the resources, time-based manufacturers were able to deliver new products much quicker to the market [3]. This enabled quick response to changing market preferences, and the continuous introduction of innovative technology. Time-based manufacturers were able to continually introduce new products with more features, increasing the variety offered to customers. From the success of time-based competition emerged a new paradigm – mass customisation.

Mass customisers develop, produce, market and distribute goods and services with such variety that nearly everyone finds exactly what they want at a price they can afford [2]. Manufacturers must look beyond the provision of standard products at low cost, to better meet the needs and desires of customers. Customer purchasing decisions are based on a complicated set of interacting factors. With low cost, high quality and quick delivery simply qualifiers in the purchasing process, manufacturers must personalise products to meet customer needs and stimulate market demand [4].

2.2. Integrating the customer

The extent to which customisation strategies impact the value chain, indeed the extent to which mass customisation is embraced by the manufacturer, depends upon the ability of the customer to change the product and the point in the value chain at which these changes occur. Manufacturers may choose to proliferate the market with variety, in effect pushing the variety into the market and anticipating the demands of the customer. While the customer can choose from a mass of products, there is no integration into the manufacturing and design processes, and the customer is unable to alter the product in any way. In contrast, the customer may be involved with the conception of the product, working with the product designers to determine the design and features of the product to best meet their needs.

The ability of the customer to change the product, and the point at which these changes occur in the value chain is described by Lampel and Mintzberg with their continuum of strategies model [5]. The value chain is described as a series of four processes – design, fabrication, assembly and distribution. Standardisation of all processes, effectively neglecting the needs of the customer and pushing products into the market, defines the traditional mass production strategy. Four further strategies are developed as the needs of the customer are progressively integrated with each upstream process. This culminates in a strategy of pure customisation, where the customer is integrated into the design process.

The Panasonic National Bike Company is a well-documented example of pure customisation [4,6–9]. In a dedicated showroom, the customer is measured to provide the dimensions for a particular frame design. Other components are carefully
chosen to match the dimensions of the customer, and features are selected from a choice of options to the customers preferences. This specification is sent directly to the manufacturer, where flexible manufacturing systems fabricate the frame and other components to exact requirements, and assemble the remaining parts to deliver the bike to the customer in under two weeks.

This example is described by Ross as core mass customisation, in his summary of five approaches for providing customers with choice in a mass-market [6]. With the exception of core customisation, the approaches focus on the opportunities available to the manufacturer without interacting with the manufacturing or design processes. The presence of a third party between manufacturing and the customer enables standard products to be altered to the needs of the customer. The customer must interact with the third party, to convey their needs and ensure the required solution is achieved. Alternatively, manufacturers can design products that are self-customising, enabling the customer to change the product at any time to suit their own preferences. Other manufacturers are simply pushing variety into the market in the expectation that customers will find what they want. This strategy relies on a strong understanding of the needs of the market, and a close coupling of these needs to the manufacturing system, that must be able to quickly respond to fluctuating demands.

As Pine II and Gilmore describe [10], some manufacturers have realised that changing the presentation of the product creates another dimension of customisation. Combining the ability to customise products with the ability to customise presentation creates four distinct strategies. Manufacturers involved in a dialogue with the customer, to identify their needs and establish the requirements for the product, practice collaborative customisation. Both the product and its presentation are specific to the partnership created, impacting every process in the value chain – pure, core and collaborative customisation are effectively the same strategy. Adaptive customisation enables the user to customise the product to their requirements, as illustrated by Ross [6].

When a standard product meets the basic requirements of the market, the customer need not be integrated with the processes upstream of distribution in the value chain. The cosmetic customiser presents the product differently to each customer, whether through packaging or similar changes in distribution, or in the service it provides. In contrast, transparent customiser’s provide unique products or services in a standard form to each customer, without the customers knowledge that the product or service is customised. Fig. 1 compares the approaches discussed by Lampel and Mintzberg [5], Ross [6] and Pine II and Gilmore [10], showing where customisation occurs in the value chain.

2.3. Automotive customisation

Three distinct strategies for customisation can be derived for the automotive industry – form, optional and core customisation. These strategies reflect the progressive integration of the customer with the design, manufacturing and distribution processes respectively, as illustrated in Fig. 2.

Core customisation, involving the customer with the design process of the vehicle, occurs in low-volume, specialist vehicles. Where the vehicle is designed to meet a specific market requirement, there may be a limited scope for the customer to request changes that affect the core design of the product. Land Rover manufacture classic all-terrain vehicles, with optional features available to the customer to satisfy individual tastes. Beyond offering the classic vehicle, customers may contact the manufacturer to discuss their needs for specific applications and environments. The special vehicles team collaborate with the customer to provide a vehicle based on a standard Land Rover with changes to any of the core elements of the design. Similar collaborations exist between low-volume luxury car companies and their customers, as the nature of the manufacturing process enables customers to modify designs to suit individual preferences.

Core customisation is available for low-volume applications at a cost premium to the customer above that of the standard product. For mass customisation, the costs of the customised product must be comparable to the standard product. VM are providing customisation for high-volume vehicles through optional customisation. Optional
Fig. 1. Comparing approaches to mass customisation.

Fig. 2. Automotive customisation.
customisation allows the customer to choose their vehicle from a plethora of options, though the design of the vehicle may not be changed in any way. The customer is integrated into the manufacturing process as vehicles are assembled to their requirements, based on the decisions they make. This strategy differs from pushing excessive variety into the market as the VM is not predicting customer preferences. In addition to the choice of body style and colour, customers select the model of the vehicle to define the standard features, and can supplement these features with options available at a price premium.

Some features requested by the customer can be incorporated at the distributor. Either new parts are added to the vehicle or standard parts are changed to give the customer the feature they require. This is one aspect of form customisation – changing the form of the standard product at the distributor. In addition to limited changes or enhancements to the actual vehicle, form customisation includes the customisation of the terms of sale to the customer. Distributors offer a package of services that help to differentiate the vehicle from their competitors, and tailor the sale to the needs of the customer. These packages include financing options, warranty and service options, insurance and membership with recovery services.

2.4. Cost-effective customisation

The challenge for VM is to formulate an effective strategy that satisfies the needs of customers without compromising the cost, quality and delivery of the vehicle. VM must offer customers a wider choice of vehicles and features to meet their individual needs.

For most vehicles only a limited number of peripheral features can be changed at the distributor. Unless the design of the vehicle is changed, most features must be incorporated in the assembly process before delivery to the distributor. To enable more changes at the distributor would require a transformation of both the vehicle design and the assembly process, with the management of the supply chain shifting from the VM to the distributor. As vehicles become more modular in design and assembly, some of the configuration tasks to customer requirements may be transferred to the distributor. However, most of these tasks will remain in the assembly process of the VM for the foreseeable future. VM must focus on optional customisation strategies for cost-effective customisation in high-volume manufacturing.

3. Automotive industry

3.1. Acquisitions and alliances

The automotive industry is awash with rumours of mergers and acquisitions between VM, as competitors seek to establish long-term security and growth in the turbulent global market. It is difficult to establish precisely who has an interest in whom, and what outcomes are likely to emerge. Seemingly without exception, VM are considering strategic options in response to the fierce competition and disparate demands of the market.

Over the past two decades, many VM entered into strategic alliances involving the exchange, sharing or co-development of products. Though wishing to protect the core competencies from their competitors, VM formed alliances in the belief that they would gain more benefits than they would without the alliance. Often a separate entity was created, in the form of a joint venture of shared equity, where the participating VM shared the risks and rewards.

Joint ventures offered many benefits to the collaborators. VM collaborated to acquire technology, enhance process capabilities and develop product competencies. From this perspective, joint ventures were seen as a mechanism for gaining access to the resources and competencies that were embedded in other organisations [11]. General Motors’ collaboration with the Toyota Motor Company in the NUMMI venture enabled the former to learn the techniques that established Toyota as the global benchmark for LP. As Hamel et al. [12] describe, these joint ventures provided shortcuts for western producers racing to improve their production efficiency and quality control.

From a market perspective, alliances enabled VM to significantly reduce the costs and risks of penetrating a strategic market sector, essential for
manufacturers to successfully compete globally. From a study of Japanese joint ventures in the US, Hennart and Reedy [11] suggest Japanese manufacturers tended to form joint ventures with partners with a strong presence in a targeted region, as a privileged way to enter the market. Entering the NUMMI partnership enabled Toyota to develop its market share, while testing the feasibility of transferring the Toyota Lean Production System to the US.

The high costs of developing new models forced many VM to consider alliances to penetrate sectors of the market characterised by low volume, high risk and potentially high profit. Sharing product development and investment costs in manufacturing enabled participants to extend their coverage of the market to niches that otherwise were financially unfeasible. These collaborations were clear to the customer, with models differentiated by brand recognition only.

However, collaboration failures are evident in the automotive industry. In contrast to its success with Toyota, General Motors has seen its partnerships with the Daewoo Corporation and Isuzu Motors deteriorate, and similarly Chrysler has experienced failure in ventures with Mitsubishi Motors and Maserati [13]. Bleeke and Ernst [14] suggest that participants do not evaluate the impact of the collaboration on future performance, and may enter the alliance with perceptions that can be self destructive. For example, entering into an alliance with a much stronger partner to improve core skills is particularly dangerous. Studies have shown that where collaborators compete directly, the weaker partner fails to improve its capabilities and consequently is acquired by the stronger partner [14].

Concerned that competitors will exploit the opportunities to transfer competencies and knowledge beyond the intended scope of the collaboration, manufacturers erect barriers preventing the real benefits of the collaboration to emerge [13]. Hamel et al. [12] suggest the diffusion of such skills and knowledge is a core element of the learning opportunities for the partners, and can prove mutually beneficial if partners believe they can learn while limiting access to their particular proprietary skills.

The danger of knowledge transfer to competitors is forcing many VM to evaluate their strategic alliances. Those who have exploited their collaborations are consolidating their position in the global market, and are seeking opportunities to extend market coverage and extend capabilities through strategic acquisitions and mergers. Many experts suggest there may be as few as six truly global VM emerge over the next decade as manufacturers consider acquisitions or enter mergers. Those that have failed to establish manufacturing and development facilities in target markets are exposed to acquisition by the global VM, or must face operating in a constrained sector of the market. Similarly, niche manufacturers with desirable brands are subject to acquisition as the global VM use their marketing and distribution competencies to lever increased value from the brand.

3.2. Designing variety

As VM consider strategic acquisitions, many other initiatives are enabling manufacturers to expand the range of products offered to customers to respond to fierce competition and satisfy market demands. These can be considered design strategies to manage escalating complexity. Computer aided engineering is transforming the vehicle design and development process. The desire to provide customers with extensive choice is creating masses of data, requiring better systems to cope with this increasing complexity. Product data management (PDM) systems have emerged to bring this data under control, and support concurrent engineering activities to reduce time to market and development costs for new products [15]. As manufacturers search to combine resources and expertise effectively at disparate locations, PDM systems are enabling design teams to integrate, manage and simultaneously access common data, and ensure conformance to the requirements of diverse markets.

These systems are the foundation of the drive among many VM to reduce their number of global vehicle platforms. By creating common platforms, manufacturers are able to reduce investment in body fabrication processes that account for a significant proportion of new vehicle costs. Sharing the same understructure, designers can change exterior
styling at relatively low cost to suit preferences in regional markets. As designers focus on creating more derivatives for each platform, the VM delivers wider choice to the market while maintaining scale economies in core body fabrication. The Ford Puma, based on the Fiesta platform, delivered to market in 17 months from concept to production illustrates how derivatives for profitable niche markets can be rapidly produced from a high-volume vehicle.

As common platforms enable many models to be produced from a core design, modularity enables standard parts to be combined in numerous ways to increase the end variety of the product. Parts designed for ease of assembly onto a core module can be rapidly configured to suit specific requirements. In this context, modularity is a solution to the growing complexity in assembly processes [16]. VM are dictating that system suppliers deliver large modules to reduce and simplify the number of tasks in the assembly process [17]. Suppliers that traditionally delivered to the VM are now supplying the powerful system suppliers that have emerged from the on-going consolidation of the supply base, radically transforming the traditional relationships in the supply chain.

VM are examining their relationships with suppliers, and where appropriate are developing outsourcing alliances that involve suppliers in design and development. As Kamath and Liker describe [17], supply partners possess superior capabilities and knowledge to the extent that they suggest solutions to the VM to meet the requirements for the design and delivery of complex modules. Similarly, mature suppliers deliver complex modules, though have seemingly inferior capabilities to the VM and subsequently less influence on design.

3.3. Manufacturing challenges

More variety and customisation implies increased manufacturing costs, and is by no means a guarantee to better satisfying customer needs and desires. This is the situation facing many of the VM. The desire to offer customers numerous choices of appearance, performance, comfort, safety and security is at the expense of escalating complexity and cost in assembly and the supply chain.

While strategic and design initiatives to increase market coverage and product variety are well developed, the response of the manufacturing system is very much experimental. Virtually without exception, VM have recognised that applying LP techniques to the assembly process enables high product conformance at competitive cost for high-volume, low-variety manufacturing. These techniques have been diffused by the VM to the supply chain, with substantial benefits to part quality and cost. However, implementing LP does not ensure a successful manufacturing system. Internal and external issues that constrain performance, emanating from strategic decisions beyond the direct influence of manufacturing, may not be resolved by implementing these techniques in isolation.

It is not clear how the assembly and supply chain model engendered by LP will meet the challenges of mass customisation. In their domestic market, Japanese manufacturers flooded the market with prolific variety to the extent that this differentiation failed to create any sustainable advantage over like-minded competitors [18]. Conflicting with mass customisation, this variety escalated manufacturing costs and stressed suppliers. Exceptional orders were placed so frequently that manufacturing batch quantities became too small and deliveries too frequent even for their proficient LP systems. Manufacturers were forced to explore ways to modify or moderate their LP approaches at the expense of manufacturing efficiency [1].

3.4. Assembly and the supply chain

VM are experimenting with alternative models of assembly and the supply chain as a definitive cost-effective means of mass customisation is yet to emerge. The responses of the VM can be seen to represent a continuum of supplier involvement in the assembly process, represented in Fig. 3. Remote suppliers are uncoupled from the assembly process by large stocks in the supply pipeline and at the VM facilities. Stock shortages emanating from uncertainty of demand and delivery cause costly emergency deliveries of parts and unless managed effectively can continue to cause fluctuating demand to the supplier. In response, many remote or dispersed suppliers have located facilities close to
the VM to guarantee just-in-time deliveries and absorb fluctuating demand by maintaining sufficient stocks. The local proximity of these facilities enables rapid replenishment of stocks coupled to the actual flow of orders in the assembly process.

The devolution of assembly tasks from the VM to selected system suppliers dictates the supply of complex parts to synchronously match the flow of orders in the assembly process. System suppliers locate facilities adjacent to and often linked to the VM, assembling the complex parts when the actual flow of orders is known, and delivering just-in-time and in order sequence to the point of fit in assembly. Modular consortia extend the involvement of the system suppliers as they locate within the VM facilities to manage the assembly of their module directly into the vehicle. In a unique consortium of co-dependence, as Collins et al. [19] describe the supplier assumes responsibility for modular assembly, the final module assembly into the vehicle, an investment stake in the operation and the management of the module supply chain.

Each model represents an attempt by the VM to find an optimum balance between total manufacturing costs, the retention of control of the supply chain, and the devolution of risk and responsibility to suppliers. The involvement of suppliers in the assembly process must develop concurrently with the devolution of design responsibility from the VM – the supply of complex modules dictates integration with the vehicle assembly process. As VM realise the initial cost benefits of outsourcing assembly activities, suppliers must learn to manage a larger and more diverse supply chain to ensure total manufacturing costs do not escalate. However, VM must understand that the increasing involvement of suppliers is at the risk of losing core competencies and the favourable balance of power with suppliers.

4. Constraining customisation

4.1. Constraints

A study of the assembly operations of a global VM identifies issues in the manufacturing system that impact the implementation of an effective optional customisation strategy, as shown in Fig. 4. Many of these issues are imposed by strategic decisions beyond the direct influence of manufacturing.

The supply chain is not characterised by any single model of supply – the VM uses remote, dispersed, local and system supply models. Cost reduction initiatives are stressing suppliers to
deliver to tight just-in-time schedules and reduce the stocks in the supply pipeline. Marketing initiatives are aiming to significantly reduce the order fulfilment time, creating uncertain and fluctuating schedules for manufacturing. This uncertainty dictates sufficient stocks to accommodate the changes in demand, conflicting with the cost reduction aims. The result is shortage of parts, causing transient schedules and reactive actions to ensure output volume from assembly is maintained at all times.

For greenfield facilities, VM can eliminate or significantly reduce the effect of issues in supply and logistics by requiring suppliers to locate locally. When developing their transplant facilities in the US, Toyota ensured suppliers located nearby to replicate the excellent performance of their domestic Toyota Production System [20]. Similarly, installing new technology improves processing capabilities, producing a wider variety of products with increased conformance to reduce the effect of issues in fabrication and assembly.

4.2. Capabilities

Capabilities of mass customisers are shown in Fig. 5. Often these capabilities can only be realised through the elimination of a combination of the causes of issues shown in Fig. 4. The co-dependence of issues means that VM will not realise a specific capability by removing an issue in isolation. Many issues can be removed or effects reduced for greenfield facilities, enabling VM to lever maximum value from modular designs and the devolution of responsibility to suppliers. To reduce the effect of
Fig. 5. Capabilities for mass customisation.

− Effective IT planning and logistics system
− Real-time visibility of demand throughout supply chain
− Adaptive planning enabling late changes to schedules
− Leveled and balanced schedules
− Visual factory techniques
− Mixed-platform and mixed-model processes
− Modular, cellular processes
− Highly skilled and empowered employees
− Responsive supply chain
− Integrated assembly with supply partners
− Just-in-time logistics
− “Total cost of supply” management
− Concurrent engineering enabled by PDM systems
− Modularity and redundancy
− Standardisation of parts across platforms and models
− Ease of manufacturability and assembly

Fig. 6. Decision support system.

Understand Relationships & Co-dependence of Issues
Inform Decisions to Achieve Capabilities
these issues for brownfield facilities requires the continuous effort of focused teams, or the installation of new technology and processes with the introduction of a new vehicle programme. However, many of the issues remain due to constraints imposed by the previous facility, technology or work practices.

The authors believe that an effective approach for quantifying the value of removing issues must be developed to support decisions on initiatives aimed at promoting customisation and preventing escalating costs in the manufacturing system, refer to Fig. 6. This approach must identify the interactions between the assembly process and its supporting supply chain, to understand the relationships that drive performance and cost, and inform investment decisions on process and technology management.

5. Conclusion

VM in the developed world are faced with saturated home markets and sophisticated customers. Nevertheless the markets are so large that they remain attractive to emerging competitors from developing countries, typically entering the market with low price and relatively unsophisticated products. The established manufacturers seek to protect their margins by offering sophisticated products tailored to individual customer demands. This move to mass customisation creates conflict in the manufacturing system that has been optimised for high conformance, low cost, LP with relatively low variety.

This paper has argued that VM can pursue an optional customisation approach to realise mass customisation. To sustain the provision of high variety tailored to customer needs, manufacturers must seek cost-effective capabilities to counter increasing costs and manage growing complexity. It is unclear how the manufacturing system engendered by LP will meet the challenge of mass customisation. Manufacturers are experimenting with increased supplier involvement in the assembly process as they find a balance between cost management and the devolution of risk and responsibility to the supply chain. As VM push the boundaries of the traditional manufacturer–supplier relationship with co-dependent consortia, the success and implications of these models will begin to emerge. Where they are successful, these supply chain models will be extended globally.

VM that have exploited alliances in product development and manufacturing, and established a strong presence in target markets are consolidating and seeking to expand their position in the global market. Smaller manufacturers must accept a more restricted sector of the market in this intense competition, or face acquisition as their global competitors seek to complement existing market coverage and lever increased value from their brand, market position and unique competencies. As manufacturers extend market coverage through acquisitions and mergers, global platforms and modular design initiatives are increasing the choice of models and features offered to customers. This increasing variety is at the expense of escalating costs and complexity in the manufacturing system.

Existing facility layouts, installed technology and established work practices constrain the realisation of manufacturing capabilities for increased customisation. Furthermore, these capabilities cannot be realised by removing existing issues in isolation. This paper has identified the need to understand the relationships in assembly and its supporting supply chain, and to develop an effective approach to inform investment decisions in technology and process management, to create an optimum system for mass customisation.

References


