MASS CUSTOMIZATION IN THE AUTOMOTIVE INDUSTRY – NEED FOR NEW SOLUTIONS

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ABSTRACT

In today's economies, customer-driven markets experience high demand fluctuations, turbulence of which is often amplified by arrival of new products and new technologies. To stay competitive under these conditions automotive original equipment manufacturers (OEM) companies need smart technical solutions for product development and quick adjustment of production capacities and functionalities.

For most of the past century automotive industry has followed a single paradigm – mass production – established by Henry Ford on the foundations of scientific management principles developed by Frederick Taylor. The mass production paradigm, even with productivity improvements cannot competitively sustain the auto industry. A glaring example is the American auto industry, where manufacturing processes have become super-efficient (e.g., low labor hours per vehicle), while other parts of value-creation are neglected. As a result, customers have been alienated by being forced to make compromised choices from a limited number of products which do not satisfy their specific needs.

This paper argues for the importance of the customization approach for the future of auto industry. It reviews current mismatch/discontinuity in the automotive business model by pointing out the inefficiencies and inflexibilities of the current value chain.

KEYWORDS

Automotive, business model, build-to-order, customization.

1. INTRODUCTION

Automotive industry worldwide is experiencing a variety of competitive pressures which in the long term will lead to its complete transformation. In the short term, however, these factors are causing a number of painful transitions, most visible in particular in the automotive North American sector [15].

For the past 100 years automotive industry has been a solid foundation of prosperity in many mature economies. On one hand the auto industry has splendidly responded to the ever growing societal needs for individual mobility by delivering its products – automobiles. On the other – the use of these products has profoundly transformed societies by providing universal access to basic means of personal transportation. Automotive jobs, similarly to manufacturing jobs in general, have a big economic leverage: each job in automotive companies is connected on the average to 7 corresponding jobs in the supporting industries.

Current difficulties in the auto sector are attributable to many factors, including globalization, saturation of the mature markets, and commodization of automobiles, to mention just a few. According to most recent predictions, number of cars on a global scale in use will reach 1 billion sometime before the year 2020. Today one statistical car falls for approximately 8 people (by 2020 it should be one per 6½ people) – these cars, however, are not evenly distributed. While car density is highest in the countries with advanced economies and corresponding infrastructures (approx. 500-600 cars per 1,000 people), in the poorest developing countries cars are much more scarce (in extreme cases below 1 car per 1,000 people). In the developed countries continuing infusion of new automobiles is causing visible market saturation; at the same time countries from the low end of the spectrum are striving to get more of them and expand necessary infrastructures.

Automotive industry on the global scale exhibits most of the characteristics of mature industries, and consequently follows their business cycles. While demand for cars remains strong, it shows definite signs of slowdown (see Fig. 1) [19]. This exacerbates impact of some existing issues, such as global excess of production capacity, continuing industry consolidation, and strained relationships with suppliers and dealers.

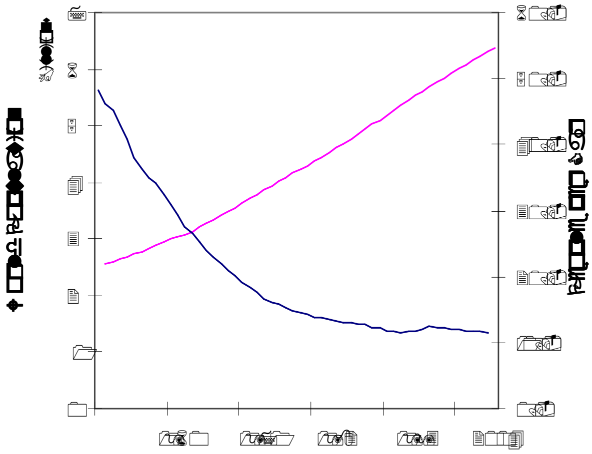

Figure 1. Global population compared with global people per car statistic 1950-2004 [19]

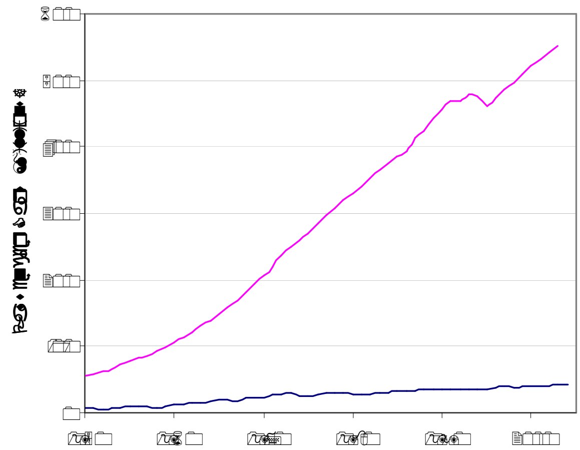

Figure 2. Global passenger car fleet compared with global production of new vehicles, 1950-2004 [19]

2. NOT ONLY NEW CARS

Traditionally, the main focus in the auto industry has been on the introduction of new products to the market. That is where most of the publicity, media, and consumer attention concentrates. Not surprisingly, though, failure of automotive companies is often blamed on the unsatisfying lineups of product offerings. Consequently, a lot of auto strategies also revolve around addressing specific market needs, understand market segmentation, and identification and targeting of specific customer needs.

Thus it is easy to overlook a simple fact that while all current (2002 data) car production levels amount globally to 57 millions (will grow to 76 millions by 2020) [8], the actual majority of cars on the road will be older vehicles, most likely not driven by their original, first owner. The existence of the used car market has been undeservedly ignored, especially when one considers individual customer perspective (Fig. 3). What effectively matters for an individual consumer is not only the moment of acquisition, but the life-long use experience. Thus it is important to review the content of that experience from various angles. One of them, most commonly considered, is the total cost of ownership (TCO). TCO is a financial estimate designed to help consumers (and enterprise managers) assess direct and indirect costs related to the purchase of any capital investment. In the automotive context, TCO denotes the cost of owning a vehicle from the purchase, through its maintenance, and finally its sale as a used car. Comparative TCO analysis between various models help consumers choose a car to fit their needs and budget.

TCO is an important, but unexplored metric. Given the continuously shrinking vehicle content provided by OEMs, proper exploration of TCO components may effectively bring new sources of revenue or the enterprise.

Most consumers, as well as businesses fail to understand and properly calculate the TCO and instead rely on TCA (Total Cost of Acquisition) to make buying decisions. TCO often differs dramatically from TCA, although TCO is far more relevant in determining the viability of any capital investment, especially with modern credit markets and financing. TCO also directly relates to a business's total profitability.

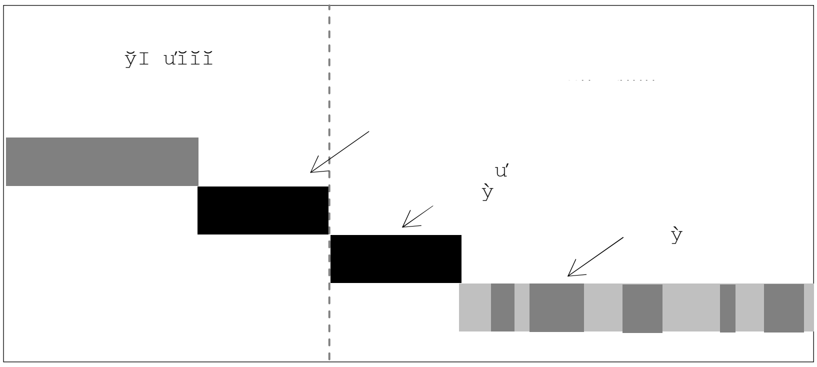

Figure 3. Example Total Cost of Ownership (TCO) breakdown over vehicle lifecycle (10 yrs/100,000 mi)

3. AUTOMOBILE CUSTOMIZATION

Concept of the core customization is not new in the auto industry and was exercised by the car enthusiasts for as long as volume-manufactured cars are available. Automobile customization refers to car modifications in terms of either visual appearance or performance. Initially, the custom cars were made from the old “junker” cars by creating a combination of most powerful engines available (that would fit into existing engine compartment) with the lightest frame and body set. These cars were a result of a labor of love, and their transformation process, while delivering striking and unique results, was also extremely time consuming and costly.

A very specific fan culture has developed surrounding these cars; they often were (and still are) also an inspiration for car designers of the day. With eventual proliferation of high performance cars which became commercially available, customization has declined. Increasingly, due in part to the growing complexity of the engine and transmission technology, customization efforts have been reduced in recent years to appearance modifications.

A unique market serving these appearance modification needs has appeared, offering body kits – a collection of exterior modifications, typically consisting of bumpers, fenders, side skirts and spoilers. While originally body kits were offered by specialized aftermarket kit manufacturers (represented by Special Equipment Manufacturers Association, SEMA) and needed to be applied in specialized body shops, factory fitted body kits are becoming more common due to OEMs interest in growing their market reach.

The automotive specialty equipment industry originally relied on racing and performance products. In the early days of the industry, home-grown inventors created solutions to make cars go faster. As their innovations proved successful, they were proliferated among friends and competitor’s vehicles. In no time these home-grown inventors found themselves in business. The story has repeated itself again and again and in the process spawned some of the biggest names in the industry today. The specialty equipment market breaks down into three major segments:

- Accessories and Appearance 57%
- Racing and Performance 19%
- Wheels, Tires, and Suspension 24%

According to SEMA, the most surprising and yet most important factor driving growth of the accessories industry is the “soccer Mom.” It’s a label used to identify parents who use their vehicles to support and transport young athletes in a wide range of sports, not just soccer. The primary household vehicle (SUV, minivan etc.) makes any such task easier and does a better job when modified for the particular situation. Whatever equipment (for sports, music, construction, etc.) the car is hauling, it can be customized to do a better job.

Personal transportation is very important to Americans and as they find out that there are acceptable changes that can be made to their vehicles that make life easier, more productive or just more fun, they are willing to invest in automotive specialty equipment products. This trend is also in line with a general product convergence process, best seen perhaps in electronic industry due to miniaturization, where functions of multiple, independent products, due to breakthroughs in technology, are being merged into one, multi-functional combination. Thus automobiles are being increasingly equipped with a variety of products, initially in the form of add-on enhancements, which then become almost an integral part of the car interior. Industry studies estimate that 10-15% vehicle owners purchase accessories for their car or truck. Those truck drivers who accessorize, spend on average $1,500 per vehicle, and 80% of that amount is spent after the initial purchase. Accessories most frequently acquired by the truck owners are shown in Fig. 4. A few, less frequently encountered car additions are shown in Fig. 5.

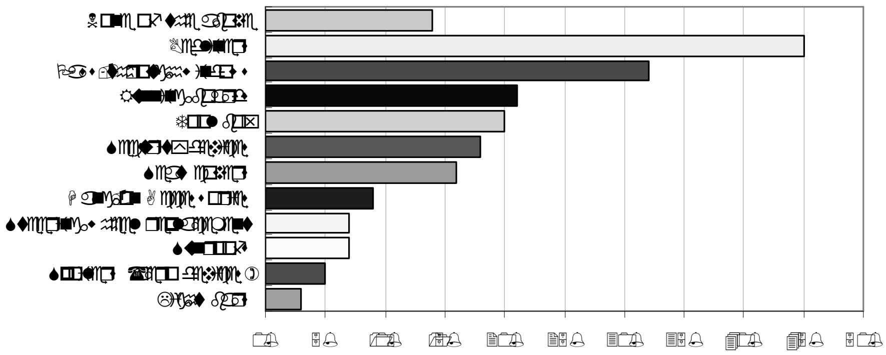

Figure 4. Breakdown of aftermarket accessories in pickup trucks

Figure 5 Examples of automobile interior enhancements: a) laundry appliances (Ford), b) pizza oven (RoadPro), c) tailgate grill, and d) dog space (Honda)

As the time spent by individuals in their automobiles grows, more of these enhancements are expected to appear on the market, along with the growing amount of time spent in the automobile. Cars always could offer a retreat from the outside world, but long commutes are increasing some consumers' desire for an increased level of comfort and convenience. That means a growing demand for the built-in comforts equivalent to those available at home.

A lot of these enhancements installed in the car interior are competing for the car driver and the passengers attention, thus creating an increasing number of distractions. To counter these negative effects cars are now increasingly being equipped with variety of safety enhancements, although not always to the best effects.

4. COMPLEXITY OF AUTOMOTIVE PRODUCTS

Today's cars are very complex and technologically advanced products. According to the Motor & Equipment Manufacturers Association (MEMA) it takes approximately 3,800 different components (identified by unique part numbers) to build an average car. Many components, however, are used in multiplicities (e.g., car has five tires), thus it takes nearly 35,000 separate items to build each car.

High complexity of the automobile products and the market pressure to reduce delivery times and costs is making the OEMs to turn in search for a variety of modular strategies.

Increasingly, vehicle contents is either electronic or software-based in nature. As such, unfortunately, it can bring 6 to 7 times more faults than normal mechanical parts. Initially all this technology outstripped the knowledge of the vast majority of service technicians.

Software controls now everything from radio tuning to the fuel injection. More advanced technologies found in luxury cars, such as assisted parking or emergency braking also rely on advanced computing. Over the past 40 years car software has grown from the primitive 100 lines of code to a sophisticated 1 million lines, and is expected to grow to 100 million by the year 2010.

Unfortunately, software technology is not something that traditional OEMs are comfortable with, even though over 60% of new development efforts are invested in software. There are a number of issues related to that, such as, for example:

- Electronics is continuously evolving
- Carmakers have not built up expertise in electronics and software development
- Most of the on-board car systems are created ad-hoc, what makes them impossible to test properly
- Increasing electronic content give more control/ownership of the vehicle to the suppliers

5. CUSTOMIZATION AND MANUFACTURING

Over the past two centuries fulfillment of customer needs has turned full circle, i.e., from originally focusing on the (wealthy) individual, to focusing on the product (and cost-effective manufacturing), and now back again focusing on the individual customer in the Mass Customization paradigm and, to an even greater extent, in the Personalized-Production paradigm [16, 18].

The role of a customer role in relationship with product/service manufacturers/providers changes with each paradigm shift. In Mass Production customer role is reduced only to making choice from the (very limited) manufacturer's offerings and no opportunity to provide feedback; products are driven primarily by production efficiency (which works best with no product variation).

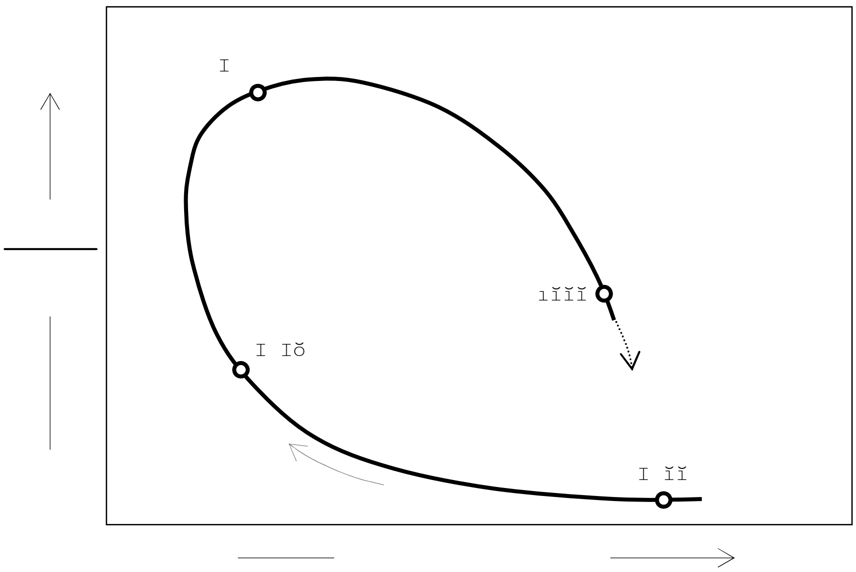

Figure 6. Evolution of manufacturing paradigms (volume vs. variety)

In Mass Customization, the manufacturer has to make the strategic decisions about the product basic architecture (e.g., a "platform" in the auto industry) as well as the number of variations and options. The customer can only select the option that best fits his/her preferences and price. The Personalized Production paradigm has a more complex decision and interaction sequence, and in fact converges almost to that of Craft Production, as shown in Figure 6.

Even though the goal of both the Mass Customization and Personalized Production is to create a better fit between product offering and customer's preferences by producing "build-to-order" products, the strategic decisions by the manufacturer differ significantly. In Mass Customization, the strategic economic decision that the manufacturer has to make is the number of variations and options. On one hand the increased number of product variations adds complexity and cost; but on the other it also increases the size of the market (number of potential product buyers). In Personalized Production, however, the typical product has a modular architecture, and the manufacturer's decision is focused on the number of product modules from which the customers can select their preferences and their structure. Both of these decisions depend on the product basic architecture that allows economic product configurability. The Personalized Production provides the enhanced involvement of the customer, when the level of involvement and product price are traded. Eventually it also leads towards the reverse flow of ideas about the products (from customers to manufacturers) in what is called "democratized innovation."

A typical model of the Mass Customization in automotive industry area is based on the "option package" [1, 2] For example, once the initial auto manufacturing market leveled off from its extreme supply-driven mode, designers began looking for ways to offer products that were different from the norm but not so different as to significantly alter their costs or their manufacturing schemes. Car makers started offering sets or "packages" of options to appeal to various niche markets. They maintained the "standard" option of a fully functional vehicle, but in addition also offered a "sports model" and typically, a "luxury" edition as well. The sports model may offer a more powerful engine, different transmission, tires, wheels, seats, and a distinctive paint scheme. But from the manufacturer's point of view, the sports model (even though its target customer is young, single professional) is still largely the same car as was originally designed for a family of four. The luxury edition attends more to comfort features which in the past included heating and air conditioning, but also aesthetic improvements such as furniture wood and metal finished interiors, better sound dampened interiors and powered controls. The marketing of option packages which remains a business model in use today, focuses more on the unique features being offered; and these features may or may not actually add significant cost to the end product. Options packages do add to a manufacturer's menu of offerings enabling them to reach markets otherwise unaccessible without creating a whole new vehicle program. And, through the option package model, manufacturers are able to sell the packages at much higher markups to customers who want and are willing to pay for the novelty of those unique features.

In the option package model of the automotive Mass Customization, many options are designed and available, but only the product with the set of options which was ordered is eventually made. While from the product design point of view this is still a push-type business model, from the manufacturing perspective, it is a pull-type model (i.e., built-to-order). The combined design and manufacturing aspects thus create a push-pull type business model.

Offering a range of options was a significant step up in the marketing of products, but at this stage the option packages are just pre-defined bundles of options. In reality the customer has only a limited number of choices. A customer cannot choose features from one package and mix them with features of other packages because it would cause significant strain on the marketing, distribution, and manufacturing systems that provide them. Most manufacturers cannot (or chose not to) try to accommodate the buyer's desire for more choices since doing so increases the complexity of their operations and reduces their profit on the end product.

For example, at the Mercedes Car Group of DaimlerChrysler customers can order their customized cars according to built-to-order principle. High levels of available variety are appreciated by customers, but lead to high process complexity. As a result, in statistical terms, only two out of 500,000 vehicles built in one of the DCX plants each year are identical. For a C-class sedan, customer can have multiple selections of:

Engines:	9
Steering system:	2
Transmission:	3
Country variants:	3

which results in basic 96 production variants. Additionally, one can also choose from 80 options, 14 exterior paint colors, 5 interior colors, and 3 types of fabric. All this leads to 6,635 thousand trillion possible combinations just for a single model! On top of these possibilities, customer still have an opportunity to make changes in his order up to 7 days before the beginning of production of a chosen vehicle. All this flexibility places an extreme burden on the logistics and operation of manufacturing plant [11].

One of the basic differences between the paradigms of Mass Customization and Personalized Production can be observed in their respective output products. In Mass Customization there will be similar products in the market. With Personalized Production, on the other hand, almost every product is one-of-a-kind, because the customer is involved in his/her product design. The modular product design methodology found in the Personalized Production paradigm enables its low-cost advantages.

6. GLOBAL POTENTIAL OF AUTOMOTIVE CUSTOMIZATION

Automotive OEMs have long recognized that for production efficiency, satisfactory product variation flexibility, and control of new product development costs they have to base their designs on modular product architectures. Manufacturers are striving to optimize the number of variants derived from a limited number of basic platforms. The balancing act requires them to decide whether a limited platform strategy can deliver product differentiation while retaining the benefits of economies of scale. However, moving it too far into cost-cutting territory may backfire: customers sometimes perceive that too much modularity and components sharing yields too indistibguishable products. Hence the development of many “global” product vehicle platforms, which can be appropriately tailored to specific needs of local markets. However, these modular solutions are slow in coming and not overly successful, primarily because three major elements have to be effectively meshed together:

- Vehicle architecture
- Interfaces
- Manufacturing systems.

An example of commonly defined architectural subsystems in passenger vehicles is shown in Fig. ??? In general, components comprising the vehicle architecture, while essential from the functional point of view, are in practice transparent (e.g., invisible, but expected as granted) to the customer and do not affect the customer’s primary decision process while purchasing it.

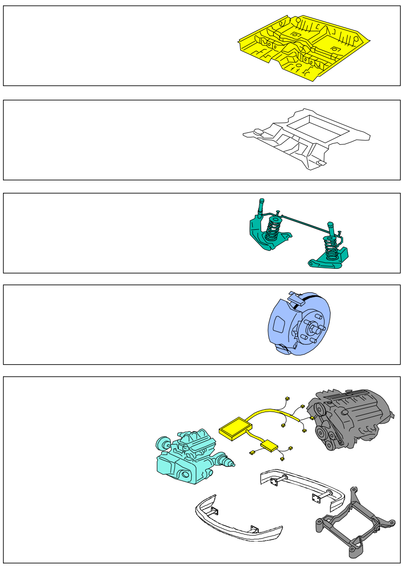

Figure 7 Elements of vehicular architectural framework (GM)

While the physical product architecture can be relatively straightforwardly defined, major issues appear in defining necessary interfaces, which are particularly acute when it comes to the electronic contents of the car. These issues (in particular unanticipated interactions between car modules and its software) have become so complex, that finally industry is taking an adopting the concepts of open architecture (AUTOSAR consortium) to enforce some implementation standards and hopefully reduce product complexity. Increased electronic contents in the vehicles is also setting much higher demand for power, so corresponding power electronic systems (e.g., 42 V power supply standard) also have to be put in place.

The equally important issue in vehicle production is development of corresponding manufacturing system. Vehicle manufacturing, however, is no longer a matter of a single, vertically integrated OEM. Increasingly, OEMs are taking on a role of final assemblers or system integrators. Therefore manufacturing systems are in fact vast, global supply networks providing necessary components for the final assembly in time-coordinated fashion. Traditional manufacturing facilities still exist, but have to be much more responsive to product changes and demand variations. New concepts, such as reconfigurable manufacturing are being developed, but it may take some time before they are fully accepted and effectively used in industry. The trend towards outsourcing and increasing role of the suppliers will continue. According to [8] over the next 10 years OEMS will shed most of the activities formerly considered as their “core” business (see Fig. 7), such as powertrain and body manufacturing.

The proliferation of internet with the vast trove of information resources on one hand, and success of companies such as Dell or Amazon on the other, has profoundly transformed the consumer culture. Consumers today are much more educated about their possible choices, are used to instant access to information and are using it effectively. This has created customer expectations that also affect auto industry. One significant element of the vehicle acquisition procedure can be also shared globally, primarily due to the ubiquity of the information technologies. That element is the process of customization/personalization of the vehicle to be purchased. An example of such process is shown in Fig. 9. Many alternative solutions have been proposed and are under development [6, 7, 10, 17].

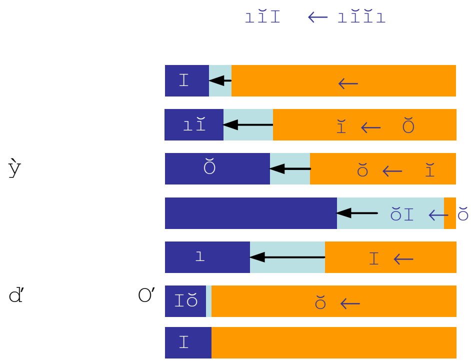

Figure 8. Trend towards collaborative vehicle production: transfer of manufacturing responsibilities from OEMs to suppliers [8]

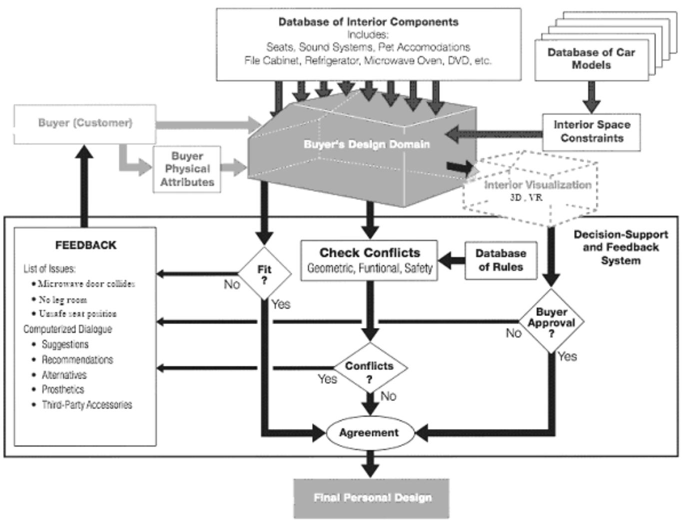

Figure 6 Block diagram of a customized vehicle selection process

7. NEED FOR A NEW BUSINESS MODEL

Improvements in the vehicle design (Design-for-X, DfX: manufacturing, assembly, etc.) and in the manufacturing processes (through lean manufacturing and similar initiatives) had significant impact on productivity and today most leading OEMs spend similar, low number of hours of total labor per vehicle (that includes assembly, stamping, and powertrain operations). For example, General Motors reaches 34.33 hrs/vehicle, DaimlerChrysler – 35.85, and Ford – 36.98. Similarly, assembly productivity is equally high: 23.09 hrs/vehicle at GM, 24.48 hrs at Ford, and 25.17 DaimlerChrysler [12]. For comparison, Toyota, which is an industry benchmark achieves 27.9 hrs per vehicle overall, and 19.46 hrs in assembly. These productivity results are quite remarkable, but most of their impact is eventually lost as the produced cars tend to sit on the dealers lots for 30-80 days waiting for an interested customer. Sometimes backlog of these unsold vehicles is even higher, but OEMs are logging the vehicles as "sold" as soon as they are moved to the dealer inventory.

Obviously this is not an effective business model. Under the current circumstances manufacturing processes have become super-efficient, but the other parts of the value-creation process in auto companies has been neglected and is causing a rupture. OEMs are disconnected from the customer and in the long run cannot sustainably run such a broken business model.

As a fix to these woes, a build-to-order process has been proposed [13]. The authors argue that "as we enter the second automotive century, the winners will not be those firms that search for larger and larger scale, or those that run efficient factories, or those that squeeze the last drop of profitability from their suppliers. The winners will be those that build products as if customers matter." Their prescription, however is still highly technical and relies on effective control of a complex supply chain system. Similar argumentation is also presented in [14].

However, the new, competing paradigms are slowly emerging. One, which is quite promising when coupled with mass customization is the concept of offering mobility instead of selling cars. Such concepts has been adopted from other industries, such as aerospace, and adopted to automotive specifics by A. T. Kearney consultants and is currently under practical development [9]. The idea relies on utilization of virtual enterprise, operating mostly via internet with direct delivery t the customers. However, instead of selling products (automobiles) what is offered is functionality needed (e.g., mobility). Company based on this concept, InDeGo plans to launch its operations in 2006 in the UK. It offers access to automobile(s) based on the need at a cost of 6€ per day and the company's management promises profitability on the 22% level (the most profitable automotive OEM is Toyota, which has 7% profitability). The company plans to offer a bundled package of services and maintain lifetime relationship with its customers. It has an ambitious plan to start delivering cars in 3 years, and become profitable in another 3. Under this concept a number of broad issues, environmental, technology upgrades, etc., can be handled much more effectively.

On perhaps another end of the automotive spectrum are plans by the Indian conglomerate Tata Motors to launch "people's car" which targets very poor segment of society. Tata's plan is to offer a rudimentary vehicle for the price of 100,000 rupees ($2,200). Development of that car model relies on low-cost engineering skills. The car is to be made of steel, composite parts, even reinforced wastepaper and based on spaceframe technology. Main components are to be held by held together by adhesive, rivets or nuts and bolts. There are no plans to include air conditioning, perhaps even no windows. Car is treated as a commodity. This concept is now under development, and is promised to be available by 2008. The main attraction there is the vast expansion of potential markets. If carried out right, with TCO in mind and sensitivity to the changing customer needs over the long term, it may offer a winning solution.

These two concepts represent a radical departure from the current practice of automobile making and marketing. Being around for over 100 years automotive OEMs have perfected the car design and manufacturing perhaps beyond what is actually necessary to satisfy the customer needs related to transportation, and find now themselves trapped in the "innovator's dilemma" [5]. Extension of the two new concepts by the mass customization principles opens promising opportunities:

- Cars can be configured and re-configured based on current customer needs
- Existence of a particular configuration is dictated by a period of need
- After a particular period of use cars can be either disassembled or reconfigured again
- Car technology can be readily upgraded
- etc.

However, implementation of such an approach requires fundamental changes both on the consumer and industry side. Consumer would need to accept use of a vehicle that he/she does not own and only for specific amount of time; his/her particular needs in return can be satisfied by adequately equipped configuration. (Similar idea was also present in the GM hydrogen-powered concept car Autonomy; however after initial presentation of this concept most upgrade efforts went into fuel cell drive, not accommodation of varying customer needs [3]). In the low end markets customers may acquire the vehicles in the bare-bones configurations that they can afford and then add enhancements as they become available and affordable.

Automotive industry, on the other had, becomes a service industry, aimed at satisfying individual and temporary needs of multiple customers. It can maintain a fleet of vehicles which are loaned for specific amounts of time and configured specifically to the customer requests. After use the vehicles are being set up for the next user, maintained and their technology upgraded.

8. CONCLUSIONS

Mass customization concepts in application to automotive products require not only completely new product architectures, but also new way of conducting business. There is, however, and enormous potential that can be explored in such solutions. On one hand, it allows the customer to focus on required service of mobility. On the other, it transforms the role of automotive industry into a service provider. Much works still needs to be done to refine such concepts. It is also obvious that they will coexist with automotive legacy before they become viable.

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