The Challenge of Building Cars to Order – Can Current Automotive Supply Systems Cope?

Matthias Holweg  
Senior Researcher, 3DayCar Programme  
Lean Enterprise Research Centre  
Cardiff Business School

Professor Daniel T. Jones  
Co-Director, Lean Enterprise Research Centre, Cardiff Business School  
Director International Car Distribution Programme (ICDP)

---------

In this article, Matthias Holweg and Professor Daniel Jones of the Lean Enterprise Research Centre at Cardiff Business School, investigate whether current vehicle manufacturer order fulfillment systems are able to exclusively deliver ‘built-to-order’ cars, as part of a demand driven production system.

Building cars to order could revolutionise the way the car industry works and provide the potential solution to overproduction, the resulting stockpiles of finished vehicles sitting in airfields, and the current low industry profitability - itself induced by high discounts needed to support current ‘push’-based selling.

This article is based on initial findings of the research of the 3DayCar Programme, a three year joint initiative involving Cardiff Business School, The University of Bath and the International Car Distribution Programme (ICDP), and sponsored by a consortium of car manufacturers, suppliers, logistics companies, IT service providers and the UK government. The aim of 3DayCar Programme is to develop a framework in which a vehicle could be built and delivered to customer specifications in minimal lead times – with three days order-to-delivery time as the ultimate goal.

---------

Recent news about the car industry has tended to focus on three major topics. First, the waves of mergers and acquisitions, which appear to aim to build critical mass to support further R&D costs and economies of scale. Second, the over-capacity problem, estimated at 5.8 million units in Europe alone. And third, concern over supposedly high consumer car prices (especially in the UK). However, a forth topic has emerged in the midst of these issues: ‘build-to-order’ or demand driven production. The question asked - inspired by successful implementations of customer driven assembly operations in other industry sectors, (such as in the often praised Dell Computers supply chain) - is whether the customer still plays a central role in the current system.

Initial evidence suggests that the car industry does not seem to have adopted the principal of putting customer demand into the driving seat of the vehicle supply system. At present, the manufacturers attempt to forecast likely customer demand (both in terms of volume and specification) many months in advance, and figure out
an attractive product mix both in terms of balancing labour in the assembly plant and financial terms.

Actual customer orders that are received are either fitted into the plan laid out by the production programme months ahead, or the forecast orders in the system are amended to customer requirements – to the extent the production flexibility allows. However, neither approach is able to provide the customer with an Order-to-Delivery lead time of less than 40 – 60 days for a custom-built vehicle.

Currently, the auto industry is excessively focussed on the easily measured performance in the assembly plant and the volume of sales in the market, and is failing to deliver specific customer ordered vehicles within a satisfactory timeframe. Current production programming - and hence scheduling - seems rather guided by line balancing and financial objectives to achieve a profitable mix, than by customer service measures. This has been prioritised at the expense of market responsiveness – with the result that although plants are often efficient, a vast number of cars are produced that do not match customer requirements, ending up as finished stock at dealers or central stocking locations throughout the country. However, due to increasing product variety and market volatility, forecasting demand has become exceedingly difficult and wrong guesses immediately result in redundant stocks and costly stock clearing initiatives.

Current Systems Failure

The new car buying process tends to be a very frustrating experience for customers. In the UK for example, a typical volume car customer has to wait, on average, 48 days for his or her custom-built vehicle from the factory to arrive - in some cases it is even longer than 60 days.

For an increasing number of customers, this delivery time is beyond their tolerance limit, so inevitably many compromise on specification to obtain a car within an acceptable timeframe. In the UK for example, ICDP research in 1997 showed that 26% of customers are not willing to wait longer than 7 days, only 19% are willing to wait 30 days. Across Europe, this tolerance level varies, with Germany showing the most patient customers. Yet even in Germany, only for 71% of the customers a 30 days waiting time is an acceptable proposition.

However, even if customers decide to order a custom built vehicle from the factory, they are likely to experience even further delays, as the delivery date given at the time of the purchase of the car can not be kept in 24% of the UK new car purchases. In general, dealers across Europe (being aware of this unreliability) add on average 9 additional days to the promised date given by the manufacturer, to give a more realistic delivery date to the customer.

The current system of vehicle supply, it can be argued, not only fails to deliver the right product within an acceptable timeframe to the customer, but also puts strain on the manufacturers and dealer networks. The industry has burdened itself with a distribution system characterised by massive levels of finished stocks in order to ensure that it can supply automobiles that are reasonably similar in specification to those demanded by the customer. The magnitude of the stocking problem is illustrated by the situation in the US, which has an annual sales volume of around 17 million light vehicles, and a supply pipeline of 45 days, amounting to just over two million vehicles. This results in multi billion-dollar stock financing costs - not to mention cost of insurance, damage and quality defects.

Yet holding stock not only ties up capital, but also incurs all sorts of other costs. For an average UK dealer with an annual sales of 400 vehicles, insurance costs for new
car stock will be £5,000 – in other words, £125 per new car sale are direct costs the customer has to pay for the dealer’s stock.

<table>
<thead>
<tr>
<th>Region</th>
<th>Manufacturer category</th>
<th>Average stock levels in days of sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>Volume</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Japanese</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Specialist</td>
<td>40</td>
</tr>
<tr>
<td>USA</td>
<td>Volume</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Japanese</td>
<td>45 – 110</td>
</tr>
</tbody>
</table>

Table 1: Stock levels in the marketplace

Furthermore, both the sales volume targets given by manufacturers to dealers, and the incentives granted to persuade customers to settle for alternative specification, result ultimately in low dealer and manufacturer margins. Dealer margins on new car sales, which theoretically range from 10 to 20%, in practice are quite often close to zero.

From the manufacturer’s viewpoint, it might even be argued that only the profit made by financial and aftersales / repair operations actually justify building the vehicles in the first place. In the case of Ford of Europe for example, 25% of the profits over the life time of a vehicle come from financing and insurance, 29% from aftersales and bodyshops, yet only 1% from originate from car assembly, and 3% from car retailing. Similar proportions can be observed for most manufacturers.

Consequently, the current system not only frustrates customers (and dealers) with long lead times and unreliable delivery dates, it also incurs high cost for the manufacturers in terms of cost of capital and vehicle distribution. For the dealers, the current system results in low margins on new car sales and a further strain on residual values, especially if airfields full of stock finally need to be cleared by heavy discounting to push them into the marketplace.

The effects of this massive discounting (up to 30-40% below the recommended retail price) and sales incentives on the whole system are not yet fully understood. Clouded by accounting practices and dispersion into manufacturing, sales and distribution figures, the manufacturer does not see what costs actually occur by producing and distributing a particular vehicle. In practice, the profit for the manufacturing operation is already accredited as the vehicle leaves the factory. Yet the actual cash intake from the customer can take up to a year, while the car remains subject to stock financing agreements and potential incentivised sales between National Sales Company and the dealers.

Therefore, the feedback on what costs are actually caused by producing vehicles to stock and then discounting and pushing them into the market remains invisible. So the critical question still remains to be answered by the 3DayCar Programme: which is more profitable - to push cars into a market at a discount, or to produce cars to order, pulled by the customer?

It might even be argued that the current system operates in a vicious circle, whereby the quest for volume and market share tend to foster forecast-driven production. As a result, the long order lead times and the pressure to sell the existing stock encourages dealers to sell the existing stock, generally involving discounts to cater for alternative specification. In return, this results in lower margins and profitability,
demanding even higher economies of scale. Additionally, push-based selling prevents manufacturers from seeing actual demand in the market, further fostering forecast driven production.

The Vicious Circles

- More volume needed to achieve economies of scale
- Reduced margins and pressure on residual values
- Make Vehicles to Forecast
- Distorted demand information
- ‘Push’-based selling using discounts and incentives
- Long lead times for custom-built vehicles
- ‘Build-to-order’ discouraged

Figure 2: ‘Vicious Circles’

Failure Recognition
Public announcements by the industry suggest that there is some recognition of this failure. Concerned about the inefficiency of an intensive dealer network, aware of the growing use of incentive payments to manage demand and, like so many mature industries, equally terrified and enthralled by the possibilities of e-commerce, it is slowly realising that there may be a better way of doing things.

What started with groundbreaking news in the Wall Street Journal back in August was an article offering the shattering news that Toyota were about to break the mould in vehicle supply by producing their Camry Solara Coupe in five days on a ‘made-to-order’ basis. Compared to the industry average, this was an incredible claim - and so it turned out to be. What Toyota aims to achieve is that (by means of a novel logistics system recently installed) it would be possible to change the specification of car up to five days before production.

However, even car makers such as Ford, GM and Renault have recently announced their intentions and projects to reduce Order-to-Delivery times, yet initiatives so far have been focussed mainly on the organisation downstream of the factory gate. While there are undoubtedly gains to be made in distribution, it is inevitable that the manufacturers will soon realise that they cannot improve their ability to match cars to customer requirements without realigning the order fulfilment process to support demand-driven production.

Renault’s ‘Projet Nouvelle Distribution’ is probably amongst the first to have recognised this challenge, and the objective of a stock reduction of 300,000 vehicles across Europe by the end of 2000 sounds promising.
Is ‘Build-to-Order’ the Solution?

Attempting to supply the customer with a product of the right specification within an acceptable timeframe sounds like a sensible business premise. In this context, ‘build-to-order’ seems as obvious approach - to have a demand-driven production system which aims to provide custom-built vehicles in a minimal lead time. One would imagine that the car industry, no longer enjoying the luxury of having demand exceeding its ability to supply (as it did for the last decades), would be governed by these objectives anyway. Whilst the grand scale of investment needed to deliver a product to the market at an economically competitive price creates certain constraints, providing the customer with a car that meets his exact requirements as quickly as possible, has unmistakable logic.

If companies could provide custom built vehicles to order, as opposed to make them to forecast, it could solve the major deficiencies of the current system:

- **Redundant stocks** would not occur, as cars would only be manufactured to customer order, relieving manufacturers and dealers of the stock financing burden - and the airfields full of cars would disappear.
- Cars would be sold without **discounts**, as there is no need to grant discounts for alternative specification or to clear stock - hence allowing for reasonable margins for both manufacturers and dealers.
- **Customer service levels** would rise, as right specification and acceptable lead time are the major objectives of the Order-To-Delivery system.

However, despite this obvious logic, concerns are uttered, particularly from the manufacturers, whether a ‘build-to-order’ system can replace the current ‘make-to-forecast’ or order amendment system. To discuss the potential pitfalls of the ‘build-to-order’ system, a closer examination of what the order fulfilment process means is needed.

In fact, the order-to-delivery time relates to five different types of order fulfilment, as there may different loops or ways in which new cars can be supplied to customers, as shown below in Table 2.

In this context, it should be noted that the term ‘build-to-order’ is sometimes incorrectly used by manufacturers to describe the order amendment function (loop 4), whereby forecast orders in the pipeline are amended to customer requirements. In the 3DayCar scenario, this loop is excluded, as it generally is nothing else but another level of sophistication of the ‘push-based’ supply system; consider the fact that if no customers arrive, hence the forecast orders (that have been decided months ahead) are built and pushed into the market place. Hence, the percentage of orders actually amended to real customer requirements could be claimed as ‘built-to-order’, but all other orders are still pushed. The main reason behind the order amendment function is basically to ensure that volume targets are met.

<table>
<thead>
<tr>
<th>Loop</th>
<th>Order-to-Delivery Approach</th>
<th>Order-to-Delivery Time (UK data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop 1</td>
<td>Dealer Stock</td>
<td>The car is bought from the stock at the visited dealer.</td>
</tr>
<tr>
<td>Loop 2</td>
<td>Dealer</td>
<td>The car is located at another dealer in the country, and transported to the dealer. The additional cost occurring is</td>
</tr>
</tbody>
</table>
Table 2: Order Fulfilment Loops

<table>
<thead>
<tr>
<th>Loop</th>
<th>Distribution Centre</th>
<th>The vehicle is sourced from a central stock location, controlled by the manufacturer. Generally the dealer does not hold any new cars in his own stock, so most sales would be made from the DC itself.</th>
<th>4 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop 4</td>
<td>Order Amendment</td>
<td>Orders are laid out as forecast in the first place, and once the customer specifies his order, these unsold ‘pipeline’ orders are amended to customer requirements.</td>
<td>Variable, 11 days on average</td>
</tr>
<tr>
<td>Loop 5</td>
<td>Build-to-order</td>
<td>This implies that the order is entered as a new order into the system. This happens only in 32% of the new vehicle purchases in the UK at the moment, which an average order-to-delivery lead time of 48 days</td>
<td>40 – 60 days</td>
</tr>
</tbody>
</table>

Each of these approaches, or loops, comes along with different advantages and risks, as shown in table 3. For loops 1-3, and obvious risk of redundant stock is present, as the vehicles are already built. Also, a ‘specification risk’ occurs, as those cars in stock might not be the right spec for the customer. Potential stock redundancy and wrong specification then relate to the overall risk that discounting might have to be used to sell those cars.

As customers are not prepared to wait, a potential risk of lost sales occurs, if the Order-to-Delivery time exceeds the customer’s waiting tolerance. The customer not willing to wait might instead buy from a different brand offering shorter Order-to-Delivery times. This risk is called ‘lead time risk’ or ‘lost sales risk’.

Also, as the provision of vehicle production capacity is one of the major costs incurred, manufacturers tend to strive for the most efficient utilisation of their production and assembly facilities. And this is where the ‘build-to-order’ is most often criticised. Manufacturers fear for their efficiency of their plants, as ‘real’ customer orders might not arrive in a sequence that most suits the production schedules of the plants.

However, there seems to be some misunderstanding: in the long run, ‘build-to-order’ has on long term same capacity utilisation risk as a forecast driven production system – if there is no demand, there is no justification for build in either system. ‘Build-to-order’ is as sensitive to pricing and incentivising as ‘make-to-forecast’, with the simple difference that in the ‘build-to-order’ scenario the production volume would need to be supported - as opposed to clearing existing stock from the airfields. The actual risk of ‘build-to-order’ is short-term volatility - what happens if no orders come in the first week of the month, but all arrive in the second week?

This fear is justified, as under the current reactive management there is no way of catering for short-term volatility. However, the flaw is not to be seen in the ‘build-to-order’ approach, but in the manufacturers’ abilities to manage demand. Car makers these days do not understand and manage their demand, but simply react to incoming orders, and increase marketing efforts if the market share target seems under threat.

In contrast, a ‘build-to-order’ system would require a proactive management of demand and a segmentation of demand. Why not use non-urgent orders, such as demonstrator and showroom cars for dealerships, the cars for use of the own employee and even large fleet orders – which generally provide visibility for several weeks ahead – to buffer the service for those customers who require short delivery times of their custom-built vehicle?
A buffer of those orders would then enable the manufacturer to overcome short term fluctuations. Again, seems obvious, but as some assembly plants do not see whether a vehicle is a customer order or a stock car, this would be a leap forward.

<table>
<thead>
<tr>
<th>Sales sourcing</th>
<th>Stock Redundancy Risk</th>
<th>Alternative Specification Risk</th>
<th>Discounting Risk</th>
<th>Lead Time Risk</th>
<th>Capacity Utilisation Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dealer</td>
<td>++++</td>
<td>++++</td>
<td>++++</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>Dealer transfer</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Distribution centre</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Order amendment</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Build-to-order</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>++++</td>
<td>++++</td>
</tr>
</tbody>
</table>

Table 3: Risk Profiles of Order Fulfilment Loops

[ 0: No risk, +: Low risk , ++: Moderate risk, +++: High risk, ++++: Very high risk ]

In conclusion, the ‘build-to-order’ approach offers the best risk profile, and in combination with demand management to cater for short term volatility, seems the obvious strategy to adopt. The only risk occurring is the actual lead times involved, as potentially sales might be lost if the order lead time exceeds customer’s waiting tolerance. Hence the central question: are current vehicle supply systems capable of delivering short enough lead times to support ‘build-to-order’?

Are current vehicle supply systems able to support ‘build-to-order’?

To answer this question, 3DayCar researchers analysed the order fulfilment processes of major European manufacturers – basically ‘stapling ourselves to a customer order’ as it is being processed, and the vehicle is manufactured and delivered.

At each step of the process the system-related delays were researched, and the minimal time delays recorded. As the order processing time depends on several factors which could falsify the results (for example, a waiting list for a high demand product), the vehicle supply system capability was analysed, which reflected the optimal throughput time for an order – any waiting queue, rework or part unavailability will further extend the evaluated order-to-delivery time.

The minimum throughput times refer to the minimum time required for an order to stay at each stage, determined, for example, by only once a week data transmission, over-night runs of computer systems, or the physical layout and line speed of the assembly track. The average order fulfilment times therefore tend to be even longer, yet depend on the demand and supply situation for each product, but do not provide a basis for comparison.

To understand why custom-built vehicles require 40 days or more to be delivered, figure 3 below shows a simplified version of the ‘spaghetti-world’ of different IT systems, departments and processes the orders have to fight their way through. Each of these steps shown are major processes related to the order fulfilment, with the red path highlighting the way customer orders flow through the process.
Figure 3: Order-to-Delivery process

The major steps are:

- **Order entry**, which is a check whether the orders are feasible to be built, and if they are, transfers them into the order bank.

- **Order bank**, which holds all unsold orders until they are scheduled for production. The order bank does not fulfil any real purpose apart from providing a 'comfort' buffer for the manufacturer to achieve efficient production.

- **Order scheduling**, which picks the orders from the order bank and assigns them to build periods (generally weeks) at the different plants. The scheduling tool takes parts availability, market and dealer fair share allocations and mix constraints into account, most of which are decided in the production programming meeting. Once scheduled, the orders are generally held for two weeks, although nothing happens to them. The general excuse used here is to blame the suppliers, claiming that this 'drop-dead' period is required by suppliers to schedule their production. However, our research indicates that today's component suppliers are generally capable of supporting much shorter scheduling cycles - and that these scheduling procedures are as much a legacy as the IT systems that execute them.

- **Order sequencing**, where the scheduled orders for a build week are re-shuffled into a sequence of build orders for the assembly plants. The sequencing tool needs to take build constraints into account, as for example, the assembly line balance might only cope with 50% estate cars – hence every other car will be a less labour intensive 3 door or 4 door model. In any case, only after the orders are sequenced, do suppliers actually receive their final call-off of what is required, as only then it is actually defined what parts will be needed. This is another reason why holding scheduled orders is of very limited use, and explains why the schedules issued by the manufacturers show such a high degree of fluctuation!
Manufacturing. Once sequenced, the orders are sent to the body shop, where the order is generally identified with the physical floorpan, which then becomes a complete body. After the body shop, the body enters the body-in-white storage, the only purpose of which is to achieve efficiency in the paint shop by accumulating bodies that are meant to be sprayed in the same colour. Paint batching surprisingly is still an issue, although the actual savings by doing so are hardly more than £1 per car. The downturn of batching is that the initial production sequence is distorted, hence it becomes unpredictable for all subsequent operations as to what cars are coming down the process. After paint, the cars are generally re-shuffled again before they are sent on the assembly track, to ensure the mix of cars is aligned with the constraints opposed by the line balancing activities.

Despatch. Once the cars leave the assembly track, they undergo different tests and checks, and generally have to be reworked to some extent. In fact, as little as 33% of cars leave the factory without having been reworked at all. However, once ‘passed to sales’, the cars are driven into load lanes in the plant and await transportation – for a whole day on average.

Distribution. Several different distribution strategies are operated in Europe – either direct distribution to the dealer via distribution hubs, or the cars are shipped into several regional or one national distribution centre, and then forwarded to dealers as required. Generally, current distribution systems require at least 4-5 days to transport a car from an UK factory to any UK dealer.

In summary, several obstructions to the free order flow are built into current vehicle supply system and inhibit short response times to customer orders. These inhibitors are allocations both at market and dealer level, which essentially restrict the dealer to stick to the allocation given, even if some other dealer in a different country is not using his allocation to the maximum, making the dealer wait until the next allocation period.

The allocations are decided in the production programming meeting, which is heavily influenced by financial interests – giving priority to markets with high profitability, i.e. UK, Germany, and France. Also, the decisions concerning the product mix obstruct the order flow. It is much more profitable to produce a rich mix of specifications, then just to build ‘standard’ cars. If however more ‘standard CL’ vehicles are ordered, they would simply be delayed to allow for production of more GTIs and GLXs to be built – whether there are customer orders or not!

Deeply hidden in the departmental functionalism, current IT systems also are a serious inhibitor to responsive order fulfilment. The reason is the batch layout of the system, which was necessary due to technological constraints at the times those systems were introduced; current IT systems itself require 4-5 days to process an order - ‘today’s problems were yesterday’s solutions’.

It does not come as a surprise that the order-to-delivery process for a custom built order, on average, needs more than 40 days to complete. Analysing the distribution of where these days are lost is shown in figure 4.
Manufacturing, surprisingly, is clearly not the issue in terms of delays. The actual assembly operation only takes 6-8 hours, the complete production hardly more than 22 hours - plus additional time for testing and rectification. Most of time, 85% in fact, is lost in the information flow, whereas the actual manufacturing operation hardly exceeds 1.5 days.

In the past, time compression initiatives in the automotive industry have concentrated on the assembly area, which we clearly see as 'shop-floor myopia'. In the physical production process probably only minutes are to be gained in assembly - maybe hours in case of de-coupling body and paint shop from assembly. The problem clearly lies in information management. The major gains for time compression are to be gained in the information flow, where the savings can be measured in weeks.

However, there is one issue with current manufacturing practices. As mentioned above, due to frequent rescheduling and resequencing it is not foreseeable, in which sequence the vehicles are coming off the line. As about 65% of all vehicles spend some time being reworked, it becomes impossible to predict the output of the plant. The problem with this arises in distribution, whereby an efficient utilisation of the resources requires advanced planning and scheduling. Yet, as the sequence is unreliable, the truckloads are only consolidated after the vehicles have come off the line - simply waiting an additional day in the plant.

In summary, it can be argued that the current system is not laid out to provide built-to-order vehicles to customers. Not surprisingly, the ICDP research findings in the UK show that 68% of customers are served from existing stock or amended orders in the pipeline, yet only 32% are new orders put into the system. And it is only this ratio that can provide cars within the tolerance of the customer’s expectations.
Figure 5: Order Fulfilment Times v Preparedness to Wait

Figure 5 shows the current order fulfilment – dealer stock, central stock, order amendment and custom-built vehicles – weighted by their average sales and compared to the average waiting tolerance of customers. What can be seen is that, at the moment, lead time is not an issue, as most sales are most from existing stock. The inventory and discounts granted cover the manufacturers and dealers against their inability to provide custom-built vehicles in a short period of time.

But what if manufacturers were to adopt a ‘build-to-order’ strategy – using current systems? If the order fulfilment philosophy would change under current systems, the result would be devastating for the customer service level, leaving a big performance gap, as illustrated below in Figure 6:
Figure 6: Implications of increased ‘Build-to-Order’ Content

The supply system is unable to provide vehicles within the expected lead time of customers, hence the manufacturers face the risk of lost sales, as customers might buy a different brand with better availability.

The conclusion that has to be drawn is that current vehicle ordering and supply systems cannot support a higher degree of ‘built-to-order’ vehicles, as they are not capable of delivering responsive order fulfilment. If the degree of cars built to order were raised, customer service levels would further drop. So current systems have to rely on high levels of finished vehicle stock to provide a reasonable service to customers.

Redesigned systems are necessary if vehicle manufacturers are to embrace this new philosophy to provide custom-built vehicles within an acceptable timeframe for the customer. Piecemeal improvement, as sometimes promoted as the way ahead, is simply futile, as the whole concept behind it is based on ‘push’ or wholesale supply system, which also has left its legacy in the IT systems that have grown ‘organically’ alongside over the years.

The Five Challenges

The 3DayCar research clearly shows that current vehicle supply system is a frustrating experience for customers, and puts heavy financial strain on supply, manufacturing and distribution of new vehicles. We strongly believe that a ‘build-to-order’ approach has the potential of alleviating current constraints in the system at the risk of potential decreased capacity utilisation in the short term and less efficient assembly operations, by catering for more flexibility in the process.

The authors believe that there are five major challenges that need to be overcome to turn the legacy of ‘building to forecast’ into a responsive ‘build-to-order’:

1. **Abandon ‘push-based’ system mindset.** A new mindset with new key performance measures is needed, promoting customer service and total costing, as opposed to volume and market share. Total costing of the complete order-to-delivery process is needed to visualise sunk cost in the current system, which are not yet visible. The challenge is to resist overproduction in order to maintain
margins and residual value, which are both essential to maintain a strong brand. A build-to-order culture needs to be planted, avoiding overproduction and discounting / incentive scheme.

2. **Enable demand-driven production**: Separate tactical allocation decisions from the operational order scheduling, and enable daily scheduling processes, or even direct order booking into the production sequence to ensure minimal order-to-delivery times. To achieve this, the organisational layout needs to be changed from 'departmental chimney' structure to a cross-functional approach.

3. **Understand real demand** - and provide the appropriate service. The challenge is to both to understand current demand structures and customer expectations, and to manage these expectations. This knowledge is essential to support the demand-driven production system. Differentiation in order treatment is imminent, although heavily resisted by the manufacturers. However, with changes in the vehicle ownership model - manufacturers converting into a service mobility provider, rather than just being a manufacturer - this point will gain momentum.

4. **Information visibility & integration**: ‘build-to-order’ will not be achieved without integration of both suppliers and logistics providers. For both, the provision of appropriate demand visibility is crucial, hence an online access to the order bank would be the logical thing to do. Also, adversarial behaviour and short term bidding needs to be replaced by long-term partnering. With the growth of ‘mega-suppliers’, changes in the power base in the supply chain are foreseeable in the near future.

5. **Break dependency on current Economies of Scale (EOS)**. A major future challenge will be to escape the constraints of steel stamping and painting. Exploring other body structure and assembly techniques is a long-term challenge, yet will determine the ability to develop and produce profitable volume cars in a market with steadily decreasing life cycles and increasing variety. The standard steel monocoque will need to be replaced by modular spaceframe or composite bodies, embracing modular assembly and supply strategies. Modules should be standardised across models and maybe even brands. Also, complexity and variety reduction will further alleviate R&D cost coverage requirements.

The systems research within the 3DayCar programme is currently developing direct order booking system, whereby an order will be directly entered into the assembly sequence. Furthermore, the customer order will not be identified with the physical vehicle before the start of the assembly line (de-coupling), treating body and paint shop as internal suppliers to the actual assembly operation.

The direct order booking system will be validated using an holistic simulation model. However, initial findings indicate each manufacturer will require an individual solution towards an optimised order-to-delivery approach, with particular strategies or hybrid approaches being more suitable than for one or the others.

To achieve a build-to-order system requires not only a redesigned ordering and supply system, but first of all a significant change in company philosophy. And changing the mindset might even prove to be even more of ‘legacy’ than to redesign the outdated IT systems, as ‘build-to-order’ challenges the most established measures in the car industry - capacity utilisation and market share.

So far, the car industry has been getting away with ignoring customer demand by producing against forecasts and supplying from stock. We believe that in the light of overcapacity and competitive pressure in the world automotive industry this approach
has reached its limit – and a ‘build-to-order’ strategy might prove to be just the cutting edge required to survive in today’s markets.

5498 words