Prepared by the 3DayCar Research Team

Towards a Customer Driven System

A summary of the 3DayCar Research Programme

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The 3DayCar Programme

The 3DayCar Programme took place from 1999 to 2001.

The research was carried out by three institutions – the Lean Enterprise Research Centre at Cardiff University, the School of Management at the University of Bath and the International Car Distribution Programme – and supported by the Engineering and Physical Sciences Research Council, plus some 20 industrial sponsors drawn from all areas of the new car supply chain.

Its aim was to establish how the automotive supply chain could move from a predominantly 'stock push' system to one that built most cars to customer order and delivered them within short lead times – promising significant benefits to manufacturers, suppliers and customers.

This report provides a summary of the main findings of the research and its recommendations for future implementation.

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Summary

3DayCar is a vision of a system in the UK where every customer receives a car produced exactly to specification and delivery date. Building-to-order in short lead times offers a double prize: eliminating supply chain stock and the reliance on retail discounting.

A. 3DayCar is Feasible and Attractive

- To reform the new car supply system a radical change is required that allows all customers to buy a car that is built specifically for them. Under this approach, all new cars would be built to order and none for stock – the only exception being cars specifically for display or demonstration purposes. The ability to build cars quickly in response to customer orders - ideally with a three day response capability - is a vital ingredient of this stockless new car system, as some customers will be unwilling or unable to wait longer than this. The proportion of customers demanding a car in three days is expected to increase over time.
- A stockless supply system is not only attractive to customers, it is also financially rewarding to vehicle manufacturers, especially to the companies that achieve it first. The prize is potentially a net gain in profit of 10% of the retail price of a car. This is because the waste inherent in the current system, where stock is built against forecast, is far greater than the cost of implementing a more flexible supply system.
- To implement a 3DayCar does not depend upon the development of novel manufacturing capabilities. Instead, it can be achieved by reconfiguring many of the existing manufacturing structures and practices, driving out waste to respond to true market demand. Accurate and transparent information flow in real time is essential to achieving a responsive supply system. All of the above implies major change in capabilities and culture.

B. The Core Ingredients of a 3DayCar

- The current supply system cannot meet customers' needs without building significant stocks of vehicles – the average process lead time required for a car built to order is 40 days. The time taken in processing the order from the customer to the assembly line is the single greatest bottleneck in the whole supply chain, accounting for 34 days in a typical current system. The largest overall time saving in the 3DayCar approach would be achieved by switching to a system of direct order input to assembly line 'slots'.
- Direct order booking entails a corresponding change in operational production planning, based on sold orders instead of forecasts. While this will require some additional flexibility at various stages in the supply chain, it will eliminate the artificial swings in output that are often caused by unreliable market forecasts.
- Within the assembly plant, the paint shop is the largest single barrier to achieving flexibility and short lead-times. Small paint batches increase environmental impacts and impair already unreliable quality. Using current technology, it is necessary to de-couple the paint shop from final assembly by holding buffer stocks of painted bodies. While new paint technologies appear to open the way to batches of one, reducing the number of painted body types entering the assembly track to a minimum improves flexibility and reliability. Spaceframe technology that uses independent painted body panels gets around the effect of conventional inline painting by decoupling body structure and body colour from assembly. A very wide consumer choice can still be offered by adding variety in final assembly.
- Improving the ability of final assembly to cope with any mix of specifications required by the market, and moving away from the sequencing constraints caused by the current careful balancing of work content at each station, entails only a small increase in variable costs. Trends in vehicle design and assembly such as shared platforms and modules help reduce the complexity of final assembly. This helps to achieve a simpler assembly on multi-product lines, resulting in a more flexible build to order system.

- The current system stabilises production through building cars for stock. By contrast the stockless system will stabilise production by managing demand. Pricing and promotions will be adjusted continuously to smooth demand fluctuations and to stimulate early ordering for registration peaks.
- Reform of information systems is core to 3Day Car, replacing batch processing with real-time information flow through out the supply chain. This approach compresses time by cutting out several overnight updates.
- Preserving the environment is not in conflict with implementing a 3DayCar system – the increasing legislative requirements can be met by reconfiguring logistics, including operating on a multi-franchise basis.

C. The Challenge of the 3DayCar

- A whole system, industry-level change is required, away from 'shifting stock', i.e. selling cars that have already been built, to 'selling slots', i.e. selling cars before they are built. At the same time it requires a move away from minimising costs in one part of the chain. At present the assembly plant is an 'optimised island' and this emphasis must change to maximising profit across the whole chain.
- The financial gains are large but they are not achieved equally along the supply chain, nor are they always proportionate to the costs involved in switching to a 3DayCar system. A means of sharing the costs and gains across the players in a fair manner will be needed to incentivise the necessary change. A more 'open book' approach is required towards financial contracts, where all players are prepared to share their financial situations in greater detail.

3DayCar offers a large reward by eliminating supply chain stock, discounting, and creating a system that exploits true market demand. Those who implement stockless supply first will gain a significant competitive advantage.

1. Introduction

The introduction of lean manufacturing over the last 20 years has focused largely on vehicle production resulting in 'optimised islands' across the automotive supply chain. While some partners have made significant gains in the elimination of waste, others have been left behind. This research raises the stakes for the whole industry, introducing the challenge of building to order in short lead times.

In 1999, according to research conducted by the International Car Distribution Programme (ICDP), two thirds of new car buyers in the UK had their vehicles supplied from stock; in other words, from the pool of cars already manufactured and located either at dealerships or a manufacturer's distribution centre. For the other third, having a car built to their precise order involved a wait of typically six to seven weeks, and with little assurance that any precise delivery date would actually be met at the end of it.

The majority of customers are in a situation of hoping that a vehicle matching their requirements can be found within the available stock, rather than knowing that the precise specification of car they want is being built especially for them. It is often the case that they are obliged to accept a compromise specification from stock, with an incentive of additional options or a price discount. A consequence of this 'stock push' way of running the downstream end of the business is an imbalance between the production and distribution operations.

Figure 1 shows that the level of component stock within the vehicle manufacturer is very low. However, at tier 1 supplier level and below, it is high. The highest level of stock is of finished vehicles in distribution. This represents two months worth of stock, or 75% of the total value of stock held throughout the entire supply chain. It is clear that reducing the number of vehicles held as unsold stock would bring an immediate financial benefit to the whole production and distribution chain.

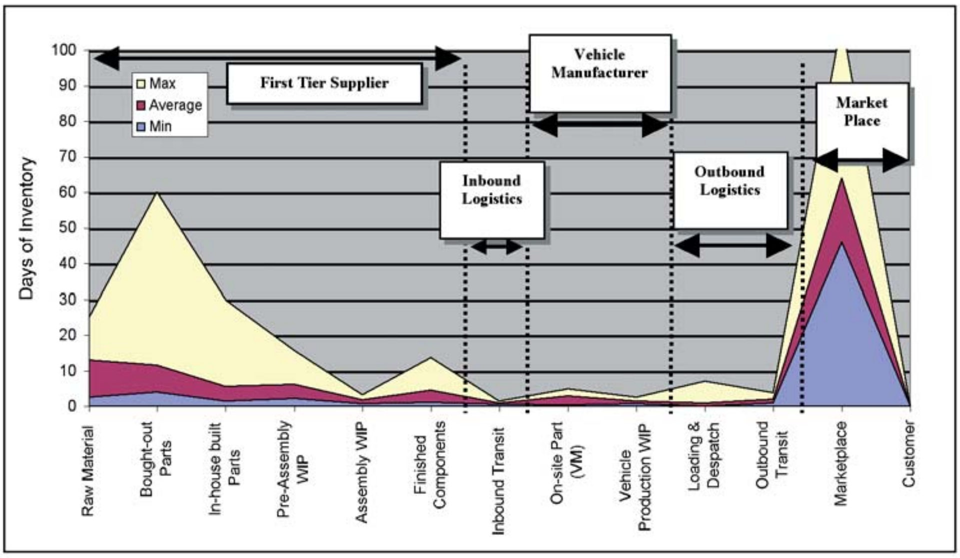

Figure 1: Inventory profile of the Automotive Supply Chain (Source: Holweg, 2002)

During the last decade, all car manufacturers have endeavoured to make improvements, and many have made significant progress in shortening their response cycles in building and supplying specific customer orders. Yet they have not succeeded to date in implementing a system that can build even a majority of cars to customer order. Nevertheless, if this area of the business is to become truly efficient, then achieving 100% build to order has to be the ultimate objective. The role of the 3DayCar programme was to show the industry how to make a quantum step on the road to build to order, to provide a breakthrough in the trade-off between satisfaction – meaning in this case speed and reliability of building cars - and cost.

The programme's title – 3DayCar - was deliberately chosen as a provocative target, one which could not be achieved by incremental change alone, and one which would force a fundamental questioning of all the many steps involved in producing a car for a customer. Behind the 3DayCar headline were the questions of how can unsold vehicle stocks be removed from the supply chain, and how can the industry provide every customer with *'the car you want, when you want it'?*

The 3DayCar programme focused closely on overall production and distribution system efficiency. It investigated a wide range of aspects relating to vehicle supply, including:

- The attitudes of customers and dealers towards a potential 3DayCar.
- The scope for managing customer demand to permit a more stable rate of car production.
- Contemporary and expected changes in vehicle and production technology.
- The development and reform of information systems.
- The impact of environmental requirements on the production of vehicles and their transport.
- The changes in organisational culture that would be demanded by the 3DayCar approach.
- The financial implications of moving to a 3DayCar.

2. What The Car Customer Wants

Prospective car buyers face an amazing array of choices between different brands and models. Even when they have narrowed their selection down to a particular model, the number of possible variants is almost bewildering. Yet once they know what they want, car buyers still have to face a trade-off because of the way the current supply system typically operates. Do customers hold out in the hope of obtaining the precise specification of car they want, or do they accept a compromise so that they can be supplied more quickly from available stock?

In making this decision, they must trade-off between:

- **Time:** how long will it take to obtain a custom-built car against one supplied from stock?
- **Specification:** how close are the available models in stock to what they would like?
- **Price:** how attractive are the incentives on offer for compromising on either time or specification?

The 3DayCar team carried out research among fleet and retail car buyers. They also investigated other industries that have recently been moving towards fast customer response, such as personal computers, spectacles, and photographic development, in order to explore customer attitudes to waiting, particularly in relation to price; to see what kind of trade-offs are made.

Those surveyed rated speed of supply very high, where 65% thought that it was either ‘very’ or ‘quite’ important to their final choice of car. When asked to specify their ideal delivery time, 19% stated that it was less than one week, suggesting that the 3DayCar title might not be so ambitious as had been thought. Nevertheless, a degree of divergence was noted depending on the brand of car the respondents were considering (Figure 2).

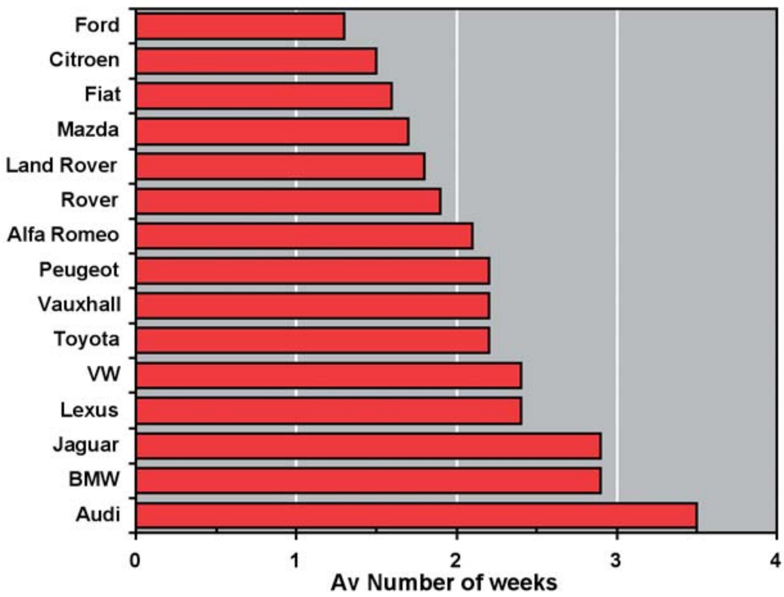

Figure 2: Ideal order to delivery time by brand (Source: Elias, 2002)

The customer groups that regarded less than two weeks as their ideal delivery time are shown in the table below.

Fleet customers, regardless of brand	30%
Retail customers for specialist brands (e.g. BMW, Jaguar)	47%
Retail customers for volume brands (e.g. Ford, Volkswagen)	63%
Retail buyers under 25 years old	84%

Table 1: Two week ideal order to delivery lead time by customer segment

As expected, this research revealed a wide range of delivery time expectations amongst customers. The 3DayCar approach is not about supplying every car within three days, it is about the capability of supplying a built to order car to the most demanding customers, within an acceptable and achievable timeframe. If this can be managed the system will cater for a broad range customers. As demonstrated by the research, those orders that are less 'urgent' can play a vital role in smoothing production in the 3DayCar environment.

The impatience of younger car customers relative to more mature buyers was confirmed by the study of other industries. The length of time customers will wait for the delivery of photographs and spectacles was also observed to be declining, and this trend is expected to continue.

The second aspect of the trade-off concerns 20% of customers compromising on specification to obtain their car within an acceptable delivery time. In addition, 6% of customers are lost because they are not offered an acceptable combination of timing, specification, and price. The opportunity for the 3DayCar is to meet all customer time needs without compromising their specification requirement.

Looking at price, the team's research into other industries showed that customers are prepared to pay a significant premium for obtaining what they want quickly. By contrast, at present the car industry offers incentives for a car supplied quickly (i.e. from stock), and charges more for cars built to order, which take longer. This is despite the cost to the overall supply chain actually being lowest when a car is custom built. The 3DayCar approach therefore offers the opportunity for the industry to move to the more logical position of charging a premium for short order lead time vehicles actually built to the customer's desired specification.

This research also highlighted a popular misconception among customers that higher quality vehicles take longer to build. In fact, this does not apply in modern automotive manufacturing, where the length of time taken for assembly varies little across brands, and is not correlated with quality for all but the most exclusive brands

The typical customer expects the new vehicle supply process to provide the specification required, within a short lead time, as part of a no-hassle one-stop order process, and that allows some variability in price. Some customers like to negotiate the price hence the system should be able to accommodate a variety of negotiation tactics. The new system must give a reliable delivery date, confirming specification, price and finance details for the new vehicle, and the residual value for the trade-in if there is one. This core data should be verified before the customer completes the negotiation process with the dealer.

Therefore, it is clear that there is strong latent customer demand for a 3DayCar approach to vehicle supply. If a manufacturer attempted to move to a stockless, 100% build to order system based on a 14 day order lead time, there would still be a risk of lost sales from customers not prepared to wait two weeks. As willingness to wait is likely to decline over time, those vehicle manufacturers who get closest to the 3DayCar will gain a significant competitive advantage, at the same time as reaping profit improvements from operating a stockless vehicle supply chain.

3. Moving From Forty to Three Days Order Lead Time

One major objective of the 3DayCar programme was to assess whether it was in fact feasible for a car to be built and delivered within the UK market, within three days of the customer's order being received.

The first stage was to establish how long this process typically takes at the moment. This was addressed by mapping all the steps in the process from a customer ordering a car to the vehicle being delivered to the dealer – effectively monitoring actual customer orders as they passed through the process. The results were surprising, not because the total length of time taken for a car to be built to order was nearly 6 weeks on average – this was consistent with earlier findings by ICDP. Rather, the surprise was that more than 80% of this time was spent processing the information flows relating to the order, with only a few days actually involved in building and delivering the car itself. The typical times taken at each stage are shown in Figure 3 below, a simplified representation of the average across the six vehicle manufacturer sponsors of the research programme.

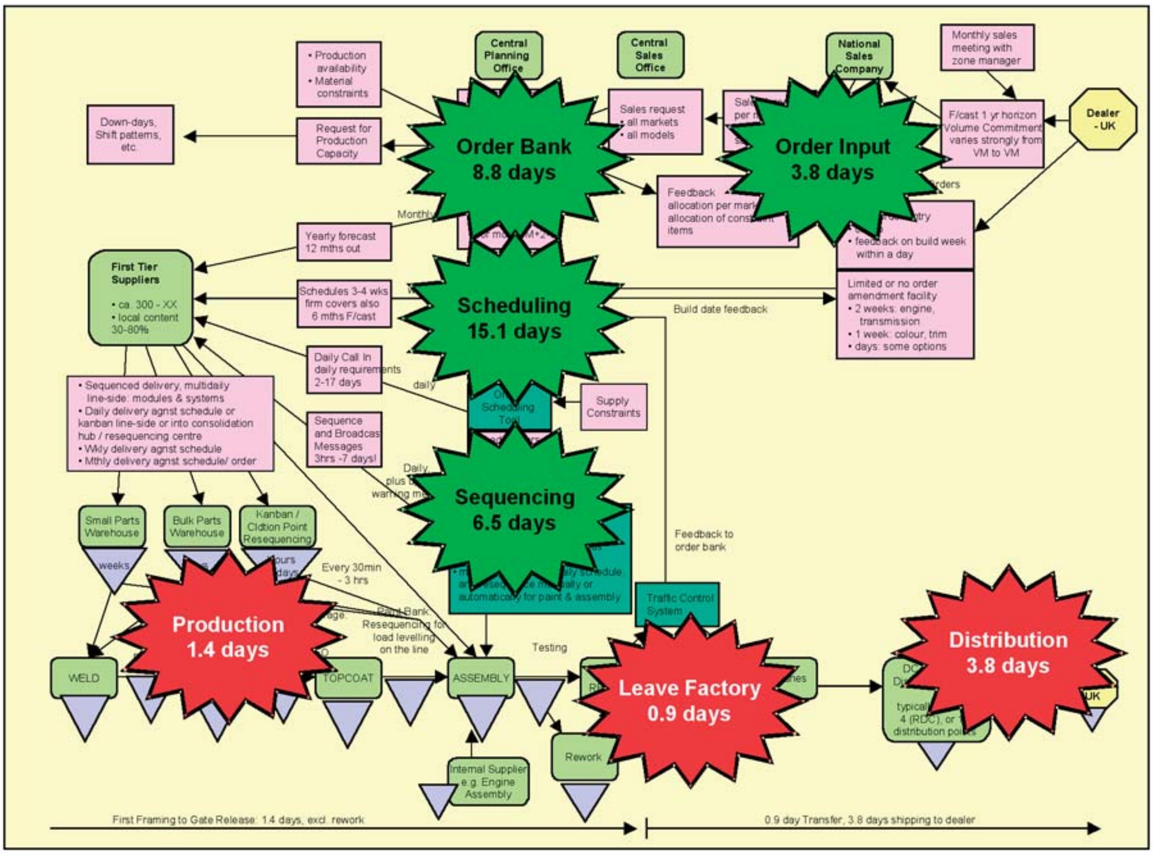

Figure 3: Generic Example of Current Order Fulfilment Process, Volume Manufacturer (Source: Holweg, 2002)

The stages in the order to delivery process are:

- Order input - usually daily or weekly from the dealer to the manufacturer, but orders are often assembled and relayed by the National Sales Company on a weekly basis.

- Order Bank (often termed the Sales Order Bank) - held centrally at the vehicle manufacturer. This is typically the first filter of orders to match them to production constraints.
- Scheduling - these are orders which have been sent to the factory in weekly batches in line with the production programme. This schedule is also notified to suppliers, but they rarely rely on this information for their planning as it is generally is too unreliable.
- Sequencing - orders are selected from the schedule on a daily or weekly basis, and are assigned a day of build. Component suppliers are informed of daily requirements anything from one day to one week in advance. Even though most manufacturers aim not to change the day of build once the sequence is set, in practice only approximately two thirds of vehicles actually get built on the day originally set. Shortages of components and quality problems at the various stages of vehicle production are the main reasons for this shortfall.
- The actual production and distribution phases take, on average, only 6.1 days. The 3.8 days taken in delivery to the dealer includes the time required to build economic loads for the high capacity transporters that are currently used.

The second stage involved translating these steps into a new process capable of delivering a 3DayCar. The critical ingredients of a three day lead time result in a greatly simplified approach, as detailed below and in Figure 4.

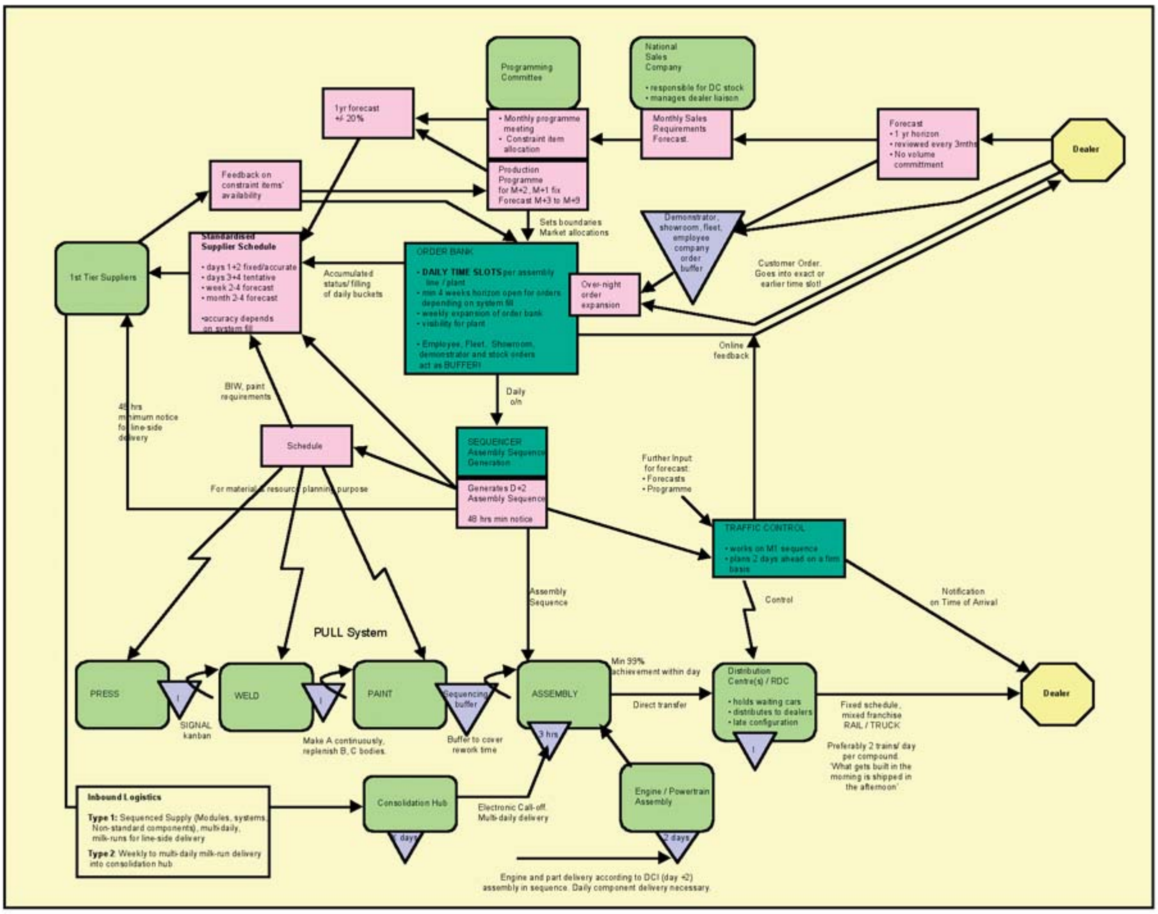

Figure 4: 3DayCar Order Fulfilment Process (Source: Holweg, 2002)

The critical ingredients for a 3DayCar are:

- Direct order booking into production slots in real time. **Time required: - nil** Orders are transmitted directly from the dealer to the factory in real time, and are placed directly into production 'slots' for the day that vehicle assembly is required to meet the delivery date agreed with the customer. This determines the production schedule, which is merged with the order bank.

- Vehicle Manufacture Sequence and Production. **Time required: – 2 days** The precise sequence of assembly is determined hourly, 36 hours prior to the start of final assembly. This gives component and logistics suppliers precise notice of hourly requirements, and allows a 12 hour window for assembly (which should only actually take 8 hours).
- Delivery from the Factory to the Retailer. **Time required: – 1 day** Achieving this will involve delivery operated around the clock on a multi-franchise basis, using a mix of sizes of car transporter to ensure optimum load size.

Achieving a three-day lead time is perfectly feasible; in fact, this is the easy part. The difficulty comes in doing it in a reliable fashion and in coping with the variations in demand over time from the market place. This is because, in the true 3DayCar world, 100% of production will effectively be given over to customer orders. The following chapters examine in more detail the ingredients for achieving this.

4. How to Achieve Reliable Timing In Production

The credibility of any build to order system depends on it consistently meeting the delivery date promised to customers. In the car industry, this reliability is generally very poor at present. 3DayCar research explored four areas of the production system offering significant scope for reliability improvements: planning, information systems, paint shop, and logistics.

A. Planning

The starting point for improving reliability in a build to order system is a fully co-ordinated production planning process. Planning should continue to be based on forecasts, but on forecasts of customer order input, and their likely lead-time segmentation, rather than on forecasts of simple sales registrations. This should in turn provide the framework for capacity planning, but should not actually set the volume and mix of cars to be made. Customer orders alone should determine what is actually produced.

It will be necessary for vehicle manufacturers to co-operate more closely with component and logistics suppliers in setting and reviewing capacity needs. The basis of forward forecasts should be given in more detail, along with a possible range of sales, rather than one expected figure.

The provisional number of days to be worked in the factory each week will be decided monthly for a period of three to six months ahead. Production capacity at the manufacturer, its suppliers and logistics providers is then adjusted in line with expected seasonal demand. The actual working days should then be determined on a weekly basis for the second week ahead. This stage is critical, since all planned production slots should be filled in order to maximise production efficiency.

If sufficient orders have not arrived to fill all the available production slots, then cars should not be built against these slots, as this would generate unsold stock. 'Captive orders', such as demonstrator cars, employee cars and even fleet orders should be used to top up production as discussed in the section on matching demand to available capacity, later in this report.

The other factors which have to be entered directly into the production slot programme are restrictions on product mix due to known component constraints (such as a shortage of diesel engines for example), and overall market/dealer allocations in the event of demand exceeding supply. These constraints ensure that orders are not taken above the maximum daily availability level.

The precise sequence of orders to be built each day should be determined on an hourly basis, 36 hours prior to being sequenced on to the final assembly track. This will give at least 36 hours notice of precise requirements to component suppliers and up to 48 hours notice for the outbound logistics companies. Actual order details should only be attached to a specific vehicle at the beginning of the final assembly track (in other words, after the body assembly and paint shop stages). This reduces the lead time for the order, and cuts down the uncertainty that can be caused by the unreliability of the paint shop process.

The assembly of a vehicle involves a huge number and variety of components, from spark plugs to complete front-end modules. To determine how the various components should be supplied to the assembly process, it will be necessary to break it down into categories according to value, complexity, type of component (whether commodity or brand specific), and delivery time to the factory. Figure 5 shows a possible break down of component type categories based on how they might fit into the 36 hour notice of precise sequence requirements on to the final assembly track.

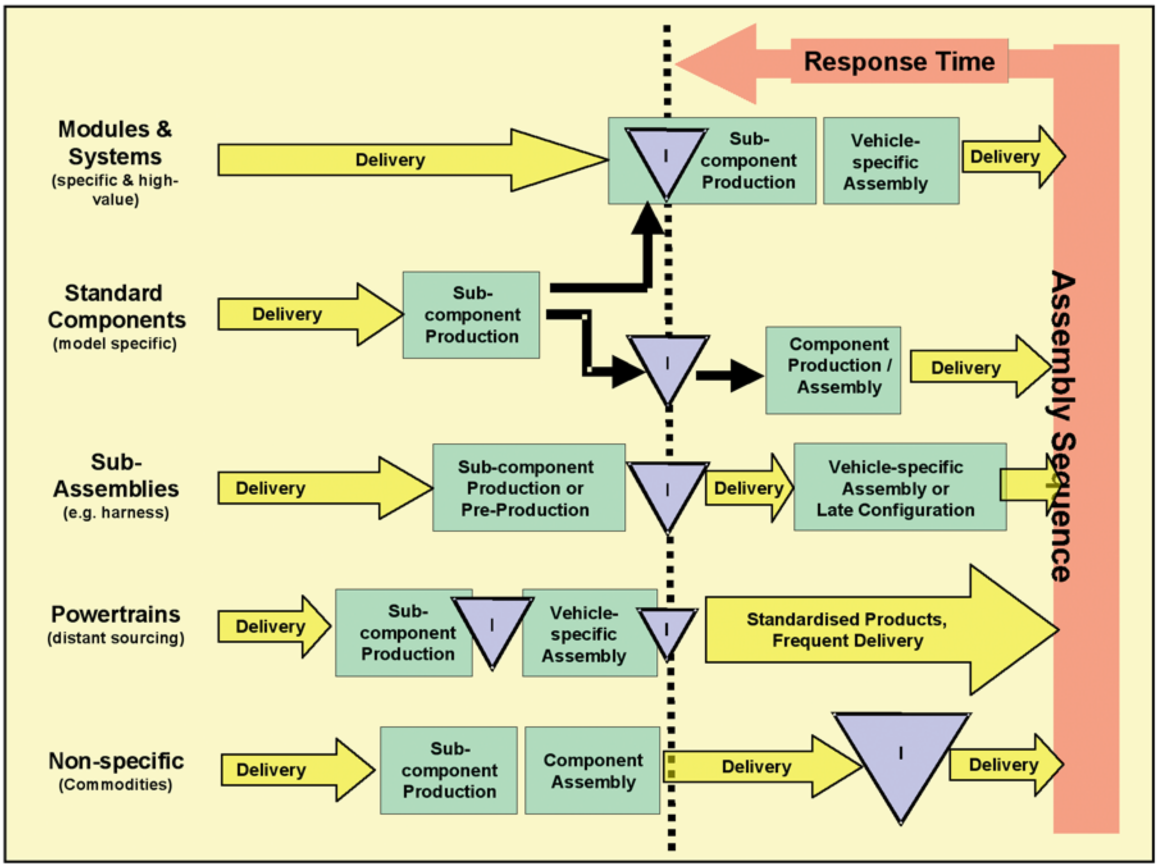

Figure 5: Component Sourcing and Stocking (Holweg, 2002)

As far as possible, high value components should be produced or assembled inside the 36 hour time scale, to avoid the need to hold stocks of them. This will increasingly be carried out at supplier parks located close to the vehicle assembly factory. For components that cannot be produced and delivered within the 36 hour window, then inventory has to be held at the de-coupling point(s) in the supply chain; these are then built against forecast rather than against customer orders. Consideration of several factors will determine where the de-coupling point should be; these will include supplier production capacity flexibility, transport distance and cost, buffer stock holding costs, average share of sold order mix and demand volatility.

Regardless of the configuration of component suppliers, it is vital that the availability of all components is checked prior to confirming a delivery date to a customer; not just to take into account those components that are known to be production constraints as currently occurs. There are several levels of checking, the highest being utilising tagging technology e.g. engines, the lowest is stock level checks for commodity parts. Problems arising would be fed back to the manufacturer by the same information system as that transmitting forecast and schedule data.

B. Information Systems

The second area where production reliability can be improved is information systems. Core data such as customer order information must be available in real time to all parties within the supply chain. The information system must provide an integrated process from customer enquiry and ordering, through the production of components and the vehicle, to delivery of the vehicle to the customer.

This represents a major challenge: the typical supply chain connected to a vehicle manufacturer often includes up to 60 separate systems, and within the manufacturing plant up to 200 systems. Many of these include legacy systems, built for a different world of IT capability, that have grown organically and are 'bolted on' to existing supply, production, and logistics operations. Legacy systems attract all sorts of process limitations such as manual hand-keying and additional paperwork, resulting in wasteful delays which as Figure 3 illustrates can easily exceed the time needed to carry out the productive tasks they are supporting.

Legacy systems were built for manufacture rather than customer-led production, and in an era where technology was associated with control. Many are over 30 years old and require extensive maintenance from the vehicle manufacturer where original IT support contracts have long since expired. Existing IT infrastructure is often too costly to replace en masse, leaving the manufacturer who runs the most complex systems with a serious disadvantage in terms of reducing order lead time.

The major information technology barrier to the 3Daycar is batch processing. The current configuration of internal systems results in individual mainframe systems updating one a day, processing batches or 'buckets' of orders in a time intensive cycle that adds 4 to 5 days to the order to delivery time of a vehicle (Figure 6). This usually has to happen overnight to process customer orders received during the day. Due to the fact that information flow is largely un-sequenced, it is possible for the output of one process to 'miss' the start of the next window, adding further delay to the process.

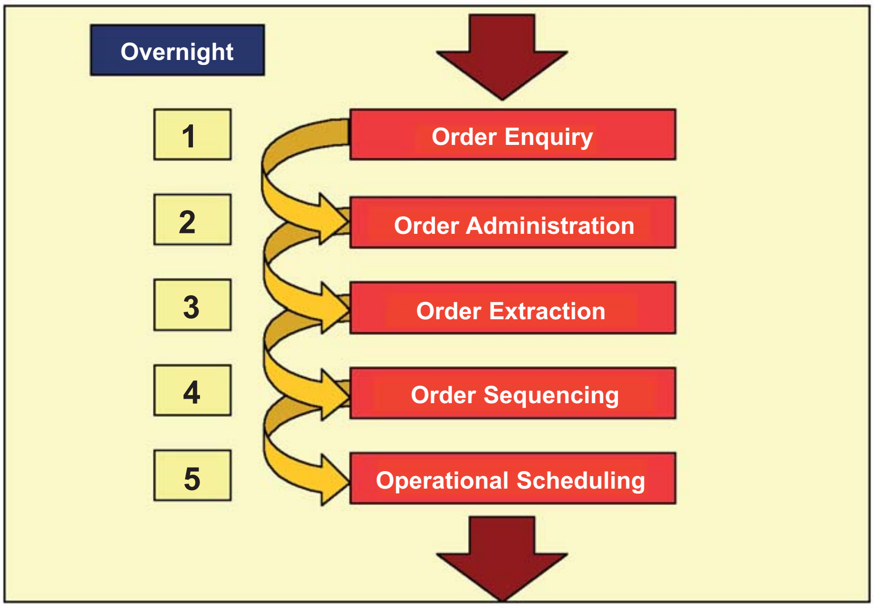

Figure 6: Batch Processing (Howard, 2000)

Despite the emergence of e-commerce, 3DayCar cannot be achieved simply by applying sophisticated optimisation technology to the current supply and production process. Building an efficient order to delivery process requires a fundamental rethink over how product and information flows across the supply chain, how this fits together, and how the overall infrastructure should be constructed around them.

The 3DayCar approach takes the customer enquiry at the dealership as the starting point of the process. An enquiry is made by the salesperson who enters the desired specification and delivery date into the system. The response from the system is an offer that is able to define a production slot, delivery date and price - having first checked that a production slot is free and that all components specific to the specification are available. The customer is then able can accept the offer that sets the requirements for component supply, vehicle assembly, and logistics in motion.

A key principle here is direct order booking - i.e. orders booked directly into assembly slots, that eliminates the delay of batch processing. This is essential to achieving short order lead times, and to give instant and reliable feedback to the customer on when the vehicle will be delivered. The Direct Order Booking System (DOBS) merges the existing order bank, scheduling and sequencing tools into one system. Figure 7 summarises the overall process, with the direct order booking system being the focus around which all other activities take place.

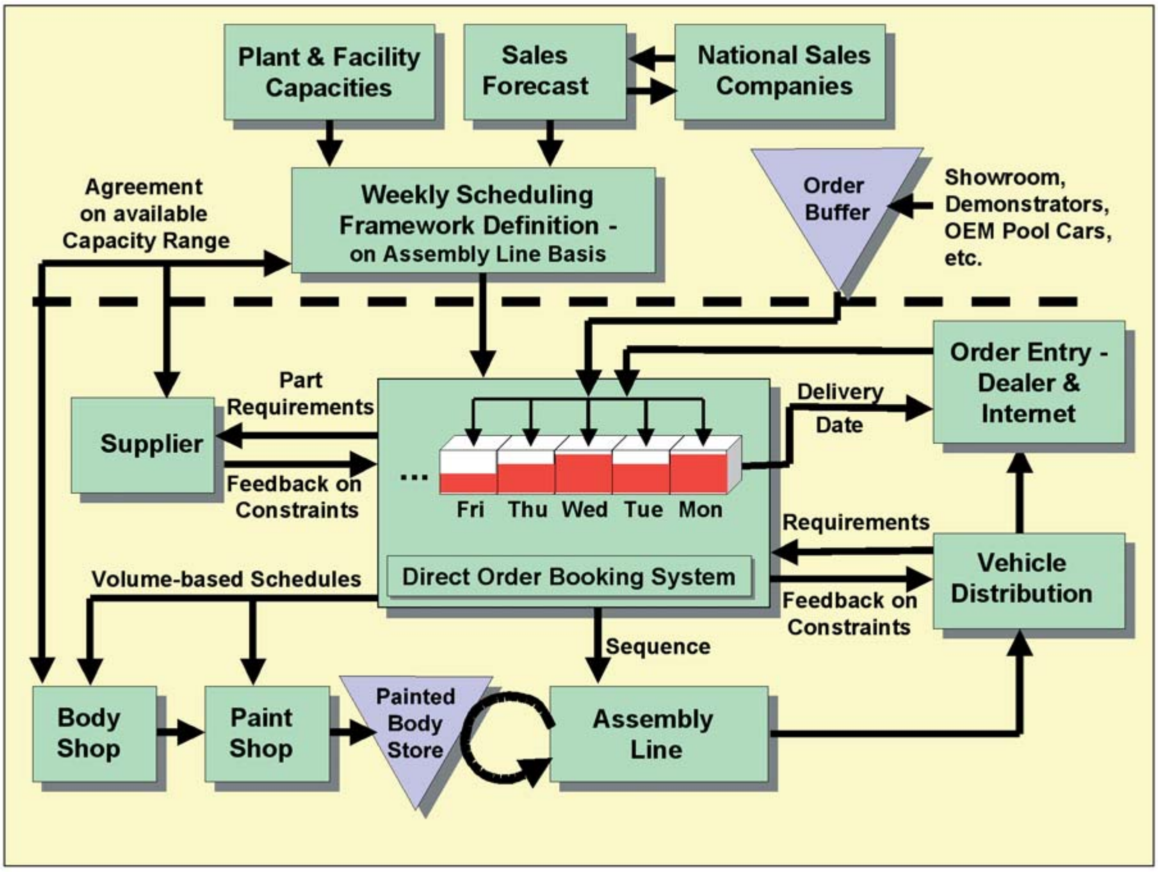

Figure 7: Direct Order Booking (Source: Holweg, 2002)

DOBS requires the order slots and their content to be visible to suppliers and logistics partners, providing operational and scheduling information, and enabling them to plan accordingly. This access needs to be in real time with a feedback mechanism to enable supply chain partners to communicate any constraints or problems back to the vehicle manufacturer. The concept of DOBS and the integration of technology such as Internet trade exchange or 'e-hubs' will have a major impact on the future efficiency of the supply chain.

In the future the core of the information system needed to operate the 3Daycar will include demand management, direct customer order booking, planning and scheduling, and logistics. The order fulfilment e-hub brings together the vehicle manufacturer, dealers, component suppliers, and inbound/outbound logistics to share information in real time (Figure 8). Customers can use the Internet to enquire directly via the hub concerning new vehicle specification, price and delivery, or simply to locate their nearest dealership.

Outside the core, other partners such as tier 2 and 3 suppliers will also able to receive real time information limited to their specific operations and service level requirements using Web-enabled personal computers. Yet many suppliers are wary of the World Wide Web over issues of cost and reliability, and are concerned over multiple EDI standards – particularly in terms of label format and system protocol. New technology such as middleware and extensible markup language (XML) offers the potential to provide a common Internet link by recognising software code to bridge different IT systems. However, further work is required to encourage world-wide adherence to operating standards.

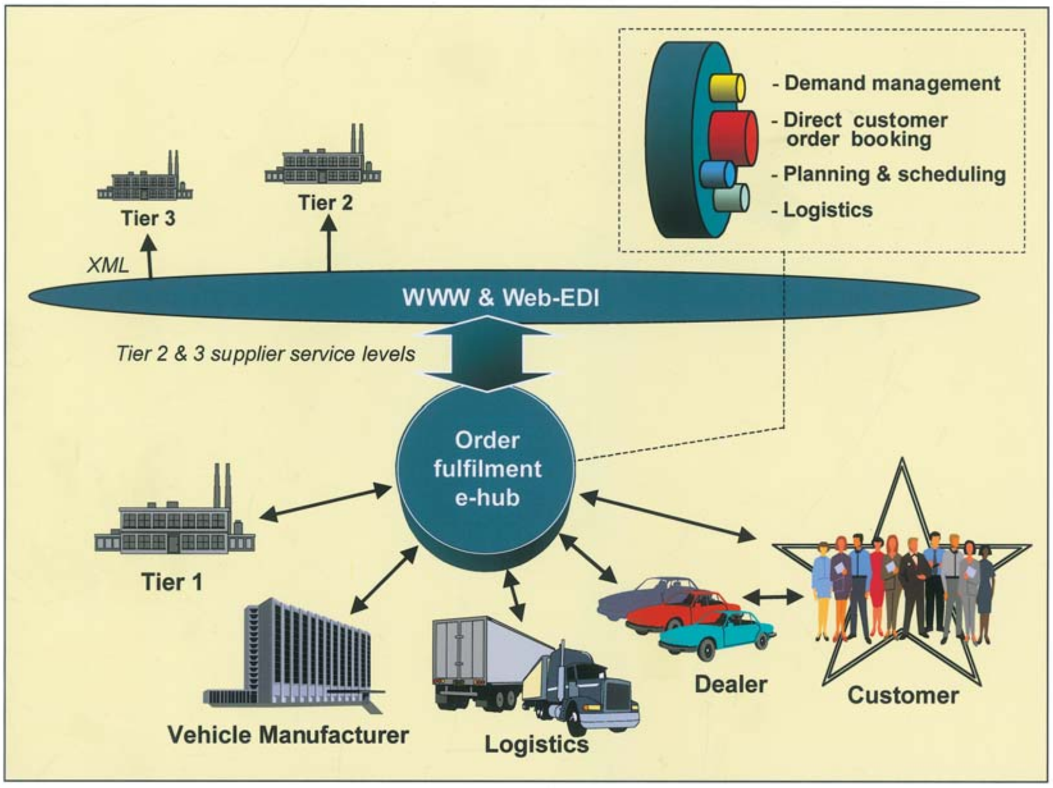

Figure 8: Core information systems for 3DayCar (Source: Howard, 2001)

Changing the information system is vital to achieving a 3DayCar, dependent on real time information flow and visibility across the whole supply chain. Yet for many supply partners this vision is a long way removed from the 'mess' their IT systems are in today. The rapid development of new information technology such as e-business cannot unravel the tangle of legacy systems, or overcome the functional mindsets that persist in industry. Despite the emergence of common coding, Web EDI, and e-hubs that enable seamless sharing across and within supply partners, developing the information system needed to deliver the responsiveness for 3Daycar is expected to be a slow process of evolution.

C. Paint Shop

The paint shop is the largest single barrier to reliability in the final assembly of vehicles. At present some 28% of all vehicle bodies need to be reworked in some way, and 4% recycled through the whole process, which typically takes 7 hours. The paint shop is also very unfriendly to the environment because of the solvents used in cleaning out the equipment between colour batches. The need to meet increasingly stringent legislative requirements has limited the scope for reducing paint batch sizes, where the average today is 12 vehicles.

Painted bodies emerging from the paint shop struggle to match a predetermined sequence of customer orders for the final assembly track. Hence, to provide a reliable selection of painted bodies to meet customer orders, many western manufacturers use a painted body store to de-couple the painted body from the final assembly track. Some stores can hold up to 800 bodies, but Japanese manufacturers consider this inefficient and wasteful. The 3DayCar approach would initially be to ensure minimum painted body levels, but ultimately the aim is to eliminate painted body stock.

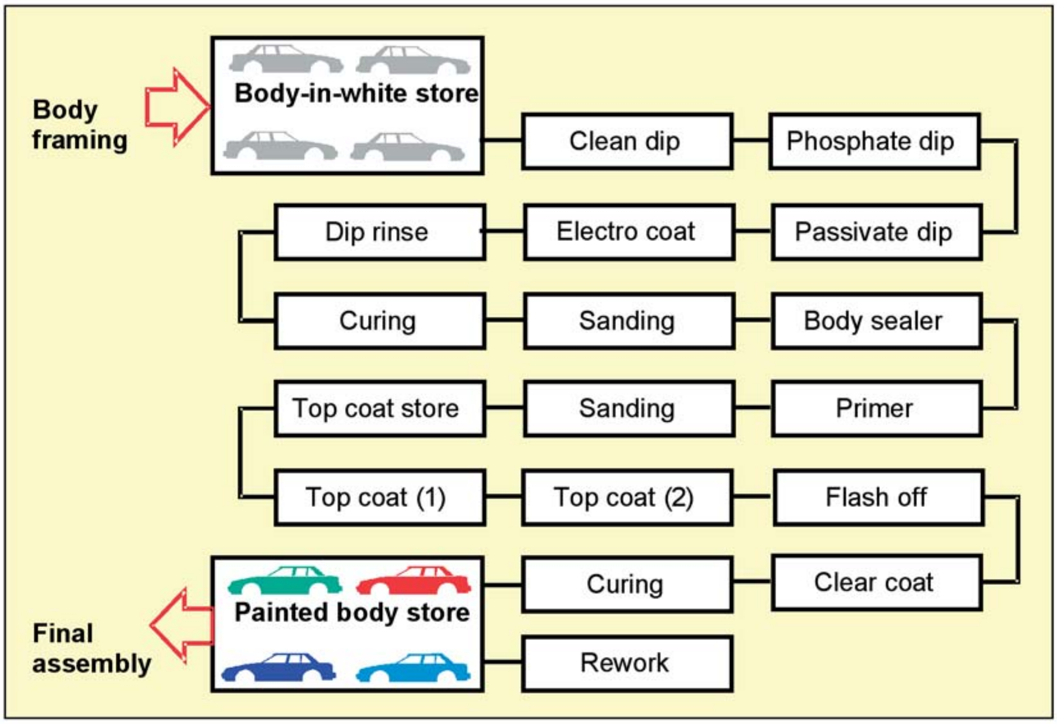

Figure 9: The Paint Shop (Source: Howard, 2000)

It is now technically possible to paint in batch sizes of one and some Japanese manufacturers are already managing to achieve a consistent paint quality level with these individual batches. The removal of sequencing constraints on the final assembly track that form part of the 3DayCar approach will also ease the demands on the paint shop. This will reduce the need for a painted body store, and maximises the probability of the assembly track being able to cater for actual market demand.

Over the longer term, changes to vehicle technology are expected to improve production reliability. The steel monocoque or 'unibody' has dominated volume production models throughout the second half of the 20th century. Yet shortening product life-cycles in the marketplace and increasing fuel efficiency requirements are stimulating manufacturers to consider alternative body construction methods in mainstream production i.e. spaceframe design or 'Independent Body and Panels' (IBP).

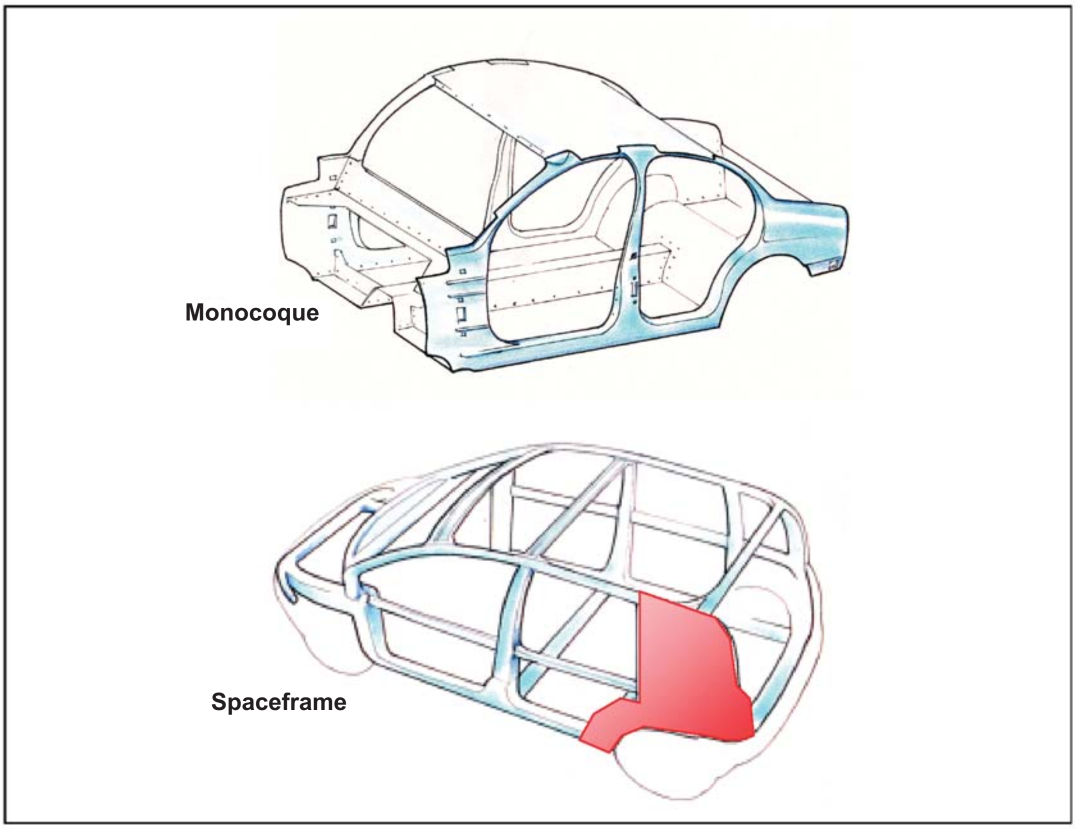

Figure 10: Monocoque and Spaceframe construction (Source: Howard 2000)

Spaceframes are more adaptable to new product changes, cater for more model variants than monocoques, and are more accessible to designs that incorporate lighter materials. They are steadily becoming more cost effective for volume build, challenging the traditional view that spaceframes are associated with expensive, low volume cars. With this technology, a minimal number of different body frames can enter the final assembly track, maximising the probability of being able to maintain the pre-determined sequence of customer orders.

As shown in figure 10, a spaceframe enables the load bearing structure of the vehicle to be separated from its exterior panels. These panels can be prepared and painted offline, or produced using some other method such as thermoplastic colour injection moulding. This has enabled several manufacturers to exploit new technology and minimise the impact of the traditional paint shop on both order fulfilment and the environment.

D. Logistics

Logistics is the physical linking element in the supply chain and so plays a critical role in supporting a 3DayCar system. The improvements that can be made here using the 3DayCar approach are as follows:

First, outbound logistics (as shown in Figure 11), from the factory to the dealer, will need to be achieved in one day. However, using current practices, achieving this would increase the cost of distribution by 33% and the environmental effects by 20%.

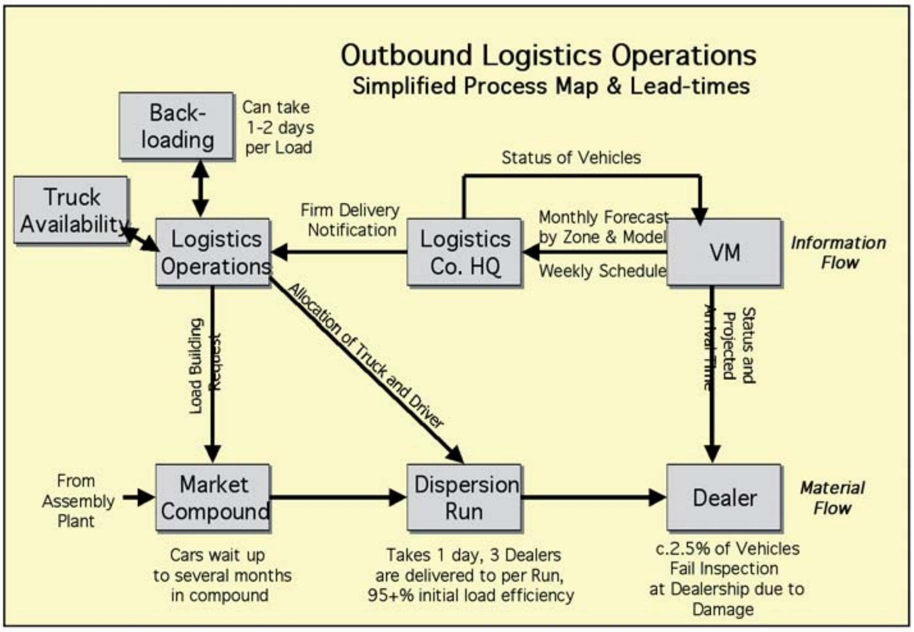

Figure 11: The current outbound logistics process (Holweg and Miemczyk, 2003)

Second, inbound logistics (as shown in figure 12), although not part of the three day lead time, is vital to achieving a reliable supply of components to the vehicle assembly track without excessive stocks needing to be held at or near the factory.

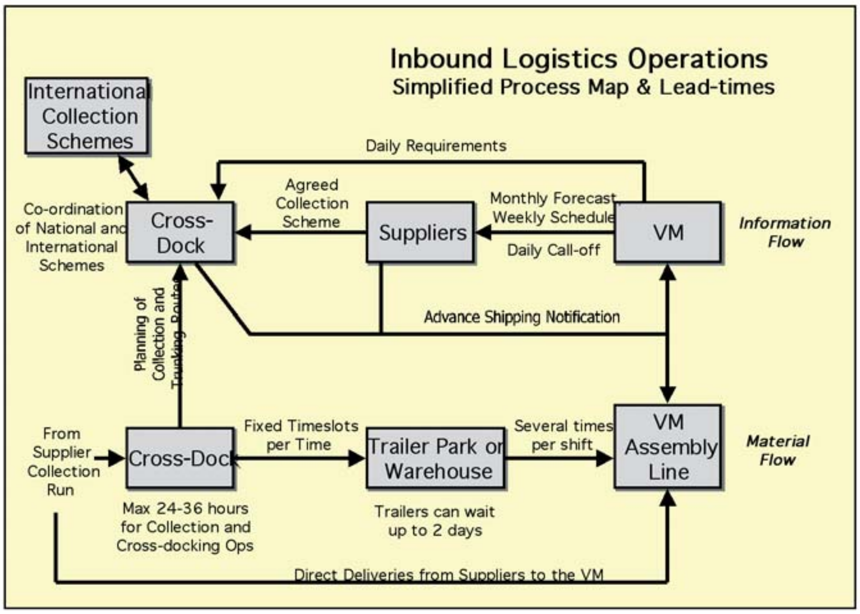

Figure 12: The current inbound logistics process (Holweg and Miemczyk, 2003)

Research with a simulation model has shown that efficient inbound logistics and a one day lead-time for outbound logistics can both be achieved without significant increase in cost or environmental impact, providing that specific operating improvements are made. The key ingredient is an improvement in the quality of information available; at the moment distribution planning often cannot start until the new vehicles are handed over to the logistics company.

Applying the 3DayCar approach to both inbound and outbound logistics requires that the following measures are taken to reduce the impact on cost and the environment. The use of mixed size fleets of delivery vehicles allows better capacity utilisation within the more frequent movement of components and vehicles. Adopting multi-franchise collection and delivery would further improve utilisation, as long as this can be incorporated within the required delivery time. Dynamic route planning systems will help to optimise routes and drive times.

24 hour per day delivery would enable more efficient use of transport and ease congestion in general, and also particularly in vehicle manufacturers' unloading facilities. This requires changes to the vehicle damage inspection process for vehicles arriving at dealerships. Performance measures should quantify capacity utilisation and the environmental effects of fuel usage and distance travelled. Measurement and benchmarking these areas would assist in making improvements.

For outbound logistics alone the following actions should be taken. First, multi-franchise delivery, combined with a rationalisation in the number of ports and distribution centres used, and in the regions delivered to from each one, would assist capacity utilisation on both delivery and back-loading (the ability for a truck to carry a load both to and from a destination).

Second, the introduction of online trading exchanges will further enable logistics companies to co-operate in maximising capacity utilisation at all stages of movement. This will be facilitated by a recognition on the part of manufacturers that back-loading has a dramatic effect on the overall efficiency of delivery operations.

To allow inbound logistics to facilitate the 3DayCar, the specific issues to address are location of suppliers and component containerization. The trend towards supplier hubs or parks next to vehicle assembly plants is likely to continue, and inbound logistics transportation will therefore tend to concentrate more on the movement of 2nd to 1st tier suppliers in future. This will be problematic for the 3DayCar, as many 2nd tier components will be sourced from Eastern Europe and Asia. To help combat these transport inefficiencies containers should be standardised and all efforts made to eliminate cardboard packaging. A significant loss of capacity utilisation occurs due to different shaped and unstable packaging.

With the 3DayCar route to production and distribution reliability set out, the next major problem to overcome is to move towards responsiveness in production so that variations in market demand can be catered for within laid down capacities.

5. How to Make Production More Responsive

3DayCar research highlighted three principal areas where production operations can be made more responsive to the variations in market demand.

These are:

- **Minimising production complexity**
- **Increasing production flexibility**
- **Matching demand to available capacity**

A. Minimising Production Complexity

The first step towards building responsiveness is to minimise production complexity. Figure 13 shows, on a logarithmic scale, how specification variation can increase during the stages of assembly.

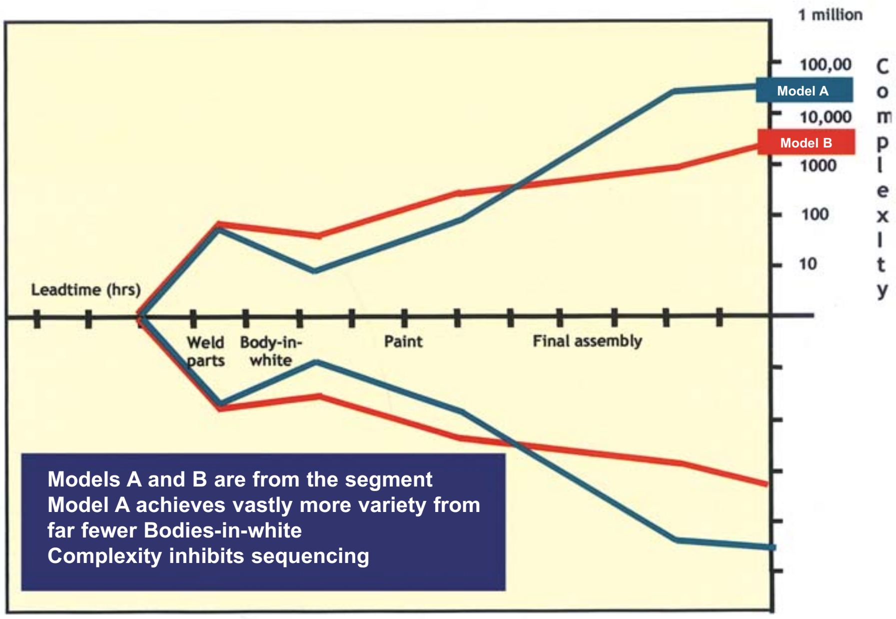

Figure 13: Product Variety Funnel: Technical Complexity (Adapted from Hines & Rich, 1997)

The addition of complexity - i.e. vehicle options until the final assembly process - can cut the order lead time by 12 to 18 hours, compared with order identification at the beginning of the body assembly line. 3DayCar research also shows that there is actually no correlation between body in white or painted body complexity and the product variety finally available in the market place. Figure 13 shows, on a logarithmic scale of variety, that Model A has 9 body-in-white and 250 painted body variations, with 500,000 specifications available to the customer, whereas Model B has 110 body-in-white and 1100 painted body variations, but actually offers the customer less than 10,000 specification combinations. The producer of Model A will have much greater reliability in building vehicles at the right time than the producer of Model B.

Spaceframe vehicle construction is also well suited for adding the variety required by customers in the latter stages of assembly since the painted panels can be attached to the body frame on the final assembly track – even, for example, a sunroof panel can be added at this stage.

While the cost-driven movement towards modules and standard components across different derivatives reduces the number of different components assembled on the final assembly track, new developments in technology give other methods of controlling variation. For instance, multiplex wiring harnesses with one central 'core' that can take any combination of electrical options can replace hundreds of different combinations of wires. Also 'plug and play' functionality is increasingly prevalent in multiplex systems; all the possible options and combinations are present in a module, but are switched on or off according to the customer order requirement.

B Increasing Production Flexibility

Once the overall complexity of production has been reduced, the total supply chain process can adjust more quickly in response to the demands of the marketplace. This capability will be enhanced by specific measures to increase the flexibility of production. The traditional focus has been on minimising manufacturing costs. The 3DayCar approach demonstrates that accepting the potential for slightly increased cost in the manufacturing phase may actually enable much higher profits to be generated across the system as a whole.

The ingredients of greater production flexibility in a 3DayCar system are:

- Increased manning on the assembly track and other relevant component areas should enable them to cope with any reasonable mix of specifications required by customer orders. This will remove the restrictions on the sequence of orders in assembly which are the result of attempts to 'balance' the production line; itself usually aimed at minimising labour costs.
- The introduction of annualised hours employee contracts allows for more variable working weeks through the year. These are becoming more acceptable to trade unions, but have so far proved more common at vehicle manufacturers than at suppliers. The phasing of employee holidays would permit production to continue throughout the year, thus making the most efficient use of available capacity.
- Increased component stocks to cover those variations in demand that cannot be matched by an equivalently rapid response in component supply. The more flexible the supply chain, the less the need to hold additional component stocks. In fact, 3DayCar's simulation model of the whole chain suggests that an overall reduction in component stocks is feasible compared with the current situation, at least in the longer term. This is brought about by passing information from the market up the component supply chain in 'real time', using the information systems prescribed by 3DayCar research.

Over the longer term, flexibility can be further enhanced by a shift to multi-product assembly lines, producing models with common platforms and other major components. This would allow better utilisation of assembly capacity as demand for different products varies throughout their lifecycle. However, the need to minimise complexity within the initial phase of vehicle design will be reinforced by a multi-product assembly line. Design both for disassembly and maintenance are also important, in view of the incoming end-of-life of vehicle dismantling/recycling legal requirements and can be complementary to minimising complexity – eg standardised fasteners.

A trend towards a more 'cellular' organisation of manufacturing is expected, particularly for high variety components. This will allow suppliers to be capable of producing small batch sizes with rapid tool changeover. However, traditional transfer lines will continue for commodity components, which will increasingly be used across a number of platforms and brands.

The geography of production may need to be re-thought, tempering the focus on components produced at low cost but at a long distance from assembly. Here the trade off is between direct production cost, delivery time, schedule horizon, and the need for safety stock. Long distance suppliers of complex components are particularly inflexible; in this respect the 3DayCar approach would require a rethink of the global sourcing policies operated by some manufacturers.

C. Matching Demand to Available Capacity

In a build to order system, production volume and mix will vary according to the pattern of sold orders and requested delivery dates. Even with a highly flexible manufacturing system, these peaks and troughs in demand prove very difficult to reconcile with the realities of the production environment where there is a limit to the extent to which plant and personnel can simply be switched on and off at will. The solution is to manage demand; to match it to the available capacity so as to limit damaging and costly fluctuations and keep the whole chain running smoothly. 3DayCar has looked in detail at the demand management techniques widely employed in other sectors of business, techniques which are also becoming increasingly prevalent in the car industry.

For cars, as with many other products, there are three key sources of demand variability:

First, there are distortions generated by the supply system itself, such as the way dealers are traditionally paid bonuses for hitting month-end sales targets; the final week of the month is undoubtedly the best time to buy a new car. The general effect of these kinds of distortions is to shift demand rather than actually to increase it overall; period-based sales incentives will tend to create spikes in demand, as Figure 12 shows.

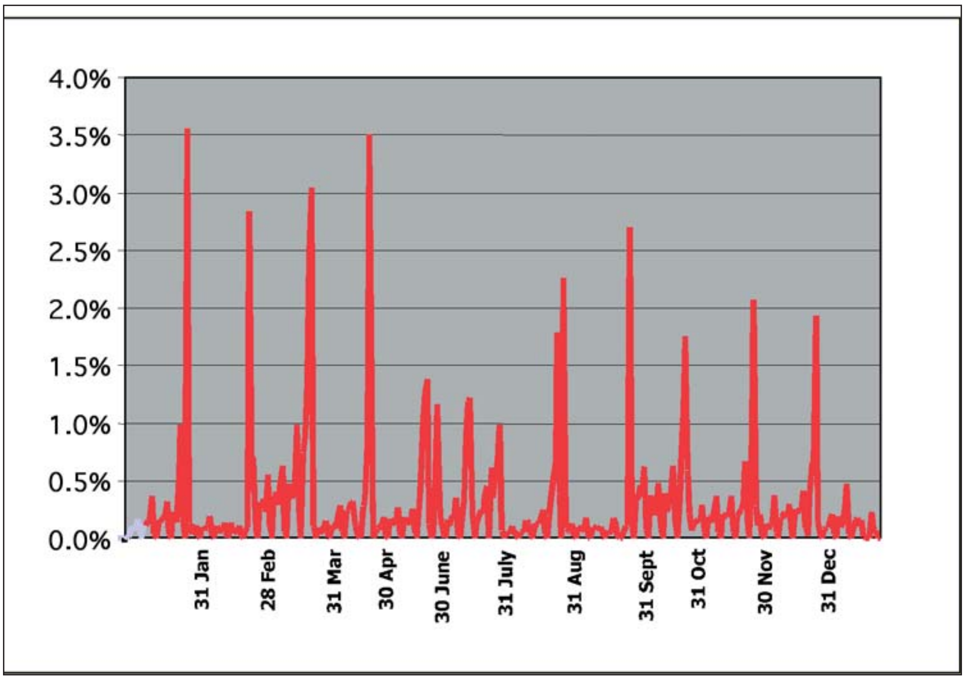

Figure 14: Effects on Demand of Sales System Measurement, Incentives and Rewards (Source: Waller, 2001)

Second, every car market suffers seasonality for a number of reasons, such as geography, holidays and the end of the tax year. In the UK, this effect is stronger than in other European markets as a result of the twice-yearly registration plate change, which causes two major peaks in demand as customers all flock to the new registration number. Despite the traditional industry view that the excitement of the registration change is vitally important in generating sales, the additional costs imposed on the supply system in coping with these huge peaks risks actually outweighing the benefits.

Third, demand also varies as a result of underlying changes in real customer demand, such as a trend towards more economical models in times of high fuel cost, or a downturn in car purchases in times of recession.

There are two ways in which demand can be managed. The first is to make use of the varying delivery times and status of the many different categories of customer order. Demonstrator, showroom, and employee orders can effectively be used as a buffer to fill empty production 'slots'. For instance, orders for employees could be raised two months before they are due to change their vehicle, and then built, by the due date, whenever it is most appropriate to fit them into the system.

The different lead time requirements for the various categories of customer can therefore be used to smooth out daily demand variations from the market; the less important can be postponed if a large number of final customer orders suddenly arrive, or brought forward to keep the factory busy during slack periods. Figure 15 shows the build up of orders as the production day approaches for different categories of customer. At one extreme is the demand from fleets, often known several weeks ahead, and at the other extreme, a small, but increasing proportion of 3DayCar customers; those who want a custom-built car as quickly as possible. If, when all other orders have been received, there remain unfilled production slots, then the buffer orders should be used. In this way, lead-time segmentation can be actively managed.

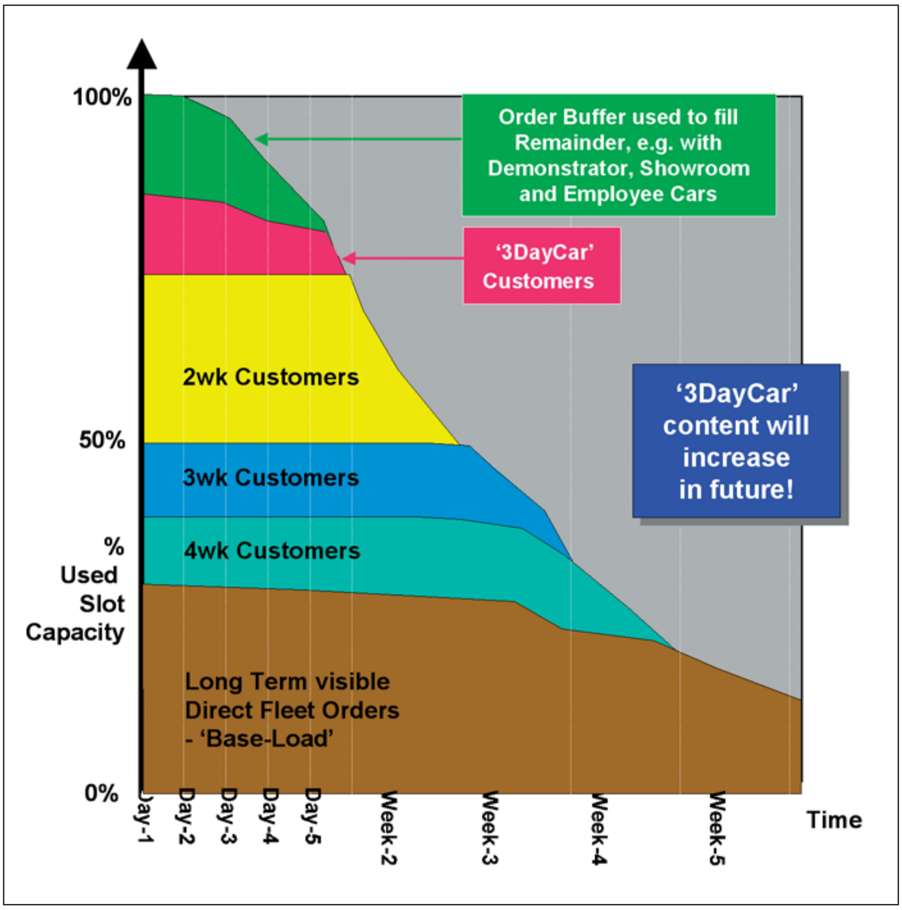

Figure 15: How Order Segmentation Improves Capacity Utilisation (Source: Holweg and Jones, 2001)

The second method of managing demand is to adjust pricing to stabilise order inflow. The manufacturer should not just react passively to orders as they arrive; this would undoubtedly lead to large swings in capacity utilisation outside the confines of the increased production flexibility that has been described. Instead, they will actively need to influence the type and pattern of orders being placed, by flexing pricing and promotions to optimise the trade-off between capacity variation and lost sales.

Managing demand involves encouraging customers to purchase during off-peak periods and to order early for peak periods; selling advance production 'slots' instead of stock. Price management can be used to stimulate orders in periods of low demand, such as the last quarter of the year, in times of excess demand, or when there are constraints on certain types of component (e.g. diesel engines or air conditioning). To do this effectively, promotional decisions will need to be made quickly and in close consultation between the marketing, production planning and logistics functions at the manufacturer, so as to ensure that the sales intent of the promotion is supported by production and logistics capabilities. Dealer incentives and bonuses will also need to be based on constantly rolling period targets, to avoid large peaks in sold orders for production at the end of each month.

These techniques are known as Revenue Management. Having been in widespread use in sectors such as air travel and hotels for a number of years, their application to the car industry is now being explored. In car retailing, a particularly critical aspect of Revenue Management is how to deal with the product mix. Traditionally, if dealers place orders for stock, they tend to order the cheapest or most popular specifications on the basis that these are more likely to sell and so will not be in stock for a lengthy period. If all dealers do the same, the profit margin of the mix of specification available tends be lower than the natural underlying demand. Figure 14 shows a typical breakdown of actual sales by derivative for a representative model; the highest sales show as pyramids. With the correct information, customers can order what they want but can be steered towards a mix that is richer and more profitable for the manufacturer and/or the dealer.

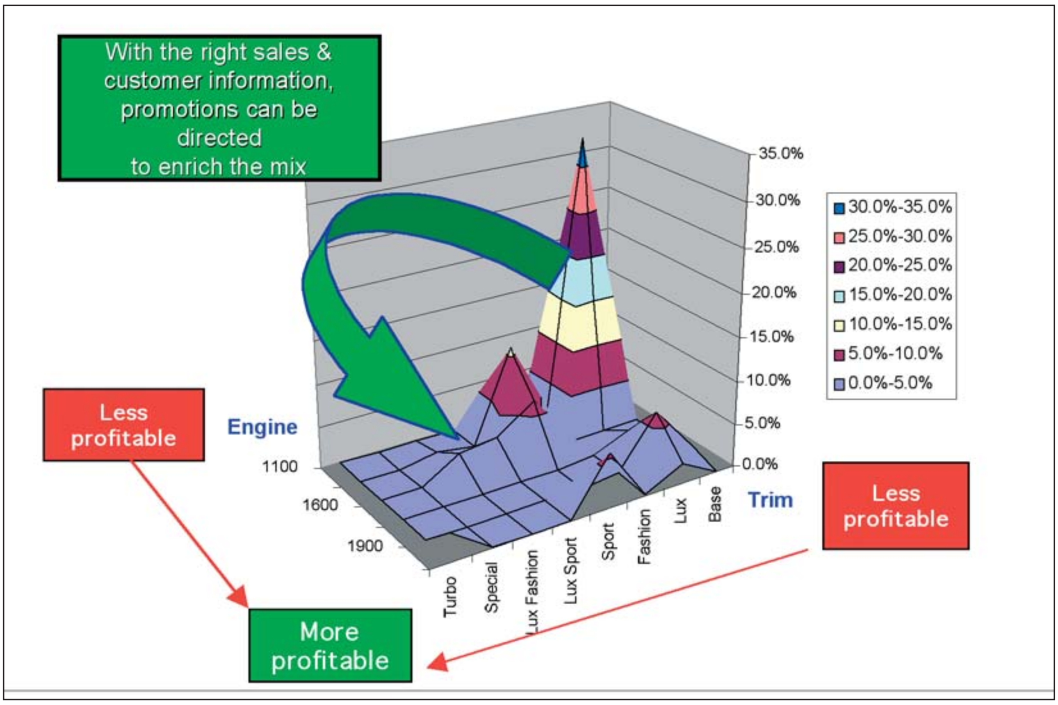

Figure 16: Managing the Product Mix – Mix of Trim and Engine Size (Source: Waller, 2001)

In summary, the benefits from properly matching demand to capacity are not merely the immediate financial ones. Orders placed on the factory will be from actual car buyers as opposed to dealers. This means that the knowledge of true demand in terms of volume variations and specification mix will be much improved than in the traditional stock push situation where whatever is produced is eventually sold at sub-optimal profit. This in turn should allow sales forecasts to become much more accurate, and the quality of information filtering back into product design to be significantly better.

6. Evaluating the 3DayCar

For industry to accept the logic set out in this research the key question must be answered: how much can be saved by introducing a 3DayCar? General predictions regarding the potential of a move to build to order suggest that savings of the order of 10% should be possible. However, there has been no previous attempt to define the additional cost of the production flexibility required to support a true build to order system. This is what the research quantifies below: an overall assessment of the financial cost and benefit of the 3DayCar.

The following summary gives the major elements of increased profit and cost expressed as a percentage of a vehicle's recommended retail price. Estimates are based on ICDP and 3DayCar research of the actual market place.

A. Increased Profit Potential

Cost savings	
Interest cost of inventory	1.80%
Inbound logistics, stock and material handling	0.15%
Finished vehicle storage and maintenance costs	1.80%
Dealer transfers	0.05%
Process improvements in terms of time involved in sale, order wholesales, etc.	0.50%
Subtotal	4.35%
Profit potential	
Removal of additional discounts on ageing stock	1.85%
Removal of additional discounts on alternative specification	0.45%
Removal of old model stock problems	0.80%
Reduction in lost sales	0.10%
Sale of more profitable product mix	2.00%
More efficient revenue management	1.00%
Improved ability to supply 'right' cars due to better forecasting	0.40%
Subtotal	6.60%
Gross increased profit potential	10.95%

Table 2: Potential % increase in profit

While the removal of stock and release of associated space is the largest area of potential increase in profit, the reduction in costs associated with the disposal of stock is extremely significant. The importance of stock turnover is demonstrated by the 1.85% potential saving on additional discounts on ageing stock and 0.8% on old model stock problems.

There is a significant profit potential from managing demand within a stockless system, rather than just selling what has already been built. The use of Revenue Management techniques, together with steps to encourage the customer to purchase a more profitable mix can make a major impact, once vehicle stock has been removed from the marketplace.

3DayCar simulation has shown that with open real time information systems and more efficient logistics, the cost of inbound logistics and stock can actually be reduced despite the system having to deal with greater variation and more frequent delivery.

B. Potential Cost Penalty

Investment	
I.T. hardware and systems throughout the supply chain	**1.00%**
Logistics capacity or environmental impact mitigation	**0.10%**
Production capacity in assembly	**0.05%**
Subtotal	**1.15%**
Operations	
Outbound logistics	**0.10%**
Manning increase	**0.20%**
Subtotal	**0.30%**
Total cost penalty	**1.45%**
Net profit potential (10.95% - 1.45%)	**9.50%**

Table 3: Potential % increase in costs & net profit potential

The increased costs are largely associated with the changes that need to be made to information systems and production. Information technology is by far the greatest increase in cost, due to the need for the development of overall supply chain systems to replace current systems designed around individual functional operation and optimisation. However, technologies do exist to convert existing operations systems as part of a gradual migration strategy towards a responsive enterprise-wide system, allowing these costs to be spread.

Manning increases - to give more flexibility and capacity in production operations - are estimated to be marginal, as are the costs of the extra production capacity that will be needed. Vehicle manufacturers in general have significant over-capacity and component suppliers can deal with variation by increasing stock levels. Outbound logistics costs are likely to increase in the short to medium term in a 3DayCar system. However, full implementation of the longer-term improvements proposed will more than compensate for this.

This cost assessment will obviously vary by product according to the supply system processes currently operating, the volume of production, and the market mix of product. In the above example, the assembly plant was assumed to be producing 100,000 vehicles per annum, with 50% for the UK and 50% for the rest of Europe.

The potential overall profit improvement of 9.5% is considered to be conservative. The effect of efficient Revenue Management and profit mix improvements have deliberately been understated in comparison to known achievements in other industries. In addition, whilst IT costs will undoubtedly be considerable, they have to be viewed in the context of the ongoing, high spend on information systems development and replacement of hardware throughout the industry.

7. Conclusion: Adopting a Lean Culture

The 3DayCar Programme is about the ultimate application of lean principles to the supply chain for vehicles. The essential principles of lean thinking are:

- That the flow of a product through a series of operations, i.e. the value stream should be optimised, rather than just maximising the efficiency of each operation separately.
- That a product should be 'pulled' through the system by customer demand at each stage, rather than being 'pushed' by the producer.

The car industry has started to gain the benefits of a lean approach to assembly, with components being pulled on a just-in-time basis. There is an even bigger prize available if this same approach can be applied to supplying the final customer.

However, this implies a dramatic shift from the culture in industry today. It involves moving from a silo mentality, in which each company (and even each function within the same company) focuses on minimising its own costs without allowing for the effect on other stages of the supply chain, towards a more holistic view. This requires all players working together to optimise profit for the whole supply chain. It is likely that some players may increase their costs to allow greater savings across the supply chain as a whole. The extra initial cost will be incurred upstream, in component supply, to reduce costs or increase profit opportunities downstream.

Within the vehicle supply chain, only the vehicle manufacturer has sufficient power to bring about this degree of change. Leadership will be a critical element, and the demonstrable commitment of top management is necessary to bring about the long term changes involved in adopting a lean approach and ensuring supply chain partners follow suit.

One cultural shift is towards team working across functions and companies, away from the strict functional structure that fosters traditional silo mentality. An example of this is sales promotions, where in future the marketing and vehicle supply logistics functions will work closely together to manage demand and supply. Rather than wait for stock to build up before re-actively promoting its disposal, it will be necessary to ensure that the anticipated range of sales effects of future promotions can be matched by supply availability.

These organisational changes will need to be supported by new performance measurements and rewards. These should focus on producing the right product, whether for vehicle or component at the right quality at the right time rather than purely on volume and cost. For instance, production management will be rewarded for the number of orders produced to the right quality on the right day, rather than purely on volume target achievement.

It will be important to share the gains among players in the chain, so that all have an incentive to participate in change towards a 3DayCar. Trust is required between all parties to operate more 'open book' financial contracts, where all players are prepared to show their financial situations in greater detail. This means everyone understands the position of others in relation to where the costs and profit opportunities reside. However, sharing will not happen if participants believe that any profit area exposed will be extracted by the most powerful player in the chain.
In summary, the 3DayCar is a highly ambitious target for the car industry to reach. The traditional push approach is unresponsive to its most important stakeholder, the end-customer. The means of driving out industry-wide compromises and inefficiencies is by introducing pure market demand in the form of true customer orders. The individual system changes and improvements proposed by the 3Daycar research programme are all within the capabilities of the today's supply partners. Yet

what is needed is an industry-level vision, a commitment to change that benefits everyone, from the supplier to the end-customer.

3DayCar Programme Sponsor Organisations

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- National Franchised Dealers Association / Retail Motor Industry Federation
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The Research Team

Lean Enterprise Research Centre

Simon Elias
Professor Peter Hines
Dr Matthias Holweg
David Simons

University of Bologna

Dr Monica Bartolini
Professor Ricardo Silvi

ICDP

Professor Jonathan Brown
Maria Brown
Ben Waller
John Whiteman
Geoff Williams

University of Bath

Professor Andrew Graves CBE
Mickey Howard
Joe Miemczyk

Back row (left to right): Matthias Holweg, Peter Hines, Ricardo Silvi, Jonathan Brown, Mickey Howard
Middle row (left to right): Simon Elias, Joe Miemczyk, Geoff Williams, Dan Jones
Front row (left to right): John Whiteman, Monica Bartolini, Andrew Graves, Ben Waller, Maria Brown

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