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Painting the 3-day car

The paint shop is the biggest bottleneck in car production today. Mickey Howard and Joe Miemczyk* analyse current paint shop strategies to identify the weak points and assess the changes needed to achieve a three-day vehicle delivery time.

In an effort to minimise lead time throughout the order-to-delivery process, the 3DayCar research programming is examining all areas of the automotive supply chain to assess their potential for time compression. The Paint Shop may not, at first sight, appear to warrant serious attention. It is true that the physical production of a vehicle only takes around one day compared with the forty days on average that it takes for an order to become reality for the customer. However, the paint shop actually determines the remainder of the entire downstream vehicle delivery process.

The requirements of rapid build to order

Building to order implies responding to individual customer requests, not simply producing large numbers of vehicles for stock and encouraging their sale by promotion and discounting. Traditionally, vehicle assembly lines have been organised to produce a fixed sequence of vehicle types, their focus being to minimise the cost of labour, rather than to cater for the flexibility of customer demand. In order to ensure this fixed mix, the Paint Shop has to produce painted bodies in a reliable manner or to hold large buffer stores. The Paint Shop is particularly unreliable, and the typical total vehicle manufacturing process only achieves around two thirds of the planned daily order schedule. Such an unreliable production and delivery process encourages dealers to sell from stock rather than place orders on the factory, and perpetuates the stock ‘push system’. Furthermore, customers don’t know whether the car they receive is truly ‘factory fresh’ or has been in stock for months. If this is to change to a ‘rapid build-to-order’ situation, more flexibility is required throughout production. Ideally each customer’s order is a batch size of one whose exact specification and delivery time must be met.

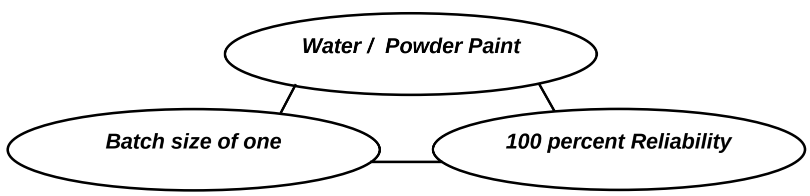
The significance of Paint

The paint shop, positioned between body pressing/welding and final assembly, represents a particular constraint to production of batch sizes of one. The typical average batch is currently twelve bodies. Not only is it severely limited in the sequence in which car bodies can be processed, but suffers from unusually high levels of rework due to surface finish quality. The replacement of solvent with water-borne systems, driven by increasing legislation, only makes matters worse. Typically, only around two thirds of the planned daily build schedule is achieved, which leaves the remainder of the downstream supply chain left to amend their delivery schedules, and dealers to answer customer complaints.

So, maintaining the optimum body sequence throughout production is vital in order to achieve productivity levels and reliable vehicle delivery. The paint shop plays a pivotal role by maintaining the mix in the painted body store in order to sustain the sequence in final assembly. Vehicle manufacturers (VMs) currently adopt two basic approaches. Either they create an individual sequence at each of the three stages of the production process in body store 'buffers', or they create one sequence and then re-sequence only where necessary e.g., in the event of machinery breakdown.

The idea of a 3DayCar Paint Shop presents a significant challenge to VMs who are currently still grappling with the conflicting demands of shorter order-to-delivery lead-time and the increasingly tight legislation governing emissions. It is proposed that all three requirements: totally water-borne powder-based paint, 100 percent reliability and the capability to handle batch sizes of one must ideally be met before the Paint Shop can provide the conditions necessary for rapid build to order, as illustrated in figure 1.

Figure 1: The Paint Shop challenge



The key facts

- **Lead-times –** Vehicle painting takes, on average, one third of total production lead-time. However this is not of major concern as it is the reliability of the current paint process itself, in terms of its impact on the daily schedule and its consequence on downstream activities, that is causing problems elsewhere in the supply chain.
- **Quality –** 'The real challenge to the Paint Shop'. Achieving a perfect surface finish every time still represents a big challenge to VMs. If they can get this right using water-borne or powder-based systems, overall sequence reliability will follow.
- **Buffering out the problems –** The use of buffers or body stores for re-sequencing at the start, middle and end of painting, to make up for lost production or rework is a practice peculiar to Western manufacturers. Typically, Japanese manufacturers create one sequence and run this straight through production. One Japanese manufacturer in the UK is currently achieving around 95 percent daily schedule reliability.

- **Costs –** Car plants, like many other commercial organisations, are still divided up and run as separate functional entities. Paint shop managers use batches as a means of reducing cost per vehicle and this may not be in the interests of the total plant or supply chain. If operating costs were viewed across the total supply chain, there could be a case for more local flexibility and higher costs.

Painting and the Environment

VMs have found that it is more difficult to achieve a good surface finish with water or powder-based paint systems than traditional solvent-borne systems. Smaller batch sizes are significantly more expensive in terms of lost paint, solvent and colour changeover lead-time. Those VMs who are currently using batch sizes of one are finding it difficult to meet required emission levels, for which legislation is becoming more stringent. Water-borne systems require longer colour change over lead-time than solvent and use more energy in the ovens due to the slower rate of evaporation. Given that these new paint systems are currently being installed by VMs due to legislative pressure, the task of achieving a reliable and cost-efficient paint process is made increasingly difficult.

Environmental concern

Paint is the biggest environmental problem that car factories face. Dealing with this takes up a major proportion of environmental expenditure. Fixed capital costs are high for emissions and waste treatment equipment. Equally, operating costs are substantial due to high energy and material use as well as material waste treatment and disposal. All this adds up to major difficulties in balancing costs in the paint plant while meeting regulatory and production expectations. The three key areas of environmental concern are as follows:

- **Air emissions –** Paint processes are currently subject to local authority regulation and visits from these authorities to ensure compliance. VOC (volatile organic compounds) emissions are the main concern in this respect, due to their potential to cause respiratory problems particularly for local communities. Thermal oxidisers are used to ‘burn off’ excess VOCs released and reduce the amount entering the atmosphere. The new European VOC Directive will bring down current emissions limits requiring either more capital equipment for abatement or alternative low solvent paints such as high solids, water-based paints or even powder coats.

- **Waste –** The primary source of hazardous waste from automotive plants is again from paint processes. Although much material is recovered, this waste is typically around 25 percent of a plant’s total hazardous waste by weight. The solvents and heavy metals left in residues mean that it is classified as hazardous through European law. Most of this results from cleaning processes in the paint plant.

- **Energy –** Curing ovens use vast amounts of energy for the paint to ‘go off’ in an acceptable time. The more speed required, the higher the energy use. This is further exacerbated by water-based paint requiring more time in curing ovens than solvent-based paint. Powder coats also require more use of ovens due to the thickness of coats for curing.

Best practice in the industry, for example at Volvo, Gothenburg and BMW, Dingolfing, brings VOC levels down to below 2kg per car. The average, however, is still around 5kg per car in Europe. Water-based paint use is certainly increasing, but those who employ it only do so on certain coats which often constitute around 50 percent of the process. No plants actually have zero VOC capability.

Powder coat systems remove the impact of VOC emissions completely and are 100 percent material recyclable. Any excess paint can be literally 'swept off the floor' and re-used. This means waste levels are also very low compared with water-based paints which have significant paint sludge and waste water outputs. However, high energy curing results as a trade-off from this.

The environmental consequences of more flexible and lean production are bound to increase when shortened lead-times and smaller batch sizes are required. These impacts can be summarised as follows:

- Faster paint lead times inevitably require high-energy use, especially for curing ovens, or greater solvent usage to speed up curing times.

- Smaller batch sizes lead to more colour changeovers, which in turn results in increased solvent and paint waste from cleaning out equipment and feed-pipes. This can raise costs per car in current systems.

- More changeovers can also increase overall VOC fugitive emissions, as they escape from the cleaning process and wastes. This makes stringent VOC regulations more difficult to meet.

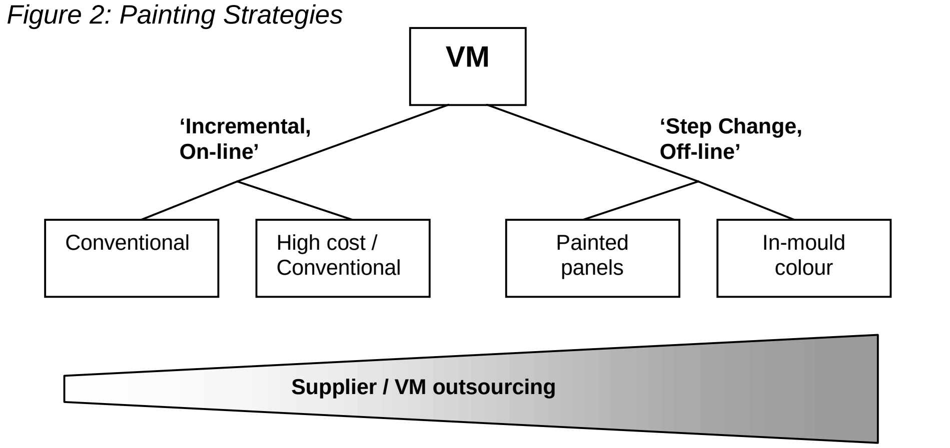
- A mixture of solvent and water-based strategies for different colours produces scheduling problems in terms of capacity balancing between the two types.

Current management of the paint shop in many automotive vehicle plants optimises environmental and operational performance. Achieving reliable delivery of the product through paint, whilst continuously reducing emissions and waste levels, will become more and more difficult. The challenge now is to reconcile these vitally important aspects of car manufacturing.

Strategy

The Paint Shop has always been viewed as an integral part of the core vehicle production activity, and currently represents around a quarter of the cost of the total facility. New developments are emerging in body construction that break the dependence on conventional line based, high-volume, ‘buffered’ painting methods and these will undoubtedly be introduced over time to the benefit of the achievement of a 3DayCar. A number of approaches towards automotive painting are emerging in the industry, which can be categorised under two headings:

Figure 2: Painting Strategies



1. 'Incremental improvement, On-line'

- **Conventional –** Current volume manufacturer's paint shops cost around 25 percent (£75m) of the total production facility**.** Key objectives include working towards a reduction of rework, of batch size, emissions and waste, and improving reliability. This will be strongly assisted by the introduction of automated sanding and spectro-photometry, and the adoption of universal paint finishing standards and benchmarking across the industry. However, the current movement towards water-borne paint will make improvements more difficult to achieve, leading to increasing reliance on partnerships between VMs and suppliers such as Durr, Gema, Eisenmann, Gericke, PPG and Herberts.

- **High cost / Conventional** – As both BMW at Dingolfing and DaimlerChrysler at Rastatt have demonstrated, powder-slurry or dry powder systems do provide all the environmental benefits of near zero VOC emissions, although the energy intensity may increase. Quality issues pivot on the cleanliness in the plant and the purity of recycled powder which inevitably increases costs compared to conventional methods. Material thickness is also greater for powder coats which also impacts on material costs. Powder slurry systems can be retrofitted to existing solvent/water-based paint shops, but dry powder systems require a completely new delivery system and high capital investment cost. For example, £100 million was spent on Dingolfing. Significant R&D investment was made during the development of these systems by suppliers, such as PPG and BASF, in partnership with the VMs.

2 'Step Change, Off-line'

The 'Step Change' approach represents a move away from current coating and application methods. On-line painting can be virtually eliminated by recent developments in spaceframe technology (Audi A2 and Fiat Multipla) and new materials (Smart), where non-load bearing exterior panels can be attached to a structural frame. This represents a significant departure from the conventional, pressed steel monocoque. Significant production lead-time reduction would be expected should this method become adopted, with associated benefits in sequence reliability and downstream assembly.

- **Painted Panels –** Steel, aluminium or composite panels are painted separately from the body and attached during final assembly. General Motors has used this concept for the EV-1 and Saturn models, both now in full production in the states. In theory, the painting of panels could be out-sourced and shipped from local plants through a JIT process.

- **In-mould Colour –** The major exponent of this approach is the Daimler Chrysler Smart car, where thermoplastic exterior panels are formed from 'Xenoy', a material developed specifically by GE Plastics. Coloured granules are added as part of the moulding process to form panels which require no further treatment, save for an optional metallic clear-coat or water based print for aesthetic purposes. The vehicle frame requires minimal treatment in a conventional paint shop where finished panels are bonded or riveted directly to the body during final assembly.

Environmental effects of in-mould painted panels

There is definite potential here to remove one of the greatest environmental problems from vehicle manufacture. Removal of the paint shop eliminates VOC emissions, or at least limits them to the much lower levels derived from use of adhesive and body frame treatment (i.e. only one colour). Not only would the waste from paint be eliminated, but also the huge energy costs of curing colour top coats and laminate coats. This would be partially replaced, however, with the energy use for plastic panels, which is undoubtedly intensive. It is also far more difficult to recycle plastic than metal, especially when it is coloured, as the industry knows from attempts to meet new recycling standards from Brussels. An increase in the diversity of coloured plastic would have even greater impacts on the economics of recovery. However, plastics do offer considerable additional benefits during vehicle usage, such as their light weight which enables better fuel economy.

The conclusion is that the overall effect on the environment of alternatives to the paint shop are not fully understood in terms of the vehicle life cycle. Far more research needs to be done to understand the relative merits of colour moulded panels over painted monocoques. Companies such as GE Plastics, PPG and Durr are increasingly providing more proactive environmental and operational solutions to the current problems facing automotive production in Europe**,** which vehicle manufacturers are beginning to implement.

Final words: who needs to do what?

It appears that a trend towards outsourcing is emerging in the automotive painting industry. While developments in conventional in-line painting will continue, the increasing emphasis on legislation will drive up costs, thus making other alternatives more attractive. The strategies outlined in Figure 2 show a graduated increase in the VM/Supplier outsourcing approach, leading to complete 'black-box' style solutions delivered by companies such as GE Plastics for

DC Smart. The authors believe that not only is this increasingly the case in Europe, but that dynamic, collaborative partnerships between VM and Suppliers are the way forward.

In order to assist this process, it is suggested that VMs should move from central, functionally based costing to total supply chain costing. Developing a bigger picture in this way will identify further opportunities for innovation and technology, such as new methods of body construction. Automakers must pre-empt legislation and embrace change: harnessing new product development as a means of achieving competitive advantage. They must also take a life cycle costing view, to understand the cost impacts of new technologies at the end of their life, an aspect VMs will soon have to pay for.

Paint Suppliers must recognise that the objectives of VMs are changing as they move towards customer pull strategies. The boundaries that once clearly separated the product from the process have been eliminated by the pace of change in the industry. They must form alliances, fast. Other suppliers, particularly new entrants in the field of plastics must develop the capability to demonstrate practical benefits of how they can be integrated into vehicle construction. Does the combination of rapid build-to-order and environmental legislation finally herald the end of the paint shop, one of most enduring features of 20th Century car production?

*Mickey Howard and Joe Miemczyk are researchers at the University of Bath's School of Management. Both have worked in the automotive industry in Industrial Design and Environmental Management respectively. They are supported by Professor Andrew Graves, co-director of the 3DayCar Programme and IMVP Europe. The authors wish to thank the EPSRC / Innovative Manufacturing Initiative and 3DayCar sponsors for their financial assistance and co-operation. This article reflects the views of the authors, and does not necessarily represent those of the 3DayCar programme or of any of its sponsors.