BUILDING CARS TO CUSTOMER ORDER - WHAT DOES IT MEAN FOR INBOUND LOGISTICS OPERATIONS?

Joe Miemczyk, *Matthias Holweg*.
Journal of Business Logistics.
Oak Brook: 2004.Vol.25, Iss. 2; pg. 171, 27 pgs

Subjects: Automobile industry, Logistics, Studies, Inventory management
Classification Codes 9130 Experimental/theoretical, 5160 Transportation management, 5330 Inventory management, 8680 Transportation equipment industry
Author(s): Joe Miemczyk, Matthias Holweg
Document types: Feature
Publication title: Journal of Business Logistics. Oak Brook: 2004. Vol. 25, Iss. 2; pg. 171, 27 pgs
Source type: Periodical
ISSN/ISBN: 07353766
ProQuest document ID: 739202181
Text Word Count 9032
Document URL: http://proquest.umi.com/pqdweb?did=739202181&sid=1&Fmt=4&clientId=10342&RQT=309&VName=PQD

Abstract (Document Summary)

The automotive industry is undergoing a strategic transition. Cost pressure from rising stock levels in the market and increasing incentives needed to sell these vehicles are forcing vehicle manufacturers to rethink their prevalent stock-push approach, building vehicles against a forecast and selling from stock, in favor of a stock-less build-to-order order fulfillment strategy. More responsive order fulfillment at the vehicle manufacturer level however will not only require flexible and responsive component supply, but will also have wide ramifications for the logistics operations. Based on three case studies of major inbound logistics operations, this exploratory study assesses their ability to support such a build-to-order approach, as well as the potential implications of such transition. The paper concludes with a set of general strategies for how these implications could be mitigated.

Full Text (9032 words)

THE "BUILD-TO-ORDER" CHALLENGE

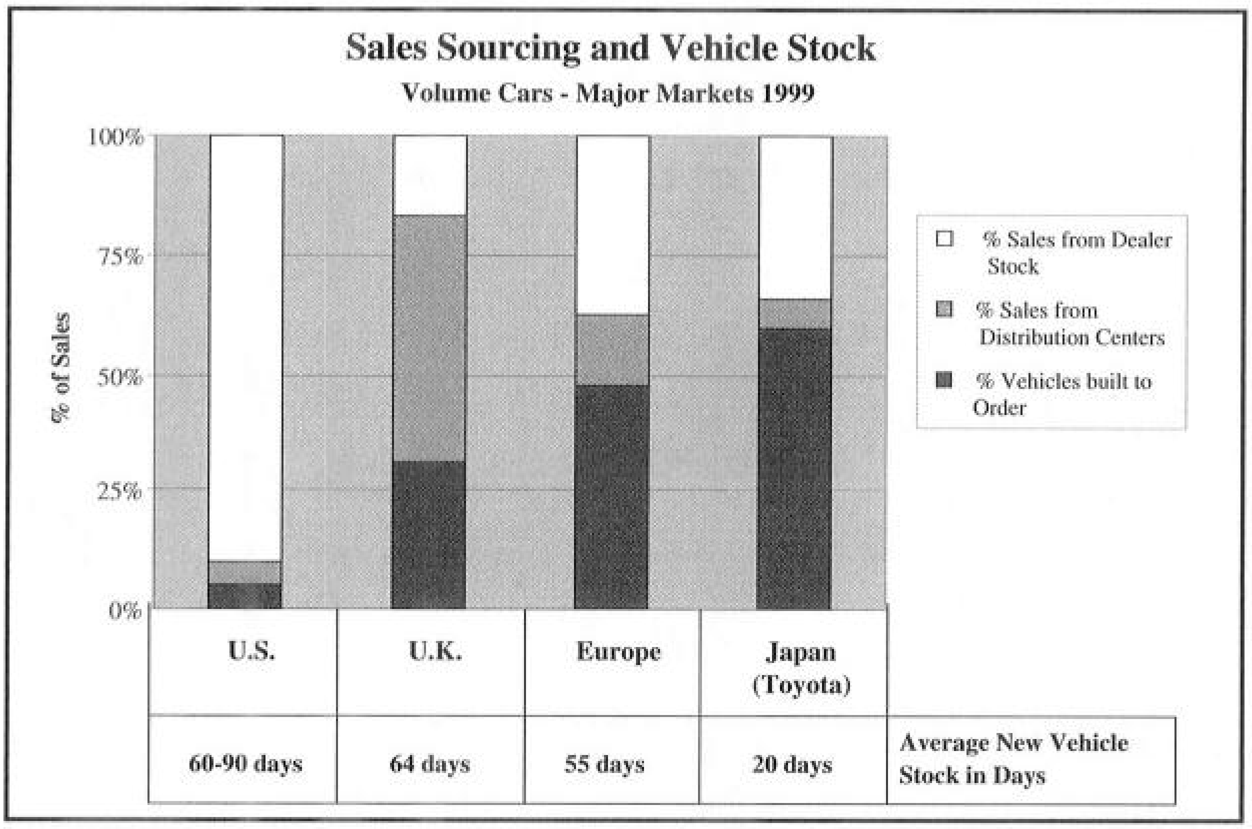
The automotive supply chain is undergoing a major transition. New vehicle supply systems, still largely based on Henry Ford's mass production paradigm or "push" logic, are proving increasingly less competitive in today's markets. Current "stock push" vehicle supply, whereby the majority of vehicles are sourced from existing finished goods inventory in the marketplace, requires holding stock at the most expensive point in the supply chain (Fisher 1997). Furthermore, the sales incentives' needed to shift this inventory incur a huge cost penalty in current vehicle distribution. It has been estimated that across Europe $9 billion could be saved by eliminating the finished vehicle stocks, with an additional $3.8 billion annual profit potential through further operational savings and increased product mix profits (ICDP 2000). In the U.S., potential savings through build-to-order have been estimated at $ 1,500 per vehicle (Lapidus 2000). Since average incentives per car sold in the U.S. was $1,873 in 2002, even this high figure seems a conservative estimate.

The key obstacle for not building an increasing percentage of vehicles to customer order is the vehicle manufacturer's inability to supply customized vehicles within timeframes customers find acceptable (Holweg and Pil 2001). Average order lead-time for customized vehicles ranges from six weeks in Europe to ten weeks or more in the U.S. - yet consumer research has shown that the majority of new vehicle buyers expect their vehicle within two to three weeks (Elias 2001), a figure which is fairly consistent across Europe, Japan, and the U.S.

As a result, the minority of vehicles in the world is actually built to customer specifications, and large stocks of finished vehicles are held at dealerships and distribution centers to enable a certain degree of choice for customers. This becomes particularly apparent in the U.S., where the distribution system is geared at "instant gratification" or "one-stop shopping." Manufacturers hold as many as 100 days of sales in the marketplace (2), and 60 days is considered to be the "optimal level" - a level that has hardly changed since the days of Henry Ford (see for example Lacey 1986). Figure 1 gives an overview on global stock levels and vehicles built to customer order across major market regions.

FIGURE 1

SALES SOURCING AND STOCK LEVELS IN MAIN GLOBAL MARKETS



Source: Holweg and Miemczyk (2002), Shioji (2000)

Currently, Japanese producers in Japan show the highest build-to-order figures for their domestic market. One reason for this is the high percentage of cars destined for export (in the case of Toyota up to 60% of production), which are largely made to forecast and can be used to buffer customer-ordered production for the domestic market. Thus, albeit high domestically, we estimate the volume of vehicles built to order as a fraction of total production in Japan to be less than 40%. This is similar to the U.K., where 33% of all new vehicles were built to order in 1999, with the remainder sold from stock. On average, just under two months stock of unsold vehicles are held at any one time in Europe (ICDP 2000).

Recent pronouncements have made it clear that there is some recognition of this failure (Andrews 2000; Cantwell 2001; de Saint-Seine 2002; Weernink, 2002) and most manufacturers have announced the intention to implement build-to-order strategies to reduce sourcing from stock. Recent projects include the "Projet Nouvelle Distribution" initiative by Renault, aiming to build vehicles to order in 14 days from order to delivery, and BMW's Customer-oriented Sales Processing (COSP), which is attempting a ten-day order-to-delivery lead-time. Volvo was an early adopter of this model, reducing order-to-delivery times in Europe from six weeks to 28 days in 1990, and even down to 14 days in 1995 - with a 100% "customer-based" production (Hertz, Johannsson, and de Jager 2001). Table 1 gives an overview of current build-to-order programs at the vehicle manufacturer (VM) level.

TABLE 1

BUILD-TO-ORDER PROGRAMS AT VEHICLE MANUFACTURERS

Vehicle Manufacturer	Program Name	Order-to-Delivery Target
BMW	COSP – Customer Oriented Sales Processing	10 days
DaimlerChrysler	FastCar/Global Ordering	15 days
Ford	Order-to-Delivery	15 days
General Motors	Order-to-Delivery	20 days
Renault	Projet Nouvelle Distribution (PND)	Initially 14 days, revised to 21 days in 2002
Nissan	SCOPE (Europe), ANSWER (Japan), ICON (U.S.).	14 days
Toyota	N/A	14 days
Volkswagen	Kunde-Kunde ("Customer-to-Customer")	14 days
Volvo	Distribution 90	14 days

A STRATEGIC SHIFT IN THE AUTOMOTIVE SUPPLY CHAIN

Building cars to order is not a new idea: the Toyota Production System (Monden 1983), the ancestor of the lean philosophy (Womaek and Jones 1996; Womack, Jones, and Roos 1990), has the guiding objective of producing products "pulled" by the customer which helps to avoid the substantive waste or "muda" inherent in overproduction. While lean efforts have fostered undeniable improvements in productivity and quality in the automotive industry, from the customer's perspective they often have failed due to their myopic focus on the factories (Holweg and Pil 2001). To maintain plant productivity, a key shareholder measure, vehicle manufacturers rely heavily on forecasts of production volume and mix despite what the market, i.e., consumers, might actually be demanding. Yet building vehicles to order as opposed to a forecast has an unmistakable logic - both for the vehicle manufacturers and the customers. The customer gets what he or she wants, without compromising on specifications, colors, or other features. The manufacturer on the other hand can operate without the costly stock and incentives, and maintain choice, a key competitive differentiator.

For build-to-order strategies to be competitive, however, one needs a sufficiently short order-to-delivery (OTD) lead-time to supply vehicles within a lead-time acceptable to customers. The lead-time reduction efforts will initially have to focus on the vehicle manufacturer, which currently accounts for 88% of the OTD lead-time despite final assembly only taking 4.5-20 hours (Holweg and Pil 2001), but subsequently affect all subsystems - component suppliers, vehicle manufacturers, and logistics operators. Additionally, increased flexibility will be demanded from suppliers and logistics operators to cater for the variability resulting from an increased percentage of cars built-to-order in short lead-times. Thus, a shift toward BTO will require not only the manufacturers to radically alter their processes, but has equally drastic ramifications for all players in the supply chain, in particular for suppliers and logistics operators.

An interesting parallel here is the application of BTO in the consumer electronics sector, in particular at Dell Computers, which has been very successfully applying the concept. The critical difference between the automotive industry and Dell however is that Dell - strictly speaking - uses an assemble-lo-order (ATO) strategy (based on Mather 1988), whereby it keeps sufficient component inventory on site in order to build computers to order once the order is received. This inventory therefore represents a de-coupling point in the supply chain that largely buffers the component supply chain from demand variability and lead-time reduction requirements. In comparison to the automotive industry however, Dell only handles 15-50 key components per computer, whereas the average vehicle consists of 2,000-4,000 components - many of which are customized by color, engine size, trim level, and body-style (Holweg and Pil 2001). Thus, holding component stock in the same fashion is cost-prohibitive in the automotive industry, and BTO strategies are dependent on a capable and responsive supply chain, and subsequently, on the logistics operations that connect suppliers to the assembly plants, and assembly plants to dealers and customers. Renault's recent experience marks a case in point. In 2002, it had to revise its order-to-delivery lead-time target from 14 days (set in 1999) to 21 days - not because of any inflexibility in the manufacturing operations, but because their distribution logistics operations could not cope with the lead-time reduction (de SaintSeine 2002). Initial research into the outbound logistics operations (Holweg and Miemczyk 2002; Holweg, Miemczyk, and Williams 2001) and the order-to-delivery process (Holweg and Jones 2001 ; Holweg and Pil 2001) has already been reported, confirming the necessity of adopting an holistic approach to logistics as the connecting element in the system.

In this paper, we provide an exploratory investigation into three major inbound logistics schemes in three vehicle assembly plants in the U.K., covering a total of 670 suppliers. The research is based on in-depth process mapping at these logistics operations, complemented with a total of 20 semi-structured interviews - eight interviews with VM logistics managers and 12 interviews with managers at five logistics service providers.

Using these three case studies, we aim to develop an in-depth understanding of the current process and provide an initial generic assessment of the implications of build-to-order for this automotive logistics subsystem. The analysis is at a necessarily high "resolution level" (Klir and Valach 1967), yet aims at laying the foundation for future, in-depth studies of specific manufacturers' logistics subsystems, or even surveys across geographical regions. Due to the inherent complexity of the automotive supply chain and the number of components involved (2,000-4,000 per vehicle), a component-by-component analysis as suggested by Griffiths and Margetts (2000) was not feasible. Furthermore, the details of manufacturing complexity and plant processes are left to other studies. The focus of this paper is inbound logistics as an enabler of BTO through responsive delivery of parts and components. More specifically, the objectives of this study are:

1. To develop an in-depth understanding of current inbound logistics operations in the automotive industry.
2. To provide an assessment of response capability of logistics operators, in particular in terms of their operational framework, their responsiveness to change, and their alignment and integration into the wider supply chain system.
3. To identify opportunities and strategies for mitigating the implications of BTO on the inbound logistics operations in the automotive industry, and more generally, the implications of more responsive logistics operations in the supply chain.

INBOUND LOGISTICS - THE LINKING ELEMENT IN THE SUPPLY CHAIN

Automotive Logistics

Bowersox and Closs (1996) describe logistics as the "connecting element" between the subsystems in the supply chain. Within new vehicle supply systems, two general types of logistics operations can be found: outbound logistics and inbound logistics. Outbound logistics or vehicle distribution from the vehicle assembly plant to the dealership directly contributes to the responsiveness of the overall vehicle supply system by representing the lead-time from the factory to customers. As Gustin, Daugherty, and Stank (1995) point out:

"Proportioning between manufacturing lead-time and distribution lead-time means little; customers only want to know when the merchandise will arrive."

The second main logistics operation in the auto supply chain is between the component suppliers and vehicle assembly plants. Although not directly impacting on the order-to-delivery lead-time, it is a potential inhibitor of the supply system's responsiveness, as our initial interviews with vehicle manufacturer staff and previous contributions in the field confirmed. Although a consideration of suppliers ' responsiveness capabilities is vital for manufacturers to respond to market shifts, we argue for analyzing the potential inhibitors of inbound logistics as the linking element between suppliers and assemblers. If assemblers are not able to call upon parts and components (which typically make-up 60-70% of the value of a vehicle) within a reasonable time-scale, costly inventory holding is needed. Excessive stocks may be held if assemblers are unable to predict the right inventory (volume and mix) in the case of building to order. This point emphasizes the need for responsive inbound logistics. In the following section, we will examine current organizational structures of inbound schemes, and discuss criteria their performance can be measured on.

Inbound Logistics - Organization

Two key factors determine the structure or "gestalt" of the inbound logistics subsystem: the number of suppliers per manufacturer, and the average distance between suppliers and the vehicle assembly plants these are supplying into. Here, significant geographical differences have been observed: the average distance between supplier and vehicle manufacturer is 447 miles in the U.S., compared to 82 miles and 129 miles in Japan and Korea, respectively (Dyer and Chu 2003). The average number of suppliers per assembly plant was 376 in the U.S., compared with 341 and 206 in Europe and Japan, respectively (Holweg and Pil 2004). Therefore, it is important to understand the logistics subsystems in relation to their national and geographical context.

A number of studies have further reported on the operations aspects of automotive logistics (Berglund et al. 1999; Skjoett-Larsen 2000;) for example emphasizing the importance of product variety in the decision to implement Just-in-Time (JIT) strategies (Cooper and Griffiths 1994). This entails altering delivery frequency depending on component value to determine which components should be subject to the most frequent Just-in-Time process (Ansary and Heckel 1987), where deliveries of more than once per day are a common feature (Raia 1990). Scannel, Vickery, and Droge (2000) find that increased flexibility is the key objective of JIT purchasing and that it leads to improvements in volume, mix, modification, and changeover flexibility at vehicle manufacturers, while Vonderembse et al. (1995) argue that while delivery lot sizes are often reduced as a result of JIT, total costs do not have a corresponding increase as might be expected. Thus, the implications and benefits of JIT applied to inbound supply logistics are well documented.

Yet despite simply altering the frequency, there are a range of options at hand for organizing an inbound scheme. Within our research, we have observed the following collection and delivery strategies, which we found to be contingent upon delivery volume and frequency, but also physical dimensions of the components and geographical factors (see Table 2). Figure 2 further illustrates the main structure of an automotive inbound logistics scheme and the interactions of these strategies.

Furthermore, third-party logistics (3 PL) companies we analyzed had taken a range of additional responsibilities including the management of local warehouses, holding buffer stock (usually from European and global supply lines) and more recently, the overall management of supplier parks, organizing the sequenced-in-line delivery (Doran 2001).

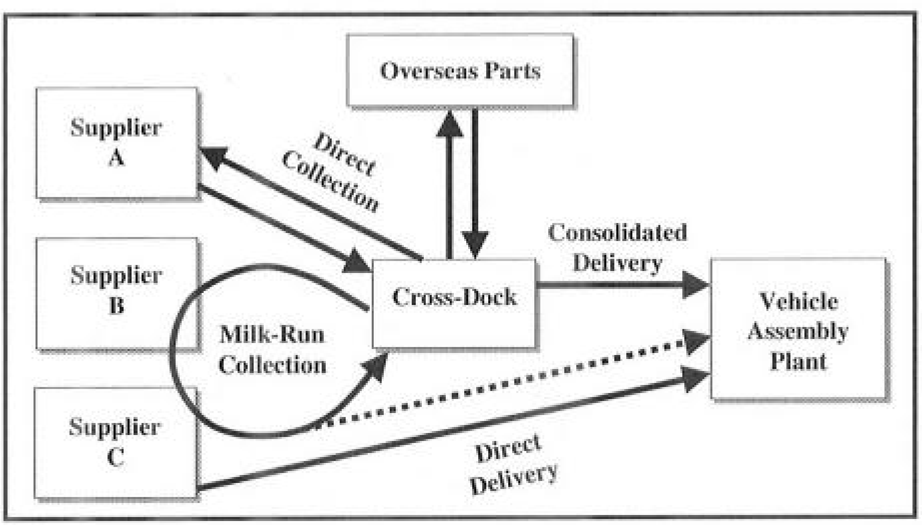
TABLE 1

BUILD-TO-ORDER PROGRAMS AT VEHICLE MANUFACTURERS

Vehicle Manufacturer	Program Name	Order-to-Delivery Target
BMW	COSP – Customer Oriented Sales Processing	10 days
DaimlerChrysler	FastCar/Global Ordering	15 days
Ford	Order-to-Delivery	15 days
General Motors	Order-to-Delivery	20 days
Renault	Projet Nouvelle Distribution (PND)	Initially 14 days, revised to 21 days in 2002
Nissan	SCOPE (Europe), ANSWER (Japan), ICON (U.S.).	14 days
Toyota	N/A	14 days
Volkswagen	Kunde-Kunde ("Customer-to-Customer")	14 days
Volvo	Distribution 90	14 days

FIGURE 2

GENERIC INBOUND LOGISTICS PROCESS



The costs of inbound logistics are not insignificant. Overall, vehicle manufacturers estimate their inbound cost to be around 10% of the manufacturing costs (plant-based costs only) and 1-2% of the cost of a finished vehicle (3). Although transport efficiency is a critical feature, it potentially conflicts with the requirements of frequent and reliable component deliveries into assembly. Thus, while an increase in logistics cost will be significant, this needs to be discussed in context to the overall vehicle price and potential savings made due to a more responsive supply chain in a build-to-order system (Holweg and Pil 2001). Thus, considering this classic trade-off between cost and delivery frequency, the question arises if inbound logistics in its current organizational format can support responsive build-to-order strategies, and more importantly, what strategies are at hand to mitigate the cost penalty and further enable such responsiveness?

A METHODOLOGY FOR ANALYSING LOGISTICS RESPONSIVENESS

Measuring the Performance of Logistics Systems

Past studies evaluating the performance of logistics systems demonstrate a great variety of "hard" and "soft" performance measures depending on the focus of the study reported. Chow, Heaver, and Henriksson (1994) identify several key types of logistics performance indicators - delivery lead-times, on-time delivery, and initial load and backload efficiency. Stock, Preis, and Kasarda (1999), taking a contingency point of view, argue that logistics performance needs to be evaluated in relation to the overall strategy, organizational structure, and the competitive environment in order to be aligned and support enterprise-wide goals. In our view, both areas need to be considered.

Initial interviews showed that currently mainly quantitative indicators such as delivery leadtimes, reliability of delivery, load efficiency, and cost are used to evaluate logistics schemes. From a research point of view however, a much more qualitative view, i.e., the perception of how the scheme functions within its wider environment, also needs to be considered. A cost-effective system that is too rigid to meet flexibility needs in the supply chain is as useless as a responsive effective system that is too costly to be sustained, yet either could be viewed successful depending on the measures used. This is a classic logistics trade-off between flexibility and cost (Bowersox and Closs 1996). For this study, we aimed to balance quantitative assessment and qualitative evaluation of the overall system in its environment.

The decision to adopt a case-study based approach following an established framework (Eisenhardt 1989; Yin 1994) was driven by several factors. First, case-based research in operations management and logistics research is well established (Ellram 1996; Meredith 1998; Voss, Tsikriktsis, and Fröhlich 2002), and second, the lack of previous research linking build-to-order strategies and inbound logistics operations in our view made a rich, qualitative research approach more suitable - as opposed to obtaining a less rich data-set across a larger sample, as for example through survey instruments. Thus an exploratory case approach was selected which Meredith (1998, p. 444) describes as suitable where the "variables are still unknown and the phenomenon not at all understood."

A Triangulated, case-based Approach

A multi-method triangulated research approach was developed, comprised of both qualitative and quantitative methods (Jick 1989; Mentzner and Flint 1997). As Voss, Tsikriktsis, and Frohlich argue, the reliability of the data collected is increased if multiple sources of data are used to probe the same phenomena. This study utilized process mapping as the common approach providing a quantitative basis for the case comparison, and used interview data to capture the rich, narrative evidence to explain the quantitative figures found in the process mapping, and further identify the root causes behind the system's performance.

The process mapping research (based on Romer and Shook 1998) is strongly influenced by the Systems approach (Ackoff 1971; Bertalanffy 1968), discussing the inbound logistics operations as a subsystem in the overall vehicle supply system. This allows for a discussion of both the system's gestalt, as well as the interactions and role within its environment (Ackoff 1971; Kühn 1975).

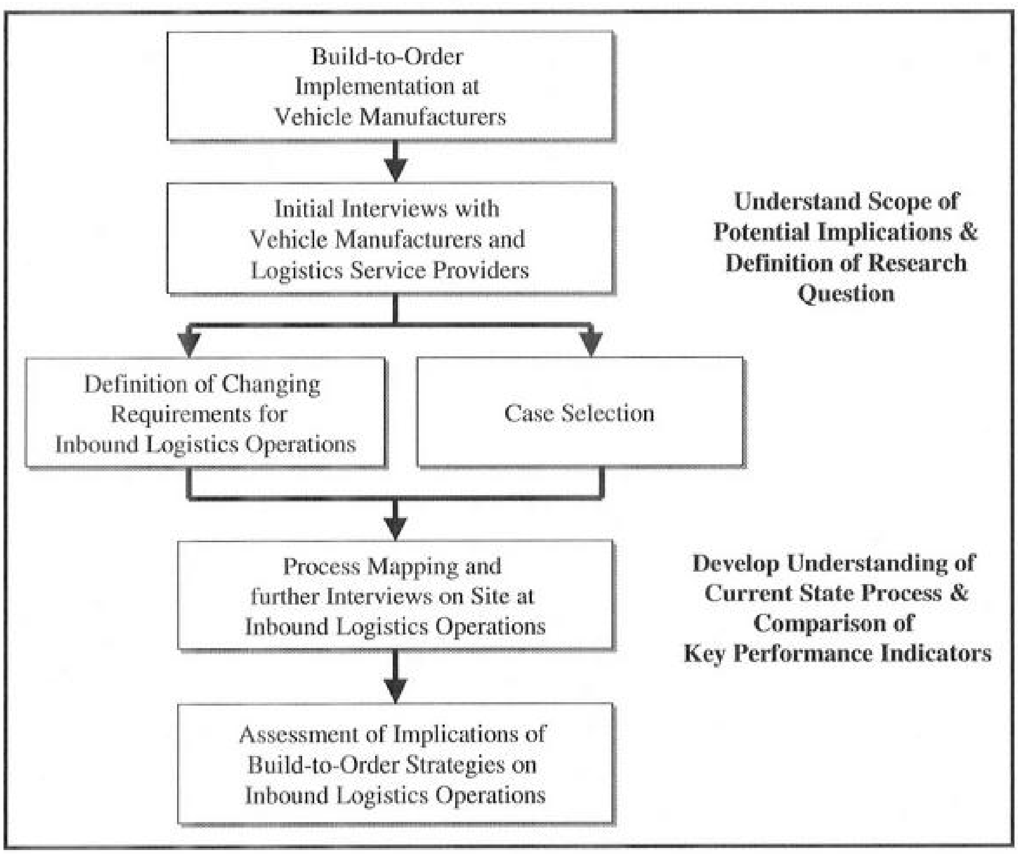
Case advocates argue that the case study methodology is one of the least understood and that generalizability can be achieved through cases (Ellram 1996), as generalization is not a matter of statistical generalization, but a matter of analytical generalization to illustrate, represent, or generalize a theory (Yin 1994). Although this was a major concern for achieving generalizability in the underlying study, it was felt that the triangulation through multiple methods across the cases, as suggested by Jick (1989), addressed this concern satisfactorily. Nevertheless, as a result we do not claim unconditional applicability of our constructs and findings over a sample beyond the subjects of analysis.

Using the theoretical sampling rationale, the criteria for case selection was based on initial interview data that described the general inbound supply chain processes at six U.K. volume assembly plants. The first case-selection criterion was to select supplier collection schemes that dealt with a considerable U.K. supply base to a U.K. assembly plant, and which were run by a single thirdparty logistics provider. At the time of the study, nine high-volume assembly plants were operational. A second criterion was "transplant" versus "non-transplant" operation, as the literature shows transplants4 to show significant different characteristics in their operations (Schonberger 1982). Thirdly, the cases selected all supply vehicle manufacturers known to have articulated their build-to-order strategies, with the clear objective to reduce overall customer order-to-delivery lead-times.

Following these criteria, the following cases were chosen, a third-party logistics provider (3PL) feeding a Japanese-owned transplant, and two third-party schemes feeding U.S.-owned plants. In total, these schemes link in excess of 670 supplier manufacturing sites to three assembly plants, thus giving a very comprehensive insight into the inbound processes - despite the limited number of logistics schemes which otherwise might have been a concern relative to validity of the findings (Silverman 1997). The research was divided into two main phases, as shown in Figure 3.

FIGURE 3

RESEARCH FRAMEWORK



Initially, eight interviews with logistics managers at three major U.K. vehicle manufacturers, as well as at five third-party inbound logistics providers were conducted to allow a basic understanding of the structure and interaction between inbound logistics operations and vehicle manufacturers, as well as to refine the research approach and guide the case selection.

The second phase comprised of further detailed interviews with site managers and scheduling staff at the three logistics companies during an on-site, one-day process mapping workshop, each complemented by a detailed visit to the three physical cross-dock facilities. The process mapping workshop applies Toyota's value stream mapping approach (c.f. Rother and Shook 1998), which was found to be particularly useful, as these value stream maps capture both information and material flows on one chart and thus provide excellent visualization of the current-state process, and second, as they allow for a simultaneous collection of operational performance data, which was subsequently used for the comparative analysis. The data collected includes, for example, the collection and delivery frequencies, number of suppliers involved, the percentage of direct and consolidated deliveries, the truck-trailer ratios and inventories held at each stage in the process. A second round of interviews, which followed the workshop, addressed further issues highlighted during the process mapping. Overall, the objective at this stage was to gain an in-depth understanding of the process and to provide a quantitative basis for comparison of the logistics schemes analyzed. All findings were reported back to the companies through a customized report on their respective performance in order to strengthen external validity (Stuart et al. 2002).

FINDINGS - COMPARATIVE ANALYSIS

Overview

This section compares the three cases on the basis of their quantitative key performance indicators derived from the process mapping activities. We have structured the key indicators into three sections: the operational framework, the responsiveness to change, and the alignment and integration of the collections scheme into the wider supply chain of suppliers and customers. The overall assessment regarding the build-to-order requirements of the wider supply chain focuses on the responsiveness and alignment of the schemes. The following section gives the relevant background for this assessment.

Operational Framework

Table 3 gives an overview of the three cases analyzed. The key difference between the cases is the number of suppliers that form part of the collection scheme. The two inbound collection schemes for the Western vehicle manufacturers show a much larger number of suppliers they collect from, and subsequently higher average points-of-calls on the collection runs. There are various reasons for this. First, this Japanese manufacturer (as do the other Japanese VMs in the U.K.) still imports a significant proportion of material from Japan, and thus has a lower content of local sourcing from a comparatively smaller supply base. In terms of direct deliveries, differences can be observed. Yet - crucially for comparison - in all three cases, the majority fraction of the shipments is funneled through the cross-docking facility.

Responsiveness to Change

With regards to the build-to-order transition, a key focus is the system's ability to respond to changes, or the generic responsiveness of the logistics scheme. Here, one needs to make an important distinction between the changes or amendments of shipping volumes, which reflect the minor changes of requirements by the vehicle manufacturer, and changes to the underlying "collection framework," which are major changes in the collection routes agreed with suppliers and manufacturers. This distinction is crucial, since the planning and routing scheduling at the logistics providers was found to mirror these levels.

TABLE 3

Category	Key Indicator	Case A	Case B	Case C
Customer		Western Vehicle Manufacturer	Western Vehicle Manufacturer	Japanese Vehicle Manufacturer
Supplier Collection	No. of Suppliers collected from	300	280	90
	Typical No. of Suppliers integrated on Collection Runs (all Routes)	3 – 6	3 – 4	2 – 3
	% of Direct Deliveries to Plant from Direct and Milk-run Collections	20%	40%	33%

The collection framework marks the backbone of the entire logistics operation between suppliers and vehicle assembly plants. This framework essentially determines the boundaries of possible collection times at the supplier, the anticipated volumes, the weight and volume of components, and the type of packaging used. Based on these factors, a generic collection and delivery route and truck capacity framework is devised. The framework forms the main input for the second level of planning - the day-to-day route planning. This framework has to be agreed to by all players involved - suppliers, manufacturers, and logistics service providers. The main constraint at the manufacturer commonly was found to be the number of receiving "doors" at the assembly plants, whereas the supplier constraint is pick-up times due to different work patterns at suppliers and vehicle manufacturers. Changes to this underlying framework may become necessary in case of major volume fluctuations, such as due to seasonal peaks, which require an alteration of the vehicle routing.

On the operational level, the day-to-day route planning by the logistics company is a consolidation of the component requirements of the vehicle manufacturer, and the collection and delivery framework. The schedules sent to the logistics company by the vehicle manufacturer or by the suppliers as in case A, showing the exact pick-up schedule are based on the requirements derived from the vehicle production schedule. Based on this schedule, the collection framework is adjusted to fit the particular daily needs dictated by the varying parts requirements. Inevitably, the varying vehicle build schedule will translate into varying parts requirements and induce a degree of uncertainty and change into the collection and delivery schedules, yet the aim is to keep these to a minimum. In particular, the delivery slots into the assembly plants are fixed by the manufacturer. In this case, the cross-dock is often used as stock buffer to cope with these variations.

Furthermore, the material controller in the assembly plant might cause late amendments to these schedules. If, for whatever reason (e.g., line stoppages, part shortages, or production problems), the controller decides to amend the incoming parts by delaying or expediting certain trucks, the logistics company has to re-plan daily operations within hours of notice. Due to their short-term nature, these late amendments are particularly damaging and often lead to load inefficiency, with one respondent of case A stating that:

"[The VM] may change the daily requirement on the morning of collection and [the 3PL] does not receive this information."

KEY INDICATOR COMPARISON - RESPONSE LEAD-TIMES

In comparison, the three cases analyzed show significantly different abilities to react to changes (see Table 4). case A actually receives the logistics requirements schedule from the suppliers, and not from the vehicle manufacturer itself. This is rather unusual, but symptomatic of the lack of integration within this case. The relationship of the logistics company and manufacturer could best be described as "arms length," similar to the relationship between some suppliers and manufacturers (Sako 1992). The logistics company is merely regarded as "transportation service," called as needed, even if that involves changes to the underlying delivery framework. In fact, one 3PL respondent stated that "[VM] wants little interaction, and treats logistics as a commodity." We see this behavior as the driver of inferior performance on various accounts, as will be discussed below.

TABLE 4

KEY INDICATOR COMPARISON – RESPONSE LEAD-TIMES

Category	Key Indicator	Case A	Case B	Case C
Information	Source of Information on Logistics Requirements	Supplier	Vehicle Manufacturer	Vehicle Manufacturer
Lead-times	Response Lead-time to Call-off Changes	1 day	2 weeks	< 1 day
	(Minor Changes)	(afternoon before pick-up)		
	Response Lead-time to Collection Framework Changes	1 day (possible)	2 weeks	1 month
	(Major Changes)			
	Average Delivery Lead-time Range (min-max): measured from Call-off to Delivery into Vehicle Assembly Plant	11 – 28 hours	10 – 32 hours	10 – 27 hours

In Case B the process is very different. Here, it takes two weeks to change either the underlying framework or the call-offs. The reason for this is largely due to the fact that (for legal and contractual reasons) the pick-up sheets are sent weekly as paper copies to suppliers and logistics companies. Since the mail takes time, the manufacturer does not permit any changes up to two weeks prior to collection.

In Case C, the underlying framework cannot be changed without a month's notice. This is to protect the tightly synchronized Just-in-Time delivery scheme operated. Importantly, the logistics company is directly linked into the vehicle manufacturer's IT systems. Thus, small changes, e.g., 10% increase or decrease in collection volume, to the collection and delivery schedules can be made multiple times during lhe day as required in reaction to changes in production. However, larger changes are more problematic. For example one manager stated that for alloy wheels "if the mix changes, the sourcing changes, as steel wheels come from Coventry [U.K.] and alloys from Belgium!"

Despite these organizational differences however, we were surprised to see that the actual lead-times from the call-off notification of the manufacturer to delivery of the parts into the assembly plant were almost equal across all schemes. Each case delivers parts after 10 - 32 hours to the plants, without holding any inventory other than in-transit stock. The ability to respond to different levels of change varies considerably, yet the finding that these differences are not reflected in the operational delivery lead-times achieved by each case is most significant. It would appear actual leadtime is less important than the responsiveness to changes. This may be attributed to two points. First the lead-time ranges are physically limited by the geographical dispersion of suppliers (which appear consistent across the three cases despite differences in total numbers). second if lead-time is held constant, it is the responsiveness that provides benefits allowing changes to volume and mix and potentially reducing the reliance on inventory to cope with variation.

Alignment and Integration

Inventory levels generally are a good indicator of the alignment of a system to its demand. For the inbound cases analyzed however, the actual inventory levels were found to be of less relevance since none of the collection schemes formally manage any inventory, and hence do not hold any stock other than transit inventory. In other words, the stock in the cross-docking facilities turns over at least once every day.

Nevertheless, inventory is still present in the system, although in a different (and often hidden) form. Most inbound schemes operate more trailers than tractors since this strategy enables them to drop a trailer and pick up an empty one without waiting for the unloading of the full trailer. That way, the expensive tractor and driver resources are used more efficiently. This strategy indirectly introduces inventory into the system, since the higher the tractor-trailer ratio, the more full trailers can be stored along the process.

As a second factor of alignment, we consider the load efficiency on the "trunking" run, the delivery into the assembly plant. We argue that the better aligned a system is, the better load efficiency it can achieve. This was partially confirmed in our interviews which confirmed the need for reliable forward planning information as a critical enabler of load efficiency, yet also raised the issue of packaging and the use of cardboard in particular. High variety in packaging complicates the load-building process and potentially compromises the load efficiency. Similarly, the less rigid cardboard packaging compromises the ability to stack containers above a certain height/weight barrier and, therefore, can reduce the load efficiency. The use of cardboard can also be caused by the lack of empty containers (also referred to as "stillages"), forcing the suppliers to use alternative means of packaging.

Thus, in order to assess the alignment and integration of the schemes into the value chain, we compared the truck-trailer ratio, the load efficiency, and types of packaging used (see Table 5).

TABLE 5

KEY INDICATOR COMPARISON – INVENTORY, EFFICIENCY, AND PACKAGING

Category	Key Indicator	Case A	Case B	Case C
Inventory	Trailer-Truck Ratio	3:1	2:1	2:1
Efficiency	Load Efficiency (Trunking: Cross-Dock to Assembly Plant)	85% cubic	63-73% cubic	70-80% cubic
Packaging	Cardboard Content	50%	25%, plus c.5% due to lack of empty stillages	N/A, estimated at c.10%
	No. of Container Sizes Standard vs. Non-standard	277 container types, 10% standard	N/A	120 containers, 60% standard

KEY INDICATOR COMPARISON - INVENTORY, EFFICIENCY, AND PACKAGING

Comparing the three cases, we were surprised to learn that case A shows the highest average load efficiencies of 85%, since one would expect that the comparatively high cardboard content and the high-variety packaging used would lower efficiencies. Upon further investigation, we discovered that this efficiency is driven by extra trailers in the system. In order to keep operational efficiency high, case A uses the extra trailers as a buffer. These additional trailers are stored at a trailer park adjacent to the vehicle assembly plant, which also explains the higher truck-trailer ratio of 3:1. While load efficiency is maximized (case A is paid on overall tons transported and is therefore incentivized to maximize load efficiency, rather than inventory), the overall inventory cost is most likely to be greater. Our interview respondents suggested that this extra inventory was used by the vehicle manufacturer to buffer against production from operational disruptions.

Whereas the other two schemes operating a 2:1 trailer-truck ratio essentially have one trailer in use and another being unloaded pre-tractor, in case A an additional fully-loaded trailer would be waiting in the trailer park. cases B and C therefore operate near minimum inventory, which in the early days of JIT was referred to as the "rolling warehouse," as the majority of stock is literally "on the road."

A final issue that emerges strongly from the case studies is the differences in organizational structures between the cases. The first point to note was that cases A and B are sites that provide a consolidation service for more than one plant for their respective customers and thus in essence have to deal with greater interface complexity between delivery sites and pick-up points. In particular the inbound operation of case B is part of a larger general groupage (consolidation) operation, serving multiple industries. Therefore, personnel at the sites were required to deal with information from multiple sources and countries. In these cases, the responsibilities tended to focus purely on operational issues - with little involvement with the systems of either their customers or the suppliers other than handling planning and scheduling data. In contrast, case C was a dedicated site, consolidating for one vehicle assembly plant. It was evident from the interviews that site personnel were closely involved with the customer, for example in the development of integrated IT systems. Notably, the 3PL's transport personnel in case C even had responsibility for booking in deliveries at the customer's site, using the customer's own IT system.

DISCUSSION

In this exploratory study, we have identified the current structure of three automotive inbound logistics operations, analyzed their operational performance, and assessed their ability to respond to the demands of greater flexibility that they are likely to face. Our research has identified managerial implications specific to the automotive industry, but also generic strategies that reach beyond the automotive industry. These implications reflect on how the increasing demands for logistics flexibility and responsiveness in the supply chain can be mitigated with regard to cost. The current competitive climate in the automotive industry, with cost reductions being pre-eminent, means that any increase in flexibility is unlikely to be supported if logistics costs are increased.

Managerial Implications

We compared the three inbound logistics schemes on a range of performance indicators. While the operational benchmarks in terms of overall lead-times and load efficiencies did not show significant differences, the responsiveness to change and the level of integration into the wider supply chain did. This is a crucial point, as current build-to-order projects at vehicle manufacturers such as BMW, Renault, and Volvo (e.g., Hertz, Johannsson, and de Jager 2001) all aim at a reduction of the planning period from order receipt to start of the vehicle production to 5-8 days. Currently, an order spends on average over a month before it reaches the factory (Holweg and Pil 2001). Such leadtime reduction inevitably reflects on the call-off lead-time for components. Operationally, this would not be an issue for the inbound schemes A and C, where daily changes are possible - as long as a minimum of 32 hours advance notice was given. On the other hand, such general lead-time reduction would have cost implications, as a manager of case C stated:

"[..] with [VM] wanting every supplier to [a two days call-off lead-time], we were forced to go to daily collection from all suppliers, even from those where volume does not justify daily collection."

Furthermore for case B the question remains whether daily changes of the collection runs would be feasible, which would require flexibility of the underlying collection framework since the scope of daily amendments might not be sufficient to cope with larger swings in demand. We would argue that the collection framework needs to be flexible enough to mirror changes in the assembly sequence made by the manufacturer, i.e., within the same 5-8 day horizon. Currently however, none of the schemes analyzed can provide such flexibility, although case A has the ability to alter the framework on a daily basis which is largely enabled by additional inventory buffers in the pipeline, and therefore clearly is not a sustainable solution. Furthermore, responsiveness cannot be achieved in isolation. For example, a manager of case C argued that:

"[VM] wants a more flexible and differential service from [their third-party logistics provider], but the problem is that negotiations with suppliers take up to a month."

A key differentiator between the cases is the level of integration. The impact of integration has been pointed out by Gustin, Daugherty, and Stank (1995), who found that the difference between integrated and non-integrated companies was in particular pronounced in the areas of logistics control and planning. Previous research has shown that this is a vital component of build-to-order systems (Holweg and Pil 2001) and the implementation of related concepts such as JIT (Bensaou 1997; Wafa, Yasin, and Swinehart 1996).

Case A can be viewed as "non integrated," typified as a "call-by-call" transportation service with one manager stating that "[third-party logistics providers] are paid by the tonne, and this is basically a vendor push system." case A might show the most flexible lead-times to react to either major changes, which seems to indicate less controlled and standardized processes, yet buffers its operation by more inventory as shown in the truck-trailer ratio.

The "semi-integrated" case B shows the least flexibility, with long response lead-times due to fixed schedules and routes. VM schedule information is received by the logistics provider but the long lead-time between receipt of schedules, transmission to suppliers, and collection mean that responsiveness is severely limited.

By contrast case C shows the best ability to cope with short-term changes, or daily volume fluctuations and can be seen as "fully integrated." This is enabled by the IT integration into the manufacturer, a rigid planning framework (which is revised on a monthly basis only) and a high degree of standardized packaging, enabling accurate load planning on a daily basis.

Figure 4 shows how the inventory levels in the case C inbound pipeline between supplier and the assembly line have developed over time. The case C respondents claimed that due to close integration and joint improvement efforts the stocks have been reduced to the current level of 0.7 days. Interestingly, in the view of the material logistics manager at this vehicle manufacturer, the continuing inventory reduction still heralds overall quality benefits, although the direct financial savings are marginal.5

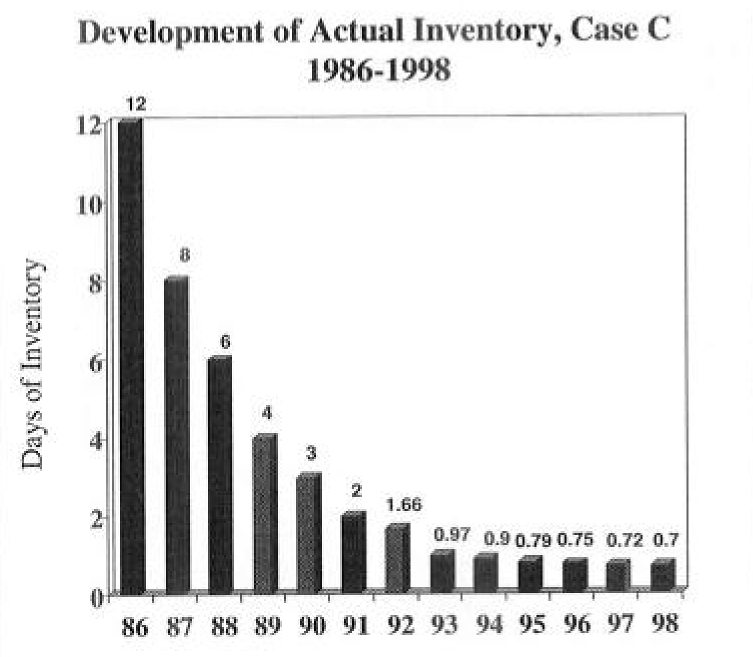
In exploring the underlying reasons for the "fully integrated" nature of case C, we argue that the vehicle manufacturer associated with case C had the most defined BTO objectives, planning to reduce the scheduling lead-times from two weeks to six days ("D-6 scheduling"). Hence we argue for a link between the level of build-to-order implementation at a vehicle manufacturer, manifest by shorter schedule lead-times, and the level of integration between manufacturers, logistics providers, and the suppliers they collect from. We also find that the ability of logistics providers to provide a responsive service at an acceptable cost is confounded by long renegotiation periods with suppliers, non-24 hour operations at suppliers' sites, fixed delivery slots at vehicle assembly plants, and variability in packaging standards.

Generalization of Findings

The results of this study in many ways mirror the results of earlier studies into the automotive supply chain (Hines 1994; Macbeth and Ferguson 1994; Sako 1992). Close integration and collaborative (as opposed to adversarial) interactions facilitate shorter lead-times and cost reduction. We would argue that greater responsiveness in the supply chain in general needs the support of relationships that emphasize an increased level of information exchange, be it between manufacturers and suppliers or suppliers and logistics companies, and trust (Handfield and Bechtel, 2002). Previous research into supply chains may have focused on the role of the component supplier. Yet, as we show, logistics is an equally important link in this chain.

FIGURE 4

STOCK LEVELS OVER TIME IN INBOUND SCHEME, CASE C



Note: Figures shown also include Transit Inventory

Source: Case Company C

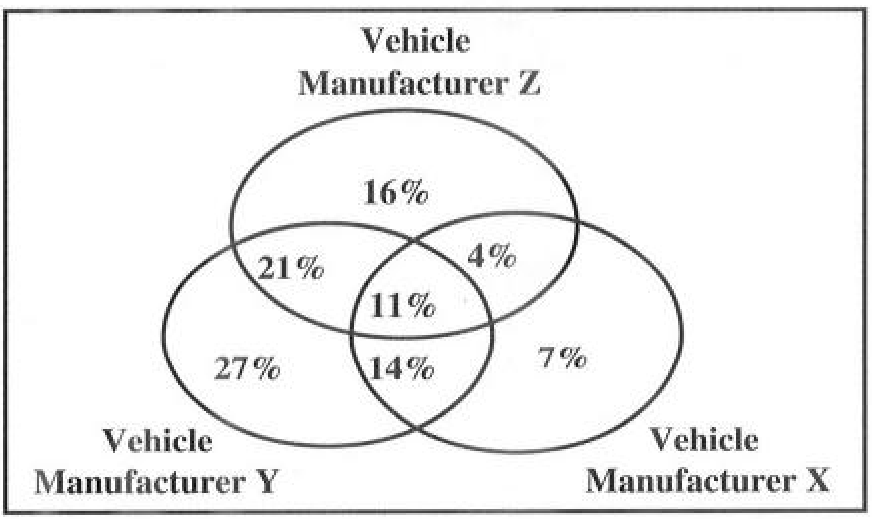
Furthermore, we observed an interesting relationship between the operational (short-term) flexibility, i.e., the ability to change collection schemes within the remits of the collection framework, and the rigidity of this underlying collection framework, i.e. the ability to implement more drastic changes in the medium- to long-term. We found that a very rigid collection framework seems to provide a certain planning stability that in turn enables short-term flexibility within certain remits. This is well illustrated by comparing case C, where the rigid framework enables tight integration and multiple daily amendments, and case A, where the general lack of such a stability only achieves comparable operational performance by buffering the operations. This behavior points to an interesting dichotomy, which can also be observed in manufacturing. Just-in-Time (JIT) concepts are known to reduce lead-times and provide greater flexibility (e.g., Schonberger 1982), for example in coping with product variety (MacDuffie, Sethuraman, and Fisher 1996), yet the underlying production smoothing or "heijunka" concepts enable this flexibility by restricting daily schedule changes to 10%. Thus, long-term stability enables flexibility in the short-term execution.

Also, we found that standardization can mitigate the adverse effects of greater responsiveness. In case C, for example, the standardization of packaging enabled a simpler planning process and helps improve capacity utilization. This has wider implications beyond automotive as standardization of packaging formats in general will enable logistics operators to arrange their loads on transporters in a more efficient manner. In addition, one could envision cross-industry load consolidation, enabled by standardization of packaging across industries, bringing about further (and to date largely unexploited) opportunities for improving transport utilization.

Even within the automotive sector, a considerable scope for consolidation is still unexploited. For example, Logistics Company A currently operates three major inbound schemes in the U.K., one each for vehicle manufacturers X, Y, and Z (see Figure 5). As many suppliers supply not only one, but in fact two or all three vehicle manufacturers, there is a considerable overlap of the suppliers that the logistics company collects from. For example, 21% of the suppliers collected from supply both VM Y and Z, 11 % of all suppliers even supply all three manufacturers. Yet, to date, the collections are made individually by VM, albeit all are performed by the same logistics company.

FIGURE 5

POTENTIAL OVERLAP OF SUPPLIER COLLECTION SCHEMES



Source: Case company A

The importance of such intra-industry, multi-customer consolidation was also emphasized in the study of automotive outbound logistics, whereby the negative effects of shorter cycle times were shown to be successfully mitigated by an increase in shared deliveries of different brands to dealerships by single logistics operators (Holweg and Miemczyk 2002).

Table 6 provides a classification of consolidation types found in this study, and outlines the advantages and disadvantages of each. An important point to note is that increasing the level from dedicated links to potentially a multi-customer, inter-industry consolidation can mitigate the costs of enhanced responsiveness (e.g., smaller lot size collections). There is also a penalty of increased interface complexity (between industries, suppliers, logistics providers, and customers) and the cost of standardizing packaging and containers.

Conclusion

We analyzed three U.K. inbound logistics schemes with regards to their current operational performance and ability to support a build-to-order supply chain strategy. Our data suggest that operationally, on a day-to-day basis, the flexibility current systems offer seems sufficient - provided the inbound logistics scheme is highly integrated into the overall supply chain process. This entails granting the logistics service provider access to the vehicle manufacturer's planning systems, as well as building on the benefits of collaborative relationships, mirroring research in the automotive component supply chain (Dyer 1996; Handfield and Bechtel 2002).

TABLE 6

TYPES OF CONSOLIDATION

Type	Level	Description	Advantage/Disadvantages
Dedicated	Intra-industry	Collection from one supplier only Delivery to one location only	• Potential loss in load efficiency • Flexible and responsive to change
Multi-plant	Intra-industry	Collection from several suppliers Delivery to one location only	• Ability to achieve high load efficiency and frequent deliveries • Complex and rigid planning framework needed
Multi-customer	Intra-industry	Collection from several suppliers Delivery to several locations	• Ability to achieve high load efficiency and frequent deliveries • Ability to balance volume and load variations within one industry • Even more complex and rigid planning framework needed
Multi-customer	Inter-industry	Collection from several suppliers Delivery to several locations	• Ability to achieve high load efficiency and frequent deliveries • Ability to balance volume and load variations across industry sectors • Very complex and rigid planning framework needed • Increase in lead-time if two-tier collection

The rigid collection framework of case C suggests that logistics systems requiring responsiveness such as in the case of building-to-order in any industry - should actually retain some aspects of inflexibility. By this we mean that longer-term inflexibility of collection structure (specific suppliers at specific locations) can allow short-term flexibility (changes in volume and mix of product collected from suppliers), enabling responsiveness to customer demand. This rationale would apply generally where manufacturers find significant component variation from individual suppliers linked to variation in customer demand and short order lead-times.

With regards to the flexibility of the collection framework however, we have our concerns. Here, joint efforts need to ensure that advances in lead-time reduction within the assembly plant schedule are not hindered by overly inflexible collection and delivery arrangements with suppliers and logistics service providers. This may result in increased inbound logistics costs in some instances, which should be outweighed by the wider benefits of adopting a build-to-order strategy.

In conclusion, this exploratory study provides an initial stepping stone towards understanding the complex implications for logistics operations of this strategic transition in the automotive industry and outlines a range of mitigation strategies, many of which have parallels in the wider context of the supply chain. Our study is limited by its sample size and geographical focus; future research hence should aim at expanding the geographical focus, assessing whether the country-specific settings in the U.S., for example, can reconfirm findings from a confined market such as the U.K.

ACKNOWLEDGMENT

The authors would like to thank the sponsors of the 3DayCar Programme including the EPSRC, the Innovative Manufacturing Research Centre at the University of Bath, the MIT International Motor Vehicle Program, and the Alfred P. Sloan Foundation for supporting this research, and the anonymous reviewers for their comments on the earlier version of this paper.

[Footnote]

1. incentives include direct cash incentives and better trade-in process for used vehicles, but also 0% financing, free servicing and free specification upgrades.
2. The U.S. is the only country where stock levels are published by the manufacturers themselves (due to a mutual agreement), whereas in Europe actual stock levels are carefully guarded.
3. Data refer to vehicle cost at "gate release," see also: Lapidus 2000; Wells and Nieuwenhuis 2001
4. Transplants are new manufacturing plants established by foreign-owned manufacturers in new markets.
5. Consider a daily production volume of 600 vehicles per day, at an average sales value of $15,000. The ex-plant cost of a vehicle hence is c.$10,500, of which the component value accounts for c.$6,900. Thus, the pipeline inventory reduction from the initial 12 days to the current 0.7 days has resulted in annual savings of c.$2.8 million in capital cost. Yet a further pipeline inventory reduction of 0.1 days would result in an annual savings of c.$2,500 (Assumption: i = 0.06%).

NOTES

- Ackoff, Russell L. (1971), "Towards a System of Systems Concepts," Management Science, Vol. 17,No. 11, pp. 661-671.
- Andrews, Fred (2000), "Can Car-makers Emulate Dell? Toyota Tries," New York Times, January 25th.
- Ansary, Adel El and J. Heckel (1987), "Just In Time: Impact on Freight and Inventory Costs," Internationaljournal of Purchasing and Materials Management, Vol. 23, No. 2, pp. 24-28.
- Bensaou, M. (1997), "Interorganizational Cooperation: The Role of Information Technology, an Empirical Comparison of US and Japanese Supplier Relations," Information Systems Research, Vol. 8, No. 2, pp. 107-124.
- Berglund, Magnus, Peter van Laarhoven, Graham Sharman, and Sten Wandel (1999), "Third-Party Logistics - Is There a Future?" International Journal of Logistics Management, Vol. 10, No. 1, pp. 59-70.
- Bertalanffy, Ludwig von (1968), General Systems Theory Foundations, Development, Applications, New York, NY: George Braziller.
- Bowersox, Donald and David Closs (1996), Logistical Management: The Integrated Supply Chain Process, New York, NY: McGraw Hill.
- Cantwell, Julie (2001), "Forrester: Build-to-Order Will Save Makers Money," Automotive News, Vol. 76, No. 5953, pp. 40.
- Chow, Garland, Trevor D. Heaver, and Lennart E. Henriksson (1994), "Logistics Performance: Definition and Measurement," International Journal of Physical Distribution & Logistics Management, Vol. 24, No. 1, pp. 17-28.
- Cooper, James C. and John Griffiths (1994), "Managing Variety in Automotive Logistics with the Rule of Three," Internationaljournal of Logistics Management, Vol. 5, No. 2, pp. 29-40.
- de Saint-Seine, Silvia (2002), "Renault Quits Build-to-Order Quest," Automotive News Europe, Vol. 7, January 14th, pp. 4.
- Doran, Desmond (2001), "Synchronous Supply: An Automotive case Study," European Business Review, Vol. 13, No. 2, pp. 114-120.

- Dyer, Jeffrey H. (1996), "Specialized Supplier Networks as a Source of Competitive Advantage: Evidence from the Auto Industry," Strategic Management Journal, Vol. 17, No. 4, pp. 271-291.
- Dyer, Jeffrey H. and Wujin Chu (2003), "The Role of Trustworthiness in Reducing Transaction Costs and Improving Performance: Empirical Evidence from the United States, Japan and Korea," Organization Science, Vol. 14, No. 1, pp. 57-69.
- Eisenhardt, Kathleen M. (1989), "Building Theory from case Study Research," Academy of Management Review, Vol. 14, No. 4, pp. 532-550.
- Elias, Simon (2001), New Vehicle Buyer Behaviour - Quantifying Key Stages in the Consumer Buying Process, SDayCar Research Report, Cardiff, www.3daycar.com.
- Ellram, Lisa M. (1996), "The Use of the case Study Method in Logistics Research," Journal of Business Logistics, Vol. 17, No. 2, pp. 93-138.
- Fisher, Marshall L. (1997), "What is the Right Supply Chain for Your Product?" Harvard Business Review, Vol. 75, No. 2, pp. 105-116.
- Griffiths, J. and D. Margetts (2000), "Variation in Production Schedules - Implications for both the Company and Its Suppliers," Journal of Materials Processing Technology, Vol. 103, No. 1, pp. 155-159.
- Gustin, Craig M., Patricia J. Daugherty, and Theodore P. Stank (1995), "The Effect of Information Availability on Logistics Integration," Journal of Business Logistics, Vol. 16, No. 1, pp. 1-21.
- Handfield, Robert B. and Christian Bechtel (2002), "The Role of Trust and Relationship Structure in Improving Supply Chain Responsiveness," Industrial Marketing Management, Vol. 31, No. 4. pp. 367-382.
- Hertz, Susanne, Johny K. Johannsson, and Flip de Jager (2001), "Customer-Oriented Cost Cutting: Process Management at Volvo," Supply Chain Management, Vol. 6, No. 3/4, pp.128-141.
- Hines, Peter (1994), Creating World Class Suppliers: Unlocking Mutual Competitive Advantage, London, UK: Pitman Publishing.
- Holweg, Matthias and Daniel T. Jones (2001), The Challenge of Building Cars to Order: Can Current Vehicle Supply Systems Cope? In Manufacturing Operations and Supply Chain Management, D. T. Taylor and D. C. Brunt, eds., London, UK: Thomson International.
- Holweg, Matthias and Joe Miemczyk (2002), "Logistics in the 'Three Day Car' Age: Assessing the Responsiveness of Vehicle Distribution Logistics in the UK," International Journal of Physical Distribution & Logistics Management, Vol. 32, No. 10, pp. 829-850.
- Holweg, Matthias, Joe Miemczyk, and Geoff Williams (2001), How to Organise Automotive Logistics in a Build to Order Environment, The BDayCar Logistics Study, SDayCar Programme, Solihull.
- Holweg, Matthias and Frits K. Pil (2001), "Successful Build-to-Order Strategies Start with the Customer," Sloan Management Review, Vol. 43, No. 1, pp.74-83.
- Holweg, Matthias and Frits K. Pil (2004), The second Century: Reconnecting Customers and Value Chain through Build-to-Order, Cambridge, MA: The MIT Press.
- ICDP (2000), Fulfilling the Promise: Is there a Future for Franchised Car Distribution? International Car Distribution Programme, Solihull.
- Jick, Todd D. (1989), "Mixing Qualitative and Quantitative Methods: Triangulation in Action," Administrative Science Quarterly, Vol. 24, No. 4, pp. 602-611.
- Klir, George J. and M. Valach (1967), Cybernetic Modelling, London: Iliffe.
- Kuhn, Thomas (1975), Boundaries, Kinds of System and Kinds of Interaction, in General Systems and Organization Theory: Methodological Aspects, A. J. Melcher, ed., Kent State University Press.
- Lacey, Robert (1986), Ford - The Men and the Machine, Boston, MA: Little Brown.
- Lapidus, Gary (2000), E-Automotive: Gentlemen, Start your Search Engines, New York, NY: Goldman Sachs.
- Macbeth, Douglas K. and Neil Ferguson (1994), Partnership Sourcing: An Integrated Supply Chain Approach, London, UK: Pitman.
- MacDuffie, John Paul, Kannan Sethuraman, and Marshall L. Fisher (1996), "Product Variety and Manufacturing Performance: Evidence from the International Automotive Assembly Plant Study," Management Science, Vol. 42, No. 3, pp. 350-369.
- Mather, Hal (1988), Competitive Manufacturing, Englewood Cliffs, NJ: Prentice Hall.
- Mentzner, John T. and Daniel J. Flint (1997), "Validity in Logistics Research," Journal of Business Logistics, Vol. 18, No. 1, pp. 199-216.

- Meredith, Jack (1998), "Building Operations Management Theory through case and Field Research," Journal of Operations Management, Vol. 16, No. 4, pp. 441-454.
- Monden, Yasuhiro (1983), The Toyota Production System, Portland, OR: Productivity Press.
- Raia, Ernest (1990), "JITDelivery: Redefining OnTme." "Purchasing, Vol. 109, No. 3, pp. 64-70.
- Rother, Mike and John Shook (1998), Learning To see: Value Stream Mapping to Add Value and Eliminate Muda, Brookline, MA: The Lean Enterprise Institute.
- Sako, Mari (1992), Prices, Quality and Trust: Inter-firm relations in Britain and Japan, Cambridge, UK: Cambridge University Press.
- Scannell, Thomas V, Shawnee K. Vickery, and Cornelia L. Droge (2000), "Upstream Supply Chain Management and Competitive Performance in the Automotive Supply Industry," Journal of Business Logistics, Vol. 21, No. 1, pp. 23-49.
- Schonberger, Richard J. (1982), Japanese Manufacturing Techniques, New York, NY: The Free Press.
- Shioji, Hiromi (2000), The Order Entry System in Japan, International Symposium on Logistics, Morioka, Japan.
- Silverman, RobertD. (1997), Qualitative Research: Theory, Method and Practice, London, UK: Sage Publications.
- Skjoett-Larsen, Tage (2000), "Third-Party Logistics - from an Interorganizational Point of View," International Journal of Physical Distribution & Logistics Management, Vol. 30, No. 2, pp. 112-127.
- Stock, Gregory N., Noel P. Greis, and John D. Kasarda (1999), "Logistics, Strategy and Structure: A Conceptual Framework," International Journal of Physical Distribution & Logistics Management, Vol. 29, No. 4, pp. 224-239.
- Stuart, F. Ian., David M. McCutcheon, Robert B. Handfield, Ron McLachlin, and Danny Samson (2002), "Effective case Research in Operations Management: A Process Perspective," Journal of Operations Management, Vol. 20, No. 5, pp. 419-433.
- Vonderembse, Mark A., Michael Tracey, Chong L. Tan, and Edward J. Bardi (1995), "Current Purchasing Practices and JIT: Some of the Effects on Inbound Logistics," International Journal of Physical Distribution & Logistics Management, Vol. 25, No. 3, pp. 33-48.
- Voss, Chris A., Nikos Tsikriktsis, and Mark Fröhlich (2002), "case Research in Operations Management," International Journal of Operations and Production Management, Vol. 22, No. 2, pp. 195-219.
- Wafa, Marwan A., Mahmoud M. Yasin, and Kerry D. Swinehart (1996), "The Impact of Supplier Proximity in JIT Success: An Informational Perspective," International Journal of Physical Distribution & Logistics Management, Vol. 26, No. 4, pp. 23-34.
- Weernink, Wim O. (2002), "Build-to-Order Drives BMW's Future Growth," Automotive News, Vol. 77,No. 6016, pp. 28.
- Wells, Peter E. and Paul Nieuwenhuis (2001), The Automotive Industry -A Guide, London, UK: British Telecommunications.
- Womack, James P. and Daniel T. Jones (1996), LeanTthinking: Banish Waste and Create Wealth for Your Corporation, New York, NY: Simon & Schuster.
- Womack, James P., Daniel T. Jones, and Daniel Roos (1990), The Machine that Changed the World, New York, NY: Rawson Associates.
- Yin, Robert K. (1994), Case Study Research: Design and Methods, 2nd Ed. Newbury Park, CA: Sage Publications.

Authors

Joe Miemczyk, University of Bath, and Matthias Holweg. Massachusetts institute of Technology

ABOUT THE AUTHORS

Joe Miemczyk is a Research Officer at the University of Bath School of Management within the Innovative Manufacturing Research Centre. His research focuses on the operational and environmental impacts of build-to-order on manufacturing and logistics systems. Previously he was a Business Systems Engineer within the U.K. automotive supply sector. Joe holds a Master of Science in Environmental Management and Assessment from Oxford Brooke's University, U.K.

Matthias Holweg is a Research Affiliate at MIT's Center for Technology, Policy and Industrial Development, and University Lecturer at the Judge Institute of Management, University of Cambridge. He is also a Principal Investigator of MIT's International Motor Vehicle Program, where his research focuses on the implementation of build-to-order strategies in the global motor industry. Matthias holds a Master's degree in Operations Management from the University of Buckingham, U.K., and a Ph.D. in Supply Chain Management from Cardiff University, U.K.