Automotive Supply Chain and Logistics Management

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Abstract— **Knowledgeable observers say that many, though not all, automotive companies are running their supply chain well. American and European automotive companies are losing their shares and profits whereas Japanese companies are increasing world market shares and gaining more profits. Therefore, the present is considered to be a transitional period for the automotive industry. The purpose of this article is to present the weak points of current systems in the automotive industry as a whole, and provide solutions and suggestions for the industry to become more profitable again. In addition, we will focus upon the unique supply chain and logistics concepts implemented by Japanese automobile companies that have allowed them to become successful, and a model of best practices for the industry.**

Index Terms — **Automotive Industry, Supply Chain Management, Lean Manufacturing, and Toyota Production System**

I. INTRODUCTION

The automotive industry is the world's largest single manufacturing activity [1]. It uses 15 percent of the world's steel, 40 percent of the world's rubber and 25 percent of the world's glass. It also uses 40 percent of the world's annual oil output. From 1951 to 1972, there was a very high production growth rate of approximately 5.9% annually for the automotive industry. But after 1973, the year of the first oil shock, the growth rate declined to about 1% per year until 2002, and came to a halt in 2003 [2]. The declining growth rate has been partly attributed to the oil shock, but the major reason for the decline was due to the saturation of the market in developed-countries. More than 70 percent of all cars and trucks are still sold in the developed world. Of course, there is high potential market growth in the developing world. But the problem is that these countries are still constrained by low income levels. Unless these developing countries reach sufficient income levels to support car consumption, they will not see the mass motorization that the developed world has. The widely expanding production capacity of major automotive companies together with the sluggish world demand results in car surpluses, and low utilization of production capacity. As a result, the profits and financial performance of many major automotive companies are deteriorating. This leads to a heavy burden of debt in the industry and makes investors wary.

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Today, the automotive supply chain practice is in a transition period. The common practice in the automotive supply chain for most of the automotive companies is that every chain is mainly tied to forecasts. The vehicle manufacturers must match supplies with demands from the first chain, raw material suppliers, to the last chain, car buyers. The variation or uncertainty of demand due to forecasting is produced from chain to chain causing bullwhip effect. The new direction for automotive supply chain is still based in part, on the forecast and, in part, on the capable and responsive supply chain with a greater strategic emphasis, and subsequently, on the logistics operations [3].

II. THE AS-IS PROCESS FOR THE AUTOMOTIVE INDUSTRY

The current systems of the automotive industry mostly rely on build-to-forecast and/or build-to-delivery as in the following diagram.

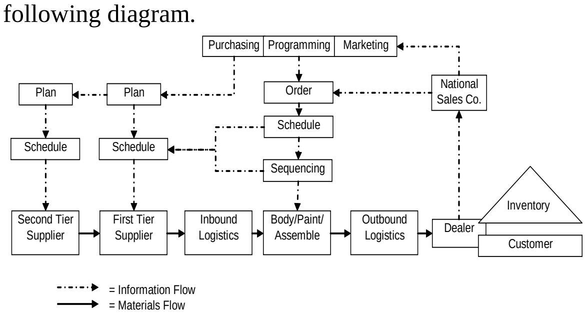


Figure 1: Build-to-forecast and build-to-delivery [4]

A. Build-to-forecast

- Sales Forecasting aggregates all dealers and national sales companies' forecasts and uses them as an input for production programming. The method is the bottom-up approach. Typically, aggregate demand forecast are more precise [5].

- Production programming is the process of consolidating forecast market demand to available production capacity to get the framework that defines how many vehicles will be built in each factory.

- Order entry is the stage in which orders are checked and entered into an order bank to await production scheduling.

- Production scheduling and sequencing fit orders from the order banks into production schedules. These orders are used to develop the sequence of cars to be built on the scheduled date.

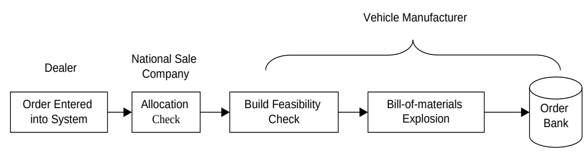
- Supplier scheduling is the process whereby suppliers receive forecasts at various times, actual schedules, and daily call-offs.
- Inbound logistics are the process of moving components and parts from supplier to assembly plant
- Vehicle production is the process of welding, painting, and assembling the vehicle.
- Vehicle distribution is the stage at which the finished vehicle is shipped to dealers.

In conclusion, build-to-forecast uses the forecasts as input and to drive production planning and scheduling. Consequently, the number of vehicles being produced and delivered to dealers is based on the qualitative method of sale forecasts. If the forecasts are significantly different from the actual sales, then there will be many vehicles stockpiled at the dealers.

B. Build-to-delivery

- Sales Forecasting starts with the national sales company asking dealers to supply their annual volume forecast several months before the end of the calendar year. Then, the national sales company resolves the sales forecasts into monthly or bimonthly groups from the dealers' baseline. Afterwards, the national sales company visits dealers to establish the discrepancies between actual sales and forecast sales. The demand forecasts become the basis or input for production programming. The dealers are responsible for supplying orders in accordance with their forecast volume up to 90 days ahead of production. The dealers must also identify certain features early on, such as model and engine type. However, they can postpone the decision on external options such as radio and air conditioning. Consequently, dealers push products in stock to the final customers by using discounts and promotion incentives.
- Production programming reconciles the production capacity and dealership sales requests. The allocation of resources is another task of production programming. The program allocates to markets major items such as engines, air conditioning, and heated windscreens. Moreover, the program can allocate short supply products to the most profitable markets. Some markets can absorb higher priced vehicles, so the volume is pushed to those markets. The decisions for production programming will be made three months in advance, and every effort will be made to adhere to them. At the latest, decisions can be changed one month before production. Such changes are usually due to unanticipated constraints, such as market, suppliers, and work stoppage. The volume and model type, such as sedan or station wagon, are determined by the manufacturer approximately three months before production, while decisions on power train and transmission are made two months before production. The decisions on color, trim and option choices are made one month before. This process is general for the automotive industry, but varies by ordering time length. As a result, the current production programming allows only minor changes in the month before actually building a car.
- Order entry begins when a salesperson enters a customer order into the system. Then, the order is passed on from the dealer to the national sales company and subsequently to the manufacturer's headquarters. An allocation check is done at the national sales company to see if the desired vehicle is available or not for the dealer and that market. Then, a ***build-feasibility*** check, which is the process of checking whether the special options and specifications are feasible for the production, follows to determine whether special options and specifications are available for that vehicle in the market. If not, the system rejects the order and the dealer must make the necessary order correction. Bill-Material-Conversion is the process of converting the orders received from the dealer to a bill of materials. This tells the manufacturers what kind of components they need to build the vehicle. The final stage in order entry is to transfer the order as a bill of material to the order bank. The order will stay in the order bank until the system transfers it into the plant's production schedule. Dealers can still make some amendments when the order is in the order bank. Then the forecast orders will be matched to the actual orders received from customers and the orders are transferred into a production schedule. However, if the forecast orders remain in the pipeline and can not find a customer to match within time to be altered, the manufacturers tend to build these vehicles despite the lack of demand.

Figure 2: Steps in order entry [6]



- Production scheduling and sequencing determines the source of all needed components from suppliers. The scheduling process fits the orders in the order bank into a weekly and later into a daily build schedule. Later, a human scheduler converts it to a production sequence. In addition, the scheduler tries to assign orders to each plant based on available production capacity. In addition, the production scheduling must be created based on the plants' overall mix and capacity constraints.
- Supplier scheduling is the process of communicating the component and material needs to first-tier and raw-material suppliers**.** Firstly, a production program driven by a long term forecast of up to 12 months is sent to the supplier. Secondly, weekly supplier schedules with 6-10 weeks of planning information are sent to supplier. The schedules provide only approximate guidelines for the plant's planned production. Lastly, the daily vehicle production schedule or "call-off" which is provided 2-10 days before production starts is sent to suppliers. However, the call-off is still inaccurate because it does not include the final assembly sequence, which cannot be determined until the vehicle exits the painted-body store. Consequently, suppliers view the information received from manufacturers as too much variation to use in planning. No one knows what is required until the actual assembly sequence is set. Therefore, suppliers generally keep higher buffer stocks, and locate their facility in proximity to the suppliers to reduce the component's delivery time.
- Inbound logistics is the process of moving components and parts from supplier to manufacturer. The cost of inbound logistics can be as high as 10 percent of the plant's manufacturing costs and thus 1.4 percent of the finished vehicle cost. Nowadays, suppliers are pushed to send components in smaller lots with higher delivery frequency. This typically can creates higher cost per shipment for suppliers [7].

- Vehicle distribution or outbound logistics is the process of transporting vehicles from the assembly plant to the dealership or final customer with large fleets. The outbound distribution logistics is always done via train, truck, and ship. Figure 3 illustrates the main volume routes - from the plant to market compounds or distribution centers, and then to dealerships or customers. The routes from assembly plant to regional distribution center and national compounds account for approximately 90 %, while the vehicles being directly transferred to local dealership account for just 1 %. Customers coming to pick-up the vehicle at the dealership account for 65%, while distribution centers delivering the vehicle directly to end users accounts for 25%.

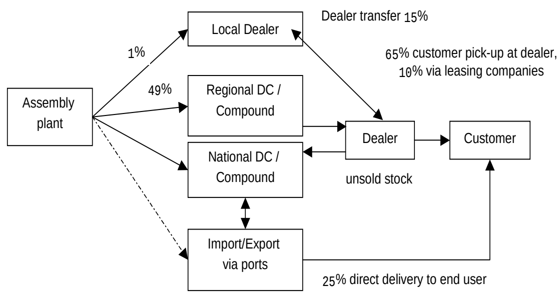


Figure 3: Outbound logistics
(an example from UK market) [8]

III. THE PAIN-POINTS AND PRACTICES

As mentioned earlier, the automotive industry today is struggling for growth and profitability in a setting that features both increasing costs and declining profit margins. There are many problems that need to be resolved, known as ***pain-points***. The pain-points are weak points in current practices that have an impact on the AS-IS process and manufacturing performance, leading to declining profitability for the whole industry. Hence, the automotive industry should try to find new practices to make the industry thrive again.

This section presents the pain-points existing in current automotive industry practice, followed by suggested reforms to cope with those pain-points.

A. The inaccuracy of sales forecasts

The inaccuracy of sales forecasts from dealers is one pain-point that affects the downstream units. Generally, manufacturers build vehicles based on sales forecasts from dealers. If actual sales are in accordance with the sale forecasts, the vehicles produced by manufacturers will be used up by customers. But if actual sales are below sales forecasts, dealers will end up stockpiling vehicles that customers do not want. The inaccuracy of forecasts is a common problem that exists in every industry. The variation between actual and forecasts results in the excess or shortage of inventory of goods.

B. A disconnection between manufacturing and customers

This is another major pain-point for the automotive industry. Lean manufacturing can create a very efficient production process with lower inventory levels. However, because it is not linked to the actual demand from customers, the dealers end up with the high stock piling in their warehouses. Manufacturers produce cars that exceed demand and hence the savings from the efficient manufacturing may be more than offset by 1) the cost of stock holding and 2) incentives offered to final customers to move the stock.

C. The self-fulfilling cycle to provide an inaccurate sales forecast, and the increasing cost of sales from incentives

This pain-point is the result of the first two pain-points. When dealers have high levels of undesired vehicle stocks, they try to push those vehicles to customers using discounts and promotions. These kinds of incentives can distort original demands because customers may accept and buy vehicles that they don't like in order to get incentives. Then, those distorted demands will be used to make a forecast which will be inaccurate since it does not capture the real demand from customers. The cycle is self-fulfilling with endless problems. Finally, incentives also end up increasing the cost of sale.

D. The vulunerable and unreliable information or scheduling from manufacturer to suppliers

Suppliers cannot rely on the scheduling sent to them by the manufacturer. Schedules rarely match previously received forecasts, which in turn do not match the final ***call-offs,*** the process by which the assembly plant asks the supplier to deliver the components to the plant. Even the assembly plant itself does not know what the sequence of production will be until the order passes the painted-body store. In just-in-time methodology, suppliers are given only 8-10 hours before the final call-off sequence. This can create very high buffer stocks at suppliers

E. The delay in order entry

Actually, the allocation and checks take only about 2 hours. But, orders require days before being converted into the lists of required parts. The national sales company often batches orders. The average delay from order entry is 3.8 days [2].

F. The delay in order processing and scheduling process

Once the order is in an order bank, it must spend approximately another 8 days waiting for actual orders to come to match with it. In addition, the manufacturer must take into consideration the order priorities as well as factory and labor constraints to create a feasible production schedule. The order spends 15.1 days in scheduling and another 6.5 days in sequencing. The total delay for order processing and scheduling is 30.4 days.

G. The delay from distribution

This is another delay pain-point with average delay about 10 days. According to research in the UK [9], a vehicle waits 0.9 days in the factory before being loaded onto a transporter and another 3.8 days en route to the dealer. Surprisingly, the actual movement time for transport is less than 24 hours. Overall, the time spent on non-value-adding activities in the distribution process accounts for 9 days.

The suggested solution to cope with pain-points 3.1 to 3.7 is to replace build-to-forecast and build-to-delivery with build-to-order. Build-to-order uses the real order instead of sale forecasts to trigger the entire value chain. However, before implementing build-to-order, an infrastructure must first be established to support it. The recommendations for Build-to-order include demand visibility, capacity flexibility, supplier flexibility, and logistics flexibility.

Demand visibility is one building block for build-to-order. Customer's need must drive the entire value chain. Therefore, demand visibility must be communicated to all units in the supply chain. In the current system, order banks operate in batch mode, and orders wait a day at each batch operation before being sent to scheduling. For build-to-order, the actual order must be communicated to each unit in the chain in real time without any distortion or delay. The automotive industry can use a direct order booking system to deal with demand. Available capacity becomes the number of free slots. Once the dealer assigns a customer a build slot, the stability of that order in that slot helps avoid information distortion in supplier schedules. Then, suppliers will know exactly how many components will be needed in the assembly plant. In addition, logistics companies plan and optimize their loads based on the complete date of production from locked assembly slots. There are two advantages for a direct booking system. Firstly, the dealer can give the customer a reliable delivery date at order entry. Secondly, order banks, scheduling and sequencing will be merged into one system which reduces the processing time. Because direct order booking locks in the build sequence once it is set, demand stays stable and visible to suppliers and logistics service providers.

Capacity flexibility is another building block for build-to-order. The plant should have a capability to alter capacity levels at relatively low costs. The flexibility may be attained by re-allocating work, and reducing reliance on massive investments. Another way to manage demand and to increase responsiveness is to integrate large and small operations. Small-scale facilities can be used to produce the lower-demand products with high variants that do not justify the use of large-scale facilities. For example, DaimlerChrysler's East London plant in South Africa produced all right-hand-drive vehicles for the Mercedes-Benz C-Class models. Another way to manage capacity is hour banks that are widely used in European countries. Workers make contracts with employers to work a certain amount of time each year. Workers might be asked to work more hours during high-demand periods and work fewer hours at other times.

Supplier flexibility is the third building block for build-to-order. Suppliers must be triggered by real orders, and the slotting orders. At the same time, suppliers must be able to provide high responsiveness. Some co-location is necessary for a successful build-to-order system. A manufacturer cannot build the car in days if it takes the supplier a week to manufacture and ship customized components.

Lastly is logistics flexibility. The logistics system for build-to-order should be able to transport vehicles in a smaller lot than the ones in the current system. The larger the transporter, the longer the time required to fill the order. The benefits of applying this solution are lower cost of sale incentives and lower inventory cost for the entire chain. This is especially true for vehicle stocks at dealerships. Another major benefit is the increase in customer satisfaction. Customers can get the types of vehicles that they really want. On the other side of the coin, the cost of the higher cost resulting from smaller truckloads will be more than offset by the benefits of higher satisfaction and shorter cash conversion cycles.

H. The high inbound and outbound logistics cost

The cost of inbound logistics can be as high as 10 percent [10][11] of the plant manufacturing costs. This is two fold. One is because suppliers ship out many parts and components. The other is because assembly plants always require smaller lots with much higher delivery frequency. The distribution cost of vehicles is extremely high at 30 % of total cost, while the distribution cost of commercial airlines is lower than 10%. The major cause of high outbound logistics cost is that there are too many franchised dealers and each one wants to establish its own individuality. This high cost comes from the redundancy of jobs and processes done by many small dealers. The operating cost per vehicle of a small dealer is relatively higher than that of a large dealer. At the same time, large dealers can keep significantly lower levels of stock than many small dealers do to support the same customer service level.

One solution to counter high inbound logistics costs is to create a cross dock between suppliers and the vehicle assembly plant. This is shown in Figure 4.

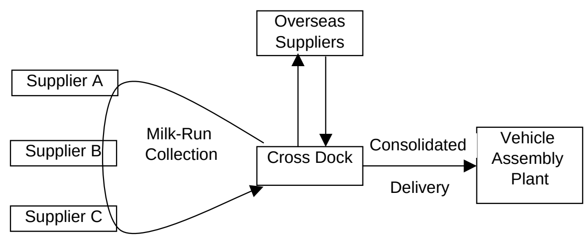


Figure 4 Cross docking [12]

The cross dock is built on a location close to suppliers. The Milk-Run Collection truck will be sent from the cross dock to pick up components from more than one supplier, for example are suppliers A, B, and C in Figure 4. Upon its return back to the cross dock, the components will be consolidated and sent to the vehicle assembly plant in a single truckload. This strategy enables firms to use trucks more efficiently. It also allows more frequent deliveries. This yields decreased logistics costs and allows assembly plants to maintain supply stocks.

Another solution is to allow franchise dealers to offer more than one brand to customers - a "car supermarket" concept. Job redundancy will be reduced by combining different franchised dealers together, and customers will have a centralized place for automotive shopping. The conglomeration of dealers will enable them to offer a wide range of products, lower overhead cost structure, reduce management and stock holding, and increase economies of scale. Furthermore, incentives costs will be lower because dealers can supply vehicles that customers really want. However, dealers should conduct extensive market research before implementation to determine the optimal number of brand offerings so that they minimize total costs and maximize customer satisfaction. As a result, the operating cost of the dealer industry as a whole will be decreased. In addition, the service level will be increased with lower costs and reduced customer purchasing cycle time. The customer service level is directly related to the probability that no part will be out-of-stock [7].

I. Product proliferation

This is the last pain-point of the automotive industry. To counter the low rates of expansion since the 1970s, vehicle manufacturing has responded by increasing the content of their vehicle. They have also immensely increased the range of models available, in the hope of stimulating more buyers, regardless of the added economic cost. The increasing number of content and models result in higher production costs, because of the changeovers [13]. Furthermore, the greater the variety of contents and parts, the higher the cost of stocking these items [14].

The recommended practice to cope with product proliferation is to reduce the internal variety. The internal variety is the variation in processes and parts to create products while the external variety is what the customer sees. Body style, engine, exterior color, and radio type are the most considered features, while other features and options are less critical. For example, customers cannot see the difference between the less than 1,000 variants of the Honda Accord and the trillions of variants on the Mercedes E-class [15]. In other words, the downstream value chain is quite important. However, customers do not recognize the variants between Honda and Mercedes. Thus it is preferable to deal with Honda's 1,000 versus Mercedes 17,424 variations.

BIW (body-in-white) is a welded steel monocoque (shell) which is the starting point of most vehicles. BIW might vary based on the engine type or the presence of air conditioning, sunroof, and other options. The more options offered, the more varied BIW becomes. According to research, the BIW variety does not correlate with the number of body styles offered in the market and has little relation to external variety overall. Consequently, as buyers focus on external variety, the automotive industry can reduce the cost of proliferation by reducing the number of BIW variants. Furthermore, another benefit from reducing the number of BIW variants is flexibility. Plants can separate body and paint before assembling, and use the interim paint-body store to house bodies that are ready to be customized. Lastly, we can also increase the number of vehicles and body types per platform to improve the average production volume per platform.

Another solution to deal with product proliferation is to create ***mutable support structure.*** This means that the components have been designed to support multiple product configurations. Mutable structures have standardized and generic interfaces, but they do not require standardized parts. The plant can swap one support structure for another that makes the assembly sequence more predictable and stable. Decreasing internal variety will lead to a lower production cost and a lower inventory cost for both suppliers and assembly plants. Suppliers will be able to keep fewer kinds of components and raw-materials for final components production that goes into the vehicle. At the same time, assembly plants will be able to lower BTW and platform stock levels to satisfy dealers and customers.

IV. TOYOTA: THE WORLD'S GREATEST MANUFACTURER

Toyota's production system has been held as a model for the industry based on market share and the profitability of Japanese manufacturers. There are three elements here: lean manufacturing; the Toyota production system (TSP) and theory of constraint; and the lean product development of Toyota.

A. Lean manufacturing

Lean manufacturing is the concept created by Toyota to make production development and the production system more efficient and remove waste from the process. It consists of three building blocks – creating continuous process flow, the pull system, and leveling out the workload.

The first building block for implementing lean manufacturing is to create continuous process flow to bring problems to the surface. Most business processes are 90% waste, and 10% value-added work [4]. Firms can conduct a process mapping to find the non-value-adding activities, and remove them. Shortening the elapsed time from raw materials to finished goods will lead to the best quality, lower cost, and shortest delivery time. The lower inventory levels can also expose problems. The goal of lean environment is to create one piece flow. The traditional mass production thinking focuses on grouping similar machines and similarly skilled people together. The production is done in large batches which leads to overproduction and inventory sitting idle. On the other hand, lean manufacturing focuses on optimizing the flow of material so it can move more quickly through the factory. Consequently, the batch size will be reduced. In addition, when a defect occurs manufacturers can solve the problem immediately because the product is built piece by piece. In contrast, producing in large batches creates high number of parts that are work-in-process; if there is a defect in the product, correction comes far too That is, a batch of 100K parts produced will not be identified until much later in the supply chain. This means instead of correcting maybe 100 items, the manufacturer will correct 100,000 items.

The second building block for lean manufacturing is the pull system. Toyota borrowed this concept from super markets. Once the order is purchased from the shelf, it will trigger the supermarket to replenish the product. The inventory replenishment will be done based on the demand, rather than using a push system. However, since there are natural breaks in flow from transforming raw materials into finished products delivered to customers, some inventory is necessary.

The third building block is leveling out the workload. If product is built exactly to the quantity ordered, it may be building huge quantities in one week, which the company ends up paying for with overtime; employees and all equipment are over worked. Then if orders are light the following week, workers will have little to do and the equipment will be underutilized. Lean manufacturing instead takes the total volume of orders in a period and levels them out so that the same amount and mix of products are being made each day.

B. Toyota production system and theory of constraint

Obviously, Toyota has successfully applied Theory of Constraint to develop lean manufacturing. Constraint management is a framework for managing the constraints of a system in a way that maximizes the system's accomplishment of goals or throughput. Throughput is defined as the rate at which the system generates money through sales. Constraint is the part of the system that determines the output. The rate of throughput of the whole system is equal to the rate of the throughput of the constraint. Once one constraint is removed, it will be moved to another part of the system, and so on.

Formerly, manufacturers produced vehicles based solely on sales forecasts. If the sale forecast was inaccurate, manufacturers would produce cars that customers did not want, and as a result end up with high stock at dealerships. Manufacturers might have a very high-tech and extremely efficient production system. Moreover, manufacturers always produced the vehicles in the same model with very high volume in order to gain the economy of scale. However, those efficient productions would lead to very high end vehicles that no one wanted and hence vehicle manufacturer would lose profit. The constraint was the lack of linkage between manufacturing and customer demands that lead to excessive inventories at dealerships. Toyota knew about this problem, and had developed the lean manufacturing and the Toyota product development system to counter such problems. Toyota had put customers into the first process of production development by creating customer-defined value, and using it as a core value to drive other processes. This ensures that the vehicles Toyota manufactures would be as close to customer preference as possible. In addition, Toyota created the standardized product platforms that can be used with various vehicles' models so they can produce a large volume of product platforms to achieve the economy of scale, while still being able to customize the product in the assembly process with respect to customer preference.

Another technique created by Toyota to counter this constraint is transforming the batch processing to continuous flow. This creates tremendous flexibility for manufacturers so that they can adjust production in accordance with demand. This is because manufacturers produce one piece at a time. Implementing these techniques enabled Toyota to remove the linkage constraint between manufacturer and customer demands, maximize the throughput and minimize inventories and operating expenses that leads to a higher return on investment.

C. Lean product development of Toyota

The Lean Toyota Production System has been applied not only to the manufacturing function, but also to the product development. There are many companies which try to apply the TPS, but never succeed because they replicate only the surface parts of the Toyota methodologies. The lean in the point of view of Toyota is much broader than manufacturing. It includes customer focus, continuous improvement through waste reduction, and tight integration with upstream and downstream processes. Obviously, improvements at the early stage of product development will have much higher impact than the improvement in later stages. Consequently, Toyota has applied and created the lean concepts and principles for the product development stage.

The first principle is that the right process will yield the right results. Customer-defined value should be established. The customer is always the starting point for any process. Any processes that do not add customer value should be eliminated.

Front-loading the production development process is also very important for the lean concept. This concept is about doing it right the first time to avoid very costly downstream design changes. Exploration should be conducted in an early stage with a wide range of potential problems and alternative solutions.

Creating a leveled product development process flow is another element for lean product development. Like the manufacturing process, Toyota views product development as a process.

There are a number of recurring cycles of activity, and improvement could be achieved by reducing them. The workflow is especially erratic. Sometimes, there is more work than people or machines can handle, while at other times there is not enough work. The work load should be evened out to create a smooth process flow.

Another aspect of lean product development is using rigorous standardization to reduce variation and to create flexibility and predictable outcomes. The challenge in production development is to diminish variation while preserving the creativity that is essential to the creative process. Toyota creates higher-level system flexibility by standardizing lower level tasks. Standardization of platforms allows Toyota to share critical components, subsystems, and technologies across vehicles platforms. Standardization of skill sets of engineers gives flexibility in staffing and program planning, and minimizes task variation.

The next backbone of lean product development is to adapt technology to fit people and processes. Toyota recognizes that technology seldom provides a significant competitive advantage. It is more important to ensure that the technology fits and enhances already optimized and disciplined processes, and highly skilled people.

Lastly, integrating people, process, and tools and technology into a coherent system is a key element of lean production development. The excellence of each small part in the system may not lead to system excellence. There must be an alignment and integration of each element in the system to provide the optimized outcome.

V. Conclusion

As mentioned earlier, the automotive industry is presently in a period of transition. It is useful to see the picture and the problems of the automotive industry as a whole. This paper assembles weak points and suggestions on how to solve them. These suggestions have been implemented by different automotive companies and other industries. Many papers state that the current practice in the automotive industry lies in between build to forecast and build to delivery, and build to order. However, none have been completely transferred to the complete build to order process. Therefore, it is argued here that the concept of build to order is considered the key reform of the current automotive industry's supply chain.

Another important issue in our paper is about lean manufacturing and Toyota production system. Several automotive companies and other industries have attempted to study and implement these concepts, with a high return on investment. Yet their effort is still considered as the implementation of only the surface core concepts. Therefore, this paper argues for introducing the concepts of lean manufacturing and Toyota production system in product development as well as manufacturing. Such reforms will improve the financial health of the industry at large.

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