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*Full Length Research Paper*

# Strategic supply chain framework for the automotive industry

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**The changing business conditions of the 21st century has led to companies facing issues ranging from globalisation, economic uncertainty to new technologies and increasing consumer demands. In the automobile industry, as manufacturers design and build vehicles globally, their supply chains become increasingly complex with challenges that often stand in the way of profitability and higher shareholder value such as long order-to-delivery lead times, unreliable production schedules, excess inventory across the supply chain, lengthy demand planning cycles and lack of visibility of suppliers. The effect of the global economic meltdown increased the pressure on automotive executives to make right decisions about their supply chain for better performance. In a highly challenging and competitive environment such as today, where supply chain is a popular tool for improving the organisational competitiveness, an efficient and effective supply chain strategy is a must for automotive manufacturers and their component manufacturers so as to meet changing consumer demands. The paper explores the concept of lean and agility as generic supply chain strategies and presents a strategic supply chain framework for the automobile industry as a possible strategy to respond to changing consumer demand.**

**Key words:** Supply chain management, strategies, automobile industry.

## INTRODUCTION

Fierce competition, fluctuating market demand and rising customer requirements has led to customers becoming more demanding with increased preferences (Zhang and Cheng, 2006). This is as a result of today's marketplace, characterized by shorter product lifecycles, more competitive product introductions and volatility in demand, which makes life-cycle demand more uncertain and difficult to predict (Christopher and Rutherford, 2004). In the automotive industry, the 21st century, participating largely in globalization has created significant opportunities, and at the same time, put pressure on manufacturers to enhance quality, improve styling, increase organizational efficiencies and drive innovative features into their products in an effort to attract customers and expand into new markets (BCC, 2005). These challenges imply that automotive manufacturers need to be flexible and responsive to customer demand in order to succeed.

The critical role of supply chain management (SCM) in enhancing the automotive performance cannot be underscored. Authorities and organisations such as (Gunasekaran and Ngai, 2004; Hugo et al., 2004; Wei and Chen, 2008; IBM, 2009) have in one way or the other acknowledged the role of supply chain as source of competitive advantage to the automobile industry. The industry has undergone significant structural and other changes in the last decade (Michalos et al., 2009).

In light of this, the last 20 years has seen SCM practices developed toward more lean process approaches, in order to increase supply chain efficiency (reducing costs and eliminating inefficiencies). Concepts such as just-in-time; supplier base rationalization; virtual inventory; outsourcing; customized and global networks; reduction of buffers in material, capacity and time; and reduction in the number of distribution facilities have led

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to improvements in supply chain performance particularly in reducing costs.

Due to vulnerability and turbulence in the business environment, lean supply chain cannot cope with changing customer demands. As stated by Sweicky and Gerth (2008), the characteristics of the traditional downstream supply chain (lean) do not make provisions to respond to changing business environment but for low cost and waste minimisation (value stream mapping). Therefore, lean is not a universal solution to meet all the needs of the supply chain. To achieve a high degree of flexibility and customer responsiveness, a combination of lean philosophy and new technology is required to quickly design new streamlined operations on the shop floor and beyond. Agile supply chain systems permit fast cost-effective responses to unpredictable and ever-changing product demand, and support rapid product launches for previously unplanned products tailored to meet changing customer desires (Elkins et al., 2004).

Recently, scholarly attention has geared towards leagile supply chain strategy (a hybrid approach) based on the combination of lean and agile strategies. The "leagile" concept (Naylor et al., 1999; Mason-Jones, 2000) has become a popular way to more effectively adapt to changes in the business environment and to address market and customer needs in a more proactive manner while maintaining high levels of operational efficiency (Lee, 2004). However, despite the popularity of this hybrid strategy, much has not been done to uncover this strategy in automotive companies in South Africa. There is the need for more practical examination and illustration of this hybrid strategy.

Against this backdrop, the paper explore the concept of supply chain management to (1) determine the different types of supply chain strategies that exists, (2) the conditions for implementing the strategies and (3) to develop a supply chain strategy that would respond to changing customer requirements. The paper employs a theoretical analytical approach supplemented by a case study of BMW (Bayerische Motoren Werke) Rosslyn plant in Pretoria, South Africa. The paper concludes by suggesting a framework for leagile supply chain. The paper contributes to the knowledge of total supply chain management and the application of the leagile supply chain framework will optimise automotive supply chain performance. The remaining section of the paper presents: (i) Supply chain management (SCM) (ii) Supply chain strategies (iii) research method (iv) case study of BMW Rosslyn plant and (iv) framework for leagile supply chain.

## Supply chain management

The fiercely competitive global business environment and increasing customer demands have led to the development and continuous evolution of a number of related disciplines including SCM (Sahay et al., 2006). Supply chain management (SCM) can be defined as the design and management of seamless, value-added process across organisational boundaries to meet the real needs of the end customer (Fawcett et al., 2007). Generally, SCM involves relationships and managing the inflow and outflow of goods, services and information (network) between and within producers, manufacturers and the consumers (Christopher, 2005; Samaranayake, 2005; Gripsrud, 2006). A supply chain includes all activities, functions and facilities (directly or indirectly) in the flow and transformation of goods and services from the material stage to the end user (Sherer, 2005). It consists of an upstream supplier network and downstream channel (Klemencic, 2006). Today, many organisations have become part of at least one supply chain. They have to perform equally well in order to achieve better performance. A typical supply chain may include suppliers, manufacturers, distributors, retailers and customers.

## Automotive supply chain

The automotive industry is made up of supply management and physical distribution management. The industry supply chain stretches from the producers of raw materials through to the assembly of the most sophisticated electronic and computing technologies (Tang and Qian, 2007). The major component of the supply chain include suppliers (tier 1 - 3), OEMs, distribution centres, dealers, customers (Hugo et al., 2004). Most automotive OEMs create 30 to 35% of value internally and delegate the rest to their supplier (Dietz, 2004). Manufacturers purchased entire subassemblies, such as doors, power trains, and electronics from suppliers. The desire to work with partners to outsource subassemblies is leading to a radically new infrastructure to support the design, procurement, and logistics processes of the manufacturers (Benko et al., 2004). Tang and Qian (2007) comprehend that to improve their innovative ability, get cars to market faster and reduce errors, automotive manufacturers need to improve their development and management abilities through advances in computer-aided design (CAD), computer-aided process planning (CAPP), computer-assisted manufacturing (CAM), computer-aided engineering (CAE), concurrent engineering (CE), product data management (PDM), business process engineering, etc.

## Structural changes in the automotive supply chain

The automotive industry has undergone a transformational evolution over the last two decades (Swieki and Gerth, 2008) . Hugo et al. (2004) noted that the traditional method for designing an automotive supply chain requires a fully integrated, lean materials flow pipeline,

certain design constructs and activities have to be engineered into the supply chain. Historically, the industry operated under a "push" model. In this model, marketing and sales takes a best guess at market demand and then feed these forecasts into the design, engineering, financial and manufacturing teams to determine make and/or model production volumes (Howard et al., 2006). With the boom of the Internet, data has become much more accessible to both manufacturers and consumers of automobiles (GXS, 2005; Tang and Qian, 2007) . The industry focused primarily on lean, "Just-In-Time" manufacturing processes and their supporting technologies. OEMs and suppliers spent millions of dollars and millions of man-hours re-engineering processes and technologies to support a demand-driven model. Because the price tag for reengineering and supporting technologies, for example, ERP was prohibitively high, efforts were limited to OEMs and their Tier 1 suppliers. Significant progress was made to "commonize" process and technology within the "four walls," however, these efforts were creating a widening process and technology gap between OEMs, Tier 1s and the rest of the automotive supply chain. As the Internet became a common fixture in automotive business-to-business (B2B), competitive pressures grew exponentially (Tang and Qian, 2007).

In mature markets, automotive firms face stiff competition and demanding customers. Mass production (forecast driven) has led to overstocking, extra marketing expenses and low profitability (Holweg and Pil, 2004; Zhang and Chen, 2006).

## Supply chain strategies

Businesses today do not only operate at a lower cost to compete, but has to develop core competencies to distinguish itself from competitors and stand out in the market (Hugo et al., 2004). Supply chain strategy is part of the overall business strategy, designed around a well-defined basis of competition (innovation, low cost, service, quality) (Cohen and Rousell, 2005). It is integrated with marketing strategy and with customers' needs, product strategy as well as power position. In a rapidly evolving global economy, no firm exist in a vacuum (Hugo et al., 2004). A supply chain strategy is defined, relative to its competitors' set of customer needs that it seeks to satisfy through its products and services (Chopra and Meindl, 2007). This involves decisions relating to the selection of suppliers, the location of facilities and the choice of distribution channels. As noted by Christopher et al. (2006), it is now increasingly accepted that "one size does not fit all" when it comes to designing a supply chain strategy to support a wide range of products with different characteristics sold in a diversity of markets. Therefore, supply chain strategies should be tailored to match the required 'order winning criteria' in the market place with appropriate product/market conditions (Christopher, 2005).

There are three basic principles in developing a supply chain strategy that will meet the taste of the customer needs (Taylor, 2004; Hines, 2006; Fawcett et al., 2007; Chopra and Meindl, 2010). These include: understanding the customer and degree of uncertainty; understanding the supply chain capabilities; and evaluating the options and selecting the design. Fisher (1997) developed a framework to help managers understand the nature of their product and devised the supply chain that can best satisfy that demand (Jacobs et al., 2009). Lee (2002), Selldin and Olhager (2007) and Jacobs et al. (2009) based on Fisher (1997) framework, stated that products can be categorised as either primarily functional or primarily innovative. Each of the categories requires distinctive different kinds of supply chain leading to the root cause of the supply chain problems. These classification and categorisation resulted in four types of strategies based on the nature of demand and supply characteristics. These strategies include: efficient supply chains, risk-hedging supply chains, responsive supply chains and agile supply chains (Kaipia and Holmstrom, 2007; Jacobs et al., 2009), where efficient supply chain is lean supply chain.

However, Manson-Jones et al. (2000), Christopher and Towill (2001), Christopher (2005), Hull (2005), Simons and Zokaei (2005), Hallgren and Olhager (2009), Vinodh et al. (2009) and Pandey and Garg (2009) acknowledged two main strategies in the supply chain. These strategies are term 'generic' supply chain strategies and include "lean and agility". 'Lean' works best in high volume, low variety and predictable environments, whereas 'agility' is needed in a less predictable environment where the demand for variety is high (Christopher, 2005) . Identifying the types of supply chain strategies might be appropriate in different circumstances to position the product in an organization's portfolio according to their supply and demand characteristics.

## Lean supply chain

The term "lean" means series of activities or solutions to eliminate waste, reduce non- value added (NVA) operations and improve the value added (Wee and Wu, 2009). Rahiminia et al. (2009) define it thus: "leanness means developing a value stream to eliminate all waste, including time and to ensure a level schedule". Lean is a systematic approach to identifying and eliminating waste (non-value-added activities). As acknowledged by Castle and Harvey (2009) and Womack and Jones (2003) identified that in order to meet customer's needs; an organisation must identify what customers think of waste. Elimination of waste and ensuring value is the core objective of lean. Hines et al. (2004) and Kollberg et al. (2007) stated that the idea of lean production was born in the 1950's and did not reach readers outside Japan until the 1990. The term does not have a clear and concise

definition.

According to Simons and Zakaei (2005), Comn and Mathaisel (2005) and Salman et al. (2007), in Western communities, the term was introduced through the book: "The Machine that changed the World" - The story of lean production (Womack et al., 1990). The book documents the evolution of the automotive industry from craft production, through mass production to ultimately lean production. The concept of lean is associated with Henry Ford in the 1920s when he applied the concept of 'continuous flow' to the assembly line process. The practice focused on reduction by improving quality through output. The aim was to bridge the gap in performance between Toyota and western car makers using mass production systems (Kollberg et al., 2009). In 1996, the concept was further elaborated in Womack and Jones book "Lean Thinking" (Womack and Jones, 2003). The concept extended from the shop floor to include the entire organisation, not only manufacturing function (Kollberg et al., 2009). Hines et al. (2004) termed this process "extension" to include a new design based on the lean principles. As noted by Papadopoulou and Ozabayrak (2005), the origin of lean is associated with two concepts: Toyota Production Systems (TPS) and Just-In-Time (JIT) philosophy.

A lean supply chain is a strategy that produces just what and how much is needed, when it is needed, and where it is needed. Lean is a supply chain term defined as the "enhancement of value by the elimination of waste" (Womack and Jones, 2003). The primary objective of a lean supply chain can be realised by integrating the most basic forms of data communication on inventories, capacities, and delivery plans and fluctuations, within the framework of just-in-time (JIT) principles. The aim of integration is to ensure commitment to cost and quality, as well as achieving minimum distortion of plans, schedules and regular delivery of small volumes of orders. Lean supply chain is mainly concerned with cost reduction by operating the basic processes at minimum waste. Lean philosophy is applicable when market demand is predictable and buyers' decisions are highly dependent on the lowest price criterion. Due to the fact that market demand is predictable, product supply is based on forecasts (Gattorna, 2006). Customers in lean supply chains are delivered value through "low production cost and logistics achieved by using all available synergies and economies of scale" (Gattorna, 2006). However, lean is unable to deal with turbulent market conditions because it is a low cost strategy (Sweicki and Gerth, 2008).

**Agile supply chain**

The concept of agility is widely adapted to the area of contemporary business (Agarwalet al., 2007). Gunasekaran et al. (2007) stated that the requirements for organisations and facilities to become more flexible and responsive to customers need led to agile manufacturing. According to Christopher (2005) and Vinodh et al. (2009), the term "agility" was first introduced as a management paradigm in 1991, when the Iacocca Institute of Lehigh University (USA), released its report "21st Century Manufacturing Enter-prise Strategy: An Industry-Led View" (Christopher, 2005; Kispersker-maron and Swierczek, 2008; Rahminia et al., 2009). Agility has been expressed in different ways and agility had its roots in time- based competition and fast-cycle innovation. It is built on a foundation of some, but not all of the practices common to lean thinking.

Agility has been introduced as a total integration of business components. As noted by Gunasekaran et al., (2007) one of the factors contributing to agility becoming an agile manufacturer has been the development of manufacturing support technology that allows marketers, design and production personnel to share a common database of parts and products and to share data on production capabilities and problems.

According to Iskanius (2006) as noted by Preiss (2005), "agility is a comprehensive response to the business challenges of profiting from rapidly changing, continually fragmenting, global markets for high-quality, high-performance, customer-configured goods and services. Gunasekaran et al. (2009) defines agility as "using market knowledge and a visual corporation to exploit profitable opportunities in a volatile market". Pandey and Garg (2009) defined agility as a business-wide capability that embraces organisational structures, information systems, logistics processes and, in particular, mindsets. Therefore agility means different things to different enterprises in different contexts. As companies faces changes and pressures differently, the degree of agility required by individual companies will be different and therefore agility could stem from different issues.

The application of agility to the concept of supply chains was introduced to transfer and apply the winning strategy of agility to that of supply chains (Rahminia et al., 2009). Agility in the context of SCM focuses on "responsiveness" (Christopher and Towill, 2000). Li et al. (2008), professed that in today's complex and challenging supply chain, agility is critical in global competitiveness. Kisperka-manson and Swierczek (2009) stated that the drivers behind the need for agility in supply chains are similar to those that drove the introduction of the agile manufacturing concept and stem from the rate of change and uncertainties in the business environment. Agility in a supply chain, according to Ismail and Sharifi (2006), is the ability of the supply chain as a whole and its members to rapidly align the network and its operations to dynamic and turbulent requirements of the customers. The main focus is on running businesses in network structures with an adequate level of agility to
respond to changes as well as proactively anticipate changes and seek new emerging opportunities. It is a measure of how well the relationships involved in the

processes can be enhanced and widely accepted as winning strategy for growth (Christopher and Towill, 2000; Ismail and Sharifi, 2006; Kisperka-manson and Swierczek, 2009). As denoted by Gunasekaran et al. (2007), agility should not only be based on responsive-ness and flexibility, but also on the cost and quality of goods and services. Hence, lean is a prerequisite for agility.

**Leagile supply chain**

Numerous researches have shown that lean and agility approaches can be integrated in a variety of ways (Faisal et al., 2006; Krishnamurthy and Yauch, 2007; Hilletofth, 2009). This is because they are common to each other; and can be linked to evolve a new manufacturing paradigm under the name leagile (Vinodh et al., 2009). Krishnamurthy and Yauch (2007) define leagility as "a system in which the advantages of leaness and agility are combined". Leagile supply chain aims to infuse competitiveness in an organisation in a cost effective mannar. Leagility is the combination of lean and agile paradigms within a total supply chain strategy by positioning the decoupling point so as to best suit the need for responding to a volatile demand downstream yet providing level schedule upstream from the decoupling point (Hull, 2005; Vinodh et al., 2009; Rahiminia and Moghadasian, 2010).

Vinodh et al. (2009) noted that leagile supply chain was developed exclusively to enhance the performance of supply chains. Mistry (2005), studied the evolutional development of the concepts of lean and agile supply chains. He developed an integrated framework for the evolution of lean and agile supply chain. Christopher and Towill (2001) and Hilletofth (2009) visualized three distinct lean-agile hybrids. Christopher (2005) noted that the goal of a hybrid strategy should be to build an agile response upon a lean platform by seeking to follow lean principles up to the decoupling point and agile practice after that point. The first is founded on the Pareto Rule, recognizing that 80% of a company's revenue is generated from 20% of its products (Christopher, 2005). It is suggested that the dominant 20% of the product assortment can be managed in a lean manner, given that demand is relatively stable for these items and that efficient replenishment is the appropriate objective, while the remaining 80% can be managed in an agile manner (Goldsby et al., 2006).

The second lean-agile hybrid is founded on the principle of base and surplus demand, recognizing that most companies experience a base level of demand over the course of the year. Krishnamurthy and Yauch (2007) suggested that the base demand can be managed in a lean manner, while demand peaks over the course of peak seasons or heavy promotion periods can be managed in an agile manner (Christopher and Towill, 2001; Goldsby et al., 2006). The third lean-agile hybrid is founded on the principle of postponement. The foundation of postponement is that risk and uncertainty costs are linked to the differentiation of products that occurs during the activities in the supply chain (Hilletofth, 2009). Costs in the supply chain can be reduced, or fully eliminated, by postponing certain activities (logistics and manufacturing activities) in the supply chain until customer orders are received (Faisal et al., 2006). The decoupling point is most cited amongst the three hybrid strategies (Wikner and Rudberg, 2005). It separates the lean and agile paradigms. As noted by Hull (2005), this is the point where the product characteristics to which customers' orders penetrate (Rahiminia et al., 2009). That is the point where order driven and forecast meet. Krishnamurthy and Yauch (2007) and Rahiminia and Moghadasian (2010) noted that lean and agile systems do not co-exist; they have a demarcation between them. Figure 1 illustrates an example of a de-coupling point of lean and agile paradigms.

The decoupling point approach employs the concept of postponement which is now increasingly widely used by organisations in a range of industries (Hull, 2005; Wikner and Rudberg, 2005; Rahminia and Moghadasian, 2010). The concept of postponement dates back to 1920. It can be defined as "the delaying of operational activities in a system until customer orders are received rather than completing activities in advance and then waiting for orders (Krishnamurthy and Yauch, 2007). The basic idea is to hold inventory in some generic or modular form and only complete the final assembly or configuration when the precise customer order is received (Christopher, 2005; Jonsson, 2008). A company may delay the forward movement (distribution) of the products as long as possible in the chain of operations, and that product(s) are kept in storage at central locations in the distribution chain (Hilletofth, 2009). This can be through assembly (assembly-to-order), production (make-to-order) and source or even design (engineer-to-order).

The choice of a supply chain strategy is intimately related to the positioning of the decoupling point (Wikner and Rudberg, 2005). The types of manufacturing strategies in which to place the decoupling point in order to determine supply chain paradigms have to be well documented (Rahiminia and Moghadasian, 2010). Four most common manufacturing activities based on speculation and customer order commitments are make-to-stock, make-to-order, configure-to-order and engineer-to-order (Taylor, 2004; Cohen and Rousell, 2005; Shapiro, 2007; Webster, 2008; and Bowersox et al., 2010). This means that manufacturing strategies deter-mine the strategic positioning of the decoupling point in an organisation.

Hence, employing a leagile supply chain ensures that an organisation will minimise cost, maintain stability while at the same time be flexible and responsive to customer demand. This will lead to competitive advantage through innovation, cost, service and quality as shown in Figure 2. Agile supply chain is a winning strategy for growth while

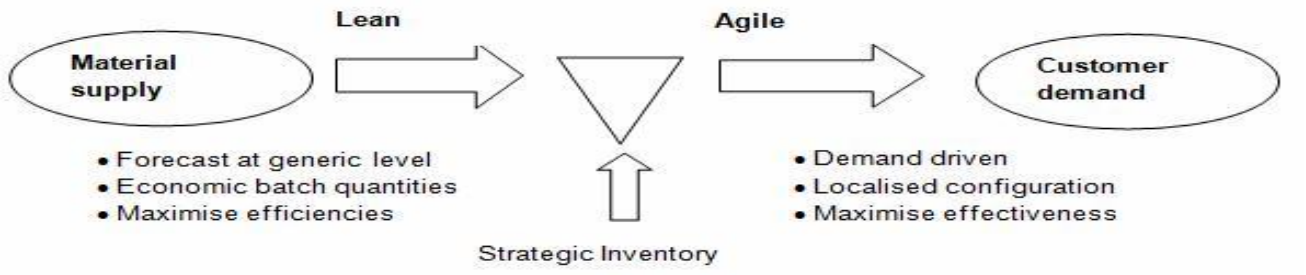


**Figure 1.** The decoupling point. Source: Christopher (2005).

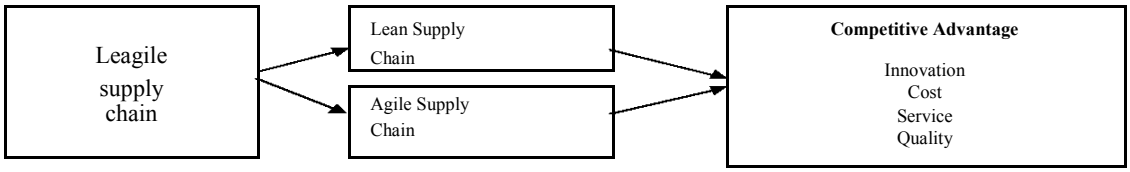


**Figure 2.** Achieving competitive advantage through leagile supply chain.

lean supply chain is a pre-requisite for the creation of an agile supply chain; hence leagile supply chain is a strategy for competitive advantage.

## RESEARCH METHODOLOGY

The paper employs a theoretical analytical approach to examine literature related to supply chain management and strategies in the automotive environment with the objective to determine the types of supply chain strategies that exist and to suggest a framework for supply chain that would respond to market changes. A case study of BMW Roslyn plant, located in Pretoria, South Africa was used to supplement the paper. The objective was to determine the types of supply chain strategies in the manufacturing plant. In this regard, the authors conducted an information interview with the supply chain manager at the plant to examine how supply chain operations were performed. The responses to the questions coupled with documented practices of BMW to develop a case study. A checklist about supply chain practise was established to benchmark the characteristics of lean and agile supply chain in the manufacturing plant. The findings indicated that BMW possess features or characteristics of both lean and agile supply chain strategies.

## Case study of BMW Rosslyn plant

### Background

BMW Rosslyn plant is located in Pretoria, Republic of South Africa. Rosslyn plant was the first BMW assembly line established outside Germany, with production starting in 1973. Rosslyn plant exports over 50,000 3 Series cars a year and has a significant increase in local content. It employs about 2,500 people and produces about 220 units per day. The Rosslyn Plant makes Four Door 3 Series Sedan, right and left hand drive for both local and overseas market. About 80% of the cars produced by the plant are exported to countries such as USA, Japan and Australia while the remaining is for the South African market. Rosslyn plant is fully integrated in BMW's worldwide supply network and has established itself as the fastest growing BMW plant in the world. It is the only subsidiary outside BMW Group in Germany that combines the vehicle manufacturing business and the national sales and marketing organisation into one company. It is at the forefront of the most technologically advanced automotive manufacturing plant in the southern hemisphere, as well as a sales and marketing division spearheading an aggressive product offensive and commanding impressive market share compared to other parts of the world. There is diverse range of challenges and exposure opportunities such as hi-tech, world-class vehicle manufacturing based on a multitude of engineering and process disciplines.

### Supply chain processes

The supply chain process at BMW starts from the costumer and ends with the customer. BMW uses built-to-order system to give their customers what they want. Customer makes their request through the dealers. The information is then communicated to Munich (Germany). The information is captured in a central data base. Bill allocation is done to determine cost of manufacturing and deciding where the car will be manufactured. This is informed by the nature of the product, the lead time and the cost involved. All parts are supplied on built-to- stock basis on the model life of the car imported. Parts are received at the Cape Town international airport by shipment. It is conveyed to the Rosslyn plant in Pretoria where the assembly takes place. Once assembled, it is taken to the warehouse where it is transported to the dealers ready for collection by the customer (Kaps, 2006). Some of the manufacturing processes at Rosslyn plant include production of cars, painting, suppliers of parts, distribution of cars, exportation, quality standards at BMW and the use of mySAP technology for enhancing communication. These processes can be explained as follows.

#### *Production*

The production process of cars goes through different shops where specific technologies are applied to ensure that quality cars are delivered to customers. The process starts at Body-in-White Shop, where different pressed body parts are assembled into a body shell. The next process is the Paint Shop, where it is painted according to

the customers' order. Finally the painted body goes to Assembly Shop where parts are fitted as per specification requested by the customer. The central issue is flexible manufacturing.

***Painting of cars***

BMW is committed to using environmentally friendly, technologically advanced processes to enhance the quality of paintwork, both in terms of appearance and functionality. The Paint Shop at Plant Rosslyn provides BMW with the flexibility to manufacture cars which meet the customers' specific requests. Colour is an important criterion for the customer selecting a car and is a powerful marketing tool. Each customer is provided with the particular model they require, with all the options and personalised features ordered, calls for an extremely high standard, not only in assembly but also in production and vehicle delivery management. One of the major activities on the assembly line occurs at the marriage point: the point at which the engine and drive train are "married" to the body of the car. Improvements made on the assembly line have made it possible for plant Rosslyn to produce all the 3 Series 4-door model derivatives and option requirements for the local and export market.

***Suppliers***

BMW Rosslyn has about 44 local suppliers. Suppliers bring more than 60% of the components of each car to the line. Just in time (JIT) supply processes ensure that certain parts of the vehicle arrive on the assembly line just in time to be fitted to the particular vehicle they are made for. JIT supply systems are used to bring door panels, exhaust systems and front and rear axles to the right point on the assembly line. Using a JIT supply system saves space by minimizing stock on the premises. Typically, there is only one and a half hours worth of stock on the line at any given time. This prevents damage to stock and saves storage and transport costs. The Roslyn plant delivers world-class quality products to customers across the globe. All production operations are managed for delivering uncompromising, optimum quality. Each and every process involved in manufacturing the car is checked for process capability and inspections are implemented where required.

***Distribution***

BMW Rosslyn Vehicle Distribution Centre (VDC) has a cost-effevtive storage and distribution facility, allowing the protection and quality preservation of the vehicles. The facility has a dedicated railway siding on which a 200-vehicle car -train loads export vehicles and off-loads import vehicles each day. It has about 196 dealers locally. Vehicles destined for dealers are loaded onto car carriers and delivered to dealerships around the country, so saving the vehicle from any undue wear and tear prior to delivery to a customer. Associates at the VDC inspect all vehicles prior to loading to ensure that the highest possible levels of delivery quality to dealers are maintained. The VDC also has a mechanical and paint/body workshop for the service and repair of company vehicles as well as approved used cars. Vehicles manufactured are transported to Durban (SA) for export. Transportation of vehicles to Durban port takes place on a daily basis. BMW South Africa has two train carriers, each with a storage capacity of 176 units. The trains are used to transport imports units from Durban harbour to the VDC in Rosslyn. At the Durban harbour the vehicles are loaded onto car-carrying vessels, known as RORO ships. These ships transport vehicles to various markets at the opposite ends of the earth. Cars are shipped on a bi-monthly basis to the Far East, USA and Australia, respectively. The transit period varies according to the destination: Japan - 23 days, USA - 29 - 49 days, Australia - 13 - 22 days.

***Quality Standards***

To ensure optimum customer satisfaction, the built quality of the vehicles produced at Rosslyn Plant is measured through a process called Complete Product Audit. This audit compares the quality of a unit to the customer's requirements, including technical specifications, fitment and function. These audits are performed throughout the build process at specified points. These strict audit standards are set at BMW Germany by the Central Quality department and are the same for all BMW plants.

***Using mySAP at BMW***

BMW uses mySAP Automotive to monitor production status in real time. mySAP automotive registers production confirmation and parts consumption information every three minutes. Parts consumed during assembly are removed from the inventory count, and costs are posted to calculate the value of work in process. mySAP automotive helps to reduce order-to delivery time, strengthens supply chain activities in the areas of demand planning and tracking and tracing of material deliveries, and improves inventory accuracy across plant – enabling significant reduction time-to customer. It also receives custom-configured manufacturing orders from BMW's planning system. The orders include all the parts required to build each car. BMW sends these long-horizon forecasts and short-horizon JIT delivery schedules to its suppliers. Larger suppliers receive the information via electronic data interchange (EDI). Other suppliers access the mySAP automotive supplier portal, where BMW posts the requirements to provide up-to-date information on its delivery needs. Using only an Internet browser, suppliers can view this information in real time, including release schedules, purchasing documents, invoices, and engineering documents. When they ship parts, the suppliers send BMW advance shipping notifications (ASNs) to provide the car manufacturer with exact information on parts counts and delivery dates. Parts arriving at the BMW dock are then received and transferred directly to the line.

## CASE ANALYSIS

BMW Rosslyn has fully integrated systems and network worldwide. It uses a service management system as part of a wider plan to improve supply chain lifecycles. The platform is triggered by complexities in the technology embedded in its cars and subsequent demand for systems to support servicing. It uses a portal to integrate information and systems with its suppliers. This leads to quicker information platform for communication. It also uses advance technology applications such as mySAP, just-in-time manufacturing, built-to-order which are all characteristics of lean manufacturing and innovations. Despite the efficient supply chain processes, technology behind the process needs to be seamless and as fast as possible for survival in these uncertain times. Table 1 shows a checklist of features of lean and agile characteristics of BMW Roslyn plant.

As demonstrated in Table 1, BMW Roslyn plant is flexible to customer demands giving the choice for them

to dictate the type of cars they want at the appropriate price available. Cars are built-to-customers orders rather than by mass production. For example, differentiation techniques are used during painting as well as choices of the car features for comfort, hence flexible manufacturing. They do not hold inventory because the strategy is focused on built-to- order, so cars are made in sequence as the orders are placed using advanced technology such as mySAP which communicates demand planning across the actors of the supply chain. Hence, BMW possess characteristics of lean and agile supply chain. Therefore the implementation of a framework for leagile supply chain is possible so as to react to changes in the market.

Traditionally, the auto industry has employed mass production focusing on cost reduction strategy (Zhang and Chen, 2006). But due to changes in the business environment, globalisation etc, there has been a shift from the practice (Elkins, 2004; Sweicki and Gerth, 2008). The case analysis is based on BMW and should not be generalized to the auto industry. BMW Rosslyn and the automobile industry in general have felt the results of the global economic meltdown resulting in a noticeable decrease in sales and export across the globe. In responding to this challenge, BMW has focused on cost reduction strategies with suppliers and reducing manufacturing plants as a measure to alleviate the situation. Not surprisingly, cost containment is a concern that figures prominently on the automobile agenda. As noted by IBM (2009) survey, there are five primary challenges facing auto makers in these uncertain times. This includes visibility, risk, cost containment, customer demand and globalisation. More to this, are rising energy cost and raw materials, strong fluctuation and interest rates. In this uncertain business climate, in addition to lean manufacturing, automobile manufacturers should be agile and responsive in addressing change. A superior supply chain is a must to help auto manufacturers redesign and differentiate themselves. Therefore there is the need to redefine and redesign the automotive supply chain strategies, layouts and operations so as to be able to respond to changing market demands. It should be accepted that the automobile industry possess certain agile characteristics and the implementation of a leagile supply chain is vital for the survival of the automobile industry in this uncertain times and for the years to come.

**Leagile supply chain framework**

The automotive industry is currently witnessing rapid increases in the number of models and model variants that are available on the global market. The industry is now required to offer ever increasing levels of product variety. A key issue in the industry is the reliability of the production and delivery process. An unreliable production and delivery process perpetuates the stock push system as dealers sell from stock rather than place vehicles on order and risk upsetting customers. Each customer order must become a batch-size- of one, meeting exact customer requirements in terms of specification and delivery date. Therefore, a fundamental change in mindset is required to shift towards build-to-order, suggesting dramatic rise in flexibility and responsiveness across supply chain partners. Leagile is the combination of the lean and agile paradigms within a total supply chain strategy by positioning the decoupling point so as to best suit the need for responding to a volatile demand downstream while providing level scheduling upstream from the marketplace. In order to achieve leagile supply chain, the upstream of the decoupling point should be designed to be lean while downstream agile as shown in Figure 3. The framework is explained in terms of lean supply chain, agile supply chain and the decoupling point. Figure 3 depicts the framework for leagile supply chain in the automobile industry.

**Lean supply chain**

A lean supply chain employs continuous improvement efforts that focus on eliminating waste or non-value steps along the chain. It is supported by efforts to achieve internal manufacturing efficiencies and setup time reduction, which enable the economic production of small quantities and enhance cost reduction, profitability, and manufacturing flexibility to some degree. The short setup times provide internal flexibility, but a lean supply chain may lack external responsiveness to customer demands, which can require flexibility in product design, planning and scheduling, and distribution in addition to manufacturing. As the rate of change increases in the market, the lean supply chain approach has evolved into ‘‘multiple niche competition,’’ which is the production of any volume, even a single unit, combined with the ability to satisfy multiple market segments. Automobile organizations should recognize that along with the added variety and responsiveness squeeze, they must remain adaptable to future changes. Customer requirements are continuously evolving and product life cycles are growing shorter, therefore, along with being lean, supply chains must respond to the market.

**Agile supply chain**

The aim of the agile supply chain is to carry inventory as generic as possible. This is the concept of postponement. Postponement can increase the efficiency of the supply chain by moving product differentiation (at the decoupling point) closer to the end user. Postponing the decoupling point reduces the risk of being out of stock and of holding too much stock of products that are not required. Furthermore, products can be offered at lower total cost with a higher level of variety, enabling strategies of “mass-customization” to be pursued. One of the classic examples of this strategy can be the post-ponement of the colour of paint to the retailer/customer

**Table 1.** A checklist of features of lean and agile characteristics.

| Features of BMW | Lean characteristics | Agile characteristics |
|---|---|---|
| Just-in-time manufacturing | | |
| Total quality management | | |
| Reengineering | | |
| Build-to-order | | |
| Benchmarking | | |
| Market sensitivity | | |
| Differentiation | | |
| Flexibility | | |
| Competency | | |
| Adaptability | | |
| Collaborative relationships | | |
| Information systems and integration | | |

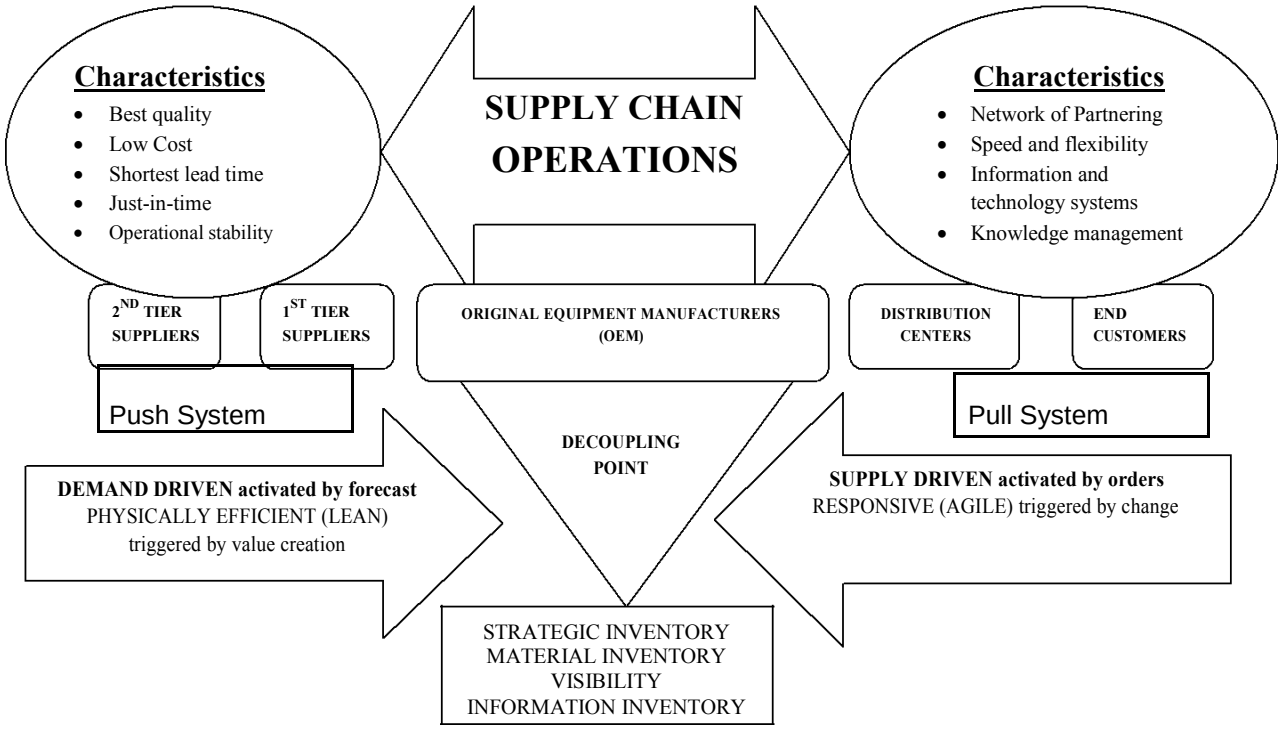


**Figure 3.** Framework for leagile supply chain in the auto industry.

level. Rather than holding a wide variety of premixed colours, retailers began to stock paint in a neutral colour, and customize the final colour upon specific customer orders.

## Decoupling point

The supply chain decoupling point is situated at the boundary between the push part and the pull part as depicted in Figure 3. It is the point at which the switch from the built-to-forecast mode to the built-to-order mode takes place. The inventories of supplied and made-in-house components are kept at this point and their corresponding levels are determined by means of Stochastic methods. Due to their position in the supply chain, these inventories are sometimes called decoupling inventories. The customization process is initiated in the pull system after the customer order arrives. The necessary components are picked out from stock and combined in the main assembly line into customized products which are shipped to customers. From the

Original Equipment Manufacturer (OEM)'s perspective, there are two positions which are worth to be highlighted: the differentiation point and assembly line decoupling point. The study defines a differentiation point in the assembly line as a point in which variety increases. For example, the painting station in the automotive industry represents a point of differentiation in which the car bodies assume their unique colours. It should be noted that in the assembly process, there is not only a single but many differentiation points at which the products acquire more identity.

In the main assembly line, it is more advantageous to delay downstream which is the first point of differentiation. Thus, prior to the first differentiation point there are more standardized steps which are common to the entire end product mix. In doing so, the proliferation of variety in the assembly line can be reduced and the assembly time for customized products can be decreased. In this way, the supply chain decoupling point can be even moved to the position of the first differentiation point if the main common subassembly is produced on stock according to demand forecasts. Whereas the differentiation point is a real point in the process, the assembly line decoupling point is a fictive point which represents an aggregation of the positions of the distinct differentiation points (Figure 3).

For the same extent of product variety offered, the closer the decoupling point is to the customer, the better would be the performance of the assembly system. By adopting a JIT approach to inventory, component manufacturers can ensure they have enough stock to meet current and expected customer requirements. As any problem in the supply chain can damage a supplier's ability to deliver, which could be very costly, effectively managing the supply chain is critical. Supply chain management focuses on the processes that are needed to synchronise supply to customer demands, allows the optimisation of inventory held, and minimises waste. For supply chains that involve suppliers overseas, it is important to have visibility of what is happening with goods in transit, to keep track of associated costs and to get accurate landed costs. For most component suppliers, managing the forecasts, schedules and call-offs from OEMs is difficult. Most monthly or weekly fore-casts are only accurate to about 10%; daily call-offs are far more accurate. Balancing stock against ever -changing manufacturing schedules and reconciling the different plans against prior dispatches and forecasts requires sophisticated requirements planning, order and procure-ment handling, material control and inventory management.

## Conclusion

The fierce competition, fluctuating market demand and rising customer requirements is a key challenge in the automotive industry. Lengthy demand planning cycles and lack of visibility to supplier, material, and pro-duction constraints have caused scheduling delays and short-term production changes. Customers are more demanding and the sheer varieties of cars create an increasingly complex challenge, different preferences and specific requirements for each car, which includes the range of body-styles, engine sizes, colours, options, and trim levels, etc. The automotive industry requires flexibility and responsiveness in their supply chains. In order to maintain and improve levels of efficiency, quality and cost effectiveness, automotive component suppliers will have to look at different areas across the board to streamline their operations.

The generic supply chain strategies are lean and agile supply chain. While leanness is most appropriate to be used in a stable and predictable environment, agility can achieve more benefits in a volatile and unanticipated environment. The leanness paradigm pays more attention to the low cost, high quality and is more focused on technology and systems. On the contrary, the agility may put higher emphasis on the flexibility and quick delivery to the customers. An agile manufacturer needs to maintain a certain degree of buffer capacity to cope with the volatile demand and high variety of products and is focused on people and information. Furthermore, the paper suggests a framework for leagile supply chain for the automobile industry. Application of the framework would ensure cost minimization and at the same time respond to customer demand.

The industry is faced with global financial crisis. This has led to increased pressure on the automotive competitive performance. Hence, leagile supply chain is the strategy of the millennium that can alleviate the automobile industry from the current challenges and suggesting a framework for leagile supply chain strategy is of utmost importance to the industry.

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