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**A Dynamic Simulation Model for the Long Term Analysis of the Indian  
Automotive Industry**

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**Abstract:** This paper presents a new model for long term analysis of deregulated Indian auto market. In this model we try to capture the main factors affecting long term development of the Indian auto industry. Investor's lack of perfect foresight, together with construction delay could possibly result in periods of over capacity or capacity deficits in the system in the global supply chain. By using a dynamic simulation model and analysis framework, it's possible to analyze the Indian auto market and analyze the industry over the next 10 years. Under different delay and risk conditions, policy experimentation is carried out considering various global economies and their degree of development. A detailed sensitivity test is carried out to examine the robustness of the model. The research recommends some strategies for a global supply chain that could improve flexibility across the chain, reduce lead time, reduce inventory and enhance supply chain efficiency.

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## 1. Introduction

In the past decades, growth of Indian automobile sector was crucial. There has been a remarkable transformation of the car industry in India from 1990's onwards. At the beginning of the decade, there had only been a very limited involvement of multinational firms and total production volumes remained modest. Matured Latin American and European market, liberalization and free trade agreements between ASIAN countries, growing ASIAN market, and stable economy are some of the reasons that changed the global auto industry's landscape. Figure1 depicts the global auto manufacturers and their migration to developing ASIAN market.

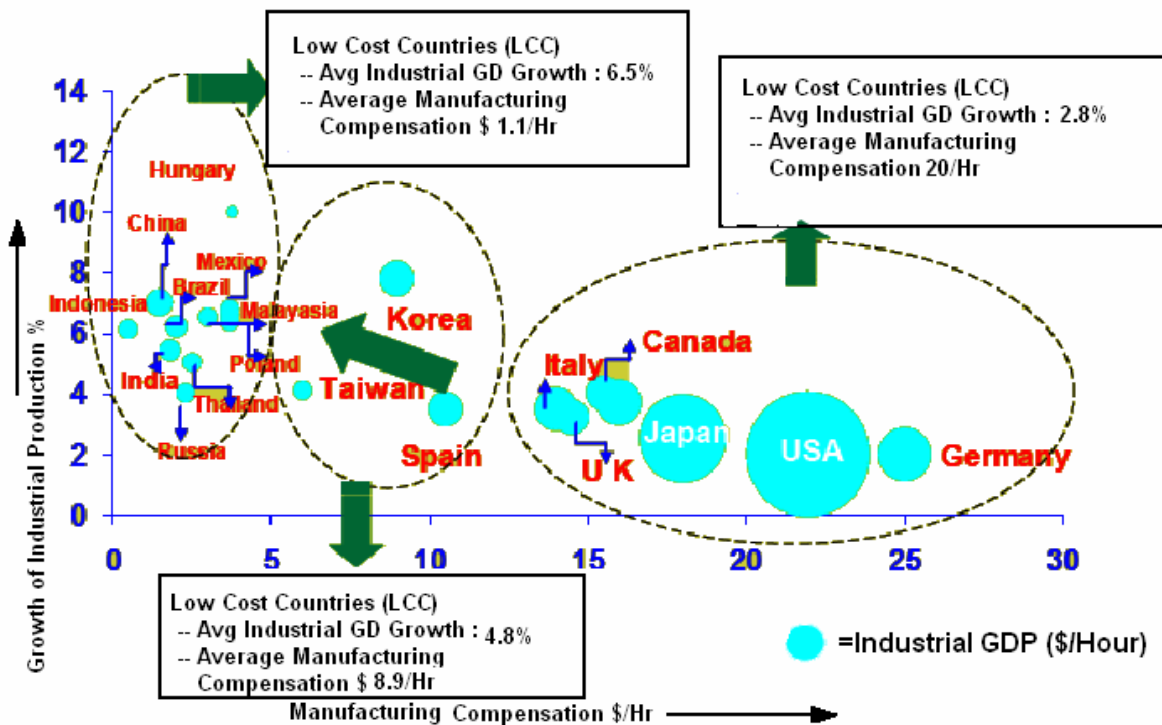


Figure 1 - Global Auto Manufacturers and their Migration to developing ASIAN market

Source: World Bank, 2006

High industrial GDP growth (>6%) and low manufacturing compensation (< \$2.Hr) also attracts major auto manufactures including big three players to Asian market. The analysis shows that there exist migrations among auto players (basically OEMs), first tier suppliers and second tier suppliers to emerging markets to reap the benefit

## **2. Indian Automotive Industry: An overview**

In 1991, India produced about 209,000 cars and foreign involvement started with a link up with Suzuki, forming the Suzuki-Maruti company (now Maruti Udyog) which was a success (Sutton, 2004). From the early 90s onwards, a wave of multinational firms entered into India's markets. Many Multinational Companies (MNC's) have had their assembly units in India. But still in the global automobile production market, India is a player of little consequence. These entrants were required to achieve a high level of domestic achievement within a specified period (typically, 70% within 3 years). For at least some of the new entrants, this was seen as an unreasonable target as domestic suppliers could not meet the price and quality requirements of the car makers. Achieving the 70% target required the car makers to switch rapidly from reliance on imported components to sourcing from local vendors; and this in turn gave the car makers a strong motivation to work closely with (first-tier) suppliers, to ensure the quality standards, within an acceptable price. Table 1 shows the leading car manufacturers in India; their number of unit's production per year and their market share. Most of the multinational automobile companies keep their assembly and distribution centre in India while having the main research and development, design and manufacturing centre in their home countries.

Table 1: Leading Car Makers in India (2001-2002)

| Type of Makers                             | Number of units produced | Market Share |
|--|--------------------------|--------------|
| 1 Maruti Udyog Ltd (Suzuki joint venture)  | 3,51,949                 | 62.2%        |
| 2 Hyundai Motor India Ltd.                 | 93,888                   | 16.5%        |
| 3 Tata Engineering and Locomotive Co. Ltd. | 64,712                   | 11.5%        |
| 4 Hindustan Motors Ltd.                    | 19,398                   | 3.4%         |
| 5 Ford India Ltd.                          | 14,306                   | 2.5%         |
| 6 Hero Honda Motors Ltd.                   | 10,310                   | 1.8%         |
| 7 General Motors India Ltd.                | 8,135                    | 1.4%         |
| 8 Daimler Chrysler India Pvt. Ltd.         | 1,415                    | 0.2%         |
| Total Production (All firms*)              | 5,64,113                 | 100%         |
| Share of top eight                         |                          |              |

\*A small number produced by Fiat and by Daewoo is not available.

Source: ACMA, Facts and Figures: Automotive Industry India, 2001-2002

Literature about Indian auto industry (SIAM Data (2006), Cygnus report (2006), World Bank report (2006), ADB report (2006), Automotive Resources Asia (2006)) reveals that domestic sales have grown at CAGR of 14.27% from 2001-02 to 2005-06 (See Figure 2).

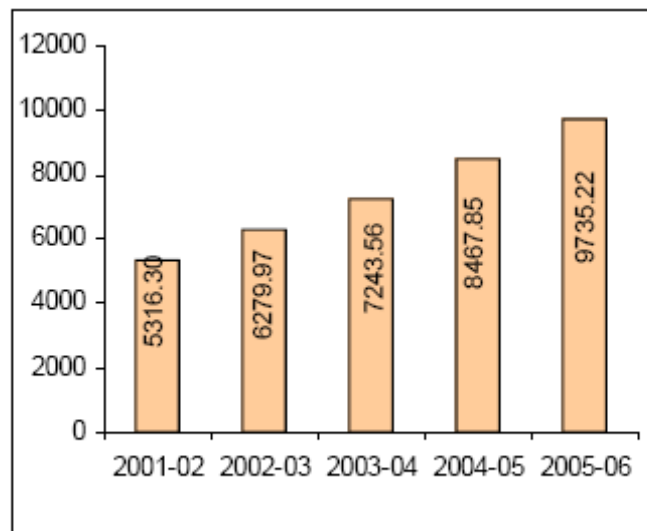


Figure 2- Automobile Production trend in India ('000 units), Source: SIAM, (2006)

The commercial vehicle segment, in particular, has increased at CAGR of 24.35% during the above-mentioned period; whereas total sales of passenger cars in domestic market have increased at CAGR of 14.02%. In terms of production, commercial vehicles have registered a CAGR of 24.55% from 2001-02 to 2005-06; while passenger vehicles have registered a CAGR of 18.24%. There is a declining trend in mopeds production as well as in sales in the domestic market. During 2001-02, mopeds production and sales have declined at CAGR 2.93% and 5% respectively. Table 2 shows the segment wise production of Indian automotive industry from 1996 to 2001. This data depicts the demand trend and the changes in consumption pattern. One of the major reasons for the performance of Indian automobile industry in the world market is the inefficient supply chain structure.

Table 2 – Segment wise vehicle production in India; Source: Sopti (2003)

| <b>CATEGORY</b>    | <b>1996-97</b> | <b>1997-98</b> | <b>1998-99</b> | <b>1999-2000</b> | <b>2000-2001</b> | <b>2001-2002</b> |
|--------------------|----------------|----------------|----------------|------------------|------------------|------------------|
| M & HCVs           | 155696         | 95854          | 80528          | 112308           | 88210            | 90849            |
| LCVs               | 84855          | 65040          | 55363          | 61213            | 63869            | 55348            |
| TOTAL CVs          | 240551         | 160894         | 135891         | 173521           | 152079           | 146197           |
| CARS               | 411145         | 401002         | 390709         | 577243           | 504654           | 564126           |
| MUVs               | 134583         | 134653         | 113328         | 124307           | 125938           | 123748           |
| TOT. CARS & MUVs   | 545728         | 535655         | 504037         | 701550           | 630592           | 687874           |
| TOTAL 4 WHEELERS   | 786279         | 696549         | 639928         | 875071           | 782671           | 834071           |
| SCOOTERS           | 1312920        | 1279467        | 1315055        | 1259423          | 879707           | 870213           |
| MOTORCYCLES        | 988233         | 1125958        | 1387286        | 1794078          | 2183785          | 2961906          |
| MOPEDS             | 678074         | 667242         | 672167         | 724510           | 694974           | 491525           |
| TOTAL 2 WHEELERS   | 2979227        | 3072667        | 3374508        | 3778011          | 3758466          | 4323644          |
| 3 - WHEELERS       | 221619         | 234867         | 209033         | 205543           | 203234           | 212753           |
| <b>GRAND TOTAL</b> | <b>3987125</b> | <b>4004083</b> | <b>4223469</b> | <b>4858625</b>   | <b>4744371</b>   | <b>5370468</b>   |

Increasing uncertainty of supply networks, globalization of businesses, proliferation of product variety and shortening of product life cycles have forced Indian organizations to look beyond their four walls for collaboration with their supply chain partners. This research is focused to analyze the Indian automotive industry in a dynamic state subject to various supply chain delay conditions, uncertainty behaviors and risks related to the link. It's also aimed to analyze the relationship between auto industry growth with country's GDP growth. The following section enumerates the analysis in greater depth.

### **3. Dynamic Analysis of the Indian Automotive Industry**

The concept of System Dynamics was introduced by Forrester way back 1961 in his industrial model analysis (Forrester 1961 & 1971). Since then it has been applied to numerous industrial, urban sociological systems study purposes. Today the Indian automobile industry has grown one of the core competencies of Gross Domestic Product Growth with an average growth rate of 16.33% from 2001-02 to 2005-06 in terms of production (Cygnus Report (2006)). Booming Information Technology (IT) or IT Enabled Services sector, manufacturing industry (namely textile, pharmaceutical and engineering) and real estate have contributed to this high growth in automobile industry in the country. Albeit its dynamic growth the industry facing lots of challenges and threats when compared to other ASIAN emerging markets such as China, Korea and Thailand (Japan auto market is considered as developed scenario). Hence understating the dynamic nature of this industry is always essential amidst having inhibitors. For modeling easiness, the complex automotive industry has been classified into three groups namely Finished Vehicle Segment, Auto Parts Segment and Auto Logistics Segment.

Causal Loop Diagram (CLD) has been developed among the identified variable showing interactions among them as shown in Figure 3.

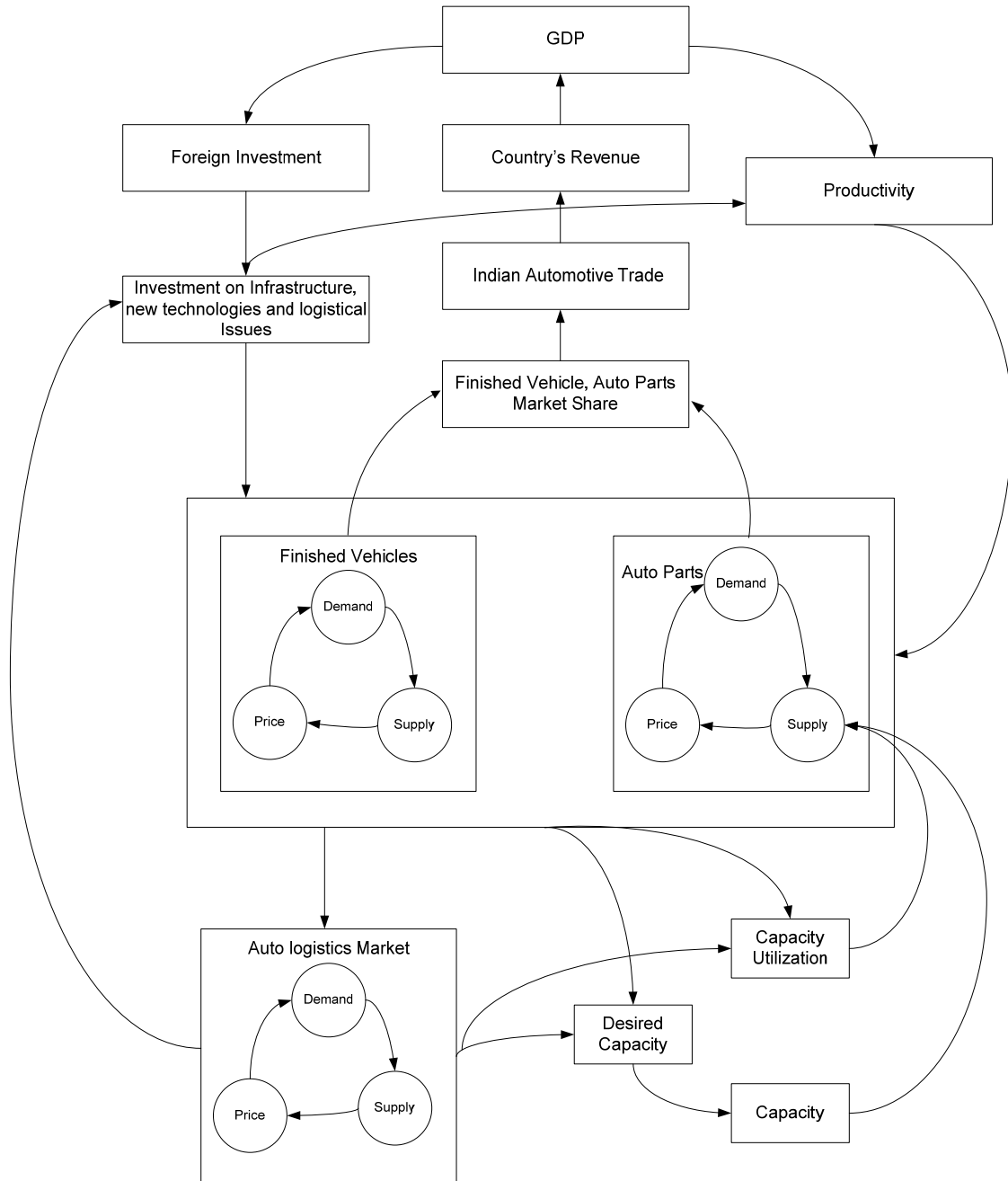


Figure 3 - Causal loop relationship between auto industry variables

Increasing finished vehicle demand increases the profitability of automotive firms and this in turn increases finished vehicle market share. Any increase in demand of finished vehicle market share has overall effect on desired capacity and this influences the Auto parts market. Increased supply of Complete Built-up Units CBU/FVs has positive effect on Outbound Auto Logistics Service Providers (OALSPs) and this demand in turn increases the demand of finished vehicle market. Thus all the elements pertained to this loop form a positive loop. Increase in finished vehicle and auto parts market share tend to enhance positive national trade value. Increase in vehicle trade has positive effect on GDP growth this in turn improves foreign investment, investment on infrastructure, new technologies and logistical issues. The entire CLD diagram has been converted into Flow Diagram using Powersim V0.7 simulator in order to feed the rate, impact and noise disturbances in the model developed. The dynamic equations associated with the model are depicted in Appendix A.

#### **4. Indian Auto Market Growth Forecasts**

Data about Indian auto Industry has been collected through the data access system of IIT Roorkee library. The collected data are statistically validated against its sample size and are fed into the model under study. The simulation results are shown from Figure 4 to Figure 7 in this section and it reiterate the expectation of several industry analysts that liberalization would generally affect the industry's development. Base year for the simulation is considered as 2003 since the data sets starts from 2003 and ends at 2006. Therefore the rest of the years in the simulation results are forecasted value for the respective category. Hence the market is forecasted for 10 years (Upto FY 2017).



Vehicle production by Indian auto manufacturers and its forecast is shown in Figure 4 and this is expected to cross 20 millions by volume by 2016. This trend has already been the aggregate vehicle production of APAC countries excluding Japan and China's production value. There is a great demand for future auto cars inside India but still Indian car makers managed to export with an expected export growth rate of 32.4%. From 2001-02 to 2005-06, total exports of automobile sector has gone up at CAGR of 44.56%. Exports of motorcycle segment have registered highest annual growth rate of 61.42% during this period. This has clearly indicated that Indian automobile sector is going global. The only big competitor to India in the APAC region in the developing auto market segment is China.

Figure 5 and Figure 6 shows the current and expected growth rate of Indian automotive industry from the base year 2003 against different segment (two wheelers, three wheelers, LCVs, MCVs, HCVs and Tractors). This forecast excludes trucks, sea equipments and earth movers). It shows the Indian passenger car market overheats in its present growth rate and is expected to cross 2.5 million units by 2016. Among the classified listings the growth rate of Scooters alone is less than 10%. This trend is expected to happen if the supply chain risk remains below 10%. Growth of automobile industry has driven India's auto components industry as well. Indian auto components industry has increased at Combined Aggregate Growth Rate (CAGR) 20.3% from 2000-01 to 2005-06 in terms of production. During 2005-06, production of automotive components was worth of US\$10 billion from US\$8.7 billion in 2004-05. It is expected to reach US\$14.7 billion by 2009 and US\$25 billion by 2016 (see Figure 7) whereas export is expected to reach US\$5 billion by 2016. More than 70% of auto parts are being consumed by internal customers.

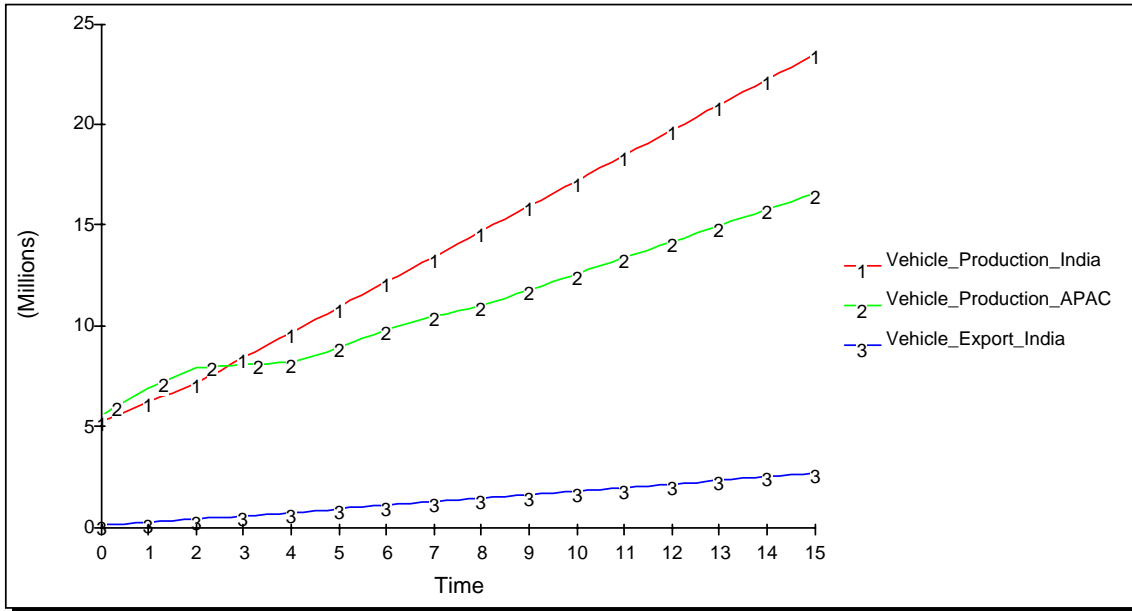


Figure 4 - Vehicle Production of Indian and APAC countries (excluding Japan and China production); Data : SIAM data (2006)

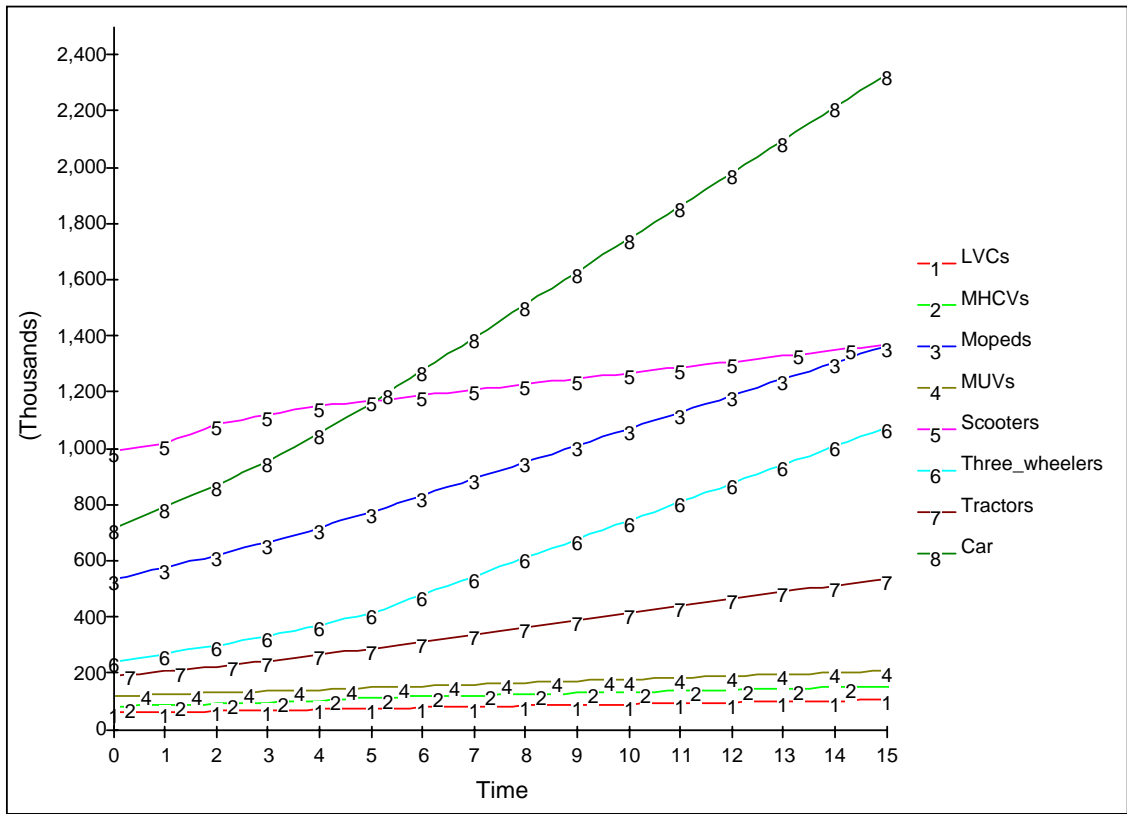


Figure 5 - Demand Forecasts of Indian automotive industry excluding motorcycle demand (Base year 2003); Data : SIAM data (2006)

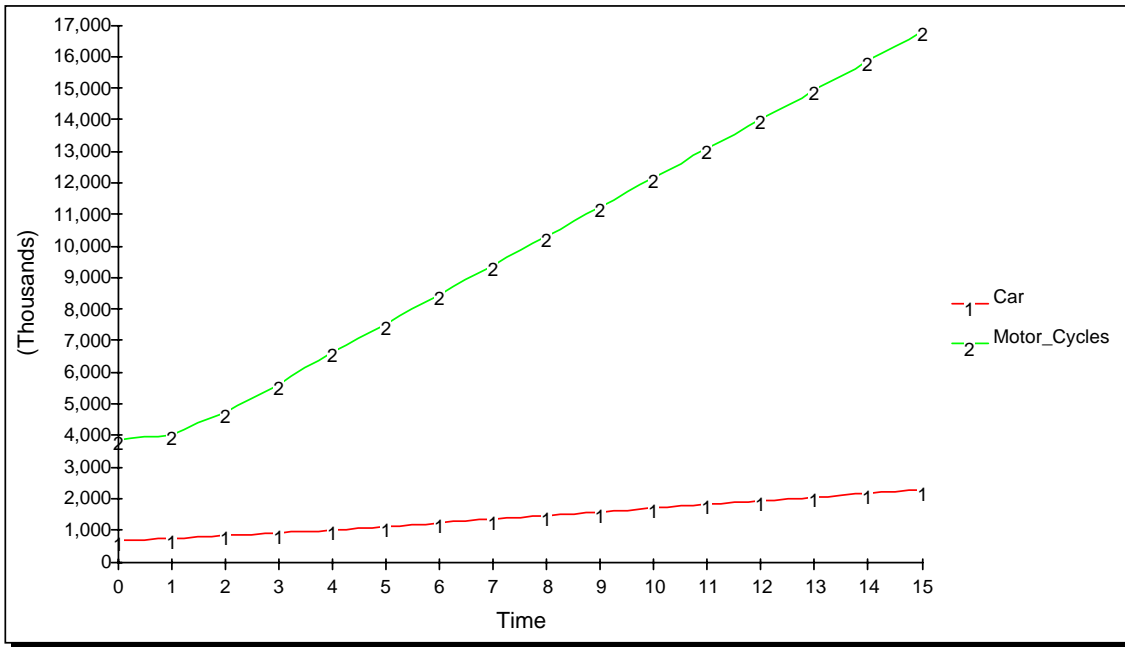


Figure 6 - Demand Forecasts of Passenger cars and motor cycles (Base year 2003)

Data : SIAM data (2006)

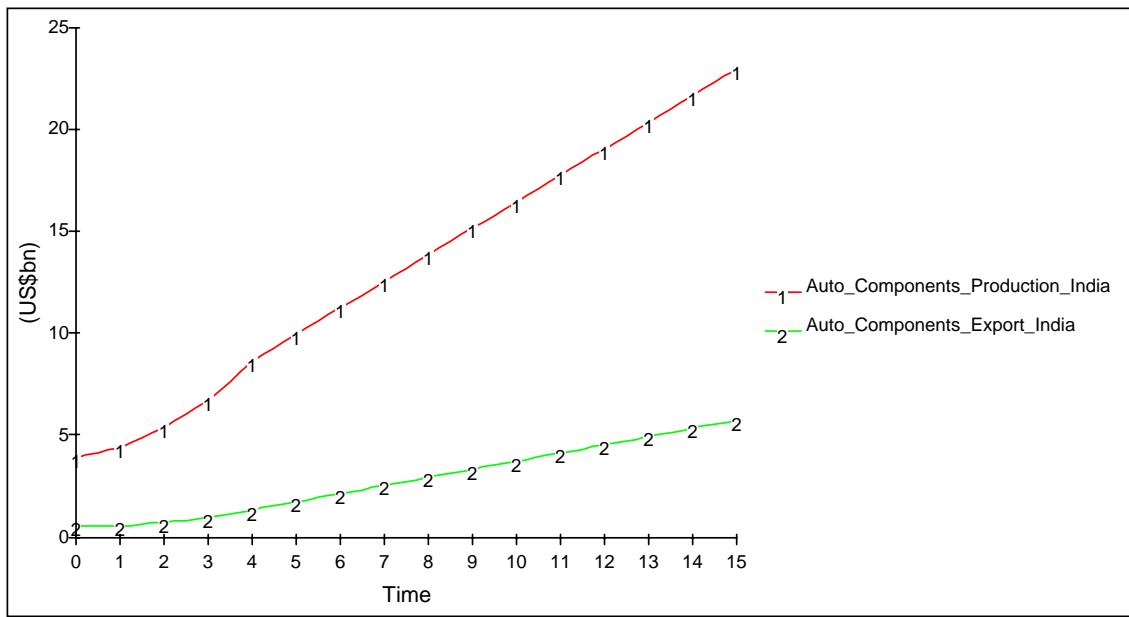


Figure 7 - Growth forecast of Auto components for the next 10 years (Base year 2003)

Data Source: SIAM data book (2006)

## 5. Sensitivity Analysis

Sensitivity analysis is used to determine how sensitive a model is to changes in the value of the parameters of the model and to changes in the structure of the model. In this research, parameter sensitivity is performed by changing the model parameter values to examine the changes in the dynamic behavior of some of the micro auto-environmental variables like capacity, lead-time, production, inventory and order. Figure 8 shows the measure of variables when the auto supply chain system imposed at higher order delay (Assumed that Indian road conditions allow higher order supply chain delay), CAQDY = 4 and CAPPRODY = 1. It reveals in a global supply chain under uncertain and delay conditions the order and price is negatively correlated. Every small reduction at low margin vehicles tends to increase the order rate in hundreds. Hence Indian auto scenario has large growth rate in small and economy cars in near future.

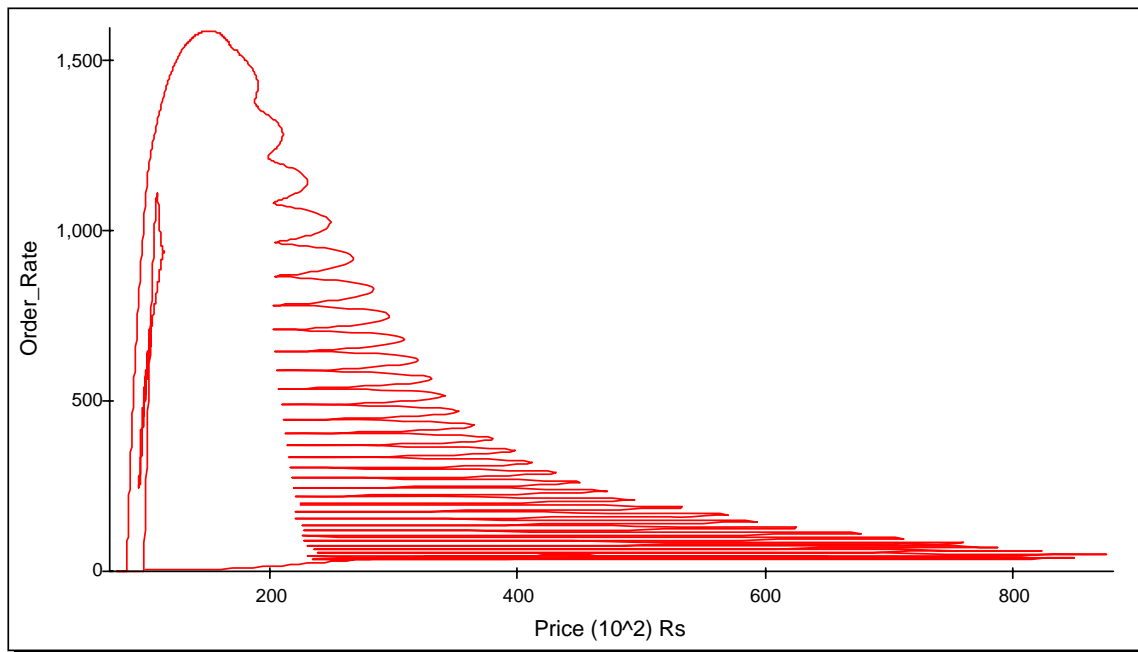


Figure 8 - Correlation between Order Rate and Price

Any increase in acquisition delay (from CAQDY = 4 weeks to CAQDY = 10 weeks) causes to amplify the intensity of the desired capacity and extend the settling time by 10 weeks. The behavior of order rate and price also studied for higher order delay conditions (see Figure 9). At the same time, increase in acquisition delay does not affect the capital stock. Any increase in acquisition delay greatly affects the desired capacity and capacity order. This results in amplification of bullwhip effect. Keeping constant acquisition delay and increasing the capital productivity improves the system performances and tries to reduce the desired capacity, capital stock and capital on order. Whereas the same increases the work in process inventory level drastically.

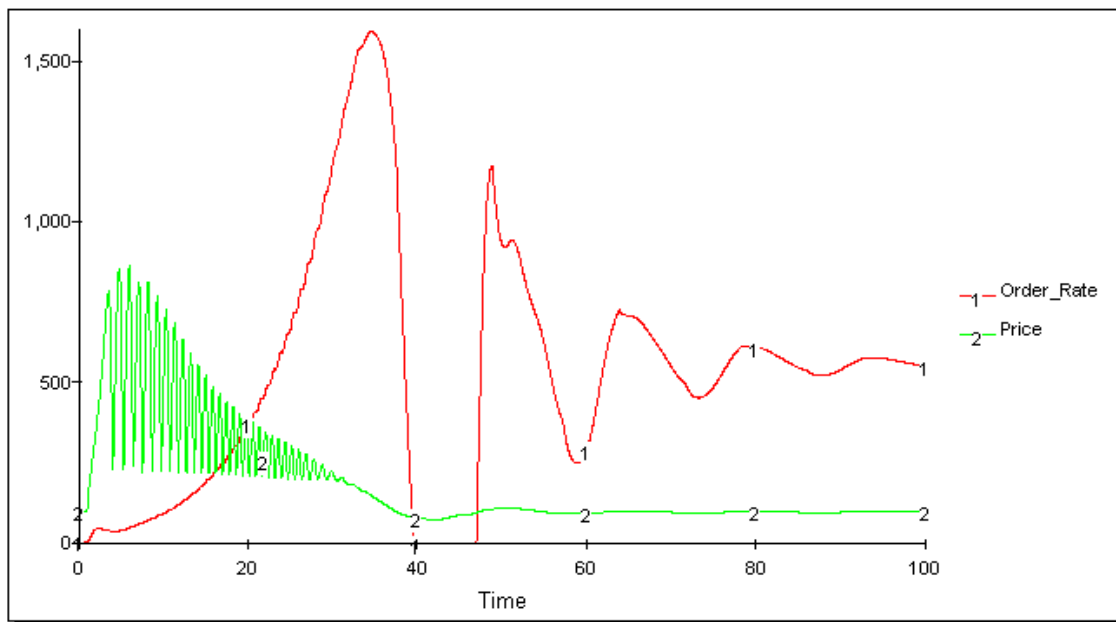


Figure 9 - Sensitivity of Price to Order Rate with Third Order Delay

The steep growth of automotive market (fished vehicle and after sales component market) tends to increase the auto logistics market growth as well. From the collected closed data set (Source: Datamonitor) the next ten years growth of auto logistics market have been identified and shown in Figure 10. It's also identified the relationship between GDP

growth and auto supply chain variables. Results reveal that these two variables have very strong positive correlation.

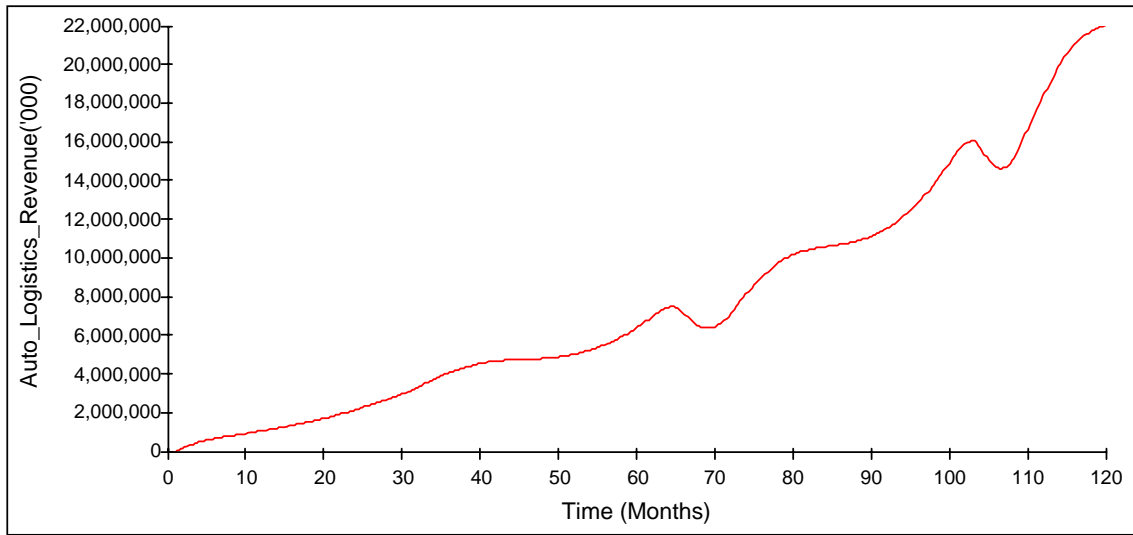


Figure 10 - Forecasted (next ten years) Indian Auto Logistics Revenue growth from the current growth rate

Data: Datamonitor

## 6. Core Competencies of Indian Auto Sector

From this investigation, we identified some core competencies where Indian automotive sector has strong growth forecasts. India is able to attract investment in this sector due to the following reasons:

- The present investment climate shows that for up to 100% of Foreign Direct Investment, no need for Govt. of India's Foreign Investment Promotion Board Approval. Only need to inform Reserve Bank of India of the plans and seek a formal clearance. Complete exemption from Customs Duty on industrial inputs and Corporate Tax Holiday for five years for 100 % Export Oriented units and units in Export Processing Zones.

- Ability to manage global automotive standards, Low cost, Highly productive, Quality oriented workforce which is capable of managing the latest in automotive technology
- A strong influence of Japanese Best practices, Partnering linkages with global supply chain with efficient Tier 2/3 suppliers, A Strategic location - access to the vast domestic and South Asian market, A potential synergy in IT/Software/ Embedded software and auto components, Sophisticated legal and financial system, Availability of a package of fiscal incentives including benefits of double taxation treaty and English is the medium of communication are identified as the principal enablers in the Indian automotive scenario.

The auto industry growing steadily in terms of installed capacity, production, technology and product diversification. With the high level of foreign direct as well as domestic investment in manufacturing ventures in the automotive industry, the component sector specially will benefit. A large number of FDI proposals to establish auto component units have been approved by Government. This is expected to grow with a growth rate of 23.4% annually. A development in latest technology is needed as is quality improvement in products to meet international requirements. With the globalization of the industry, exports of auto components have been growing steadily and will continue. The reforms adopted by Government recently such as de-licensing and rationalization of duty structure will open up tremendous investment opportunities for investment and transfer of technology. Indian auto industry could sense the market in the near future and the government would reap the benefit based on its growth rate.

## **7. Future Outlook and Growth Opportunities**

Because of the strong linkages of the automobile industry with other industries e.g; agriculture, investment in this industry acts as a driver of economic development and employment generation. An expanding manufacturing base of vehicles also leads to development of components and ancillaries with a multiplier effect. With constrained railway infrastructure, road transport is expected to grow further with private sector investment in long term growth and transformation of the rural economy which ultimately leads to greater demand for automobiles. As income levels increase, so will the number of potential buyers in the growing class especially with credit to finance vehicle purchase so that the projected turnover of C\$ 1 billion for 2005 could be attained.

Amidst its emerging market condition, in alliance with the global auto industry consolidation; the Indian auto manufacturing industry feels the same consolidation climate inside the country as well. First Tier Suppliers (FTSs) generally find difficulties in keeping face with big player in core competencies in almost all industry domains. A study conducted by Mercer consulting group in 2004 depicted that the number of automotive suppliers worldwide foreseen to be halved to 2,800 by 2015 and the number of independent automakers is foreseen to decrease from existing 12 to just 9 or 10. The expected final outcome of this selection process will be the reduction of the suppliers at every tier level as shown in Figure 10 (case of automotive supply chain). The study also reveals certain important promises such as, collaboration among the players cooperation among projects and organizational reorganization in structure in the automotive supply chain. It reduces too many players and their involvement for a particular product and paves way for less number and reliable player.



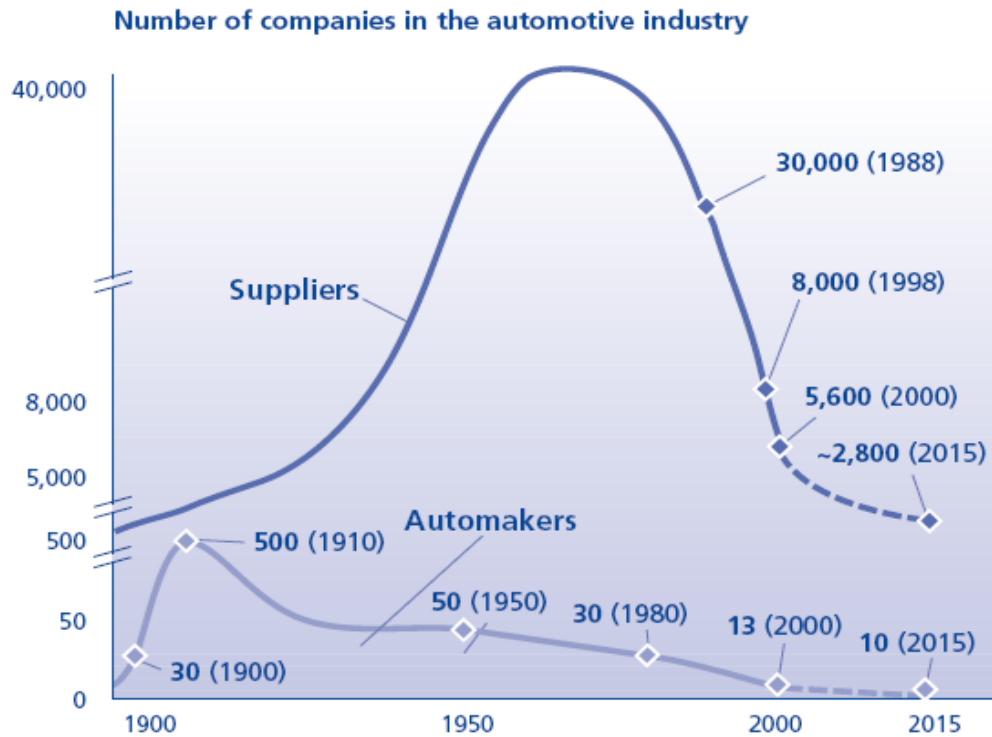


Figure 10 -Global Automakers and Consolidation with Suppliers

Source: Mercer Analyses (2004)

## 8. Conclusions

Indian automobile and auto components industry is on a roll and there is an immense scope for management for enhancing the supply chain of the sector. India has become a favorable destination for foreign companies to establish their facilities and form alliances with domestic companies. Low cost of manufacturing and conducive government support have been the major drivers for foreign companies investing in India. India's large young population, higher GDP growth, and most importantly per capita passenger car penetration is low at 8.5 car per thousand population, which creates great opportunity for industry players to offer an affordable four-wheeler alternative to the two-wheeler customers. This article prepares a strategic road map for the Indian auto manufacturers by

understanding the past five year's market and predicting future 10 year's market. This growth forecasts, market analysis, scenario planning and identified growth opportunities in a dynamic state would help auto manufacturers to take action in strategic perspective.

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### **Appendix A: Dynamic Equations of the Model**

The prime dynamic equations for the automotive supply chain market are represented as:

$$N \quad \text{Indian\_Auto\_Market.J} = \text{Initial\_Market.J} * \text{Carrying\_Capacity.J}$$

$$L \quad \text{Indian\_Auto\_Market.K} = \text{Indian\_Auto\_Market.J} + \\ (\text{Auto\_Components\_Import.JK} - \text{Auto\_Components\_Export.JK}).DT$$

$$A \quad \text{Auto\_Components\_Export.K} = \\ \text{Indian\_Auto\_Market.K} / \text{Manufacturing\_CycleTime.K}$$

$$A \quad \text{Auto\_Components\_Import} = \text{Fractional\_Import\_Rate} * \text{Indian\_Auto\_Market}$$

$$N \quad \text{Auto\_Logistics\_Revenue.J} = \text{Auto\_Revenue.J} * \text{Fractional\_Sharing\_Rate.J}$$

$$R \quad \text{Change\_In\_Recent\_Revenue.K} = (\text{Auto\_Revenue.K} - \\ \text{Auto\_Logistics\_Revenue.K}) / \text{Revenue\_Reporting\_delay.K}$$

$$L \quad \text{Auto\_Logistics\_Revenue.K} = \text{Auto\_Logistics\_Revenue.J} + \\ (\text{Change\_In\_Recent\_Revenue.JK}).DT$$

$$C \quad \text{Revenue\_Reporting\_delay} = 3$$

$$L \quad \text{Gross\_Domestic\_Product.K} = DT.K * \text{Combined\_Gross\_Domestic\_Product.K}$$

$$N \quad \text{Gross\_Domestic\_Product.K} = 8.5$$

$$A \quad \text{Combined\_Gross\_Domestic\_Product.K} = (\text{Aggregate\_Demand.K} - \\ \text{Gross\_Domestic\_Product.K}) / (\text{Production\_Adjustment\_Time.K})$$