Chapter 2

Innovation in the Indian Automotive Industry: Role of Academic and Public Research Institutions

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CHAPTER 2

Innovation in the Indian Automotive Industry: Role of Academic and Public Research Institutions

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While the story of India's economic growth over the last twenty years is well known, it is often explained as a services-driven phenomenon. However, some manufacturing sectors have played an important role in this economic growth, and the automotive sector is prominent among them.

The automotive sector's contribution is not only in terms of revenues, profits, taxes and employment, but more importantly in quality processes, efficiency improvements, and product innovation. This dynamism has been seen across the sector – in the commercial vehicles, utility vehicles, cars, two-wheelers and automobile component industries. According to a study by the Confederation of Indian Industry, quality defect rates in manufacturing dropped from as high as 12% in 1998 to 100 ppm in 2008[i] *– the Indian automotive sector which was at the vanguard of the quality movement can legitimately take credit for this substantial improvement. Companies across the automotive sector spectrum have won prestigious Deming and JQM awards.*[ii] *The automotive sector is the most prominent location of product innovation in Indian manufacturing. It accounts for the second highest aggregate spending by industry on research and development, following only the pharmaceutical industry.*[iii]

In this paper we seek to understand the drivers of innovation, corporate innovation strategies, and more specifically, the role of academic and public research institutions in the innovation profile of this sector.

Indian Automotive Sector: A Historical Perspective[iv]

In the early years after India's independence in 1947, the government of India under Prime Minister Jawaharlal Nehru adopted a strategy of creating heavy industry under a planned economic development process. While the automobile industry was already recognized by that time as a mother industry that could create positive externalities across the economy, India deliberately under-emphasized the car industry (which was seen as providing private transportation for the rich) and instead encouraged the creation of manufacturing capacity in trucks and buses. Two important companies that are prominent players to this day – Ashok Leyland and Tata Motors (then Tata Engineering and Locomotive Company Ltd. – Telco) were set up in the 1950s with collaborations with Leyland and Mercedes Benz respectively to create the beginnings of a medium/heavy commercial vehicle industry. A limited car production capacity was also set up subsequently by two companies – Premier Automobiles and Hindustan Motors. Ancillarisation was encouraged in the 1960s and a number of companies producing automobile components were set up at this time, usually through foreign collaboration. Under the then industrial policy, foreign players could not enter the Indian market on their own in either the end product or the intermediate stages – hence they were willing to provide technical collaboration and assistance to Indian players.

The automobile industry grew slowly in tune with the "Hindu rate of growth" of the economy. Lack of competition (the government did not encourage the entry of new players), foreign exchange controls, industrial licensing, and the Monopolies and Restrictive Trade Practices Act together removed any incentive or pressure to improve either operational efficiency or do much product-related innovation. The most visible form of this was the Ambassador car model of Hindustan Motors that remained largely unchanged for almost 30 years.

The Indian automotive sector came to life only after the entry of Maruti Suzuki Ltd. with its small car Maruti-800 model in 1983. Maruti Suzuki came about as a joint venture between Suzuki Motor Company of Japan and the Government of India. Maruti Suzuki was started as a means to fulfill the dream of Sanjay Gandhi, son of then Prime Minister Indira Gandhi, to build a people's car. After his sudden death in an air crash, the government decided to enter the automobile business in the form of what became

Maruti Suzuki. While the excitement at that time was around the fuel efficiency, low cost and aesthetic looks of Maruti's small car product, looking back from the vantage point of 2011 it is clear that the entry of Maruti transformed the Indian automotive sector.

Maruti not only brought in better manufacturing practices in its plant, it also ushered in Japanese quality management systems. While Suzuki brought in some of its own vendors to supply components for the Maruti car, existing component manufacturers in India had to upgrade their manufacturing processes, improve efficiency, lower costs, absorb new technologies and put in place systems for continuous improvement if they wanted to do business with Maruti Suzuki. The success of Maruti's products in terms of reliability and re-sale value reinforced the importance of quality and, by the late 1980s, India's most prominent industry association, the Confederation of Indian Industry (CII), initiated the quality movement in India.

The automobile industry soon became the arena for the first significant steps in deregulating the Indian economy with the government deciding to allow broad banding of industrial licenses (companies could now decide their product mix within the overall quantities they were permitted to produce) in the automotive sector. In parallel, the government encouraged the entry of new technology and new players into the two-wheeler and light commercial vehicle industries. Thus, in the 1980s, Honda, Suzuki, Yamaha and Kawasaki got involved in the Indian 2-wheeler industry, and Toyota, Mazda, Nissan and Mitsubishi entered the light commercial vehicle (LCV) industry through joint ventures.

The entry of these new players galvanized these industries, but not necessarily in favour of the new entrants. In the light commercial vehicle industry the eventual winner was the incumbent Telco, which used the broadband policy to enter the light commercial vehicle business, and then came up with products that were much more suited to the Indian environment in terms of ruggedness and serviceability. The Indo-Japanese LCV players lost out as their products became more expensive due to progressive hardening of the Yen vs. the Rupee and their failure to rapidly indigenize their products. In the motorcycle industry, one player, Hero Honda (a joint venture between Hero Cycles and Honda Motor) became, over time, the winner of the mass market, while, an incumbent, Bajaj Auto, came back into reckoning in the executive segment post 2000. Most noteworthy about Bajaj Auto's performance was that its most successful motorcycles were designed not by its technology partner Kawasaki, but by the Bajaj Auto team itself.

The car industry changed after the economic liberalization process gathered momentum in the early 1990s. Ford was the first to enter through a joint venture with Mahindra & Mahindra, but the Escort model they launched was already being phased out of other markets, and it did not make much of a mark in the Indian market. General Motors suffered a similar fate with its Opel Astra. The first international player to make a mark in the "new" Indian car market was Hyundai which designed a car especially for the Indian market. The Santro, launched in 1998, had quick acceleration, the ability to turn around in small spaces, good fuel efficiency, and, with its tall boy design, was differentiated from the existing cars in the market. Over the last ten years, almost all the major automobile companies have entered the Indian market – Toyota, Honda, Skoda, Volkswagen, Nissan, Fiat and Renault are all present in India in addition to Ford, GM, Hyundai and, of course, Suzuki which was the first to enter, and continues to dominate the Indian car market thanks to its strong presence in the lower end of a price sensitive car market. Several manufacturers including Toyota (with the Etios), Ford and Volkswagen have introduced cars which are specially designed or adapted to the Indian market.

In this congested market space, Indian automobile companies have managed to stake out a space for themselves. Tata Motors first entered the car market by building passenger vehicles on a light commercial vehicle platform. Later, with the in-house development of the Indica, they built their first ground-up car. The success of the Indica (initially launched in 1998, and later re-launched in an improved version in 2001) and a low end light-commercial vehicle, the Ace, in 2005, emboldened Tata to enter the car market with a disruptive innovation, the Nano, in 2008.

Similarly, in the utility vehicle space, another Indian company, Mahindra & Mahindra (M&M) first upgraded its existing jeep-like product and then launched its first successful in-house developed Sports Utility Vehicle, the Scorpio, in August 2002.[v] Subsequently, it launched another Multi Utility Vehicle based on in-house development, the Xylo, in 2009.

Another important part of the Indian automotive sector is the automobile component industry. In recent years, it has grown in size, and thanks to is enhanced quality of output, cost competitiveness, and design skills, it has become prominent in the global automobile component industry as well. Forging manufacturer Bharat Forge is a good example of this trend. In the last 20 years, Bharat Forge has grown from a small domestically focused player to become the second largest forging manufacturer in the world after Thyssen Krupp. The important steps in this transition were (1) setting up a large automated forging capacity to meet any need from any customer at high quality; (2) renewal of the workforce by inducting graduates on the shop floor; (3) building computer-aided design skills, first at the level of the dies for forgings and later in the final product; (4) implementing various efficiency-enhancing and cost-reduction processes across the company; (5) exploiting windows of opportunity in key external markets including China; (5) adding on machining skills so as to enhance value addition; and (6) gaining technological capabilities and proximity to auto OEMs by strategic acquisitions in Europe.[vi]

From the above, it is quite evident that some Indian companies across the automotive industry spectrum have enhanced their innovation capabilities considerably during the last two decades. What role has academia and public research institutions played in this? And what role will they play in the future? What can the government do to enhance such collaboration? These are the questions we seek to answer in the rest of the paper.

Methodology & Structure of the Paper

To answer these questions, we decided to study some of the prominent organizations from across the automotive sector. We have chosen 2 automobile component companies; 5 automotive companies with different strategies, business models and segments; and 3 research groups from academia that have been closely involved in research and development work related to the automotive industry.

We have built a case study around each of these companies/research groups using diverse sources of data: annual reports, case studies, data submitted to the government as per statutory requirements, and interviews with key managers/researchers. For each company, we look at the company's history, its product and innovation strategy, and the role played by academia and public research institutions. For each academic research group, we look at the expertise and background of the group and the nature of their interaction with industry.

Building these case studies allows us to build a snapshot picture of the sectoral innovation system.[vii]

After the presentation of these case studies, we identify the emerging trends in terms of the priorities of the companies related to innovation, what role academia is playing in helping the companies innovate, the role of the government, and identify possible avenues for joint working in the future.

Innovation in the Indian Automobile Component Industry: Two Cases

The Indian Automotive Component Industry has emerged as one of the most dynamic, export-oriented industries in India. It is often mentioned as one of the industries with the best export and growth potential. Both domestic sales and exports have been growing at a rapid pace as shown in Table 1:

Table 1: Indian Automobile Component Industry Sales & Exports 2000-2011 (USD Billion)

	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
Turnover Growth Rate					8.70 29%	12.00 38%	15.00 25%	18.00 20%	18.40 2%	22.00 20%	26.00 18%
Export Growth Rate	0.63 37%	0.58 -8%	0.76 31%	1.27 68%	1.69 33%	2.47 46%	2.87 16%	3.62 26%	3.80 5%	3.80 0%	5.00 32%

Source: Auto-Component Manufacturers Association http://www.acmainfo.com

1. Case 1: Tube Products of India

1.1. Company Profile & Brief History[viii]

Tube Products of India (TPI) is a constituent of Tube Investments of India (TII) Ltd., a leading engineering company with bicycle, metal forming and other related business. TII is a part of the large south Indian conglomerate, the Murugappa Group.

TPI was set up in the year 1955 in collaboration with Tube Products (Old Bury) Limited, UK to produce Electric Resistance Welded (ERW) and Cold Drawn Welded (CDW) tubes. This business was set up primarily to meet the needs of the parent company's bicycle business. However, today, TPI manufactures Precision Welded tubes for several major automotive companies in India and abroad. It has also diversified beyond automotive into other user segments.

TPI is well known for the wide variety of Precision Welded ERW and CDW steel tube in terms of size as well as material grades offered. Though it started with a plant near Chennai in south India, today it has manufacturing facilities in the north and west as well to meet the needs of its customers. TPI has also set up an exclusive export oriented unit.

1.2. Product & Innovation Strategy[ix]

Like many other engineering companies, TPI has a long history of focusing on quality and process improvements with a view to improving efficiency and productivity. However, in recent years, there is also a major emphasis on innovation, particularly development of tubes for new applications, and using new/alternate materials.

The automobile sector is looking to lower weights – "light weighting" – to enhance fuel efficiency and lower emissions (meet tighter emission norms). At the same time, safety is an important consideration for the sector. "Light weighting" means using alternate materials. But it's usually not enough to just substitute materials. There is often a need for re-design. Safety concerns focus on eliminating weldments, and looking at joinery issues. Vehicles have to be crashworthy.

TPI addresses the passenger car and light motor vehicle markets. "Light weighting" here involves bringing in materials with high strength but at the same time not losing out on shaping properties / ductility, etc.

TPI is working with auto companies on drive line and body / suspension components. One obvious area of interest is substituting tubes for rods. Tubes are lighter, but stiffness is important. Substituting a rod by a tube changes the moments of inertia. So there is a need for re-design of the components.

TPI has been working primarily with leading Indian manufacturers like Tata Motors and Mahindra, and not with multinational auto majors. To get the back-end knowledge, TPI has joined a US-based steel processing consortium, ASPPRC (Advanced Steel Processing and Products Research Center) since the last 6-7 years. ASPPRC has close links with the Colorado School of Mines. Membership of this consortium has helped learn about processing steel in a more comprehensive manner. Leading global steel makers and automobile companies are a part of this consortium, and this helps TPI get a clear product perspective.

TPI works closely with the R&D and Product Development departments at Tata Motors and Mahindra to understand their needs and co-develop alternate components. They also keep the customer's vendor development department in the loop so as to avoid any procurement issues later on. TPI has found no difficulty in working with Indian companies like Tata and Mahindra, where there are like-minded people. However, it has not been easy to get entry into MNCs.

1.3. Collaboration with Academia / Public Research Institutions

In terms of links with institutions, TPI has contractual relationships with a number of institutions. For testing methods, they work with the Automobile Research Association of India (ARAI), jointly with Tata/Mahindra or a Tier I vendor like Spicer. They also use the testing services of organizations like Structural Engineering Research Centre (a government-funded R&D institution that specializes in testing structures) and the National Automotive Testing & R&D Infrastructure Project (NATRIP), a new government sponsored programme that is setting up a national network of testing centres with industry participation.

TPI's relationship with the Indian Institute of Technology (IIT) Madras[x] is strong. The interaction is more on fundamental problems that are well suited to the competence of the faculty at the institute. TPI has 5 employees currently in the MS programme at IIT Madras. They work in areas like crack propagation. The learning of these employees from IIT Madras helps build the research capabilities within TPI.

Similarly, TPI has worked with IIT Bombay, again on a contractual basis. This is primarily in the areas of Metal Forming (working with a Professor who is part of the government-funded CAR programme) and Hydroforming. They have also worked with another professor on aluminium welding and friction welding (this is in anticipation of user shifts from steel tubes to aluminium tubes).

In the past, TPI worked with the Indian Institute of Science as well, primarily with the Prototyping Centre (APDAC) for areas like Finite Element Modeling (FEM). This was at a time when TPI's own Technology Centre's design capabilities were in infancy.

The relationship with IIT Madras (IITM) is excellent. IITM readily accepts TII/TPI people for their research programmes. Murugappa group has been a major sponsor of the IITM nano-tech centre [Rs. 30 million out of Rs. 250 million]. IITM has also helped build a Technology Appreciation programme for shop floor employees of TII/TPI. TPI's learning from this interaction is that while IITM does not have solutions to all problems, the key is to go with them for what they are good at doing.

2. Case 2: Rane Group

2.1. Company Profile & Brief History[xi]

The Rane group was founded in 1929 as a trading house. Through strategic technical alliances and access to the best technology, they have today grown into one of the important players in the automobile components industry in India.

The main companies in the group are Rane (Madras) Limited (Manual Steering & Suspension Systems), Rane Engine Valve Limited (Engine Valves, Valve Guides, Tappets), Rane Brake Lining Limited (Brake Linings, Disc Pads, Clutch Facings, Composite Brake Blocks, CV Brake Pads & Sintered Brake Pads), Rane TRW Steering Systems Limited (Power Steering Systems, Seat Belt Systems), Rane NSK Steering Systems Limited (Steering Columns & Electric Power Steering) and Rane Diecast Limited (High Pressure Die Casting Products).

Between them, these companies serve almost all the major segments of the automotive industry in India. The group turnover was USD 375 million in 2009-10.

2.2. Product & Innovation Strategy[xii]

2.2.1. Process Innovation

Rane Group has been following Total Quality Management (TQM) aggressively. Four companies in the group have received the Deming award and one is now aiming for the JQM award.

Process improvements at Rane group have been made for the last 10 years under the umbrella of TQM. Total Preventive Maintenance (TPM) has been in place since the last 5 years and there is a major thrust on lean manufacturing since the last 3-4 years. Both process improvement and equipment improvement are being pursued. Multiple Japanese advisers have been advising Rane on the implementation of these methodologies. Efficiency improvements through the identification of Mudas (source of waste) in the factory have been brought about. The company seeks to optimize movement in the factory and thereby reduce waste of men and materials. This process goes on continuously, leading to re-alignment of the factory.

2.2.2. Product Innovation

The Rane group already has a focus on products and designs. There is an awareness of the importance of new technologies and products. There is consciousness of Intellectual Property Rights and an environment for the creation of new processes and designs is already there. Innovations are being protected in a systematic manner.

For those companies in the Rane group that are Joint Ventures (JVs), the main technology source is the JV partner. Others like Rane Madras and Rane EV are standalone companies and depend on their own technology development efforts. The latter companies have their own R&D and/or engineering departments. On a case-to-case basis they acquire technologies from other sources as well. The R&D departments are also involved in improvements to existing products and have used existing technologies to develop adjacent products.

Rane does benchmarking with collaborators. They also have technical partnerships with Japanese partners for competency development.

The Rane group is active in application engineering and component-level new design. Adapting existing products to other requirements through component design is one of their core areas. In terms of such application engineering innovation projects, they have achieved proficiency at the component level. Work at the sub-assembly level is in progress, and the product level is the next frontier.

In one case, a component innovation done in a Rane group company has been accepted by the collaborator (who has a large innovation laboratory in China) for inclusion in their final product. This is in the area of occupant safety systems.

Rane group started looking at innovation as a distinct activity only recently. As a part of their leadership development activities, a professor from IIM Bangalore gave lectures to the senior management team and they are now moving forward on this. The group plans to integrate the innovation activity with their group-wide TQM approach during the coming years. A couple of senior managers have been identified to lead this focus on innovation.

The Rane group has been in touch with leaders in innovation such as the Tata group companies to learn about their innovation processes. They plan to benchmark against Tata group companies including Tata Consultancy Services and Titan Industries (jewellery division).

2.3. Collaboration with Academia / Public Research Institutions

Rane group has interactions with IITs (mainly Madras), Anna University and PSG Tech, (a leading engineering institution in Coimbatore). The PSG Tech relationship is strong because of the Rane group founders' links to Coimbatore. PSG Tech has small R&D laboratory specific projects that are undertaken as student project work.

The Rane group chairman has put together cross-functional and cross-company groups that interact with PSG in specific areas. They identify areas of possible collaboration. After that it is left to individual companies to pursue the matter.

One of the group companies, Rane TRW, is in the seat belt business. An important arena for Rane TRW is plastic reservoirs for steering systems. They have done some work on development of new reservoirs to meet emerging global standards. IIT Madras has been involved in testing and validation of NVH (noise vibration harshness) characteristics. They also have (often informal) interaction with various experts in the area of plastic components. These experts may be from CIPET (a publicly-funded institution), ex-CIPET or consultants from the industry. Areas of interest include process engineering, alternate materials, lightweighting and strength of materials (allowing lighter structures).

2.4. Innovation in the Automotive Industry: Five Cases

Like the automobile component industry, the automotive industry itself has been growing at an aggressive pace. The growth figures for the domestic market and exports are given in the following tables:

Table 2: The Indian Automobile Industry Automobile Sales (No. of vehicles)

Category	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Passenger vehicles	902,096	1,061,572	1,143,076	1,379,979	1,549,882	1,552,703	1,949,776
Commercial vehicles	260,114	318,430	351,041	467,765	490,494	384,194	531,395
Three wheelers	284,078	307,862	359,920	403,910	364,781	349,727	440,368
Two wheelers	5,364,249	6,209,765	7,052,391	7,872,334	7,249,278	7,437,619	9,371,231
Grand total	6,810,57	7,897,629	8,906,428	10,123,988	9,654,435	9,724,243	12,292,770

Source: Society of Indian Automobile Manufacturers http://www.siamindia.com

Domestically, the passenger vehicles industry displayed the highest compound annual growth rate of 13.7% over the period 2003-2010.

Table 3: Indian Automobile Industry Automobile Exports (No. of vehicles)

Category	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Passenger vehicles	129,291	166,402	175,572	198,452	218,401	335,729	446,146
Commercial vehicles	17,432	29,940	40,600	49,537	58,994	42,625	45,007
Three wheelers	68,144	66,795	76,881	143,896	141,225	148,066	173,282
Two wheelers	265,052	366,407	513,169	619,644	819,713	1,004,174	1,140,184
Grand total	479,919	629,544	806,222	1,011,529	1,238,333	1,530,594	1,804,619

Source: Society of Indian Automobile Manufacturers http://www.siamindia.com

In exports, two wheelers were the fastest growing industry segment with a compound annual growth rate of 27.5%.

3. Case 3: Ashok Leyland Ltd.[xiii]

3.1. Company Profile & Brief History[xiv]

In keeping with India's post-independence philosophy of self-reliance, what is today Ashok Leyland was first set up in 1948 as Ashok Motors to assemble cars. Consequent to equity participation from Leyland UK, the company actually started manufacturing trucks and buses since 1955.

Ashok Leyland prides itself on a tradition of technological leadership, earlier through technological collaboration, and now, increasingly through internal product development. A pioneer in truck technologies such as full air brakes and power steering, today Ashok Leyland is known for its rugged products suited to Indian conditions. More than 500,000 vehicles manufactured by the company have been used on Indian roads.

Ashok Leyland has been most successful in the public bus segment of large cities. 80% of buses used in India's metropolitan cities for public transport have been manufactured by the company.

In 1987, the control of the company came into the hands of the prominent non-resident Indian business group, the Hindujas, consequent to their taking over the overseas holding and IVECO, a multinational truck company. IVECO subsequently sold out its stake to the Hindujas in 2006. Ashok Leyland was the first Indian automobile company to be awarded ISO 9002 certification (1993) and also the first Indian automobile company to be awarded the ISO/TS 16949 corporate certification (2006). It has achieved many other certification landmarks as well.

Over time, Ashok Leyland has shifted from chassis based vehicles to (next generation) fully built solutions; many of these are the result of in-house development. In the last decade, new facilities created include an engine R&D facility at Hosur and a Technology Centre at Chennai. The number of people involved in R&D / product development has gone up from about 80 to over 1,000 during the same time frame.

In fiscal 2009-10, Ashok Leyland had sales of Rs. 73 Billion.

3.2. Product & Innovation Strategy

As in many other parts of the Indian automobile industry, innovation in the commercial vehicle (truck) segments of the Indian history has been driven by the increasing stringency of pollution control norms and enhanced competition. At the same time, demand for commercial vehicles has generally been on a growth path for the last several years except for the year 2008-09 when the market contacted due to the effects of global recession. In the commercial vehicle segments, growth has been healthy in the bottom and top weight segments as India moves towards the hub-and-spoke model of logistics that characterizes much of the developed world. Growth has also been driven by regulatory efforts to curb the practice of overloading trucks and the upgradation of bus services in metropolitan cities through the introduction of low-floor city buses.

Ashok Leyland's focus has been on providing the best "value-to-cost" equation for customers. Following the withdrawal of IVECO from the controlling structure of Ashok Leyland, the company is now aggressively creating its own technological capabilities to meet this goal. This is reflected in the increase in R&D intensity from 1.7% in 2005-06 to almost 3% in 2009-10 (see Table 4 below). The objective is to ramp-up capabilities to be self-sufficient in creating technologies for the global market. This is already visible in near-term products. In addition, technology adjacencies are being pursued such as next generation technologies, electronics, telematics, etc.

Table 4: Ashok Leyland Ltd. Expenditure on R&D (Rs. Million) During Last 5 Years

Year	Capital Expenditure on R&D	Recurring Expenditure on R&D	Total Expenditure on R&D	R&D Expenditure as a % of Sales
2005-06	485.55	563.85	1049.40	1.70
2006-07	778.78	785.24	1564.02	1.90
2007-08	954.39	1068.84	2023.23	2.30
2008-09	1500.15	1153.66	2653.82	3.98
2009-10	1024.92	1315.89	2340.82	2.97

Source: Company Annual Reports of Respective Years

Two new centres/groups have been set up – one for Advanced Engineering, and the other called Mission Summit (this group links technology to market – basically, it looks at how technology can improve the operating economics of trucks both in terms of operating costs, and usage of the asset across the life cycle).

Till 2007-08, the emphasis was on development of engines ("H" series) with common rail injection systems to meet the needs of Bharat Stage III (similar to Euro III) emission norms. In 2007-08, the company decided to launch a "Future Vehicle Development Programme" and create a "New Engine Platform "to prepare itself for even higher emission norms as well as emerging customer needs. These culminated in the UNITRUCK truck platform announced in 2008-09, a modular truck range covering the 16-49 Ton segments. This modular range is expected to help both customers (easier fleet management) and Ashok Leyland (lower number of parts, and improved supply chain management). The company also started development of a new modular "NEXTGEN" cabin and a new engine series, "NEPTUNE."

Besides increasing plant capacities to meet future needs, Ashok Leyland has sought to move away from its traditional reliance on medium and heavy commercial vehicles to form a Joint Venture for Light Commercial Vehicles with Nissan (announced in 2006-07; first vehicle expected to be on the road in 2011), move into construction equipment through a joint venture with John Deere (announced in 2008-09), and diversify into automotive electronics through a joint venture with Continental AG (the company by the name of Automotive Infotronics was formed in 2007-08). In 2007-08, Ashok Leyland also invested in a company called Albonair in Germany to develop vehicle emission treatment/control systems and products.

Ashok Leyland's innovation activities are driven by a number of recent process initiatives. A team of young employees from different functional areas was brought together as a task force to develop the business plan for 2007-08 which set more challenging targets than the traditional top-down business plans.[xv] Through a collaborative "voice of the customer" process, Ashok Leyland built a special semi low floor, front engine bus for the city of Mumbai that retained a low price but offered improved ventilation for the driver and a simple electronic management system among other improved features besides the mandatory Bharat Stage III engine. This resulted in the largest ever order of 644 buses from Mumbai's local public transport utility company, BEST.[xvi] A "Mission Gemba"[xvii] team from Ashok Leyland worked closely with a supplier of fuel tanks to optimize his plant layout and operations so that he could double his productivity and thereby meet Ashok Leyland's enhanced requirements with minimal investments.[xviii] Suggestions submitted by employees were used to lower the "Effort & Ergonomy Index" across the plant.[xix] Another company-wide team project contest titled "Improve" based on innovation by teams/quality circles resulted in 946 projects in 2005 with a benefit to the company of Rs. 32.9 million. The following year saw a doubling of the number of implemented projects and a participation rate of 40% of the company's employees.[xx] Young engineers in the company's Advanced Engineering Group are encouraged to present papers at international conferences such as the annual Society for Automotive Engineers (SAE) conference.[xxi]

Other processes in use include a "Mission Summit" programme (launched in 2007) for breakthrough innovation that resulted in the innovative IBus demonstrated in the Auto Expo of January 2008, a Six Sigma programme extended company-wide in 2007-08, a "GENMOD" process to capture the voice of the customer launched in 2008-09 and a Lean Development Process launched in 2009-10.[xxii] The Hibus, a plug in hybrid bus developed by Ashok Leyland, was demonstrated at Auto Expo 2010. A variety of consultants are involved in these process initiatives.

3.3. Collaboration with Academia / Public Research Institutions

During 2006-07, Ashok Leyland and Bosch jointly endowed a Centre for Excellence in Engineering Design at the Indian Institute of Technology Madras. This Centre was set up to offer an integrated dual degree programme in Engineering Design – a B.Tech in Engineering Design + an M.Tech with specialization in Automobile Engineering - that would improve the availability of design engineers with a practical orientation.[xxiii] Ashok Leyland and Bosch each contributed Rs. 40 Million (about USD 0.9 million) for the creation of this Centre.

Ashok Leyland has tied up with Indian research centres and laboratories for internal competence building. There are programmes with IITs as well as the Indian Institute of Science at Bangalore (e.g.in the area of Noise Vibration Harshness).

The Collaborative Automotive R&D Programme (CAR) launched by the government in 2004-05 provided a good platform for collaboration with academia. A CAR project in which Ashok Leyland participated (integrated telematics project for Koyambedu) has been scaled up and is quite successful even though it was delayed by a few years. All important stakeholders – central government, state government, International Institute of Information Technology Bangalore, Siemens VDO (now Continental) - came together on this project. Ashok Leyland's learning from this project was that the challenge is to use the right technology for Indian conditions. A new company started by Ashok Leyland in a joint venture with Continental (Automotive Informatics) will play an important role in this field of automotive electronics in the future.

Forums like SAE and SIAM have brought together automobile industry people through a Mobility Industry Group to work on competence ramp-up.

Ashok Leyland has interacted with international academics as well. They invited Prof Clayton Christensen to advise them on how to create disruptive technologies. Using that methodology, a novel concrete cement mixer was developed and displayed at the Auto Expo. This is a vehicle with a smaller footprint than traditional concrete mixers. Similarly, the eminent Japanese scholar Prof. Shoji Sheba was invited to advise on Lean 6 Sigma.

The Indian Statistical Institute, a prominent research and education institution specializing in Statistics has been involved for training and certification in Six Sigma – a number of green and black belts have been trained. This collaboration helps in terms of improvement of processes, certification, etc.

4. Case 4: Mahindra & Mahindra

4.1. Company Profile & Brief History[xxiv]

Mahindra & Mahindra Ltd. (M&M) is today a diversified Indian corporation with interests in automobiles, farm equipment, financial services, hospitality and information technology. In the financial year ending March 2010, M&M had a sales turnover of Rs. 205.95 Billion and a net profit of Rs. 20.88 Billion.

M&M entered the automobile manufacturing business in 1945 through an arrangement with Willys jeeps to import and assemble their product from kits. In 1954, they started manufacturing utility vehicles. M&M has over time become a major player in the farm equipment and tractor business, and, since 1983, has been India's largest tractor company.

In the automobile industry, M&M's traditional focus was on soft-top and hard-top utility vehicles, primarily for rural markets. In 1995, they entered the motorcar segment through a Joint Venture with Ford. However, this JV was short-lived and was dissolved in 1999, with Ford continuing the business on its own.

M&M entered the urban market for Sports Utility Vehicles (SUVs) through the launch of a new product, the Scorpio, in 2002. Prior to the launch of the Scorpio, M&M launched an upgraded version of one of its existing hard-top utility vehicles, the Armada, as the Bolero, at the upper end of the low-priced utility vehicle segment. The Bolero was quite successful.

However, M&M's major makeover came from the launch of the Scorpio. The Scorpio was first conceived in 1997 as a part of a new Integrated Design and Manufacturing (IDAM) initiative launched by M&M under the leadership of Dr. Pawan Goenka, a former General Motors executive. Originally conceptualized as a rural vehicle, the Scorpio was finally positioned as an urban vehicle when M&M management realized the potential of the product.

M&M also has a presence in Light Commercial Vehicles. It is now entering the Medium and Heavy Commercial Vehicles businesses through a Joint Venture. M&M acquired the two-wheeler business of Kinetic Motors to enter the two-wheeler industry. In 2010, M&M also acquired a controlling stake in Reva Electric Car Company, India's pioneering electric car manufacturer. M&M entered a joint venture with Nissan/Renault to manufacture the Logan passenger car for the Indian market; however M&M and Nissan/Renault have now decided to go their own ways.

4.2. Product & Innovation Strategy

The Scorpio project signified the entry of M&M into the complete end-to-end design and manufacture of an automobile for the first time. It was developed with a small team by international standards – just 120 people – but the smallness of the team also meant that it was close knit and effective. The IDAM team collaborated with a number of external agencies for the design and engineering of the Scorpio. For example, the engine was developed in collaboration with AVL, an Austrian company. The design of the Scorpio incorporated a lot of input from the increasingly sophisticated Indian consumer. While the diesel version of Scorpio was designed to meet Indian emission norms (at that time equivalent to Euro II), another petrol version compliant to Euro III standards was also developed.

Since M&M lacked resources and experience, M&M used the black box development approach and got major sub-systems developed by vendors. Most of these vendors were international suppliers, but often not the leading ones. Instead, M&M chose to work with Korean companies that had the expertise but not much prior experience. This brought costs to a level that M&M could afford. M&M has made concerted efforts to absorb most of the technologies sourced from external vendors.[xxv]

Similarly, in setting up the plant, M&M worked with relatively less known suppliers to keep costs under control. As a result, M&M was able to keep the cost of setting up a plant with a 45,000 car capacity to only USD 120 million.

Scorpio was a successful vehicle, selling nearly 35,000 vehicles in the first 18 months after launch, and winning the CNBC Autocar "Car of the Year" award in January 2003. More than that, it established M&M as an important player in the Indian automobile market capable of innovative designs and features. M&M claimed that Scorpio offered "45 new features provided through systematic capture of customer feedback."[xxvi]

The Bolero and Scorpio also formed the basis for M&M's internationalization strategy with the Bolero being launched as the Mahindra Cimarron in Uruguay (with a focus on the South American market) and the Scorpio being launched as the Mahindra Goa in Europe. M&M entered the South African market in 2004, and in 2005-06 launched a pick-up variant of the Scorpio in that country – the first time an Indian automobile company launched a new product in an international market.[xxvii]

Since then, several variants of the Bolero and Scorpio have been launched, both domestically, and internationally.

In 2008-09, M&M launched the Xylo, a bigger multi utility vehicle for urban customers. Like the Scorpio, the Xylo was received well in the market and was seen as an important alternative to established products like the Toyota Innova, the leader in that segment.

The investment in research and development at M&M shows an increasing trend

(Table 5):

Table 5: Mahindra & Mahindra Ltd. R&D Expenditure in the Last 5 Years

	2005-06	2006-07	2007-08	2008-09	2009-10
Cap Ex on R&D (Rs million)	NA	NA	538.1	2768.7	3907.2
Total Exp on R&D (Rs million)	1265.9 (rounded)	1700	2453.3	5156.5	6648.6
R&D as a % of Sales	1.33%	1.46%	1.85%	3.44%	3.23%

Source: Company Annual Reports
Note: This is the total R&D expenditure of the company and included R&D expenditure on tractors and farm equipment.

In the last three years the priorities of R&D at M&M have been evolving from an emphasis on engine development to meet regulatory norms (2007-08) to the development of alternate fuels (2008-09) and sustainable movement solutions (2009-10).[xxviii]

Representing the importance of R&D and product development to M&M, it has a board-level committee focused on research and development since 1998. Also, the head of the team that developed the Scorpio, Dr. Pawan Goenka, is today the head of the automotive business of M&M.

4.3. Collaboration with Academia / Public Research Institutions[xxix]

M&M takes special interest in collaboration with academia. The company's collaboration with academia takes 3 forms:

- Technology Development
- Fundamental Research
- Training / knowledge development

M&M has relationships with four of the Indian Institutes of Technology.

In the technology development arena, M&M gives projects to academic institutions when analytical investigation is required as they believe academics are better placed to do such work. Areas in which projects are given out include vibration analysis, combustion analysis, fluid dynamics, wave analysis, etc. This activity supplements the in-house product development undertaken by the company.

M&M has given projects to the Indian Institute of Science in the areas of vehicle aerodynamics, Computational Fluid Dynamics calculations, and simulation studies.

M&M has worked with Indian academic institutions on research projects such as hydrogen technology for engines (IIT Delhi) and biofuels (IIT Kanpur)

M&M's experience has been that the gap between academia and industry is more on non-technical issues like focus and time, not because of capabilities or competence. This gap can be bridged once there are more people with experience on both sides.

M&M works extensively with_academia for training. Their Graduate Engineer Trainees undergo a one-year training programme developed and taught by professors from different institutions. M&M prepares the outline of a training module and academia builds on this. Partners include MS Ramaiah College, VIT and College of Engineering, Pune.

Modules for existing staff are being prepared with IITs, and deemed universities that have the expertise. M&M personnel have been deputed to VJTI (a leading engineering institution in Mumbai) for MTech in Powertrain engineering. Earlier, some M&M personnel attended Masters programmes at IIT Madras.

M&M also has some international collaborative R&D projects / programmes with organizations like SRC Canada for Hydrogen diesel dual development (sponsored by Ministry of Renewable Energy), Southwest Research Institute USA and TUV from the Netherlands.

5. Case 5: Tata Motors[xxx]

5.1. Company Profile & Brief History

Tata Motors is one of the flagship companies of the globally renowned Tata conglomerate. Tata Motors sprung to international attention with the announcement of the Tata Nano, the world's lowest priced car, in January 2008.

Tata Motors was founded as the Tata Engineering & Locomotive Company Ltd. (Telco) in 1945. Telco commenced the production of trucks through a technical collaboration with Mercedes Benz in 1954. After the expiry of this collaboration agreement in 1969, Telco started designing, developing and manufacturing trucks on its own.

While Telco's technological capabilities improved over time, its ability to expand its range and capacity was constrained by the licensing regime of the government. The broad banding policy for the automobile sector announced in the mid-1980s freed Telco from this constraint. Telco was able to compete successfully with Indo-Japanese ventures such as Swaraj Mazda, Allwyn Nissan and DCM Toyota in the newly emerging Light Commercial Vehicle segment thanks to its rugged products, simple technology and strong service network.

Following the liberalization of the Indian economy in 1991, Telco entered the car and utility segments as well with products such as the Estate (a station wagon), Sierra, and Sumo (a very successful utility vehicle used in both urban and rural India for multi-passenger transportation). These products built on the capabilities Telco had built in the light commercial vehicle arena. For example, the Estate and Sierra were built on the chassis of the 207 light truck.

However, Telco's first ground-up entry into the passenger car market was through the Indica, launched in 1998 based on a decision taken in 1995. The Indica, a sturdy diesel "small" car emerged as an important competitor in the entry level market thanks to its low operating costs. It was particularly successful with taxi operators. Telco subsequently launched petrol versions of the Indica targeted at individual consumers. The Indica V2 launched in 2001 overcame many of the niggling problems that plagued the original Indica model. Later, a sedan variant on the same platform called the Indigo was launched in 2002.

Telco changed its name to Tata Motors in 2003. Subsequent significant events were:

- Acquisition of Daewoo's heavy commercial vehicle business in South Korea in 2004 (this gave Tata Motors access to advanced engine technologies for developed markets);
- A strategic alliance with Fiat was announced in 2006 to cover technology, sales and marketing;
- Launch of the Tata Ace, a one tonne, "last mile" delivery vehicle in May 2005 (more than 500,000 vehicles built on the Ace platform were sold between 2005 and 2010. This product won BBC Top Gear's Best Commercial Vehicle Design Award in January 2006);
- Launch of the Tata Nano in 2008;
- Acquisition of a controlling stake in Jaguar Land Rover in 2008.

Tata Motors reported a top line of Rs. 381.44 Billion in 2009-10 with a net profit of Rs. 22.4 Billion on a standalone basis in FY 2009-10.[xxxi]

5.2. Product & Innovation Strategy

Tata Motors has a long heritage as an engineering company. Telco set up its research and development centre as long back as 1959. Under its legendary chairman, Suman Moolgaonkar, Telco built strong engineering capabilities even though these could often not be satisfactorily exploited.

Telco's first successful internally developed product was the Tata 407 light commercial vehicle launched in the late 1980s.

The Indica was developed at a cost of Rs. 17 Billion (USD 378 million) and gave Tata Motors the confidence to build other new products. In the Indica project, Tata Motors managed the product development at a system design and integration level and involved a number of international vendors and partners in the project. These included partners / consultants for styling, body, engine design, etc. As the company's first major clean sheet car design and development project, the Indica was an important learning ground for Tata Motors' engineers.

Tata Motors has two research centres in India – one at Jamshedpur that focuses on the improvement of components and aggregates and an Engineering Research Centre at Pune set up in 1966. Work done by the Pune Centre resulted in Telco getting the DSIR National Award for R&D Effort in Industry in 1999 and the National Award for Successful Commercialization of Indigenous Technology for the Indica in 2000.

In terms of internal development processes, the Ace constituted an important step and was the precursor to the Nano. Some of the significant decisions in the Nano project were:

- Choice of a 30-year old engineer, Girish Wagh to head the development team (this was a major departure from the traditional practice at Tata Motors)
- Use of cross-functional teams in product development
- Use of the "Production-Preparation-Process (3P) in the development process
- Strict cost control through a "Design-to-cost" approach (the development budget was pegged at Rs. 2.2 billion ($49 million)).

Reflecting Tata Motors' successful use of "frugal innovation" techniques, consulting firm Booz rated Tata Motors as a highly effective innovator in its 2006-07 study of innovative companies.[xxxii]

Given the aggressive cost targets of the Nano, Tata Motors worked closely with a variety of suppliers, both Indian and foreign, to design components, sub-assemblies and assemblies that would meet very tight cost targets. Some of these capabilities were built during the Ace development process.

5.3. Collaboration with Academia / Public Research Institutions

Tata Motors has been at the forefront of developing capabilities indigenously. Towards this end it collaborates actively with institutions, firms, and consultants.

Tata Motors has been an active participant in the CAR project on Tailor-welded Blank and Hydroforming Technology for Automotive Weight Reduction being led by the Advanced Research Centre for Metallurgy and Advanced Materials (ARCI) at Hyderabad. They have also been actively involved in sponsoring projects at the Indian Institute of Science, Bangalore (see Case 10 on Centre for Product Design and Manufacturing at Indian Institute of Science).

6. Case 6: TVS Motor Company[xxxiii]

6.1. Company Profile & Brief History

TVS Motor is the third major player in the Indian motorcycle industry. TVS Motor is part of the TVS Group, a well-established industrial conglomerate in south India with a strong presence in the automobile component industry. In fiscal 2009-10, TVS Motor Company had sales of Rs. 44.2 Billion.

TVS Motor entered the two-wheeler industry through mopeds. The flagship moped *TVS50* was developed and launched in 1980 by Sundaram Clayton, a TVS group company. Numerous models and variants launched over the years helped TVS dominate the moped segment. TVS-Suzuki was formed as a joint venture between Sundaram Clayton and Suzuki Motors in 1982 to develop and launch motorcycles. The company went public in 1984, with Suzuki owning 33.7% of equity, TVS and its associates 16.7%, and general public the rest.[xxxiv] TVS's stake increased to nearly 50% in 1986 when the moped division was transferred from Sundaram Clayton to TVS-Suzuki.

The TVS-Suzuki joint venture launched the first-ever 100cc motorcycle in India in 1984. While this was markedly superior to existing products, Hero Honda soon launched four-stroke motorcycles with Honda's technology, which delivered superior fuel efficiency. TVS's in-house R&D efforts became focused on tweaking Suzuki's existing two-stroke engines to generate greater mileage.

Lacking a four-stroke model, TVS continued to be at a distinct disadvantage in the market. TVS-Suzuki launched its four-stroke model only in 1997 by which time Hero Honda had a stranglehold on the market. Difficulties in accessing Suzuki's technology and the cost of indigenizing the technology, among other issues, contributed to the split of the TVS-Suzuki joint venture in 2000.

6.2. Product & Innovation Strategy

TVS started to develop independent in-house product development capabilities even before the split with Suzuki. TVS launched *Scooty* in 1994, which quickly became the leading scooterette, and various motorcycle models throughout the late 1990s. The four-stroke motorcycle *Victor*, launched in 2001 was also an in-house effort, and gained TVS significant market share in motorcycles.[xxxv] TVS saw success with the launch of this product, resulting in their motorcycle market share zooming up to 19% in 2002-03. TVS continued to focus on fuel economies and emission controls and followed up with the launches of *Centra* and *Star* (both 100cc) in 2004. The success of *Victor*, however, could not be replicated, and Hero Honda continued to be strong in the economy segment.

While TVS continued to develop and launch new products, none of them could emulate the success of *Victor*. The surfeit of models in the economy segment from TVS and Bajaj led to the leader - Hero Honda launching a price war. As a result, TVS decided to focus on the newly emerging 125cc segment. To enter this segment, TVS licensed engine technology from AVL – an Austrian engine technology house, to be used in the new bike that was to be launched in 2007 – the 125cc *Flame*. The engine used Controlled Combustion – Variable Timing Intelligent (CC-VTi) technology. TVS claimed that the engine generated 10% more power and 10% greater fuel economy than regular engines. To protect their technology, TVS and AVL filed a patent on 23rd August, 2007 in the Indian Patent Office at Chennai.

On 30th August 2007, TVS unveiled the 125-cc *Flame*, based on CC-VTi. TVS had already started a new manufacturing facility with a capacity of 400,000 units in 2007 to capitalize on the expected success of the new bike.[xxxvi] Further fuelling TVS's expectations, *Flame* received rave previews.

However, Bajaj Auto succeeded in obtaining an injunction against the launch of *Flame*. This meant that the launch of *Flame* was delayed, and TVS finally had to launch *Flame* without the CC-VTi technology. Though the injunction was subsequently lifted by a higher court, the basic patent dispute is still pending a decision with India's Intellectual Property Appellate Board as of January 2011.

TVS Motor has been continuing an active innovation programme over the years. The company's investment in research and development has been rising steadily in the last three years. The spending on R&D is given in Table 6 below:

Table 6: R&D Expenditure by TVS Motor Company

	2005-06	2006-07	2007-08	2008-09	2009-10
Cap. Ex. on R&D (Rs million)	128.2	372.8	155.3	142.9	111.2
Revenue Exp on R&D (Rs million)	548.7	477.5	548.2	634.2	724.3
Unallocated Exp on R&D (Rs million)	83.9	175.1	-	-	-
Total Exp on R&D (Rs million)	760.8	1025.4	703.5	777.1	835.5
R&D as a % of Sales	2.3%	2.61%	2.12%	2.08%	1.86%

6.3. Collaboration with Academia / Public Research Institutions

TVS Motors is reputed to be a company with strong engineering expertise and has been committed to develop a strong technological capability of its own. While this effort is driven primarily through the company's internal efforts, the company uses collaboration with a variety of external partners to complement its internal capabilities.

As a philosophy, TVS Motors is strongly committed to the Japanese Total Quality Control (TQC) framework, and most significant internal processes are aligned with TQC. To this end, TVS Motors works closely with Japanese quality gurus to continuously enhance its quality processes. These efforts have borne fruit as reflected in several prestigious quality awards including the Deming Prize (the only 2-wheeler company in the world to have received this award) and the TPM Excellence Award 2008. TVS Motors also has one of the most effective employee suggestion schemes in the country.

TVS has worked closely with the Warwick Manufacturing Group to enhance its internal engineering and technology management capabilities. Several senior engineers in the company have been deputed to attend the Masters programme at Warwick University or the programmes offered by Warwick in India in collaboration with the Confederation of Indian Industry.

TVS has been an enthusiastic supporter of the Collaborative R&D Programme (CAR) launched by the Government of India through the Technology Information, Forecasting and Assessment Council (see Case 12). TVS has been a member of the consortium of 4 of the 10 CAR projects (the highest for any automotive company):

1. Engine Management System for Petrol Powered Small Vehicles (led by IIT Bombay)
2. Acoustics Diagnostics for 2-Wheeler Engine Assembly Line (led by IIT Kanpur)
3. Low-cost Flexible Automation using Robotic Arms (led by IIT Madras)
4. Process Development in Semisolid Forming and Squeeze Casting of Aluminium Alloy Components for Automobiles (led by Indian Institute of Science, Bangalore)

Of these, the second project listed above, viz. “Acoustics Diagnostics for 2-Wheeler Engine Assembly Line” has been installed and demonstrated at TVS Motors. This project has resulted in the development of a PC-based system for quality testing of single cylinder engines at the end of the assembly line using acoustic and vibration inputs. “Good” and “bad” engines can be distinguished based on the audio and vibration data collected from running the engine at different speeds. This helps smoothen the assembly line by matching the speed of engine testing to the production off the line.[xxxvii]

TVS Motor has been working with academic institutions at different levels to identify faculty and programmes that can help the company and the industry build basic competencies used in the automotive industry. For example, the company has identified the Welding Research Institute at Bharat Heavy Electricals Ltd., Trichy, to develop 5 basic courses on welding. With each of these partners, the company is focused on using the principles of Instructional Design to develop modules with clear goals, exercises and measurement. This effort is based on the philosophy that there is little point in talking about research and development if basic skills and competencies are not available.

7. Case 7: Bajaj Auto

7.1. Company Profile & Brief History

Bajaj Auto started with a focus on scooters, selling scooters from 1945 and manufacturing them from 1959. Bajaj entered motorcycles in collaboration with Kawasaki, but focused on motorcycles only when the scooter market started declining in the 1990s. *Caliber*, launched in 1998 was Bajaj's first success in motorcycles, and *Pulsar*, launched in 2001, the first blockbuster.

Bajaj concentrated on the 150cc+ segment (*Pulsar*, *Avenger*, etc.), and led the executive segment with nearly 60% market share. Bajaj made large investments in R&D resulting in strong new product development capabilities and innovative features like Digital Twin Sparkplug Ignition (DTS-i).

Bajaj Auto was the second largest two-wheeler company in India in financial year 2009-10 and had sales of Rs. 119 Billion during this year.

7.2. Product & Innovation Strategy

Bajaj historically dominated scooters, a fact that remained constant even with the entry of LML Piaggio and Kinetic Honda post deregulation in the mid-80s. Even till the mid-90s, the mainstay of Bajaj was the long running *Chetak*, which was based on a 25-year old *Vespa* model. In the scooter segment, Bajaj focused on adaptive changes to *Chetak*, e.g., developing a 150cc engine which was more suitable to Indian conditions. Bajaj's reputation for 'value for money' and reliability, built over the years, led to continued domination in the scooter market.

Bajaj entered motorcycles in 1985, having signed a technical collaboration agreement with Kawasaki of Japan to produce 100-cc two-stroke motorcycles. Unlike Hero Honda, the Bajaj-Kawasaki alliance was not a joint venture, and involved no equity participation from Kawasaki. The first product was the *KB 100* launched in 1986, which performed poorly in the market. The "KB" design was found to be ill-suited to Indian conditions. A modified version was soon launched in the market, which had a better sales performance.

Bajaj soon realized that Hero Honda had succeeded in moving the market to four-stroke vehicles. Bajaj's first four-stroke bike was launched in 1991 – the *Kawasaki Bajaj 4S Champion.* This was a 100cc bike, and took Hero Honda's existing *CD-100*'s value proposition head-on, with a fuel economy of 87 kmpl (against *CD-100*'s 80kmpl). Bajaj's advantage was short lived as Hero Honda again changed the shape of the market with *Splendor*. The *Splendor* was a 'modernized' design, but with the same engine as the *CD-100*, making style a major selling factor, in addition to fuel economy.

The Bajaj Kawasaki partnership continued to design and launch new motorcycles throughout the second half of the 1990s – the 100cc *Boxer*, the 111cc *Caliber*, etc., but made only a minor dent in Hero Honda's domination.

In 1999, Bajaj launched a greenfield manufacturing facility, incorporating principles from the Toyota production system. The team setting up the new facility also launched a fresh product development effort in competition with the Kawasaki-Bajaj collaboration. While the collaboration team was working on the 175cc *Kawasaki Bajaj Eliminator*, the internal Bajaj team concurrently developed the 150cc and 180cc *Pulsar.*

Pulsar was developed in collaboration with Tokyo R&D, a design studio specializing in automotive R&D. The team also created and commercialized Digital Twin-Spark Ignition (DTS-i) technology, which incorporated two spark plugs in the combustion chamber. This generates two points of combustion in the engine, and allows quicker and more efficient combustion, and hence better power, fuel efficiency and lower emissions. Bajaj applied for, and was granted a patent by the Indian Patent Office for the DTSi technology.

Eliminator was launched in January 2001 but proved too expensive for the Indian market, and failed to make a dent. *Pulsar* was launched in November 2001, at much more competitive prices, and received rave reviews from auto magazines.

Bajaj soon launched the 175cc *Avenger*, which was the Kawasaki Bajaj *Eliminator* fitted with the cheaper, more powerful and more fuel efficient Bajaj DTS-i engine. The dual success of *Pulsar* and *Avenger* made the executive segment a stronghold of Bajaj.

Bajaj continued its collaboration with Kawasaki, with Bajaj having developed competencies complementary to Kawasaki's. Kawasaki was strong in higher-end bikes (>250 cc), and Bajaj developed the capability to design and manufacture lower-end bikes cheaply. Bajaj acquired a stake in Kawasaki's operations in the Philippines and Thailand, and manufactured Bajaj vehicles for local consumption. Bajaj later moved into other developing markets, acquiring facilities in Colombia, Indonesia and Brazil. The R&D on the lower-end bikes continued, with Bajaj developing new features such as ExhausTEC a modification to the exhaust pipe that improves low/mid-range torque.
Bajaj's investment in Research and Development is given in the following table:

Table 7: Bajaj Auto Ltd. Expenditure on Research & Development

	2005-06	2006-07	2007-08	2008-09	2009-10
Cap Ex on R&D (Rs million)	263.0	473.4	481.4	310.8	312.3
Recurring Exp on R&D (Rs million)	504.4	676.9	706.0	837.9	1035.3
Total Exp on R&D (Rs million)	767.4	1150.3	1187.4	1148.7	1347.6
R&D as a % of Sales	1.03%	1,24%	1.37%	1.36%	1.17%

Source: Company Annual Reports

In 2005-06, Bajaj developed and launched a new CT 100 and Discover 110. Another newly developed motorcycle, Platina, was launched in April 2006. During this same year the following new technologies were developed: SNS suspension and a new generation DTS-I engine (with intelligent control of spark timing). The R&D infrastructure was upgraded in the areas of design, CAE, prototype and testing

In 2006-07, Bajaj launched a third upgrade of Pulsar (150 and 180cc). The upgrade included LED taillights, digital LCD speedometers, non-contact and backlit switches. The company launched the oil cooled Pulsar 200cc and a new Pulsar 220cc DTS-Fi – first fuel injected bike from Bajaj (features: port fuel injection, fixed fairing with stacked head lamps, diagnostic functions which are displayed on the speedometer, front and back disc brakes, high rigidity frame and a high performance front and back suspension system). Bajaj also introduced the Kristal-automatic scooter with fuel efficient DTS-I engine.

In 2007-08, Bajaj launched the XCD 125 DTS -Si motorcycle and the three-wheeler Gasoline Direct Injected auto rickshaw. The XCD 125 DTS -Si was engineered to cut down weight, while incorporating advanced features like LCD speedometer, LED tail lamps and tank spoilers. The 3-wheeler direct gasoline injected has a new 2-stroke engine-reduced emissions and a lighter weight.

In 2008-09, Bajaj launched the Platina 125 cc DTS-si and XCD135cc DTS-si motorcycles. The R&D department focused on expanding its design and testing teams. It enhanced its digital computational capabilities along with the ability to prototype and test the products to even higher standards. This enabled Bajaj Auto to design and produce "ready-to manufacture" prototypes for the new generation products.

In 2009-10, Bajaj launched the following new products: Pulsar 220 F, Pulsar 180 UG, Pulsar 150 UG, Pulsar 135 LS and Discover DTS-si. During this year, Bajaj's R&D completed development of the 4V DTS-I technology for outstanding engine performance. Design optimisation enabled it to be used on the Pulsar 135 LS, which competes at a lower price point. The DTS-i is controlled by a new generation CDI (Capacitor Discharge Ignition), which takes continuous load and temperature inputs to compute the optimum timing of each spark plug. In the same year, Bajaj enhanced its design, computing and test facilities. A notable addition was the commissioning of a world class NVH (Noise, Vibration and Harshness) laboratory. Bajaj Auto believed that this would give the company the ability to make even more refined products. The R&D team size in areas of design, analysis and validation was expanded.

7.3. Academic Research Groups Involved in Automotive Innovation: Three Cases

India has a large higher education system. The country produces more than 500,000 engineers every year. Though the quality of the education system is highly heterogeneous, there are several highly rated institutions like the Indian Institutes of Technology and the Indian Institutes of Science.

An initiative by the Government of India provided a conducive context for collaboration with industry in the automotive sector. The Principal Scientific Adviser

(PSA) to the Government of India mooted a programme for support of consortium-based R&D called CAR in 2003. Senior members of Indian automotive companies were enthusiastic about such a programme.

Six panels of industry and academic experts were formed, resulting in a 2005 Road Map covering 30 areas. These six panels had about 12 people each (that became the nucleus for a future network). During one year they met three times each culminating in a meeting at IIT Madras where the topics were narrowed down. The consensus was that the government should support the industry and bring in academia and research institutions to undertake pre-competitive research through a consortium approach.

The hope was that this consortium based approach would obviate the need for the complexities of technology transfer. The project is itself the transfer process – companies imbibe as much as they can through their association during the project. Given government audit regulations and problems encountered in earlier programmes, TIFAC (the managing agency) decided to make all government contributions through the institutions and as grants. The PSA believed that funding innovation in the automotive sector would have good results because being a growing industry, there was a greater likelihood of technology getting commercialized.

Finally four areas were narrowed down. The common demand driver for technology underlying these themes was fuel-saving. Various dimensions of fuel-saving were identified – size (smaller cars); light-weighting (could give up to 20% reduction in fuel consumption) with a focus on new materials and processes in steel and aluminium, not magnesium; engine improvement; electronics; fleet management; alternate fuels (including electric drive vehicles and hybrids but not hydrogen or fuel cells that were seen as too far out).

One of the challenges faced was that in many emerging technology areas of automobiles, standards were set not by the vehicle manufacturers but by their Tier 1 suppliers (such as the AUTOSAR standard of Bosch). These Tier 1 suppliers had old loyalties to specific manufacturers, but the other tiers aligned with the stand taken by the Tier 1 supplier. The Tier 1 suppliers controlled the intellectual property. So, if for example Tata Motors wanted to use the electronics covered by one of these Tier 1 supplier standards it would have to shell out high costs/royalties. An attempt would be made to create alternatives for Indian manufacturers. In some areas the contrast was stark – e.g. in electronics, a high-end foreign car would have 70 microprocessors whereas in India there would be only 4 or 5. The areas of microprocessor use would also be different. Software standards would help Indian players. In spite of the existence of a large Indian software industry, this is of not much help to auto companies because the software companies lack domain knowledge. The fear was that Indian component vendors may get locked out one day because of lack of software / electronics expertise.

A total of about Rs. 0.35 Billion has been spent on 10 consortium projects since the inception of the CAR programme. About one fourth to one third of the project budget goes to the lead institution; but the lead institution is the conduit for the funding of other dimensions of the project. The institution can commission work at the companies and pay for this e.g. prototypes, machinery, etc.

The 10 consortium projects funded were as follows:

Table 8. List of Collaborative R&D Projects under CAR Programme

	Project Title	Partners
1	Engine Management System for Petrol Powered Small Vehicles	IIT Bombay, IIT Madras, TVS Motor Company, Ucal Car Fuel Systems
2	Vehicle Tracking and Control Systems using GPS/GSM Technologies	IIIT Bangalore, Ashok Leyland, Lattice Bridge, Bharat Electronics, Pallavan Transport Corporation Consultancy Services
3	Wi-FI Based Vehicle Tracking	Amrita Vishwa Vidyapeeth
4	Development of Tailor Welded Blank and Hydroforming Technology for Automotive Weight Reduction	ARCI Hyderabad, IIT Bombay, Tata Motors, Mahindra & Mahindra, Tata Steel, ProSim
5	Acoustic Diagnostics for 2-wheeler Engine Assembly Line	IIT Kanpur, IIT Delhi, IIIT Allahabad, Kritikal, Knowledge Online and TVS Motor Company
6	Low cost Flexible Automation using Robotic Arms	IIT Madras, Systemantics, IIT Bombay, Magstorq, TVS Motor Company, Mahindra & Mahindra, Sona Koyo Steering Systems, TVS Lucas, Bosch
7	Process Development in Semisolid Forming and Squeeze Casting of Aluminium Alloy Components for Automobiles	IISc Bangalore, Sundaram Clayton, TVS Motor Company, Mahindra & Mahindra
8	Use of Straight Vegetable Oils in IC	ICAT/NATRIP, IISc Bangalore, IIT

	Engines	Madras
9	Ultracapacitor for Electric & Hybrid Vehicles	IISc Bangalore, IIT Kharagpur, NCL Pune, CECRI Karaikudi, Kaptrinics, NED Energy
10	Development of Automobile Components through Electromagnetic Forming Process	Bhabha Atomic Research Centre, Advanced Materials and Processes Research Institute, IIT Bombay, IIT Delhi, Fleur-de-lis Technologies, + Automotive Companies

8. Case 8: National Facility for Semisolid Forming, Indian Institute of Science, Bangalore

8.1. Profile & Brief History (Incl. Areas of Expertise & Infrastructure)

National Facility for Semisolid Forming (NFSSF) at IISc, Bangalore, is a research and development centre focused on new aluminium casting technologies for the automobile industry. It was set up by faculty in the Materials & Manufacturing and Thermal Sciences and Fluid Mechanics Groups in the Mechanical Engineering Department of the Indian Institute of Science at Bangalore.

According to the *Indian Foundry Journal*, NFSSF produced the first ever semi solid casting in India – an auto component in A356.2 alloy. The SSF billet used for the casting was made using an Electromagnetic Stirrer designed and fabricated by NFSSF. The special feature of the casting so produced is its excellent surface finish, the absence of porosity and the presence of the desired microstructure (dendritic globular).[xxxviii]

The NFSSF itself was originally set up by the Ministry of Mines of the Government of India to explore alternate uses for non-ferrous metals. Subsequently other government departments such as the Department of Science & Technology, and the Defence Research and Development Organisation have been involved in supporting the NFSSF.

8.2. Collaboration with Automotive Industry[xxxix]

8.2.1. Long-term Research

One of the co-founders of the NFSSF, Prof. Pradip Dutta, joined IISc in 1996. In the first few years, he did not come across many opportunities for collaborative research with industry. The situation changed after 2000 when General Electric set up its multi-disciplinary research centre at Bangalore.

In 2000, a team from General Motors visited IISc. This team was from the Materials and Processes group within GM R&D. They were looking for processes that could help them create components and structural elements with lower weight ("lightweighting") and good material properties.

GM R&D works with academic institutions in two modes: (1) a project mode where they give contracts/purchase orders with fixed deliverables and well-defined delivery periods; and (2) a long term collaborative mode. The latter is managed through a Collaborative Research Lab (CRL), a group from within the GM R&D organization. These long term collaborative projects are managed under a Master agreement (MOU). In Phase 1, the long term collaborative programme involved 5 -10 umbrella projects. The themes of these projects are inter-linked. These long term collaborative projects are usually centered on fundamental studies and publication is encouraged. GM has more than 100 years of experience in figuring out how these projects fit in with their own requirements, and also how to ultimately dovetail these with commercial developments. The long-term collaborative projects also have the flexibility to change direction if some new insight emerges and they can even allocate more money if necessary.

Prof. Dutta's group has completed two phases of the long term collaborative programme with GM and moves into its 3rd phase in 2011.

Though the MoU with GM contains an IP sharing agreement, most of the project work is in the knowledge generation mode. Publication is encouraged though prior permission of GM is required. Students are encouraged to spend their summers at GM labs. Faculty also visit GM, and sometimes collaborate with others in the US. The major learning from interaction with GM has been in terms of where technology is moving.

Other institutions like IIT Kharagpur have similar arrangements with GM.

8.2.2. Process Development

Since 2002, Professor Dutta has also been involved in the Collaborative Automotive Research Programme (CAR) of TIFAC. This is in the area of Development of Processes for Lightweighting.

The first phase of this programme was the creation of the NFSSF. This was initially set up with bulk funding from the Ministry of Mining which was looking to promote the use of non-ferrous metals in the automotive sector. This facility has been focused on the development of technology and machines for semi solid forming. This technology was first invented at MIT in the late 1970s. Some metals when stirred before solidification display a globular structure. Morten Flemings found that when reheated, these could be cast in a semi-solid form with interesting properties – basically, porosity is eliminated, thus enabling thin-walled structures with high strength.[xl] The overall process involves semi-solid forming and advanced die casting.

The patents for the original development of this technology were bought by Toyota and other high-end automotive companies. However, these companies did not exploit the technology much because of the high costs involved (3X cost of ordinary materials) and used it only in a limited set in components for high end automobiles. In the late 1990s, the patents expired, and external interest revived. The Chinese have a major interest in this area, while the Europeans are well ahead in theory.

The development of indigenous technology was completed in 2006-07 with the implementation of an electromagnetic stirring process. However, this had a relatively narrow range of success.

In 2007, as a part of the CAR programme, TIFAC asked why this technology could not be commercialized with a consortium of auto companies, with the help of SIAM. Six companies came together – Sundaram Clayton, Mahindra, Tata Motors, TVS, Bajaj and Hindalco (for making the billets). The objective was to establish the feasibility of the component technology and to make billets of the new material. Early on, Hindalco decided not to make the large capital expenditure involved, and instead IISc took up the task of making the billets itself.

The next phase will start in June 2011 with an emphasis on billet making. The Automobile Research Association of India (ARAI) will be involved because there will be a major testing component. A simplified billet making process that uses gravity will be used. This process was instigated by a small scale entrepreneur who thought that the original process of IISc was too complex and involved too much deviation from existing practice. As a result of this simplified process, the cost of the billet will be only 10% more than the normal billet.

8.2.3. Experience of Collaborating with Industry

Programmes like CAR pose the challenge of using government money effectively. Generally, industry's contribution is in kind and time rather than money. The experience of this group is that to make industry and academia work together someone has to walk the extra mile. In this programme IISc had to go into some non-research activities like getting dies made in order to make the project move ahead. Such activities involve tendering and take a long time, and institutions like IISc are not ideally geared towards such activities.

9. Case 9: Professor Shashikanth Suryanarayanan's Laboratory, IIT Bombay

9.1. Profile & Brief History (Incl. Areas of Expertise & Infrastructure)[xli]

Professor Shashikanth Suryanarayanan (Shashi) is an Assistant Professor in the Design Engineering group of the Mechanical Engineering Department of the Indian Institute of Technology Bombay (IITB). IITB is one of the Indian Institutes of Technology set up as part of a far-sighted initiative by the government of India over 50 years ago.

Prof. Shashi did his Ph.D. at the University of California at Berkeley.

Prof. Shashi's research interests are in the areas of Control Systems Design and Mechatronics. He seeks to use the tools provided by systems/control theory in the development of disruptive technologies for intelligent/clean transportation.

According to Prof. Shashi, the philosophy is as follows: "Over the years, automobile subsystems have evolved into highly complex mechanical entities. The trend today is to replace mechanical complexity with intelligent mechatronics. Mechatronic systems promise to provide the benefits of cheaper costs, better vehicle handling performance, cleaner engines, lighter vehicles, reconfigurability etc."

Prof. Shashi's group has initiated projects in automotive controls with Indian companies in pursuance of this broad trend. His group has worked on the following projects:

- Development of a low-cost Engine Management System for Petrol-powered Small Vehicles Funded By: Technology Information Forecasting and Assessment Council & Office of the Principal Scientific Advisor, Govt of India. Participating partners: IIT Bombay, IIT Madras, TVS Motor Company Ltd, UCal Fuel Systems Ltd and TIFAC.
- Development of a Steer-by-Wire Prototype Funded By: Sona Koyo Steering Systems Ltd.

9.2. Collaboration with Automotive Industry[xlii]

CAR was initiated by the PSA based on a similar programme of Collaborative Auto R&D in the US involving US auto majors like Ford and GM. The US government funded universities in this programme. The programme itself had a broad mandate – technology development, prototyping, standard development, building testing infrastructure.

CAR programme was intended to support projects done by universities of a pre-competitive nature. These projects were expected to have medium term relevance.

For Prof. Shashi, it was natural to get involved with CAR. He had a background in controls and had just returned to India. He was idealistic, and this seemed to be an interesting opportunity to work with industry. Proposals were invited by the government (TIFAC). By the rules of the programme, a consortium was to be formed. The role of the consortium was largely to validate ideas.

The project had several useful outcomes. A number of people got trained on emerging technologies. They were able to build something that no Indian group has been able to do - a fuel injection system for small engines that matches the best of international giants. This was implemented and demonstrated in a real vehicle. It exceeded expectations. It became the setting for a new company set up by Prof. Shashi. However the prototype developed under the CAR programme was not commercialized.

Prof. Shashi was not surprised that the prototype was not commercialized because there is a big gap between building a prototype and commercializing it – you need to understand technology, market, pricing; organizational priorities also come in the picture. There has to be enough time, and the top leadership of the concerned companies has to be interested.

10. Case 10: Centre for Product Design & Manufacturing, IISc, Bangalore

10.1. Profile & Brief History (Incl. Areas of Expertise & Infrastructure)

The Centre for Product Design and Manufacturing (CPDM) is a Centre of Excellence at the prestigious Indian Institute of Science (IISc), Bangalore. IISc is arguably India's top science and technology university.

The CPDM focuses its research on the areas of Design Theory and Methodology, Human Factors in Design, PLM and, Vehicle Design, Simulation and Testing. It offers courses at the Masters and Doctoral levels.

CPDM advocates a synthesis of research in design and design in practice based on a belief that product designers and design researchers are complementary to each other. "While designers create products to improve the society, design researchers develop effective design methods and techniques for better design."[xliii]

10.2. Collaboration with Automotive Industry[xliv]

10.2.1. Research Projects

CPDM faculty have been receiving funding from automobile companies for open-ended research. For example, General Motors has funded faculty on more abstract research projects which do not have immediate applications. Professor Deb of CPDM is working on modeling dynamics. Prof Gurumoorthy of CPDM is working on Large Assembly dealing with design changes. These are 3-year research projects without the immediate prospect of commercial outcomes. Research papers and some algorithms are the principal outcome of these projects. While these projects have been completed, a new project on more sustainable drivetrain for 3 wheelers is under discussion.

10.2.2. Design & Development Projects

CPDM is involved in several projects related to design of automotive systems. The main areas of work are:

1. Safety issues, crash resistance, passenger and pedestrian safety
2. Joining materials and processes for crash resistant structures
3. Electric mobility, electric vehicles

CPDM has had interaction with large Indian automotive companies such as Tata Motors, Mahindra & Mahindra and Ashok Leyland.

CPDM's most intense relationship has been with Tata Motors on joining techniques for non ferrous alloys with a particular emphasis on strength and durability. Tata Motors was seriously involved in this project and even took a space in the facility of the Society for Industrial Development (SID – the arm of IISc that facilitates industry collaboration) at IISc to be close to the project. One employee of Tata Motors registered in the PhD programme. Though technically successful, it is not known to what extent Tata Motors has used this technology / development in its own facilities.

Mahindra & Mahindra used the services of CPDM for a crash analysis project. However, there has not been any significant repeat interaction.

Ashok Leyland has also been involved in a one-off exercise on crash evaluation. However, the Ashok Leyland connection also led to IISc offering three workshops for SAE on noise & vibration, design and crash and safety.

CPDM faculty also work through the APDAP (Advanced Product Design and Prototyping) Centre at IISc. Faculty bid for participation in external projects through the ADPAP. Through this channel, they have done projects for several companies including TVS, Pricol (an instrument and dashboard manufacturer), Minda (an Indian company involved in the manufacture of automobile components), IFB Autolive, Ford, etc. These design projects are not blue sky projects. They are reasonably known technologies. To bring in an element of novelty, CPDM tries to do the design from scratch.

The project for Pricol was on instrument clustering. It involved value engineering to reduce cycle time for manufacturing and reduction of cost. The design was supplied to Pricol but was perhaps not implemented because of some unrelated issues at Pricol. The project for Minda was of a similar nature and involved value engineering for 2-wheeler instrument panel.

The project for IFB Autolive involved the design of a passenger restraining system under very tight and increasingly stringent weight constraints. The solution was technically very good, but not accepted/implemented by the client due to changing priorities. The faculty involved are now trying to retrieve the product to pursue other possibilities.

A current project is for a cycle manufacturer to develop an all composite (high end) bicycle. The project involves material selection and characterization.

A roofrail for a new car was developed for Ford. This is likely to be used on international models of Ford.

10.2.3. Experience working with Companies

CPDM's experience has been that, relatively speaking, Indian manufacturers have less patience to work with academic institutions. Almost all companies (Indian or foreign) negotiate hard and seek to squeeze costs out of the project even though they change the specifications often. Indian companies expect complete solutions while MNCs are relatively happy with lab prototypes. From CPDM's perspective, the biggest challenge has been in completing projects on time.

10.3. Synthesizing Across the Cases: Innovation Trends & Role of Academia / Public Research Institutions

Innovation in the Indian automotive sector is broadly driven by the following:

1. Emission Norms: The increasing stringency of pollution control/emission norms has been perhaps the single biggest driver of innovation in the automotive industry. Their continuing impact is very visible in the innovation priorities of Ashok Leyland, M&M and TVS Motor Company.

2. Competition: The need to differentiate products from existing products has been another driver of innovation. This includes creation of new segments (M&M Scorpio, Bajaj Pulsar, Tata Ace) and the development of disruptive products (Tata Nano). Another result of competition is changes in styling, appearance, etc. (particularly visible in Bajaj and M&M).
3. Fuel efficiency / cost of use: Indian consumers are price and value conscious. They are constantly seeking a better value proposition. They want lower costs but don't want to give up features or benefits. Volatile and increasing fuel prices continue to induce companies to look for options that enhance fuel efficiency. This is particularly evident in the 2-wheeler industry where consumers want fuel efficiency, styling and power. The emphasis on lightweighting as seen in the case of tube supplier TPI and more complete combustion (multiple spark plugs used by Bajaj and TVS) are specific examples of this trend. Cost reduction is also a major driver of the Government's Collaborative R&D Programme.
4. Alternate Fuels: Rise in fuel prices and their volatility has drawn attention to alternate fuels, electric cars and hybrids. This trend is in its infancy, but there are signs of Indian companies (e.g. M&M) paying more attention to this in their most recent R&D and strategic (e.g. acquisition of Reva) plans.

Before we investigate the implications of these trends for industry-academia relationships in the future, it is useful to reflect on what role industry-academia links have played in the last few years as covered by these case studies.

1. By and large, there have been limited links between automotive companies and academic institutions in the automotive sector.
2. In the absence of the CAR programme, these links would have been even weaker.
3. The most prevalent role of academia is in competency development and training. Other major activities include analytical studies and testing.
4. Academic institutions can provide some services needed by automotive companies (e.g. the design services provided by CPDM at IISc) but academic institutions may not have a distinctive advantage in providing these. They will have to be cost competitive with other providers to win such projects. And the research content will typically be low.

5. Since most Indian companies start from a small resource base, they are very demanding on what they get from institutions and what tangible results are obtained. This is in contrast to the long term research programmes being funded at the Indian Institute of Science by General Motors.
6. However, some companies have been willing to support long term education / research initiatives of academic institutes in the larger social interest e.g. Ashok Leyland's sponsorship of the Design Engineering programme at IIT Madras.

From our discussions with the CAR programme officials and the academics involved, we learnt that this programme was very useful in terms of creating a network of people in the broader automotive innovation system. We also learnt that:

1. Not too many Indian companies were keen to join the CAR programme consortia even though there was no financial commitment expected.
2. There is an inadequate number of mature engineers in the country. As a result, the companies find it difficult to evaluate new technologies or innovations. Things are changing slowly as more and more people with experience and expertise are coming in (often returning from the developed world).
3. Corporate partners provide support only in kind. Often, the firm's support is constrained by its own priorities, and the institution undertaking a project gets only the residual time or capacity available.

One of our respondents tried to explain that the limited interest of companies is natural:

> "The role of academia in innovation has to be understood in the context of the automotive industry. The industry is very consolidated and typically not more than 5 – 10 companies dominate every space. Decisions regarding technology are not really made in India. Local decision makers only decide on timing – the development happens elsewhere. Local innovation – in terms of features – does not involve the kind of technology where academics can participate. Hence the role of academics is limited.
>
> "In India, technology is more an adaptation story, driven by the process of homologation or localization.
>
> "Academics here can at best put out ideas or prototypes that have promise. The Indian environment has some shortcomings – you need someone listening to you who can do something beyond patting your back. Whatever contribution is

made is in spite of the system. This is not because of any sinister design on the part of the companies; it is because not enough work is done here, there is no critical mass of expertise, no broader ecosystem, no confidence and credibility that something worthwhile will emerge. The level of expectations from academia is low. At best, companies hope to get some trained manpower out of the projects. These employees can manage the acquisition of technology from outside.

"The big challenge in the automobile industry is that quality and reliability is essential. No idea can go into a product without extensive testing. The overall process involves a long cycle time. Unless you have gone through this cycle a few times, you won't have confidence about how it works."

Indian automotive companies have been steadily increasing their outlays on research and development. For many companies, it is now in a healthy range of 2-3% of sales. Their ability to find companies or consultants who can fill in their gaps, particularly from outside India, is well developed (e.g. development of Tata Indica and M&M Scorpio). They have a good ability to integrate across vendors and across technologies; they also appear to have learnt how to absorb technology within a short timeframe.

What is not as clear is how they will manage emerging technologies like hybrids and alternate fuels. These are areas in which consultants will be difficult to come by. And the expertise available with the employees of Indian companies, even those who have had extended stints with global auto companies, would be limited.

10.4. Policy Implications

Before we make recommendations for polices that could enhance the innovation ecosystem in the Indian automotive sector, its useful to summarise the existing policy framework that supports innovation.

10.4.1. Current Policy Support for Innovation[xlv]

India already has several policy measures in place to support innovation.

Support for Academic Research: Academic institutions can apply for project-specific research grants from the Department of Science & Technology (DST), Government of India, under the SERC programme. This programme is being upgraded into a full-fledged National Science & Engineering Foundation that will enhance autonomy of the grant programme as well as the quantum of support for academic research. The DST administers joint R&D programmes with other countries that offer support for basic research. Apart from the DST, other ministries of the Government also have support programmes for scientific research.

Support for Industrial Research & Development: From a taxation perspective, India already has a supportive environment for innovation. Tax breaks are available for R&D spending. Automobiles and automobile components are already included in a special set of industries that have a higher (i.e. 150%) deduction of R&D. Payments for R&D to designated academic institutions and national laboratories are also entitled to a higher level of write-offs. Besides taxation benefits, the government offers excise duty concessions for locally developed technologies that are covered by patents in two or more specified countries. Under its Technology Development and Demonstration Programme (TDDP), the Department of Scientific & Industrial Research offers low-cost loans for technology development. The Technology Development Board (TDB) offers low cost loans for technology commercialization.

Support for Collaborative Programmes: The New Millennium India Technological Leadership Initiative (NMITLI) of CSIR supports joint R&D programmes in emerging areas between companies, R&D institutions and academic institutions by providing grants for the portion of work undertaken by public R&D / academic institutions. Another collaborative initiative supported by the government is a scheme to support the creation of Centres of Research Excellence (COREs) in engineering institutions; under this scheme managed by TIFAC, the government provides a matching grant to the contribution of industry and the institution.

Sector-specific Programmes: The CAR programme, discussed above, was one of India’s first consortium R&D programmes. The Government has other sector-specific support programmes for innovation such as the Small Business Innovation Research Initiative (SBIRI) of the Department of Biotechnology that offers research grants to small biotech companies and loans to larger companies. The Drug Development Programme of the DST supports joint R&D projects between pharmaceutical companies and research institutions by underwriting the work undertaken by the R&D institution.

Support for Technology-driven Entrepreneurship: The Government of India has two main programmes. The National Science & Technology Entrepreneurship Development Board supports the creation of incubators in technology and management institutions, and provides seed funding for some of the enterprises housed in these incubators. The Technopreneur Promotion Programme (TePP) provide grants and loans to entrepreneurs who are trying to scale up their innovations.

It is clear that India has a plethora of programmes designed to strengthen academic research, collaborative R&D programmes, and R&D by industry. We now identify gaps and propose additional policy measures.

10.4.2. Strengthening the Role of Academic & Research Institutions in Automotive Innovation

Our earlier discussion identified the following roles played by academic research and research institutions in automotive innovation:

- Teaching / training / capability development
- Long-term research
- Analytical, design and testing services
- Pre-competitive R&D (such as in the projects of the CAR programme)

In addition to the existing policies of the government, some policy measures that would help enhance these roles are:

Creation of Centres of Excellence in Areas related to the Automotive Industry: There are a number of emerging areas in automotive technology including new materials, alternate fuels, and electric and hybrid vehicles. These will be the areas of the future, and in many cases there are no established technologies. Firms will be seeking to learn and develop capabilities in these areas. The government would do well to give grants to the leading educational institutions to create centres of excellence in these areas.

Institute Challenges/Contests at the National Level: Another way of creating deep yet relevant capabilities in academia is by throwing challenges to university teams of professors and students to develop new technologies. The DARPA in the US has used this method very effectively to create capabilities for the development of unmanned and remotely controlled vehicles that work reliably on non-uniform terrain.

Mandate Practical / Design Projects for Engineering Students: Another useful way to enhance innovation and design capabilities among students and in academic institutions is to require all graduating engineering students to complete a working design prototype before they graduate.

Simplify Administrative Functioning / Rules for Commercial Activities by Educational Institutions: Academic institutions face many bureaucratic and administrative challenges in executing large collaborative projects (such as the CAR programme) or participating in consulting and design projects. Academic institutions should be not only permitted but encouraged to set up non-profit corporate entities that can perform commercial activities on behalf of the university / academic institution in a more effective manner.

Facilitate Boundary Spanners between Academia and Industry: Industry and Academia often speak in different languages, and one of the challenges in promoting academia-industry collaboration is having people on both sides who understand each others' language. Enhanced mobility between academia and industry would help such boundary spanning activity. The government, industry, and academic institutions should get together to create innovative programmes to enhance such mobility.

Allow faculty to start and participate in new ventures: Service rules often prevent faculty members from participating in new ventures as investors or promoters. But, we have seen in Case 9 how it is sometimes necessary for a new venture to be started to take a new technology to market when existing players are unable or unwilling to commercialise the technology. Government should proactively amend service conditions to allow such ventures to be created, and support the ventures through incubators and seed-funding schemes.

10.4.3. Other Policy Implications

In the Indian case, we have seen one set of companies actively engaged with Indian educational institutions in the context of innovation is the Indian companies such as Tata Motors, M&M, Ashok Leyland and TVS Motor Company. While direct support for the development of local firms may conflict with WTO rules, there is a case for support of a local automotive industry to enhance domestic innovation efforts.

The Collaborative Automotive Research (CAR) Programme has been quite successful. Apart from creating a large network of people with automotive expertise, the CAR programme has resulted in specific outcomes such as the demonstration of semisolid forming for the first time in India. There is general agreement that a success rate of 20-30% is a good rate to achieve for such a programme, and by this measure the CAR programme has been successful. Government should therefore continue to support such collaborative research programmes in specific areas which are relevant to the future development of the Indian automotive sector.

But there are some learnings from the CAR programme as well that could be applied to future consortium-based programmes:[xlvi]

1. Such programmes should insist on high quality standards and focus on attracting really committed applicants.
2. There needs to be a strong review process. Since new technology development has to be globally competitive, the government should not hesitate to call in the best people in the world to do reviews if there is inadequate expertise available locally.
3. Companies should be encouraged to play an active role in such pre-competitive collaborative programmes. But they should not have the final word on deciding the continuation of such projects because they may lack the expertise or they might stop the project due to extraneous considerations.

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[x] IIT Madras was founded about 50 years ago and is a part of the network of IITs (leading engineering education institutions) set up by the Government of India.

[xi] This section is based on information available at http://www.rane.co.in/groupprofile.htm This site was last accessed on January 19, 2011.

[xii] This section and the next are based on an interview with Mr. S. Mohan, one of the leaders of the Rane group's innovation initiatives on January 13, 2011.

[xiii] This case has been written based on information in the public domain (primarily from the company's annual reports) and an interview with Dr. Aravind Bharadwaj, CEO, Automotive Informatics (a joint Venture of Ashok Leyland). Dr. Bharadwaj was earlier the head of the Advanced Engineering Group at Ashok Leyland. He was one of the

founders of the Collaborative Automotive R&D Programme of TIFAC, Government of India.

[xiv] Based on http://www.ashokleyland.com/history.jsp?name=history accessed on January 16, 2011.

[xv] Ashok Leyland Ltd., Annual Report 2006-07, pp. 6-7.

[xvi] Ashok Leyland Ltd., Annual Report 2006-07, pp. 10-11.

[xvii] A company-wide programme that aims at world class performance through empowered employees.

[xviii] Ashok Leyland Ltd., Annual Report 2006-07, p. 12.

[xix] Ashok Leyland Ltd., Annual Report 2006-07, p. 15

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[xxv] This is reflected in the technology absorption statements contained in successive years' annual reports.

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[xxxviii] *Indian Foundry Journal*, Vol. 55, No. 8, August 2009, p. 95

[xxxix] Based on an interview with Prof. Pradip Dutta, December 24, 2010.

[xl] Flemings, M.C. "Behavior of Metal Alloys in the Semisolid State, Metallurgical Transactions A, Vol. 22A, 1991, pp. 957-981.

[xli] The information in this section is based on http://www.me.iitb.ac.in/~shashisn/ This site was last accessed on January 19, 2011.

[xlii] This section is based on an interview with Prof. Shashikanth Suryanarayanan on January 13, 2011.

[xliii] Based on information downloaded on January 16, 2011 from http://www.cpdm.iisc.ernet.in/about.php

[xliv] Based on an interview with Prof. B. Gurumoorthy, Professor, CPDM, IISc, Bangalore, on January 13, 2011.

[xlv] For more details, see Krishnan, Rishikesha T., *From Jugaad to Systematic Innovation: The Challenge for India*, Utpreraka Foundation, 2010,

[xlvi] These recommendations came from one of our interview respondents.