Chapter IV

Tata Motor’s Response to Technological Changes

Existing technologies in the industry, as well as technologies under development, always face the possibility of being pushed aside by alternative developments. In order to assess the productive and market potential of a given technology, its module must be analyzed in terms of the key technologies being used, current trends and future innovations. The chances and risks of a given technology are influenced by the different market structures, competitors’ strategies and their business models in each segment. Innovation cycles are constantly shortening while development costs are rising due to the higher complexity.\(^1\)

In the above context an attempt is made in this chapter to delineate the pattern of Tata Motor’s response to technological changes occurring in the automobile industry at the global level.

4.1 TECHNOLOGICAL INNOVATIONS IN THE AUTOMOBILE SECTOR

The study conducted by Hypovereinsbank & Mercer Management consulting group in 2008 identified number of leading technologies in the automobile sectors. Some of the technologies are discussed below.\(^2\)

The major innovations are DI engines, Anti-lock Braking System, Air bag, Continuously Variable Transmission (CVT), Hybrid vehicles,
Common rail direct fuel injection and Electric vehicles. These innovations are considered important because of the following reasons:

- In a garden-variety gasoline engine with fuel injection, gasoline takes a more round about route than it does with the direct injection method. This indirect approach causes all manner of inefficiencies in burning the fuel, and it can result in a lot of usable energy getting wasted -- and we are not getting the most for the money that we spent at the pump. In a direct injection engine, however, the fuel skips the waiting period it would have to endure inside a standard engine and instead proceeds straight to the combustion chamber. This allows the fuel to burn more evenly and thoroughly. For the driver, that can translate to better mileage and greater power to the wheels. Thus DI engine is found to be more effective.  

- In an emergency braking situation the braking force created by the driver may be greater than the tyre can handle: the wheel locks. The tyre can no longer transfer any lateral traction forces. The vehicle becomes unstable and unsteerable. The stopping distance increases. In a vehicle equipped with an Antilock Braking System, the ABS control unit constantly evaluates the speed of all wheels. If the ABS wheel-speed sensors placed at each wheel detect a lock-up, ABS intervenes within milliseconds by modulating the braking pressure at each individual wheel. In this way ABS prevents the wheels from locking during braking, thus ensuring steerability and stability combined with the shortest possible braking distance. ABS also prevents tyre
Locked wheels on dry asphalt can create flat spots. The tyres can then no longer ensure optimal braking.

- Cars consist of several objects, including the vehicle itself, loose objects in the car and, of course, passengers. If these objects are not restrained, they will continue moving at whatever speed the car is traveling at, even if the car is stopped by a collision. Stopping an object's momentum requires force acting over a period of time. When a car crashes, the force required to stop an object is very great because the car's momentum has changed instantly while the passengers' has not -- there is not much time to work with. The goal of any supplemental restraint system is to help stop the passenger while doing as little damage to him or her as possible. What an airbag wants to do is to slow the passenger's speed to zero with little or no damage. The constraints that it has to work within are huge. The airbag has the space between the passenger and the steering wheel or dashboard and a fraction of a second to work with. Even that tiny amount of space and time is valuable, however, if the system can slow the passenger evenly rather than forcing an abrupt halt to his or her motion.

- Unlike traditional automatic transmissions, continuously variable transmissions don't have a gearbox with a set number of gears, which means they don't have interlocking toothed wheels. The most common type of CVT operates on an ingenious pulley system that allows an infinite variability between highest and lowest gears with no discrete steps or shifts. A continuously
variable transmission (CVT) is a transmission which can change steplessly through an infinite number of effective gear ratios between maximum and minimum values.6

- There is great demand for Hybrid vehicles. The reason is twofold: to reduce tailpipe emissions and to improve mileage. Hybrid vehicle uses two or more distinct power sources to move the vehicle. The term most commonly refers to hybrid electric vehicles (HEVs), which combine an internal combustion engine and one or more electric motors.7

- The common rail system of fuel injection is a simple and more efficient system even. Recent trend in the automobile industry is the usage of common rail direct fuel injection systems in some modern vehicles. Some of the engines in the automobile sector introduce this common rail system of injection not only in diesel engines but also in petrol/gasoline engines. Common rail engines require no heating up time and produce lower engine noise and emissions than older systems.8

- Electric cars are something that show up in the news all the time. There are several reasons for the continuing interest in these vehicles: a) Electric cars create less pollution than gasoline-powered cars, so they are an environmentally friendly alternative to gasoline-powered vehicles (especially in cities), b) any news story about hybrid cars usually talks about electric cars as well, c) vehicles powered by fuel cells are electric cars, and fuel cells are getting a lot of attention right now in the news.9
In what follows, we present a brief overview of the aforesaid technologies:

a. DI engine

In internal combustion engines, gasoline direct injection is a variant of fuel injection employed in modern two- and four-stroke petrol engines. The petrol/gasoline is highly pressurized, and injected via a common rail fuel line directly into the combustion chamber of each cylinder, as opposed to conventional multi-point fuel injection that happens in the intake tract, or cylinder port (Lenz 1999: 55-67).

In some applications, gasoline direct injection enables a stratified fuel charge (ultra lean burn) combustion for improved fuel efficiency, and reduced emission levels at low load.

The first use of direct gasoline injection was on the Hesselman engine invented by Swedish engineer Jonas Hesselman in 1925. Hesselman engines used the ultra lean burn principle and injected the fuel in the end of the compression stroke and then ignited it with a spark plug, it was often started on gasoline and then switched over to run on diesel or kerosene. The hesselman engine was a low compression design constructed to run on heavy fuel oils (Heck 1995: 156-167).

Direct gasoline injection was used on production aircraft during WWII, with both German (Daimler Benz) and Soviet (KB Khimavtomatika) designs. The first automotive direct injection system used to run on gasoline was developed by Bosch, and was introduced by Goliath and
Gutbrod in 1952. The 1955 Mercedes-Benz 300SL, the first sports car to use fuel injection,[citation needed] used direct injection (Challen 1999: 98-105). The Bosch fuel injectors were placed into the bores on the cylinder wall used by the spark plugs in other Mercedes-Benz six-cylinder engines (the spark plugs were relocated to the cylinder head). Later, more mainstream applications of fuel injection favored less expensive indirect injection methods.

During the late 1970s, the Ford Motor Company developed a stratified-charge engine they called "Pro Co" (programmed combustion),\textsuperscript{10} utilizing a unique high pressure pump and direct injectors. One hundred Crown Victoria cars were built at Ford's Atlanta Assembly in Hapeville, Georgia utilizing a ProCo V8 engine. The project was canceled for several reasons: electronic controls, a key element, were in their infancy; pump and injector costs were extremely high; and lean combustion produced nitrogen oxides in excess of near future United States Environmental Protection Agency (EPA) limits (Blair 1999: 77-79). Also, the three way catalytic converter was proven to be a more cost effective solution.

b. ABS

An anti-lock braking system, or ABS is a safety system which prevents the wheels on a motor vehicle from locking up (or ceasing to rotate) while braking. A rotating road wheel allows the driver to maintain steering control under heavy braking by preventing a skid and allowing the wheel to continue interacting tractively with the road surface as directed by driver steering inputs (Agagino 1996: 46-50).
While ABS offers improved vehicle control, and may decrease stopping distances on dry and especially slippery surfaces, it can also increase braking distance on loose surfaces such as snow and gravel.

Since initial widespread use in production cars, anti-lock braking systems have evolved considerably. Recent versions not only prevent wheel lock under braking, but also electronically control the front-to-rear brake bias (Pomerlau 1996: 77-84). This function, depending on its specific capabilities and implementation, is known as electronic brake force distribution (EBD), traction control system, emergency brake assist, or electronic stability control.

Anti-lock braking systems were first developed for aircraft in 1929, by the French automobile and aircraft pioneer, Gabriel Voisin, as threshold braking an airplane is nearly impossible. An early system was Dunlop's Maxaret system, introduced in the 1950s and still in use on some aircraft models.

Chrysler, together with the Bendix Corporation, introduced a true computerized three-channel all-wheel anti-lock brake system called "Sure Brake" on the 1971 Imperial. It was available for several years thereafter, functioned as intended, and proved reliable. General Motors introduced the "Trackmaster" rear-wheel (only) ABS as an option on their Rear-wheel drive Cadillac models in 1971.

In 1975, Robert Bosch took over a European company called Teldix (contraction of Telefunken and Bendix) and all patents registered by this joint-venture and used this acquisition to build the base of the ABS system introduced on the market some years later. The German firms,
Bosch and Mercedes-Benz, had been co-developing anti-lock braking technology since the early 1970s, and introduced the first completely electronic 4-wheel multi-channel ABS system in trucks and the Mercedes-Benz S-Class in 1978 (Shiller 1995: 77-87). The Honda NSX was the first mass produced automobile with the modern 4-channel ABS system sold in the United States and Japan, it applies individual brake pressure to each of the four wheels. ABS is offered, or comes standard, on most road vehicles produced today and is the foundation for ESC systems, which are also rapidly increasing in popularity.

A typical ABS is composed of a central electronic control unit (ECU), four wheel speed sensors — one for each wheel — and two or more hydraulic valves within the brake hydraulics. The ECU constantly monitors the rotational speed of each wheel, and when it detects a wheel rotating significantly slower than the others — a condition indicative of impending wheel lock — it actuates the valves to reduce hydraulic pressure to the brake at the affected wheel, thus reducing the braking force on that wheel. The wheel then turns faster; when the ECU detects it is turning significantly faster than the others, brake hydraulic pressure to the wheel is increased so the braking force is reapplied and the wheel slows. This process is repeated continuously, and can be detected by the driver via brake pedal pulsation (Singer 1995: 83-89). A typical anti-lock system can apply and release braking pressure up to 20 times a second.

The ECU is programmed to disregard differences in wheel rotative speed below a critical threshold, because when the car is turning, the
two wheels towards the center of the curve turn slower than the outer two. For this same reason, a differential is used in virtually all road going vehicles (Spooner 1995: 35-67). If a fault develops in any part of the ABS, a warning light will usually be illuminated on the vehicle instrument panel, and the ABS will be disabled until the fault is rectified.

c. Airbag

An airbag is a vehicle safety device. It is an occupant restraint consisting of a flexible envelope designed to inflate rapidly in an automobile collision, to prevent vehicle occupants from striking interior objects such as the steering wheel or window (Chee 1995: 77-90).

An American inventor, John W. Hetrick, a retired industrial engineer, designed the original safety cushion for automotive use in 1952 at his kitchen table. His patent lasted only 17 years - long before mainstream automotive usage (Kachroo 1995: 111-120). Dr. David S. Breed, invented and developed a key component for automotive use: the ball-in-tube inertial sensor for crash detection. Breed Corporation then marketed this innovation first in 1967 to Chrysler. A similar "AutoCeptor" crash-restraint, developed by Eaton, Yale & Towne Inc. for Ford was soon offered as an automatic safety system in the USA, while the Italian Eaton-Livia company offered a variant with localized air cushions.

Airbags for passenger cars were introduced in the United States in the mid-1970s, when seat belt usage rates in the country were quite
Ford built an experimental fleet of cars with airbags in 1971, followed by General Motors in 1973 on Chevrolet vehicles. The early fleet of experimental GM vehicles equipped with airbags experienced seven fatalities, one of which was later suspected to have been caused by the airbag.\textsuperscript{16}

In 1974, GM made the ACRS or "Air Cushion Restraint System" available as a regular production option (RPO code AR3) in some full-size Buick, Cadillac and Oldsmobile models. The GM cars from the 1970s equipped with ACRS have a driver side airbag, a driver side knee restraint (which consists of a padded lower dashboard) and a passenger side airbag. The passenger side airbag protects both front passengers and unlike most new ones, it integrates a knee cushion, a torso cushion and it also has dual stage deployment which varies depending on the force of the impact (Eskafi 1995: 1167-1181). The cars equipped with ACRS have lap belts for all seating positions but they do not have shoulder belts. These were already mandatory equipment in the United Stated on closed cars without airbags for the driver and outer front passenger seating positions.

The automotive industry's first passenger side knee airbag was already used on the 1970s General Motors cars; it was integrated in the passenger airbag that had a knee cushion and a torso cushion. The development of airbags coincided with an international interest in automobile safety legislation. Some safety experts advocated a performance-based occupant protection standard rather than a standard mandating a particular technical solution, which could rapidly become outdated and might not be a cost-effective approach.
As countries successively mandated seat belt restraints, there was less emphasis placed on other designs for several decades.

Manufacturers emphasize that an airbag is not, and can not be an alternative to seatbelts. They emphasize that they are only supplemental to a seatbelt. Hence came the commonly used term "Supplemental Restraint System" or SRS. It is vitally important that drivers and passengers are aware of this. In the majority of cases of death caused by air bags, seat belts were not worn (Rault 1995: 99-105).

Various manufacturers have over time used different terms for airbags. General Motors' first bags, in the 1970s, were marketed as the Air Cushion Restraint System. Common terms in North America include Supplemental Restraint System (SRS) and Supplemental Inflatable Restraint (SIR); these terms reflect the airbag system's nominal role as a supplement to active restraints, i.e., seat belts. 2007 Tata Motors introduced airbags in its vehicles (Annual Report Tata Motors 2007-2008: 56).

d. Continuously variable transmission (CVT)

A continuously variable transmission (CVT) is a transmission which can change steplessly through an infinite number of effective gear ratios between maximum and minimum values. This contrasts with other mechanical transmissions that only allow a few different distinct gear ratios to be selected. The flexibility of a CVT allows the driving shaft to maintain a constant angular velocity over a range of output velocities. This can provide better fuel economy than other
transmissions by enabling the engine to run at its most efficient revolutions per minute (RPM) for a range of vehicle speeds (Bloomfield 1996: 36-39).17

Leonardo da Vinci, in 1490, conceptualized a stepless continuously variable transmission. The first patent for a toroidal CVT was filed in Europe in 1886, and a US Patent for one was granted in 1935. In 1910 Zenith Motorcycles built a V2-Motorcycle with the Gradua-Gear which was a CVT. This Zenith-Gradua was so successful in hillclimb events, that it was eventually barred, so that other manufacturers had a chance to win. 1912 the British motorcycle manufacturer Rudge-Whitworth built the Rudge Multigear.18 The Multi was a much improved version of Zenith's Gradua-Gear. The Rudge Multi was so successful that CVT-gears were eventually barred at the famous Tourist Trophy race (which was the world's most important motorcycle race before the Great War) from 1913 on (Chee 1995: 46-49).19

In the summer of 1987 the Ford Fiesta and Fiat Uno became the first mainstream European cars to be equipped with steel-belted CVT (as opposed to the less robust rubber-belted DAF design). This CVT, the Ford CTX was developed by Ford, Van Doorne, and Fiat, with work on the transmission starting in 1976 (Deshpande 1996: 88-92).

The 1992 Nissan March contained Nissan's N-CVT based on the Fuji Heavy Industries ECVT.20 After studying pulley-based CVT for years, Honda also introduced their own version on the 1995 Honda Civic VTi. Dubbed Honda Multi Matic, this CVT gearbox accepted higher torque than traditional pulley CVTs, and also includes a torque converter for
"creep" action. Toyota used a Power Split Transmission (PST) in the 1997 Prius, and all subsequent Toyota and Lexus hybrids sold internationally continue to use the system (marketed under the Hybrid Synergy Drive name). Although sold as a ECVT it is in fact not such a device as the gear ratios are fixed. Audi has, since 2000, offered a chain-type CVT as an option on some of its larger-engine models, for example the A4 3.0 L V6. Fiat in 2000 offered a Cone-type CVT as an option on its hit model Fiat Punto (16v 80 PS ELX, Sporting). Ford introduced a chain-driven CVT known as the CFT30 in their 2005 Ford Freestyle, Ford Five Hundred and Mercury Montego. The transmission was designed in cooperation with German automotive supplier ZF Friedrichshafen and was produced in Batavia, Ohio at Batavia Transmissions LLC (a subsidiary of Ford Motor Company) until March 22, 2007. The 2007 Dodge Caliber and the related Jeep Compass and Jeep Patriot employ a CVT using a variable pulley system as their optional automatic transmission. The 2008 Mitsubishi Lancer model is available with CVT transmission as the automatic transmission. DE and ES models receive a standard CVT with Drive and Low gears; the GTS model is equipped with a standard Drive and also a Sportronic mode that allows the driver to use 6 different preset gear ratios (either with the shifter or steering wheel-mounted paddle shifters) (Eskafi 1995:1121-1130).

e. Hybrid vehicles

A hybrid vehicle is a vehicle that uses two or more distinct power sources to move the vehicle. The term most commonly refers to hybrid
electric vehicles (HEVs), which combine an internal combustion engine and one or more electric motors (Amann 1998: 85-89).

**Two-wheeled and cycle-type vehicles**

Mopeds and electric bicycles are a simple form of a hybrid, as power is delivered both via an internal combustion engine or electric motor and the rider's muscles. Early prototypes of motorcycles in the late 1800s used the same principles.

In a parallel hybrid bicycle human and motor power are mechanically coupled at the pedal drive train or at the rear or the front wheel, e.g. using a hub motor, a roller pressing onto a tire, or a connection to a wheel using a transmission element. Human and motor torques is added together. Almost all manufactured models are of this type (Berta 1993: 99-105).

In a series hybrid bicycle (SH) the user powers a generator using the pedals. This is converted into electricity and can be fed directly to the motor giving a chainless bicycle but also to charge a battery. The motor draws power from the battery and must be able to deliver the full mechanical torque required because none is available from the pedals. SH bicycles are commercially available, because they are very simple in theory and manufacturing (Charles 1997: 77-89).

**Heavy vehicles**

Hybrid power trains are used for diesel-electric or turbo-electric railway locomotives, buses, heavy goods vehicles, mobile hydraulic machinery, and ships. Typically some form of heat engine (usually diesel) drives an electric generator or hydraulic pump.
which powers one or more electric or hydraulic motors. There are advantages in distributing power through wires or pipes rather than mechanical elements especially when multiple drives—e.g. driven wheels or propellers—are required. There is power lost in the double conversion from typically diesel fuel to electricity to power an electric or hydraulic motor. With large vehicles the advantages often outweigh the disadvantages especially as the conversion losses typically decrease with size. With the exception of non nuclear submarines, presently there is no or relatively little energy storage capacity on most heavy vehicles, e.g. auxiliary batteries and hydraulic accumulators—this is changing (Braess 1995: 1004-1023).

Parallel hybrid systems, which are most commonly produced at present, have both an internal combustion engine (ICE) and an electric motor connected to a mechanical transmission. Most designs combine a large electrical generator and a motor into one unit, often located between the combustion engine and the transmission, replacing both the conventional starter motor and the alternator. Series hybrid vehicles are more like a battery electric vehicle in design than an internal combustion vehicle or parallel hybrid. In a series hybrid system, the combustion engine drives an electric generator instead of directly driving the wheels. The generator both charges a battery and powers an electric motor that moves the vehicle. When large amounts of power are required, the motor draws electricity from both the batteries and the generator (Khovakh 2005: 201-212).
In 1997 Toyota released the first series hybrid bus sold in Japan. BYD Auto's F3DM sedan is the world's first mass-produced series hybrid automobile, which went on sale in China on December 15, 2008.

Power-split hybrids or series-parallel hybrids are parallel hybrids. They incorporate power-split devices allowing for power paths from the engine to the wheels that can be either mechanical or electrical. The main principle behind this system is the decoupling of the power supplied by the engine (or other primary source) from the power demanded by the driver. General Motors, BMW, and DaimlerChrysler have developed in collaboration a system named "Two-Mode Hybrid" as part of the Global Hybrid Cooperation. The technology was released in the fall of 2007 on the Chevrolet Tahoe Hybrid (Blackmore 2006: 45-49). The system was also featured on the GMC Graphite SUV concept vehicle at the 2005 North American International Auto Show in Detroit.

A full hybrid, sometimes also called a strong hybrid, is a vehicle that can run on just the engine, just the batteries, or a combination of both. The Toyota Prius, Ford Escape, and Mercury Mariner Hybrids are examples of this, as these cars can be moved forward on battery power alone. General Motors followed the pickup truck hybrid with their BAS Hybrid system, used in the 2007 Saturn Vue Green Line.

f. Common rail direct fuel injection

Common rail direct fuel injection is a modern variant of direct fuel injection system for petrol and diesel engines. On diesel engines, it features a high-pressure (over 1,000 bar/15,000 psi) fuel rail feeding
individual solenoid valves, as opposed to low-pressure fuel pump feeding unit injectors (Pump nozzles). Third-generation common rail diesels now feature piezoelectric injectors for increased precision, with fuel pressures up to 1,800 bar/26,000 psi.

In gasoline engines, it is utilized in gasoline direct injection engine technology (Kiencke 2000: 67-75). The common rail system prototype was developed in the late 1960s by Robert Huber of Switzerland and the technology further developed by Dr. Marco Ganser at the Swiss Federal Institute of Technology in Zurich, later of Ganser-Hydromag AG (est. 1995) in Oberageri.

The first successful usage in production vehicle began in Japan by the mid-1990s (Powers 2000: 75-78). Dr. Shohei Itoh and Masahiko Miyaki of the Denso Corporation, a Japanese automotive parts manufacturer, developed the common rail fuel system for heavy duty vehicles and turned it into practical use on their ECD-U2 common-rail system mounted on the Hino Rising Ranger truck and sold for general use in 1995. Denso claims the first commercial high pressure common rail system in 1995.

Modern common rail systems, whilst working on the same principle, are governed by an engine control unit (ECU) which opens each injector electronically rather than mechanically. This was extensively prototyped in the 1990s with collaboration between Magneti Marelli, Centro Ricerche Fiat and Elasis (Craig 1997: 3214-3219). After research and development by the Fiat Group, the design was acquired by the German company Robert Bosch GmbH for completion of development and refinement for mass-production. In hindsight the
sale appeared to be a tactical error for Fiat as the new technology proved to be highly profitable. The company had little choice but to sell, however, as it was in a poor financial state at the time and lacked the resources to complete development on its own. In 1997 they extended its use for passenger cars (Baba 1985: 55-58). The first passenger car that used the common rail system was the 1997 model Alfa Romeo 156 1.9 JTD, and later on that same year Mercedes-Benz C 220 CDI.

Common rail engines have been used in marine and locomotive applications for some time. The Cooper-Bessemer GN-8 (circa 1942) is an example of a hydraulically operated common rail diesel engine, also known as a modified common rail.

Vickers used common rail systems in submarine engines circa 1916. Doxford Engines Ltd. (opposed piston heavy marine engines) used a common rail system (from 1921 to 1980) whereby a multi-cylinder reciprocating fuel pump generated a pressure of approximately 600bar with the fuel being stored in accumulator bottles. Pressure control was achieved by means of an adjustable pump discharge stroke and a "spill valve" (Furakawa 1992: 77-87). Camshaft operated mechanical timing valves were used to supply the spring loaded Brice/CAV/Lucas injectors which injected through the side of the cylinder into the chamber formed between the pistons. Early engines had a pair of timing cams, one for ahead running and one for astern. Later engines had two injectors per cylinder and the final series of constant pressure turbocharged engines were fitted with four injectors per cylinder. This
The common rail system is suitable for all types of road cars with diesel engines, ranging from city cars such as the Fiat Nuova Panda to executive cars such as the Volvo S80.

Common rail engines require no heating up time and produce lower engine noise and emissions than older systems.

Diesel engines have historically used various forms of fuel injection. Two common types include the unit injection system and the distributor/inline pump systems. While these older systems provided accurate fuel quantity and injection timing control they were limited by several factors: They were cam driven and injection pressure was proportional to engine speed. This typically meant that the highest injection pressure could only be achieved at the highest engine speed and the maximum achievable injection pressure decreased as engine speed decreased. This relationship is true with all pumps, even those used on common rail systems; with the unit or distributor systems, however, the injection pressure is tied to the instantaneous pressure of a single pumping event with no accumulator and thus the relationship is more prominent and troublesome (Kachroo 1995: 66-78).

They were limited on the number of and timing of injection events that could be commanded during a single combustion event. While multiple injection events are possible with these older systems, it is much more difficult and costly to achieve.
For the typical distributor/inline system the start of injection occurred at a pre-determined pressure (often referred to as: pop pressure) and ended at a pre-determined pressure. This characteristic results from "dummy" injectors in the cylinder head which opened and closed at pressures determined by the spring preload applied to the plunger in the injector. Once the pressure in the injector reached a pre-determined level, the plunger would lift and injection would start.

In common rail systems, a high pressure pump stores a reservoir of fuel at high pressure — up to and above 2,000 bars (29,000 psi). The term "common rail" refers to the fact that all of the fuel injectors are supplied by a common fuel rail which is nothing more than a pressure accumulator where the fuel is stored at high pressure. This accumulator supplies multiple fuel injectors with high pressure fuel. This simplifies the purpose of the high pressure pump in that it only has to maintain a commanded pressure at a target (either mechanically or electronically controlled). The fuel injectors are typically ECU-controlled. When the fuel injectors are electrically activated a hydraulic valve (consisting of a nozzle and plunger) is mechanically or hydraulically opened and fuel is sprayed into the cylinders at the desired pressure. Since the fuel pressure energy is stored remotely and the injectors are electrically actuated the injection pressure at the start and end of injection is very near the pressure in the accumulator (rail), thus producing a square injection rate. If the accumulator, pump, and plumbing are sized properly, the injection pressure and rate will be the same for each of the multiple injection events (Puri 1995: 46-49).
g. Electric vehicle:

An electric vehicle (EV), also referred to as an electric drive vehicle, is a vehicle which uses one or more electric motors for propulsion. Depending on the type of vehicle, motion may be provided by wheels or propellers driven by rotary motors, or in the case of tracked vehicles, by linear motors. Electric vehicles can include electric cars, electric trains, electric lorries, electric airplanes, electric boats, electric motorcycles and scooters, and electric spacecraft.

Electric vehicles are different from fossil fuel-powered vehicles in that they can receive their power from a wide range of sources, including fossil fuels, nuclear power, and renewable sources such as tidal power, solar power, and wind power or any combination of those. However it is generated, this energy is then transmitted to the vehicle through use of overhead lines, wireless energy transfer, or a direct connection through an electrical cable. The electricity may then be stored onboard the vehicle using a battery, flywheel, super capacitor, or fuel cell. Vehicles making use of engines working on the principle of combustion can usually only derive their energy from a single or a few sources, usually non-renewable fossil fuels. A key advantage of electric or hybrid electric vehicles is their ability to recover braking energy as electricity to be restored to the on-board battery (regenerative braking) or sent back to the grid (V2G). At the beginning of the 21st century, increased concern over the environmental impact of the petroleum-based transportation infrastructure, along with the spectre of peak oil, led to renewed interest in an electric transportation infrastructure. As such, vehicles which can potentially be powered by
renewable energy sources, such as hybrid electric vehicles or pure electric vehicles, are becoming more popular. Chrysler, Ford, GM, Honda, Nissan and Toyota, in 2003 launched the electric vehicles. In Tata Motors electric vehicles came in 2009.

4.2 TATA MOTOR'S RESPONSE TO THE TECHNOLOGICAL CHANGES

The pattern of Tata Motor's response to the technological changes occurring in the automobile industry at the global level is analyzed below on a case by case basis:

CASE - I: DI Engine

The company's Engineering Research Centre played a vital role in safeguarding the long term interest of the company. In the light of the world wide diesel scarcity during 1970s, maximum attention is being given by the Research centre to improve fuel efficiency of the engines fitted on the products. Thus in 1971 Tata Motors introduces DI engine with foreign technical collaboration.24

CASE- II: Anti lock Braking System (ABS)

The ABS is a four-wheel system that prevents wheel lock-up by automatically modulating the brake pressure during an emergency stop. By preventing the wheels from locking, it enables the driver to maintain steering control and to stop in the shortest possible distance under most conditions. In 1970 ABS is introduced in the Automobile Industry, the same has been introduced in Tata Motors through foreign technical collaboration with Autoliv in 2002. 25
CASE- III: Air Bag

An airbag is a vehicle safety device. It is an occupant restraint consisting of a flexible envelope designed to inflate rapidly in an automobile collision, to prevent vehicle occupants from striking interior objects such as the steering wheel or window. In Tata Motors the instruction of air bag took place through foreign technical collaboration with Bosch and partly in-house effort of Tata Auto Component system in 2001. 26

CASE- IV: Continuously Variable Transmission

The job of the transmission is to change the speed ratio between the engine and the wheels of an automobile. In other words, without a transmission, cars would only have one gear -- the gear that would allow the car to travel at the desired top speed. Imagine for a moment driving a car that only had first gear or a car that only had third gear. In Jan 1st, 2007, Tata Motors has entered into a License Agreement with Torotrak, to apply Torotrak's full-toroidal traction drive technology to a wide range of Tata Motors' products. The license covers use of the Torotrak technology in four fields of application (passenger cars, light commercial vehicles, medium & heavy commercial vehicles, and construction equipment) and also allows Tata Motors to manufacture and sell transmissions to other customers of Torotrak in the Indian market. Torotrak is a world leader in full-toroidal traction-drive transmission technology, focused on the development of IVT (Infinitely Variable Transmission) and TCVT (Toroidal Continuously Variable Transmission) systems which deliver outstanding levels of
performance, functionality and commercial advantage in automotive, truck, bus, outdoor power equipment, agricultural, off-highway and ancillary drive applications.

CASE- V: CRDi

Tata Motor has entered the CRDi segment in 2003 where a number of competitors have launched vehicles. It launched the DiCOR first in Safari. A 2.2-litre DiCOR engine on the Safari, the company at that time has not planned to completely shift to the DiCOR engines at one go but decided to offer customers the existing diesel engine and shift to DiCOR technology only in a two-year window. The DiCOR engines are at least 40 per cent more powerful than the conventional diesel engine.

Thus, Tata Motors indigenously developed 3-litre, direct injection common rail diesel engine on the Safari Dicor delivers 115PS at 3000 rpm with a torque of 300 Nm at 1600-2000 rpm. The engineers have designed the head cylinder to incorporate the delphi multec 1600 common-rail system. This system is integrated with a 32-bit microprocessor, which electronically monitors and controls pressure at the time of fuel injection into the engine, ensuring a highly receptive and powerful performance and enhanced fuel efficiency. The safari has been entirely developed on CAD/CAM giving it extra features like accuracy and better control. The new Safari DICOR has greatly improved in terms of quality and finish, compared to 1998 safari.28

CASE- VI: Hybrid & Electric vehicles

October 14th, 2008 Tata Motors’ UK subsidiary, Tata Motors European Technical Centre plc, has acquired a 50.3% holding, at an acquisition
cost of Kroner 12 million (Rs.9.40 crores), in Miljo Grenland/Innovasjon, Norway, which specializes in the development of innovative solutions for Hybrid and electric vehicles.  

4.3. TIME LAG IN ADOPTION OF NEW TECHNOLOGY

To assess the degree of proactiveness in Tata Motors response to technological changes an attempt was made to measure the lag between the times of launching of the product/process as described above at the global level and the times of its launching in Tata Motors in India. The time lag in the different cases are shown in Table 4.1

Table 4.1: Time Lag in Tata Motors response to global technological changes

<table>
<thead>
<tr>
<th>Major Technological Innovations in the Automotive Sector</th>
<th>Year of Launching of New Product/Process at Global Level</th>
<th>Year of Launching of the Product/Process by Tata Motors</th>
<th>Time Lag In Years (Col 3 - Col 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DI engine</td>
<td>1955</td>
<td>1971</td>
<td>16</td>
</tr>
<tr>
<td>2. ABS (Anti lock braking system)</td>
<td>1970</td>
<td>2002</td>
<td>22</td>
</tr>
<tr>
<td>3. Airbag</td>
<td>1970</td>
<td>2001</td>
<td>21</td>
</tr>
<tr>
<td>4. Continuously variable transmission (CVT)</td>
<td>1987</td>
<td>2007</td>
<td>20</td>
</tr>
<tr>
<td>5. Hybrid Technology</td>
<td>1997</td>
<td>2007</td>
<td>10</td>
</tr>
</tbody>
</table>


Table 4.1 shows the different innovations in the automobile industry and the time lag in adoption of the technology in Tata Motors. The DI engine that was introduced in the automobile industry in 1955, and Tata Motors adopted it in 1971, thus a time lag of 16 years is found here. The technology Anti lock braking system (ABS) which was
introduced in the year 1970 and the same has been adopted in Tata Motors on 2002. Therefore there is a time lag of 22 years in ABS. Air bag was introduced in the year 1970 in automobile industry, same has been adopted in Tata Motors in 2001. In this case the time lag is 21 years. The innovation Continuous variable transmission (CVT) innovations in automobile industry came in 1987, the same has been adopted in Tata Motors in 2007, thus there is a time lag of 20 years. Hybrid technology which has been introduced in the automobile field in 1997, has been adopted in Tata Motors in 2007, there by a time lag of 10 years. Common rail direct fuel injection (CRDFi) has been introduced in automobile field in 1997, the same has been introduced in Tata Motors in 2008, thus a time lag of 6 years is noted here. And lastly electric vehicles introduced in automobile industry in 2003, but the adoption in Tata Motors in 2009, there is a time lag of 6 years.

Table 4.1 shows clearly how over time the time lag in adoption of the technology in Tata Motors has been coming down. This may be taken as suggestive of the progressively higher degree of proactiveness in Tata Motor's response to technological changes and also of the company's growing in-house technological capabilities that made faster adoption possible.

4.4 MODE OF BRIDGING THE TECHNOLOGY GAP

Every single innovation leads to the creation of a gap between the innovating firm (normally base in a developed country) and others, in that the innovator of the given product or process takes a lead over others and enjoys for the time being a monopoly advantage. For ensuring their survival, the other firms in the industry then start
making desperate bids for bridging the technology gap. The common modes adopted for the purpose are outright purchase of the technology, purely technological collaboration or technological-cum-financial collaboration with the technology owning firm. Alternatively, a firm may also by using the strength of its R & D wing go for parallel innovation, imitation or even development of superior products or processes. Which mode would ultimately be adopted is a strategic decision and is governed by such factors as the complexities of the technology in question, its ready availability in the technology market and the status of development of the company’s in-house technological capabilities.

Table 4.II shows the mode adopted by Tata Motors in case of the seven selected products/processes for bridging the technology gap:

<table>
<thead>
<tr>
<th>Major Technological Innovations in the Automotive Sector</th>
<th>Company which First Launched the Product/Process &amp; the Year of Launching</th>
<th>Mode Through which Tata Motors Bridged the Technology Gap</th>
<th>Commercial Production of the Product/Process Started In Tata Motors in Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DI engine</td>
<td>Bosch, 1970</td>
<td>FTC</td>
<td>1971</td>
</tr>
<tr>
<td>2. ABS (Anti lock braking system)</td>
<td>Bosch and Mercedes-Benz, 1970</td>
<td>FTC</td>
<td>2002</td>
</tr>
<tr>
<td>3. Airbag</td>
<td>General Motors, 1970</td>
<td>In-house development + FTC</td>
<td>2001</td>
</tr>
<tr>
<td>5. Hybrid Technology</td>
<td>Toyota, 1997</td>
<td>In-house development + FTC</td>
<td>2007</td>
</tr>
<tr>
<td></td>
<td>Chrysler, Ford, GM, Toyota, 2003</td>
<td>In-house development + FTC</td>
<td>2009</td>
</tr>
<tr>
<td>7. Electric Vehicle</td>
<td>Honda, Nissan and Toyota, 2003</td>
<td>In-house development + FTC</td>
<td></td>
</tr>
</tbody>
</table>

FTC means Foreign Technical Collaboration

Source: 1. Annual Reports Tata Motors (various years),
For DI engine, Tata Motors had gone for the mode of Foreign Technical Collaboration in order to bridge the gap. Also for Anti lock braking system Tata Motors had gone for the mode of Foreign Technical Collaboration in order to bridge the gap. While for Airbag, Continuously variable transmission (CVT), Hybrid technology and electric vehicles it opted for a combination of Foreign technical collaboration and In-house development to bridge the technology gap. In case of Common rail direct fuel injection Tata Motors depended solely on in-house development.

From Table 4.II it is clear that although initially Tata Motors was depending primarily on foreign technical collaborations for acquiring its needed technology, progressively its reliance on external sources came down and the company was depending either wholly or in part on its in-house R & D wing for bridging technology gap. The outcome of this strategic stance of Tata Motors' management of putting emphasis on developing in-house technical capabilities is borne out clearly by its growing reliance on in-house sources in the matter of acquisition of new technology.

4.5 PRODUCTS/ PROCESSES FOR WHICH TECHNOLOGY WAS ACQUIRED FROM EXTERNAL SOURCES

In order to get an even clearer idea about the strategic aspects of management of technological change, the particular products or processes for which technology was acquired by Tata Motors from external sources was carefully examined. The details on this are presented in Table 4.III:
<table>
<thead>
<tr>
<th>Product / Process Technology Acquired</th>
<th>Collaborating Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Manufacture of automotive aluminum casting.</td>
<td>KSM, Germany</td>
</tr>
<tr>
<td>3. Manufacture of ‘EX’ series of hydraulic excavators.</td>
<td>Hitachi, Japan</td>
</tr>
<tr>
<td>4. Improvement in performance of diesel engines for lighter range of vehicles and conversion to a petrol version.</td>
<td>AVL List GmbH, Austria</td>
</tr>
<tr>
<td>5. Spot &amp; arc welding robots.</td>
<td>Nachi-FujiKoshi Corporation, Japan</td>
</tr>
<tr>
<td>7. Design &amp; Styling of body of a small, 5 door &quot;Hatchback&quot; passenger car.</td>
<td>Institute for development automatic engineers, SPA Italy.</td>
</tr>
<tr>
<td>8. Design and body styling of four wheel drive, five door passenger vehicle.</td>
<td>International Automotive Design, UK</td>
</tr>
<tr>
<td>9. CNC Cylindrical grinding machines.</td>
<td>Schaudt, Maschinenbau, GmbH, Germany</td>
</tr>
<tr>
<td>10. Application work on engine management system for petrol engine.</td>
<td>Robert Bosch, GmbH Germany</td>
</tr>
<tr>
<td>11. Design &amp; Styling of body of a small passenger car.</td>
<td>Institute for development automatic engineers, SPA Italy.</td>
</tr>
<tr>
<td>12. 60 tonne hydraulic excavator</td>
<td>Hitachi Construction Machinery Co. Japan</td>
</tr>
<tr>
<td>13. Back bone loader.</td>
<td>John Deere Industrial equipment Co, USA</td>
</tr>
<tr>
<td>14. Development of Diesel and Petrol engine for passenger car.</td>
<td>Le Moetier Moderne, France</td>
</tr>
<tr>
<td>15. Robots for welding, material handling, other application.</td>
<td>Nachi Fuji Koshi Corporation, Japan</td>
</tr>
<tr>
<td>16. Hydraulic Excavator</td>
<td>Hitachi Construction Machinery Co. Japan</td>
</tr>
<tr>
<td>17. Series V Hydraulic Excavator</td>
<td>Hitachi Construction Machinery Co. Japan</td>
</tr>
<tr>
<td>18. Design &amp; Styling of Sedan/ Estate variants of Passenger car Platform</td>
<td>Institute for development automatic engineers, SPA Italy.</td>
</tr>
<tr>
<td>19. Development of Diesel of modular cab for commercial vehicle</td>
<td>Stile Bertone, Italy</td>
</tr>
<tr>
<td>20. Design &amp; Development of passenger vehicles</td>
<td>Institute for development automatic engineers, SPA Italy.</td>
</tr>
<tr>
<td>21. Direct Injection common rail Euro IV engine for passenger vehicles</td>
<td>AVL List GmbH, Austria, Delphi Diesel system, France</td>
</tr>
<tr>
<td>22. Design &amp; development of crossover passenger vehicle.</td>
<td>Institute of Development in Automotive Engineering, SPA Italy</td>
</tr>
</tbody>
</table>


25. Design & Development of new generation engine for LCV/MCV

26. Design and Development of infinitely Variable Transmission based on Full Toroidal Traction- Drive Variators for various vehicle platforms.

27. Design & Development of “Flush Sliding window/ plug in window”

Source: Annual Reports Tata Motors (various years)

From Table 4.III, it is clear that instead of going for wholesale import of technology pertaining to the final product (car/vehicle in this case), Tata Motors was persistently following a policy of unbundling the technology-pack and then restricting technology-acquisition from external sources to only few crucial constituents of the whole technology-package. The specific segment, area or component for which technology would be procured from outside was being decided in each case after taking into consideration the viability or economy of developing the technology through in-house efforts.

4.6 MAJOR SOURCES OF TECHNOLOGY

A confirmation to our observation as cited in the preceding paragraph comes from Table 4.IV below which shows the major sources of new technology in Tata Motors:
Table 4.IV Major Sources of New Technology in Tata Motors

<table>
<thead>
<tr>
<th>Year Block (Decade)</th>
<th>Total Number of Product/Process Launches Reported in Annual Report</th>
<th>Technology Source</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In-House Development</td>
<td>Mainly In-House (Sourced Partly From Outside)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>1981-1990</td>
<td>7</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(100%)</td>
<td>(28.57%)</td>
<td>(0%)</td>
</tr>
<tr>
<td>1991-2000</td>
<td>30</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(100%)</td>
<td>(53.33%)</td>
<td>(3.33%)</td>
</tr>
<tr>
<td>2001-2009</td>
<td>56</td>
<td>45</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>(100%)</td>
<td>(80.36%)</td>
<td>(16.07%)</td>
</tr>
</tbody>
</table>

Figures in parentheses show percentage reliance on the different technology-sources for acquiring the product/process technology in the given year-block.

Source: Annual Reports Tata Motors (various years).

Thus from the above observation it is clear that in the year block 1981-1990 for product/process launch, Tata Motors In-house development effort was 28.57% and the effort of Foreign collaboration was 71.43%. Similarly for the year block 1991-2000 the In-house development effort was 53.33%, combination of in-house development and foreign collaboration is 3.33% where as the effort on foreign collaboration is 43.33%. Lastly in the year block 2001-2009 in house development effort was 80.36%, combination of in-house development and foreign collaboration was 16.07% and the effort of foreign collaboration is 3.57%. Thus there is a gradual shift in technology source towards the In-house development.

4.7 INDIGENISATION OF COMPONENTS

The progress achieved by a company in indigenization of components is conventionally taken as a measure of the outcome of the technology-management strategy pursued by the company. It also gives an idea of
the company priorities on which the focus of technology management strategy is placed.

Table 4.V may be considered in this connection:

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Components Used (Rs. Crore)</th>
<th>Components Imported (Rs. Crore)</th>
<th>Components Indigenously Procured (Rs. Crore)</th>
<th>Import as % of Total Components</th>
<th>Indigenous Procurement as % of Total Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-91</td>
<td>1253.53</td>
<td>126.71</td>
<td>1126.82</td>
<td>10.11</td>
<td>89.89</td>
</tr>
<tr>
<td>1991-92</td>
<td>1645.83</td>
<td>125.75</td>
<td>1520.08</td>
<td>7.64</td>
<td>92.36</td>
</tr>
<tr>
<td>1992-93</td>
<td>1700.35</td>
<td>144.59</td>
<td>1555.76</td>
<td>8.50</td>
<td>91.50</td>
</tr>
<tr>
<td>1993-94</td>
<td>1750.33</td>
<td>147.38</td>
<td>1602.95</td>
<td>8.42</td>
<td>91.58</td>
</tr>
<tr>
<td>1994-95</td>
<td>2945.9</td>
<td>191.10</td>
<td>2754.80</td>
<td>6.49</td>
<td>93.51</td>
</tr>
<tr>
<td>1995-96</td>
<td>4372.13</td>
<td>263.91</td>
<td>4108.22</td>
<td>6.04</td>
<td>93.96</td>
</tr>
<tr>
<td>1996-97</td>
<td>5445.83</td>
<td>285.36</td>
<td>5160.47</td>
<td>5.24</td>
<td>94.76</td>
</tr>
<tr>
<td>1997-98</td>
<td>3822.58</td>
<td>268.67</td>
<td>3553.91</td>
<td>7.03</td>
<td>92.97</td>
</tr>
<tr>
<td>1998-99</td>
<td>3420.5</td>
<td>226.85</td>
<td>3193.65</td>
<td>6.63</td>
<td>93.37</td>
</tr>
<tr>
<td>1999-00</td>
<td>4828.22</td>
<td>114.41</td>
<td>4713.81</td>
<td>2.37</td>
<td>97.63</td>
</tr>
<tr>
<td>2000-01</td>
<td>4470.95</td>
<td>113.37</td>
<td>4357.58</td>
<td>2.54</td>
<td>97.46</td>
</tr>
<tr>
<td>2001-02</td>
<td>4460.58</td>
<td>104.31</td>
<td>4356.27</td>
<td>2.34</td>
<td>97.66</td>
</tr>
<tr>
<td>2002-03</td>
<td>96.77</td>
<td>5339.81</td>
<td>5242.04</td>
<td>1.81</td>
<td>98.19</td>
</tr>
<tr>
<td>2003-04</td>
<td>191.95</td>
<td>7873.41</td>
<td>7681.46</td>
<td>2.44</td>
<td>97.56</td>
</tr>
<tr>
<td>2004-05</td>
<td>259.85</td>
<td>11260.25</td>
<td>11000.40</td>
<td>2.31</td>
<td>97.69</td>
</tr>
</tbody>
</table>

Source: Annual Reports Tata Motors (various years).

Out of total components procured in 1990-91, 89.89 per cent were procured from indigenous sources. This proportion steadily went up to reach the level of 97.63 per cent by the turn of the century and continued to remain at that level thereafter.
The progress in indigenization meant *pari passu* reduction of dependence on imported components which came down gradually a level of only 2.31 per cent by 2004-05.

The overall trends during the period from 1990-91 to 2004-2005 (cf., Table 4.V) indicate progressively higher reliance of Tata Motors on indigenous sources of procurement of components. As technology import from foreign sources often means perpetuation of dependence on imported parts and components, Tata Motor's success in indigenization of components indirectly indicate the focus as well as success of its technology strategy which throughout placed emphasis on development of in-house capability and indigenization.

4.8 PROGRESS OF IN-HOUSE DEVELOPMENT OF TECHNOLOGY

Patents are indicators of technological invention. Patent usually refers to a right granted to anyone who invents or discovers any new and useful process, machine, article of manufacture, or composition of matter, or any new and useful improvement thereof.

A patent is not a right to practice or use the invention. Rather, a patent provides the right to exclude others from making, using, selling, offering for sale, or importing the patented invention for the term of the patent, which is usually 20 years from the filing date subject to the payment of maintenance fees. A patent is, in effect, a limited property right that the government offers to inventors in exchange for their agreement to share the details of their inventions with the public. Like any other property right, it may be sold, licensed, mortgaged, assigned or transferred, given away, or simply abandoned.
A patent being an exclusionary right does not, however, necessarily give the owner of the patent the right to exploit the patent. Thus 'Patent' is an indicator of technological capability actually acquired / developed by an organization.

Table 4.6 below shows the number of patents applied for by Tata Motors and the numbers that it actually got registered against its name:

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Patents Applied For</th>
<th>Number of Patents Registered Against Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006-07</td>
<td>34</td>
<td>9</td>
</tr>
<tr>
<td>2007-08</td>
<td>175</td>
<td>11</td>
</tr>
<tr>
<td>2008-09</td>
<td>195</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: Annual Reports Tata Motors (various years).

While data pertaining to the earlier years were not available at the moment, Table 4.VI shows that in the year 2006-2007 Tata Motors applied for 34 numbers of patents and registered 9 patents. In 2007-2008 it applied for 175 numbers of patents and registered 11 patents. And in 2008-2009 it applied for 195 numbers of patents and got 6 patents registered against its own name. Thus, it is clear that number of patents applied for by Tata Motors had been increasing indicating thereby the growing strength of its in-house technological capability.

4.9 SUMMING UP THE CHAPTER

This chapter examined the pattern of responses of Tata Motors (India) Ltd. to the technological changes occurring in the automotive industry at the global level. Longitudinal analysis covering the period 1991-2009 showed that the response pattern had throughout been proactive.
The proactive response of Tata Motors was borne out by its

- success in reducing the time lag in launching new products,
- progressively greater reliance on in-house R & D rather than on foreign sources of supply for acquiring new product technology,
- growing ability to un-bundle technology-package and restrict acquisition from external sources to only few crucial constituents of the package,
- near-total indigenization of product parts and components,
- the progressively higher number of Patents registered against its name and, also, as mentioned earlier, the successful launching of a series of indigenously developed and designed commercial vehicle and passenger car models.
NOTES


29‘TMETC acquires 50.3% stake in Norway’s Miljo Grenland/ Innovaasjon. To launch first electric vehicle, Indica EV,’ Tata Motors Press Release, October 14, 2008.