



NANOTECHNOLOGY INNOVATIONS & BUSINESS ENVIRONMENT OF INDIAN AUTOMOBILE SECTOR: A FUTURISTIC APPROACH

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Abstract:

The Indian auto industry is one of the largest in the world with an annual production of 23.37 million vehicles in FY 2014-15, following a growth of 8.68 per cent over the last year. The automobile industry accounts for 7.1 per cent of the country's gross domestic product (GDP). Moreover, the growing interest of the companies in exploring the rural markets further aided the growth of the sector. Several initiatives by the Government of India and the major automobile players in the Indian market are expected to make India a leader in the world by 2020. The industry produced a total of 23,366,246 vehicles including passenger vehicles, commercial vehicles, three wheelers and two wheelers in April-March 2015 as against 21,500,165 in April-March 2014, registering a growth of 8.68 percent over the same period last year. Indian automobile industry is trying to make a breakthrough in improving the efficiency, durability and cost of vehicles using nanotechnology solutions along with decreasing the pollution by using hydrogen fuel or electric engines. In this paper, we have discussed the effect of nanotechnology innovations on Indian automobile sector in order to solve the problems in automobile efficiency, durability, cost, and environmental pollution. The paper also contains the discussion on the impact of these innovations on economical, political and renewable energy sector of the country.

Index Terms: Innovations in Indian Automobile Sector, Nanotechnology in Automobile Efficiency, Durability, Cost & Environmental Pollution

1. Introduction:

The Indian auto industry is one of the largest in the world growing very fast with an annual production of 23.37 million vehicles during 2014-15, with the annual growth of 8.68 per cent. It accounts for 7.1 per cent of the country's gross domestic product (GDP). As per Automotive Component Manufacturers Association of India (ACMA) the turnover of the auto component industry is INR 2340 billion (USD38.5 billion) during 2014-15, registering a growth of 11 per cent over the previous year and a Compounded Annual Growth Rate (CAGR) of 11 per cent over the last six years. The auto component industry in India is expected to scale up to Rs. 6347 billion in turnover by 2020 with exports to grow the in range of Rs, 2200-2550 billion. Indian Government is encouraging R&D in automobile industry for technological innovations by giving a 15 per cent reduction of rate of income tax on royalty and fees for technical services. To support sustainable technology development further to provide an industry perspective on emerging affordable and accessible technologies , ACMA has taken initiative to give priorities on light weighting, electrification of powertrains, improving the safety and fuel efficiency, and electronics of vehicles. In addition, Global automotive Original Equipment Manufacturers (OEMs) and suppliers identified India as a key market working on various technologies such as light weighting, electrification of power trains and safety features. Several initiatives by the Government of India and the major automobile players in the Indian market are expected to make India a leader in the world by 2020. Some of the major investments and developments in the automobile sector in India are as follows [3]:

- ✓ Global auto major Ford plans to manufacture in India two families of engines by 2017, a 2.2 litre diesel engine codenamed Panther, and a 1.2 litre petrol engine codenamed Dragon, which are expected to power 2,70,000 Ford vehicles globally.
- ✓ The world's largest air bag suppliers Autoliv Inc, Takata Corp, TRW Automotive Inc and Toyoda Gosei Co are setting up plants and increasing capacity in India.
- ✓ General Motors plans to invest US\$ 1 billion in India by 2020, mainly to increase the capacity at the Talegaon plant in Maharashtra from 130,000 units a year to 220,000 by 2025.
- ✓ US-based car maker Chrysler has planned to invest Rs 3,500 crore (US\$ 525 million) in Maharashtra, to manufacture Jeep Grand Cherokee model.
- ✓ Mercedes Benz has decided to manufacture the GLA entry SUV in India. The company has doubled its India assembly capacity to 20,000 units per annum.
- ✓ Germany-based luxury car maker Bayerische Motoren Werke AG's (BMW) local unit has announced to procure components from seven India-based auto parts makers.
- ✓ Mahindra Two Wheelers Limited (MTWL) acquired 51 per cent shares in France-based Peugeot Motorcycles (PMTM). The Government of India encourages foreign investment in the automobile sector and allows 100 per cent FDI under the automatic route. Some of the major initiatives taken by the Government of India are [3-4] :
- ✓ Encouraging automobiles manufacturers to become driver of 'Make in India' initiative, as it expects passenger vehicles market to triple to 9.4 million units by 2026, as highlighted in the Auto Mission Plan (AMP) 2016-26.
- ✓ In the Union budget of 2016-17 the Government has announced to provide credit of Rs 850,000 crore (US\$ 127.5 billion) to farmers, which is expected to boost the tractors segment sales.
- ✓ The Government plans to promote eco-friendly cars in the country i.e. CNG based vehicle, hybrid vehicle, and electric vehicle and also made mandatory of 5 per cent ethanol blending in petrol.
- ✓ The government has formulated a Scheme for Faster Adoption and Manufacturing of Electric and Hybrid Vehicles in India, under the National Electric Mobility Mission 2020 to encourage the progressive induction of reliable, affordable and efficient electric and hybrid vehicles, aims at creating a vehicle base of ~7 million electric cars by 2020 in the country by providing incentives to buyers as well as suppliers and for undertaking R&D initiatives, to create public charging infrastructure, to encourage retro-fitment of vehicles.
- ✓ The Automobile Mission Plan (AMP) for the period 2006–2016, designed by the government is aimed at accelerating and sustaining growth in this sector. Also, the well-established Regulatory Framework under the Ministry of Shipping, Road Transport and Highways, plays a part in providing a boost to this sector.
- ✓ The National Electric Mobility Mission Plan 2020 and policy of Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India aims at creating a vehicle base of ~7 million electric cars by 2020. National Automotive Board (NAB) under the supervision of the department of heavy industries has been constituted for implementation of the plan.
- ✓ The government of India has extended support to the industry by increasing customs duty on CBUs of commercial vehicles from 10 percent to 40 percent, reduction in duty on chassis for ambulance manufacturing from 24 percent to

12.5 percent, extension in concession on select parts used in the manufacture of electric & hybrid vehicles and weighted deduction up to 200 percent of expenditure on R&D for computation of expenses under Corporate Tax.

India's automotive industry is one of the most competitive in the world. The Indian automotive sector has the potential to cover 100 per cent of technology or components required and to generate up to US\$ 300 billion in annual revenue by 2026, create 65 million additional jobs and contribute over 12 per cent to India's Gross Domestic Product, as per the Automotive Mission Plan 2016-26 prepared jointly by the Society of Indian Automobile Manufacturers (SIAM) and government [3].

Some of the challenges identified in Indian automobile sector to reach its goal as per Automotive Mission Plan 2016-26, are:

- ✓ Challenge to attract capital investments required to implement roadmap developed by AMP 2016-26.
- ✓ Challenge to fulfil global emission standards and safety norms to erase the environmental footprint.
- ✓ Challenge to adopt new breakthrough technologies to make automobiles ideal for use.
- ✓ Challenge of lack of infrastructure, urban congestion, integration of smart concepts, meeting efficiency needs.
- ✓ Challenge to safeguarding intellectual property rights developed by R & D institutions.
- ✓ Other challenges like (a) Customs duty and transfer pricing issues plaguing the industry, (b) Planning and implementing simpler tax structures, (3) Policy of withdrawal for old vehicles. (c) Lack of growth opportunities for auto industry companies may attract them to invest in other sectors etc.

While the Indian government is making serious efforts on policy implementation, automobile industry is trying to make a breakthrough in improving the efficiency, durability and cost of vehicles using nanotechnology solutions [5-8] along with decreasing the pollution by using hydrogen fuel or electric engines. In this paper, we have discussed the effect of nanotechnology innovations on Indian automobile sector in order to solve the problems in automobile efficiency, durability, cost, and environmental pollution to make optimum automobiles which are free from all types of defects. The paper also contains the discussion on possible innovations in electric/pollution free vehicles, hydrogen fuel technology as intermediate technology, and nanotechnology opportunities are as permanent solutions for, auto-components, auto-engines, auto-tyres, auto-electronics, auto-seat materials, auto-bodies, aeroplanes, space crafts, and rockets, and the impact of these innovations on economical, political and renewable energy sector of the country.

2. Electric/ Hydrogen Fuel Technology for Pollution Free Automobiles:

Due to the reasons of global warming and the inevitable exhaustion of Earth's oil reserves, it has become highly desirable to find an alternative energy source for automobiles. Major challenge of Indian transport system is decreasing the automobile fuel cost and polluted gas emission. Making automobile sector free from fuel consumption, India can be made the land based, water based and air based automobiles. By means of renewable electric energy technology or hydrogen fuel technology, Indian automobile sector, can solve many of its problems and contribute heavily on development of the country by decreasing foreign payments. Generating renewable electric energy through different technologies and storing them for powering automobiles using electrical storage technology for long period is the major challenge of

automobile sector. Generation of renewable electrical energy is possible by means of solar, wind, tidal, hydro or even nuclear energy, which can be made pollution free. By using new technology batteries and super capacitors, energy storage constraints can be minimized. Indian automobile sector should focus on developing low cost, light weight, durable, efficient automobile electrical engines and low cost, light weight, high storage batteries/ storage cell technologies during next decade. This solution in turn, minimizes green gas emission and hence automobile based pollution of the country. Alternately, hydrogen fuel technology also contributes to the green power requirement of automobile sector in the country. Hydrogen fuel cells are used extensively as green fuel in developed countries even though, the cost of such technology of manufacturing and storage of hydrogen gas in the form of condensed fuel cells for powering the automobile is high. By means of developing hydrogen fuel technology the automobile sector can be made pollution free. Hydrogen storage and refilling is found to be major technological barrier to the development of hydrogen fuel cell based automobiles. To overcome this barrier, solid fuel cells are recently adopted. Solid oxide fuel cells offer a clean, pollution-free technology to electrochemically generate electricity at high efficiencies. These fuel cells provide many advantages over traditional energy conversion systems including high efficiency, reliability, modularity, fuel adaptability, and very low levels of NO_x and SO_x emissions.

Based on present strategy of Indian government's investment for research and developments in nanotechnology through nanotechnology initiative programme, it is expected that the country can find optimum solution to its automobile sector problems/requirements to increase the quality, durability and performance, and decrease the cost of land based, water based and air based vehicles. This will also improve the efficiencies and controls the green gas emission and hence controls the pollution level in the country.

3. Nanotechnology Based Opportunities:

In addition to contributing to building and maintaining lighter, smarter, more efficient, and "greener" vehicles, aircraft, and ships, nanotechnology offers various means to improve the transportation infrastructure:

- ✓ Nano-engineering of steel, concrete, asphalt, and other cementitious materials, and their recycled forms, offers great promise in terms of improving the performance, resiliency, and longevity of highway and transportation infrastructure components while reducing their cost. New systems may incorporate innovative capabilities into traditional infrastructure materials, such as the ability to generate or transmit energy.
- ✓ Nanoscale sensors and devices may provide cost-effective continuous structural monitoring of the condition and performance of bridges, tunnels, rails, parking structures and pavements over time. Nanoscale sensors and devices may also support an enhanced transportation infrastructure that can communicate with vehicle-based systems to help drivers maintain lane position, avoid collisions, adjust travel routes to circumnavigate congestion, and other such activities.
- ✓ The use of nanofluids as coolants in automobile engines would support to decrease the use of fluids and hence the small size of the radiators. This will also shrink the size of coolant pump and the automobile engines can be operated at higher temperatures to improve the efficiency. This is due to their higher conductivity and better heat transfer properties. Hence nanofluids have higher potential to improve automobile engine cooling rates by increasing the efficiency, lowering the weight and decreasing the complexity of convective heat

transfer performance. It is already reported that use of nanofluids showed about 20% increase in frictional pressure drop and 40% increase in pumping power compared with water [9].

- ✓ Nanotechnology based coatings and paints are highly scratch resistant, self-healing and dirt repellent. Such coatings and paints developed for automobile bodies last for the lifetime of the vehicle without aging, and require cleaning much less often. Paints manufactured using nanotechnology can alter their heat-reflecting properties depending on the intensity of the incident sunlight and also reflect different colours depending on surrounding temperature [10]. As a result the colour of the vehicle changes with time. The nanotechnology based paints also helps to regulate the inside temperature using air-conditioner thereby saving fuel. Nano coatings outside the glass creates hydrophobic (water-resistant) surface thereby eliminates the requirement of wipers on vehicle glass. Similar approach of use nano-coating inside the glass prevents water vapour condensing on the glass in humid conditions.

4. Nanotechnology Based Solutions:

(a) Nanotechnology Based Auto-Components:

Nanotechnology can be used to make wide range of automotive components for making new models of automobiles, making it possible to build them with extensive service life; lower component failure rate and smart materials for repairing. Automobiles developed with nanomaterials have advantageous in terms of durability, strength, efficiency and cost [11]. Nanotechnology based global automotive markets expect exponential positive returns, but hurdled by high initial investments and limited research and development. Although nanotechnology applications in automotive industry are manifold, many of the solutions are still untapped. Many features like sustainability, safety, comfortability, and eco-friendliness, leads to CO₂- free engines, safe driving, quiet cars, self-cleaning body, and windscreens etc. are expected to be real [12]. Nanotechnology is not only finding its way into every corner of automobiles, but is also bringing great benefits in several domains like frames and body parts, engines, paints and coatings, suspension and breaking systems, lubrication, tires, exhaust systems, etc. Certain nano-materials like carbon nanotubes and carbon black produced in India have enhanced mechanical, physical, and processing properties will render new functionalities. In addition, they may improve manufacturing speed and enhance environmental, thermal, and mechanical stability [13]. This means automobile bodies will undergo less wear, better gliding, thinner coating, fewer lubrication, longer service intervals, and weight reduction. Lighter vehicle bodies will use less material, without compromising the stiffness and crash resistance and will indirectly save fuel.

Nanotechnology based auto-components include nanomaterial based automobile parts, components of space elevators, components for weight reduction in spaceships and spacesuits, components of solar power satellites, bio-nano-machines for space applications, components of new breed of robots to explore the planets etc. Automotive industry will see nanotechnology benefits from advanced power train designs, lighter weight, stronger materials, sensing technology, and higher efficiency. Since almost all automobile components can be improved through nanotechnology, innovations and new markets are practically guaranteed, assuming that manufacturing costs can be kept down. In all areas like, body style, brakes, acceleration, and safety will depend mostly on the ability of the company to develop and include nanomaterials. Future applications are likely to see energy-harvesting bodywork, self-healing paint, shape-shifting skin,

and improved fuel cell performance of future electric and hydrogen-powered cars- all the next wave of innovation in the automobile sector.

(b) Nanotechnology Based Auto-Engines:

Auto engines working on oil/gas based combustion as well as based on electric energy will get benefit due to inventions and innovations in nanotechnology. Nanotech additives act like minuscule ball bearings to lubricate moving metal surfaces that come into contact inside engines, reduce friction in automobile engines and machines, and hence improves fuel efficiency. By apply nanostructure coatings to automobile engines one can make heat transfer far more efficient. Use of nanofluids as coolants in automobile engines would contributes to increase thermal conductivity by minimizing heat build-up which increases fuel efficiency and reduces wear. Due to less energy wasted through friction, which boosts instantaneous power and torque in the engine. Thus auto engines will consume less power, reduce exhaust gas and particle emission, becomes eco-friendly. Further, engine parts made by nanoparticle enforced steel will increase the durability of the engine due to decreased wear and tear. Nanotechnology supports to increase the strength of engine parts but reduces the engine weight and fuel consumption. Long term research in nanotechnology may lead to automobile engines with 100 % efficiency as in case of ideal engines.

(c) Nanotechnology Based Auto-Tyres:

One of the dreams of automobile industry is innovation to give long life to auto-tyres in such a way that if auto-tyres last long for 10 – 50 years, then the maintenance cost as well as recycling them to reduce environmental pollution will be reduced. It is found that use of nano-material additive for the rubber mixture of the tyre tread significantly cuts wear in automobile tyres. As a result, the tyre will give longer service life. It is also found that use of such nano-material additives to enhance wear resistance does not affect on rolling resistance or wet grip of the tyre. By using such nano-materials as additive at tyre manufacturing stage, Indian auto-tyre manufacturers can add values to automobiles and expand their market share. Use of nano-materials like carbon black, silica, and nano-clays are found to be promising candidates to green tyre industry. Adding such materials have the potential to decrease tyre rolling resistance, which improve the fuel consumption and decreases the CO₂ emissions, and lower wear resistance which increases tyre lifetime while maintaining wet road grip and existing safety levels [14]. Thus nanotechnology bridges the gap between the characteristics of ideal tyres and practical tyres.

(d) Nanotechnology Based Auto-Electronics:

This include Electronic control units/ Vehicle controls, Sensors, Smart functions through artificial intelligence, Telematics/vehicle communication etc. The technology of thermal interface materials (TIMs) based electronic control unit (ECU). The TIM assembly is playing a key roll in achieving good heat conductions within and from a package to heat sinking device. Emerging nanotechnology in TIMs shows that carbon nanotubes (CNTs) and carbon nanofibres (CNFs) when used as the structure of TIM or TIM filler could improve the overall thermal and mechanical properties of TIMs.

Automotive manufacturer has initiated research and development for connected vehicle systems, vehicle connectivity can prevent crashes, optimize travel routes, issue road condition warnings, and generate environmental benefits by taking advantage of continuous, real-time connectivity to vehicles, infrastructure, and wireless devices.

Electronic display units with improved performance and unique features are possible by nanotechnology. Light emitting devices, such as LEDs, OLEDs (Organic Light Emitting Diode), fluorescent or field-emissive displays, electro-luminescent and perhaps

lasers, are utilizing nano-phosphors and nanolayers to improve their performance. Lower cost laser light emission sources are possible to improved performance, longer life, higher energy efficiency, unique presentation features, reduced package size become the value proposition for adopting such new technology. An electronic display based on carbon nanotube technology (CNT) is being explored for low voltage field-emission displays which are potentially very efficient and long-lasting emitters in applications like nano-electronics.

Using nano-photonics technology, many new devices like optical thin films, non-linear holographic reflectors, micro-lenses, and light conversion films are being developed to modulate or redirect electromagnetic radiation [15]. Electronic systems can be miniaturized using nanotechnology which can also have cumulative effect in miniaturization of electronic components in automobile industry. The future automobiles based on nanotechnology will be lighter, stronger, faster, safer, and more intelligent than the driver by using nano-electronic and eco friendly components.

(e) Nanotechnology Based Auto-Seat Materials:

Textiles are used extensively in cars - from seat coverings and seatbelts to air filters and tyre cord. There is a general trend in automotive design towards replacing more and more hard surfaces inside the vehicle with fabrics, as they are an easy way to reduce weight, and improve overall recyclability. Conventional fabrics are highly susceptible to wear and tear, collection of dust and dirt, and can be a fire hazard if untreated. A wide array of nanotechnologies can be applied to textiles to improve their performance and lifetime. Nanofibre based auto interior provides safety, good looking, and comfort including good management of heat and water vapour transfer; moisture wicking, self-cleaning, anti-stain/easy to clean characteristics; antimicrobial/antibacterial properties; anti-allergic trimming; Flame resistance; antistatic properties; tear and wear resistance, UV resistance, noise reduction, and improved acoustic performance.

A product already available in the market called NANOMAN is a Spray which protects automotive fabrics and textiles from water, dirt, contaminant and stains, without affecting the fabric's appearance, colour, or feel and is easy to use, whilst remaining totally invisible. Even water, coffee and liquids are repelled from NANOMAN treated textiles and hence provides ideal protection for automobile seats and convertible roofs. The look, breakability and feel of the fabric remain unchanged. Auto seats with integrally knitted nanotechnology sensors, warn drivers when they start to fall asleep at the wheel, are also under development. Thermo-electric fabrics made by nanotechnology generate electricity by absorbing passengers/drivers body heat. The fabric made up of tiny carbon nanotubes locked up in flexible plastic fibers and made to feel like fabric that uses temperature differences to create a charge. Hence use of nanotechnology in automobile cloths and fabrics fills the gap between conventional cloths properties and ideal cloths properties.

(f) Nanotechnology Based Auto-Bodies:

The main objectives of nanotechnology usage in automobiles are weight reduction and increasing the strength of the body. This will increase the fuel efficiency and the durability of the vehicle. It is found that nanoengineered thermoplastic materials allow a weight reduction of up to 40% compared to traditional steel chassis parts. Embedded nano-particles of metallic carbon nitride can increase the permanent strength of steel to use as chassis. By means of further processes, it can be made corrosion free. This will improve the life of the automobile to greater extent. The outer metal bodies are also can be replaced by nanoplastic/polymer sheet bodies which will

further reduce the weight and strength of the vehicle. Nanocomposite glasses used in windows also contribute for weight reduction and body strength. This will also support recycling of materials and avoids environmental foot print. Thus nanotechnology supported innovations in automobile bodies decreases the body weight to the large extent without compromising in strength and durability.

The countries like India which are not independent in crude oil production, will get substantial benefit to become self-reliant. Thus the automotive industry in India will see nanotechnology benefits in all areas of automobile production including power train designs, lighter weight, stronger materials, sensing technology, and higher efficiency to become world leader in exporting automobiles and components.

(G) Nanotechnology Based Aeroplanes:

Nanomaterials with their exceptional multifunctional properties may transform the aviation industry dramatically. There are many benefits to improve aeroplane performance using nanotechnology. Some of them are:

- ✓ Use of nanotechnology to store hydrogen in solid state so that hydrogen can be used as a clean alternative to hydrocarbon based fuels in aeroplanes.
- ✓ Nanotube coating on plane outer surface would absorb radar beam making it undetectable to enemies.
- ✓ Ultrathin nanofilm coating on outer surface of aeroplane aimed at decreasing the drag and improving the fuel efficiency.
- ✓ Nanotechnology based products may help to keep the aeroplane dry and self-cleaning.
- ✓ Nanotechnology based innovations are capable to develop aircraft wings, propellers, and transport vehicles that can literally change shape to improve performance and efficiency.
- ✓ Aircraft wings with smart materials make them more aerodynamic and easier to control. Such a craft would sense conditions while in flight. Sensors in the wings will measure the pressure on each wing's surface. Using actuators, the wing can respond, even changing shape, just as a bird's wing responds to air pressure or weather.
- ✓ Lighter and stronger materials will be of immense use to aircraft manufacturers, leading to increased performance.
- ✓ Nanotech is lowering the mass of supercapacitors that will increasingly be used to give power to assist electrical motors for launching hang gliders off flatland to thermal-chasing altitudes.
- ✓ Continuous innovation in aircraft design has led to fuel savings, noise reductions and lower fares for passengers by making flights more efficient.
- ✓ Nanomaterials can fulfil the requirement of aerospace industry to improve the properties like Light Weight High Strength High Toughness Corrosion Resistance Easy Reparability & Reusability Less Maintenance & Durability of aeroplanes.
- ✓ The nanocomposite coatings are used for low friction and wear resistant applications of aircraft.
- ✓ Nano Electro Mechanical Systems offer the possibility of developing a standard fuel management unit which controls the fuel control in aero-engines.
- ✓ Nanostructured metals used in aircrafts primarily yield strength, tensile strength and corrosion resistance, coupled with low density which helps keep the total weight of the aircraft down.

(h) Nanotechnology Based Spacecrafts:

- ✓ With stated benefits of weight reduction, enhanced strength, enhance corrosion resistance, allows countries to produce low cost, high quality, smaller weight spacecrafts so that countries like India can also provide space travel opportunities to its citizens.
- ✓ Radiation shielder: certain kind of nano coating in spacecrafts can act as safe space radiation shielder for astronauts to protect them from harmful high frequency space radiations.
- ✓ Satellite protection from enemies: Nanotechnology can be used to improve the design of satellites to mitigate the threats posed by ground-based directed energy weapons and high-powered microwaves.
- ✓ Space elevator: Space elevator based on carbon nanotube cable provides a strong cable between space stations to earth surface thereby providing an easy access to space travel.

(i) Nanotechnology Based Rockets:

Innovations in rockets technology using nanotechnology has following advantages:

- ✓ Enhancement of thrust of rockets using nanotechnology: Nanoparticle Field Extraction Thruster (nanoFET) is a device based on nanotechnology in which nanoparticles are charged by losing electrons when they touch an electrode at a positive voltage. After the nanoparticles are charged, an electric field can accelerate them, providing thrust to the spacecraft.
- ✓ Nanotechnology based rocket fuels: By adding certain metallic nanopowder with solid or liquid propellant of rocket, the efficiency of acceleration can be increased.
- ✓ Based on above discussions, one can realize the challenges of automobile sector in India and the opportunities to handle such challenges using next generation nanotechnology. The table 1 contains the applications & benefits of NT in Automobile sector:

Table 1: Applications & benefits of NT in Automobile sector

| S. No | Applications | Business Benefits |
|--------------|--|---|
| 1 | Nano-clearcoats with high scratch and wear resistance | Improve scratch resistance |
| 2 | Nano-coatings with anti-corrosion performance for car bodies | Protect metal body of the vehicle against corrosive materials. |
| 3 | Smart nano-scale container anticorrosive coating | Self-repairing coatings are further enhance anticorrosive properties of metal substrates |
| 4 | Weathering resistant automotive coatings | Protecting the car body against environmental conditions and imparting desirable aesthetic appearance |
| 5 | Spark plugs | Quick start & durability |
| 6 | Smart windows based on electrochromism | Controlling all types of energy like sound, light and heat which enter the car body |
| 7 | High-strength steels for vehicle bodies | Enhance protection of vehicles and passengers safety at crashes |
| 8 | Nanostructured rubber tyres | Significantly enhance tyres durability as |

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|----|---|--|
| | | well as higher fuel efficiency. |
| 9 | Nanotechnology based seat fabrics | Novel anti-microbial textiles to avoid micro-organisms growth especially at proper humidity and temperature in contact to human body. |
| 10 | Nano-tech super hydrophobic surfaces | To create self-cleaning surface on seat & interior fabrics as well as wiper free self cleaning front glasses. |
| 11 | Nano-coatings for engine application | Act as improved Lubricator reduce load, Thermal insulator to reduce heat losses and frictional losses to improve fuel efficiency |
| 12 | Nanotube composites in the braking systems | Nanotube composites in the braking systems results in effective braking performance, and is also likely to reduce brake system weight while increasing acceleration. |
| 13 | Nano super capacitors & Nano tech solar cells | Alternative fuel for vehicles |

5. Impact of Nanotechnology on Indian Automobile Sector:

The expected inventions and innovations in automobile sector based on nanotechnology opportunities are going to do many changes in production, usage and even export of automobiles in the country. The possible impacts of these innovations on economical, political and renewable energy sector of the country are listed below:

➤ **Impact on Economical Environment:**

Based on possible decrease in cost, size, weight, environmental degradation of automobiles and increase in efficiency, durability, comfortability, demand, nanotechnology innovated automobiles are going to be very attractive in the country. By using renewable energy and enhanced vehicle lifespan there will be enhanced demand for vehicles. Due to innovations, the production cost of the vehicles is going to be very nominal and the maintenance cost is going to be zero. If India is the first innovator in this area, it can get the economical advantage by producing and exporting such automobiles to other countries. Additionally, India can get benefit of saving its foreign exchange cost on oil import which is going to give big economical advantage to the country. Thus, anticipated nanotechnological breakthrough in automobile sector will give huge economical advantage to the country both for development and for citizens' comfortability. The nanotechnology based innovations in automobile sector creates new business opportunities for which organizations have to be prepared. Organizations should plan for financial investment strategy for nanotechnology infrastructure development, investment through Research & Development and product commercialization to encash opportunities and for long term profit. The economy of the country will also get benefit through such technological innovations. The impact of such developments will be affecting on automobile garages, used vehicle sales, and also on Insurance companies to re-think their business model.

➤ **Impact on Political Environment:**

When the economy of the country is improved through technological breakthroughs, the political environment is also get affected. Changes in the structure of international business and the improvements in quality of life in the society, the political decisions on budget investment and the road map on Country development

plans should be redesigned. Since nanotechnology is general purpose technology and is expected to impact on all areas in the society, the poverty level in the country is going to be re-defined. New issues like environmental safety will become political debatable issues.

➤ **Impact on Renewable Energy Sector:**

Use of nanotechnology based solar cells with 100 % conversion efficiency will solve energy problems in all households, factories, and for automobiles. Smart homes, smart factories, and smart automobiles with zero maintenance cost are going to be common after the year 2050 with energy independency. Low cost air travel and space travel are going to be common and is going to be affordable to the common people of the country.

➤ **Impact on Public Life: (Comfortness & Luxury)**

Innovations in automobile sector and its effect on road transportation, sea transportation and air transportation in terms of cost, affordability, efficiency and availability to everyone, the quality of human life is going to be moderate in future days. In India, according to the World Bank estimate during 2015, about 17.2 crores people are below poverty line. This is about 12.4 % of the total population. If Government and private organizations invest on research and development of nanotechnology based automobile sector innovation, the poverty of the country can be reduced to zero. Alternately all the people of the country can lead comfort luxurious life in future days. In countries like India where the population of poor and the corruption in the society are considerably high, only technological solutions can be effective in solving the problems and gives hope for future generations. Low cost air travel and space travel are going to be common and is going to be affordable to the common people of the country.

➤ **Impact on Public Perception:**

Ever increasing oil prices, uncontrollable cost of vehicle maintenance, sky shooting vehicle prices, Short life of automobile vehicles due to tight emission norms, continuous degradation of environment and rise of temperature due to green gas emission, are decreasing the hope and confidence of publics on better future. Social problems like poverty, corruption, and struggle for basic needs like food, clean drinking water, low cost renewable energy, low cost affordable shelter and comfortable health are major challenge & threats in the society for human prosperity. In such bad time for the people of developing country like India got hope on future due to expected and projected breakthroughs of nanotechnology. If nanotechnology innovations are able to reach the expectations of publics unlike science fiction, the human life is going to be happy and prosperous in future generations and the dream and hope of human beings growth and perception are going to be true.

6. Conclusion:

The effect of nanotechnology innovations on Indian automobile sector in order to solve the problems in automobile efficiency, durability, cost, and environmental pollution are discussed. Nanotechnology based solutions for Auto-Components, Auto-Engines, Auto-Tyres, Auto-Electronics, Auto-Seat Materials, Auto-Bodies, Aeroplanes, Space Crafts, and Rockets are analysed. Based on applications and benefits of nanotechnology in different areas of automobile industry, the opportunities to realize the vision and roadmap of the country and possible impact of these innovations on economical, political and renewable energy sector in India are discussed.

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